



University of Minnesota

## **Physics and Nanotechnology Building**

Twin Cities Campus, Minneapolis, MN

University Project Number 01-155-08-1718

# **PROJECT MANUAL**

## **100% Construction Documents**

Clean Room

**Volume 3 of 3**

December 16, 2011

### **Project Team:**

Architectural Alliance

ZGF Architects

Research Facilities Design

Affiliated Engineers, Inc.

Meyer Borgman and Johnson, Inc.

Pierce Pini & Associates

Close Landscape Architecture

Elert and Associates

Lerch Bates, Inc.



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## SECTION 13 2100CR – CLEANROOM CONSTRUCTION

### PART 1 GENERAL

#### 1.1 SUMMARY

- A. Drawings and general provisions of the Contract, and Division 1 Sections apply to work of this Section.
- B. This specification details construction features, components, installation, performance capabilities and design requirements for a complete engineered field-fabricated environmental cleanroom.
- C. The cleanroom shall be the product of a manufacturer/installation contractor regularly engaged in the business of designing, manufacturing, installing, and certifying cleanrooms.
- D. The manufacturer/installation contractor shall guarantee that the performance of the complete cleanroom will meet all the performance criteria established by this specification.
- E. The cleanroom manufacturer/installation contractor shall provide certification from a third party source.

#### 1.2 REFERENCES

- A. International Standards Organization (ISO): Air cleanliness classification for cleanrooms and definition of terms for cleanroom work shall be in accordance with ISO 14644 Class 4, 5 and 6 (Formerly Class 10, 100 and 1,000).
- B. All cleanroom construction shall be in accordance International and Local building codes.

#### 1.3 RELATED DOCUMENTS

- A. General and Supplementary Conditions and Division 1
- B. Other Division 9 sections for floor finishes related to this section but not the work of this section.
- C. Division 3 Concrete; not the work of this section.
- D. Division 6 Wood and Plastics; not the work of this section.
- E. Division 7 Thermal and Moisture Protection; not the work of this section.
- F. Section 11 5343 – Laboratory Fittings and Fixtures
- G. Section 13 2101CR – Cleanroom Performance Testing

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- H. Section 13 2105CR – Cleanroom Construction Protocol
  - I. Section 13 2110CR – Cleanroom Ceiling System
  - J. Section 13 2120CR – Cleanroom Wall System
  - K. Section 13 2130CR – Cleanroom Automatic Sliding Doors
  - L. Section 13 2140CR – Cleanroom Chemical Fume Hood and Wet Processing Stations
  - M. Division 21: Fire Suppression
  - N. Division 22: Plumbing
  - O. Division 23: HVAC
  - P. Division 25: Cleanroom Controls
  - Q. Division 26: Electrical

#### **1.4 DEFINITIONS**

- A. Clean Zone: A defined area, including the cleanroom and adjacent spaces that are exposed to the cleanroom supply and return airstreams.
- B. HEPA Filter: High efficiency particulate air filter.
- C. Protocol Level: The phase or degree of construction completion that mandates specified activities, training, security clearance, dress, work means and methods, cleaning procedures, and system performance to maintain the cleanliness of the clean zone.
- D. Protocol Manager: The person vested with authority by the Cleanroom Protocol Contractor to supervise all construction personnel working within the Clean Zone and ensure requirements of the contract documents are met in completion of the Clean Zone construction.
- E. ULPA Filter: Ultra-High efficiency particulate air filter.

#### **1.5 PERFORMANCE REQUIREMENTS**

- A. Clean spaces are classified according to ISO 14644. Verification of room and air cleanliness shall be by measurement of the concentration of airborne particles at or above the size limits given below.
- B. Classified spaces shall be as follows:
  - 1. Refer to project drawings.
- C. Airborne particulate cleanliness classification:



1. ISO Class 4 (formally Fed Std 209E Class 100); as-built; 0.1  $\mu\text{m}$  (10,000 particles/ $\text{m}^3$ ), 0.2  $\mu\text{m}$  (2,370 particles/ $\text{m}^3$ ), 0.3  $\mu\text{m}$  (1,020 particles/ $\text{m}^3$ ), 0.5  $\mu\text{m}$  (352 particles/ $\text{m}^3$ ), 1.0  $\mu\text{m}$  (83 particles/ $\text{m}^3$ ).
  2. ISO Class 5 (formally Fed Std 209E Class 100); as-built; 0.1  $\mu\text{m}$  (100,000 particles/ $\text{m}^3$ ), 0.2  $\mu\text{m}$  (23,700 particles/ $\text{m}^3$ ), 0.3  $\mu\text{m}$  (10,000 particles/ $\text{m}^3$ ), 0.5  $\mu\text{m}$  (3,520 particles/ $\text{m}^3$ ), 1.0  $\mu\text{m}$  (832 particles/ $\text{m}^3$ ), 5.0  $\mu\text{m}$  (29 particles/ $\text{m}^3$ ).
  3. ISO Class 6 (formally Fed Std 209E Class 1,000); as-built; 0.1  $\mu\text{m}$  (1,000,000 particles/ $\text{m}^3$ ), 0.2  $\mu\text{m}$  (237,000 particles/ $\text{m}^3$ ), 0.3  $\mu\text{m}$  (102,000 particles/ $\text{m}^3$ ), 0.5  $\mu\text{m}$  (35,200 particles/ $\text{m}^3$ ), 1.0  $\mu\text{m}$  (8,320 particles/ $\text{m}^3$ ), 5.0  $\mu\text{m}$  (293 particles/ $\text{m}^3$ ).
- D. Particle count within room space shall not exceed limits for above mentioned classifications as defined by ISO Class 4 – 6 throughout room at an elevation of 760 mm (30 inches) above floor level.
- E. Levels of cleanliness apply while Cleanroom is at an “At Rest” condition.
- F. Cleanroom spaces shall be tested and certified to one ISO Class lower than intended design classification for as-built conditions with all furnishings installed and equipment operational (i.e. hoods, etc...).

## 1.6 DESIGN REQUIREMENTS

- A. Environmental:
1. Clean Bays:
    - a. Room Temperature:  $68^{\circ}\text{F} \pm 0.18^{\circ}\text{F}$ .
    - b. Room Relative Humidity:  $45\% \pm 2\%$ .
  2. Gowning:
    - a. Room Temperature:  $68^{\circ}\text{F} \pm 1^{\circ}\text{F}$ .
    - b. Room Relative Humidity: not controlled – resultant of Clean Bay humidity control.
- B. Room Pressure and Leakage:
1. Overall leakage rate of entire room and air handling system should not exceed 3 percent of total air supply with all doors closed and room in occupied condition. Positive pressure shall be sustained in operational Cleanroom spaces in accordance with the Drawings and with all equipment operating at design capacity.

<u>Cleanliness Class</u>	<u>Positive Pressure (leakage)</u>
ISO 5 (FS Class 100)	0.5 percent to 1 percent
ISO 6 (FS Class 1,000)	1 percent to 2 percent
ISO 7 (FS Class 10,000)	2 percent to 3 percent
  2. When an entry door is opened, outward airflow shall be maintained. Special attention shall be directed to ensure an airtight enclosure by caulking, including fan housings, ductwork, etc., to minimize air leakage.
- C. Lighting Intensity:
1. Lighting installation shall be meet a minimum of 100 foot-candles sustained light intensity as measured at height of 760 mm (30 inches) above floor.
  2. Lighting fixtures shall be mounted so as to not disturb airflow patterns.

3. Lighting fixtures shall be located so as to not conflict with equipment layout as shown on Cleanroom drawings.
- D. Sound Level:
1. Unoccupied Conditions: Sound level within the Cleanroom spaces shall not exceed (NC60) curve as determined by octave band analysis at height of 1830 mm (72 inches) above floor.

## 1.7 SUBMITTALS

- A. Provide samples of each type of product materials, support components, finishes, and accessories illustrating installed products, finishes, and color.
- B. Detailed manufacturer product data sheets, for each proposed product type, which provides the necessary information to describe and evaluate the product and its performance. Provide MSDS product data for all materials and finishes used in the cleanroom (sealants, paints, powder coating, etc...).
- C. Shop Drawings: Submit complete shop fabrication and installation drawings, including plans, elevations, sections, details, schedules, and 3-dimensional layouts (as necessary). Minimum scale shall be 1:50. Show relationship to adjoining materials and construction. Shop drawings shall depict final product design and installation. Shop drawings shall be prepared electronically and submitted in the form of reproducible or photocopies, prepared in standard Architectural drawing formats and scaled to defined dimensions.
- D. Upon completion of installation, operation and maintenance instructions will be furnished. Operation instructions shall include manufacturer's name, size, model, type, and serial numbers for the various elements of system; detailed drawings, wiring diagram, repair parts lists, lubrication manuals, and general maintenance instructions. Provide services necessary to properly instruct University personnel on operation and maintenance of all systems.
- E. Provide the following certified items:
  1. Operating and maintenance procedures.
  2. List of recommended spare parts.
  3. Approved shop drawings.
  4. Certified performance curves for equipment.
  5. Warranty certificates.
  6. As-built drawings.
  7. Test reports.
  8. Procedural instructions for future wall penetrations and proper sealant to be used.
- F. Upon completion of work, tests shall be completed, systems balanced and tested, and a qualified representative provided to instruct a representative of the Owner's maintenance department in proper operation and maintenance of all installed systems.

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## **1.8 CLEANROOM CONTRACTOR QUALIFICATIONS**

- A. In addition to the General Standards and as a condition of award, special standards must be met by the Cleanroom Manufacturer/Installation Contractor to demonstrate that the bidder possesses certain expertise that has been determined essential for adequate contract performance.
- B. The following will be required of the bidding contractors prior to award: A list of at least five (5) projects, completed within the last five (5) years, which included construction of ISO Class 5 (FS Class 1,000) or better certified Cleanroom spaces. These projects should be equal to or greater than this project's Cleanroom scope of work and include materials and systems of similar design and installation. Include documented experience for monitoring a cleanroom protocol program for all subcontractors working within the clean zone, including subcontractors not working directly for the cleanroom subcontractor. Include documented experience for academic and research University Cleanroom projects of equal or greater scope.
- C. Include a list of all ISO Class 6 (FS Class 1,000) or better certified Cleanroom spaces constructed within the last five (5) years or currently under construction. List should include size of filtered clean area, ISO classification, General Contractor, and Owner contact information. List should include the job title, place of performance, and the General Contractor's project manager's name, address and phone number; Owner's company name, address, name of person to be contacted and phone number.

## **1.9 WARRANTY**

- A. Provide warranties in accordance with Division 1 requirements.
- B. One (1) year limited standard warranty against defects.

## **1.10 QUALITY ASSURANCE**

- A. Deliver materials in good condition to the jobsite in the manufacturer's original unopened containers that bear the name and brand of the manufacturer, project identification, and shipping and handling instructions.
- B. Provide temporary protection of flooring, wall, and ceiling surfaces following installation as required during subsequent construction work and activities. Materials used for protection shall be suitable for Cleanroom spaces and shall not generate particulates.

## **1.11 ENVIRONMENTAL CONDITIONS**

- A. Store materials in a clean, dry, enclosed space off the ground, and protected from the weather and from extremes of heat and cold. Protect adhesives and gels from freezing. Store flooring, adhesives and accessories in the spaces where they will be installed for at least 48 hours before beginning installation.
- B. Maintain a minimum temperature in the spaces to receive the flooring and accessories of 65°F (18°C) and a maximum temperature of 100°F (38°C) for at least 48 hours before, during, and for not less than 48 hours after installation or as otherwise specified by

the flooring manufacturer. Thereafter, maintain a minimum temperature of 55°F (13°C) or as otherwise specified by the flooring manufacturer in areas where work is completed. Protect all materials from the direct flow of heat from hot-air registers, radiators, or other heating fixtures and appliances.

- C. Install flooring and accessories after the other finishing operations, including painting, have been completed. Close spaces to traffic during the installation of the flooring. Do not install flooring over concrete slabs until they are sufficiently dry to achieve a bond with the adhesive, in accordance with the manufacturer's recommended bond and moisture tests.

## **PART 2 PRODUCTS**

### **2.1 CLEANROOM INSTALLATION CONTRACTORS**

- A. Contractors: Subject to compliance with requirements, provide products and services by one of the following:
  1. AdvanceTEC, Inc.
  2. Daw Technologies
  3. FH Chase, Inc.
  4. JLC Commercial & Industrial Construction
  5. Performance Contracting, Inc.
  6. Approved equal – Subject to approval by Owner's representative obtained during bidding submittal process and prior to project award.

### **2.2 MATERIALS AND STANDARDS**

- A. Quality of materials and standards of installation not specifically called out in this section of the Specifications shall be as specified for similar items in the following Divisions of the Specifications:
  1. Fire Protection      Division 21
  2. Plumbing              Division 22
  3. HVAC                    Division 23
  4. Electrical                Division 26

### **2.3 CLEANROOM CONSTRUCTION SEALANT**

- A. Manufacturers: Products complying with this specification may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.
  1. Sikaflex.
  2. General Electric.
  3. Approved equal.
- B. Basis of Design: Sikaflex-1a Polyurethane sealant
- C. Materials:
  1. Polyurethane Sealant: One-component, gun grade, polyurethane-base material. It shall be applicable in the horizontal, vertical, and overhead joints. The

sealant shall cure under the influence of atmospheric moisture to form an elastomeric substance.

2. Any primers as required and recommended by the manufacturer.
3. Backer rod or bond breaker tape as required and recommended by the manufacturer.

**D. Performance:**

1. Properties of the uncured polyurethane sealant:
  - a. Initial Cure (Tack-Free Time): TT-S-00230C - 4 hours.
  - b. Final Cure 4 – 7 days
  - c. Consistency: non-sag.
  - d. Color: Architectural standard colors.
2. Properties of the cured polyurethane sealant:
  - a. Tensile Stress: 175-psi min.(1.37 MPa).
  - b. Elongation at Break: 550%.
  - c. Modulus of Elasticity:
    - 1). 25%: 35 psi (0.24 MPa).
    - 2). 50%: 60 psi (0.41 MPa)
    - 3). 100%: 85 psi (0.59 MPa)
  - d. Shore A Hardness (ASTM D-2240) at 21 days: 40+/- 5.
  - e. Tear Strength (ASTM D-624) at 21 days: 55 lb./in.
  - f. Adhesion in Peel (TT-S-00230C, ASTM C 794):
    - 1). Concrete: 20-lb. min. - 0% Adhesion Loss.
    - 2). Aluminum: 20-lb. min. – 0% Adhesion Loss.
    - 3). Glass: 20-lb. min. – 0% Adhesion Loss.
  - g. Service Range: -40o to 170oF (-400 to 77 0 C).
  - h. The sealant shall conform to Federal Specification TT-S-00230C, Type II, Class A.
  - i. The sealant shall conform to ASTM C-920, Type S, Grade NS, Class 35.
  - j. The sealant must comply with ANSI Standard 61(NSF Approval) for use in contact with potable water.
  - k. The sealant shall be non-staining.

**E. Installation:**

1. Surface Preparation: The joint and adjacent substrate must be clean, dry, sound and free of surface contaminants. Remove all traces of the old sealant, dust, laitance, grease, oils, curing compounds, form release agents and foreign particles by mechanical means. Blow joint free of dust using compressed air line equipped with an oil trap.
2. Mixing and Application: Per manufacturer's procedures.

**2.4 GOWNING BENCH**

- A. Manufacturers: Products complying with this specification may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.
1. Eagle Group, 100 Industrial Boulevard, Clayton, DE 19938-8902, USA; Tel: 302-653-3000; www.eaglegrp.com.
  2. Terra Universal Inc., 700-T N. Harbor Blvd., Anaheim, CA 92805, USA; Tel: 1 800 767-0100.
  3. Innotech Products Inc., Minneapolis, MN 55414, USA.

4. Approved equal.
- B. Description: Solid-top gowning bench.
- C. Product characteristics:
1. Dimensions: 12-inch wide x 72-inch length x 17-inch tall nominal.
  2. Finish: All stainless steel construction.
  3. Tops: Front and rear rolled edge with ends turned down 90-deg. 14-gauge type 304 stainless steel with stainless steel channels running underside for added stability.
  4. Legs: 16-gauge type 304 stainless steel. Provide six (6) legs for benches 72-inch and longer. Legs shall be joined by stainless steel front-to-back crossbracing. Legs to be recessed in gussets that are jointed to channels that run underside of top.

## 2.5 CLEANROOM GOWNING RACK

- A. Manufacturers: Products complying with this specification may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.
1. Eagle Group, 100 Industrial Boulevard, Clayton, DE 19938-8902, USA; Tel: 302-653-3000; www.eaglegrp.com.
  2. Terra Universal Inc., 700-T N. Harbor Blvd., Anaheim, CA 92805, USA; Tel: 1 800 767-0100.
  3. Innotech Products Inc., Minneapolis, MN 55414, USA.
  4. Approved equal.
- B. Description: Cantilever gowning rack with non-removable sliding hangers.
- C. Product characteristics:
1. Dimensions: 24-inch wide x 72-inch length x 76-inch tall nominal.
  2. Finish: All stainless steel construction. Provide #4 satin finish.
  3. Vertical Supports: Constructed of heavy gauge 304 stainless steel tubing, fully welded, ground, and polished. Provide four (4) adjustable feet constructed to dissipate a static charge.
  4. Horizontal Supports: Bolted to vertical uprights using stainless steel bolts. Constructed 304 stainless steel tubing with heavy gauge stainless steel backing plate. The bolts shall be covered with a stainless steel cap to eliminate any crevasses in which dust might settle.
  5. Hanger Rail: 1-inch diameter constructed of heavy gauge 304 stainless. Designed for sliding closed-loop hangers.
  6. Hangers: Provide single piece ¼-inch diameter 304 stainless steel closed loop stainless steel hangers with #4 satin finish.
    - a. Provide 50 hangers for 72-inch length unit.

## 2.6 CLEANROOM WIRE SHELVING

- A. Manufacturers: Products complying with this specification may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.

1. Eagle Group, 100 Industrial Boulevard, Clayton, DE 19938-8902, USA; Tel: 302-653-3000; www.eaglegrp.com.
  2. Terra Universal Inc., 700-T N. Harbor Blvd., Anaheim, CA 92805, USA; Tel: 1 800 767-0100.
  3. Innotech Products Inc., Minneapolis, MN 55414, USA.
  4. Approved equal.
- B. Description: Truss design adjustable open-wire shelving with posts.
- C. Product characteristics:
1. Dimensions:
    - a. 18-inch wide x 36-inch length x 74-inch tall nominal.
    - b. 18-inch wide x 48-inch length x 74-inch tall nominal.
    - c. 24-inch wide x 48-inch length x 74-inch tall nominal.
  2. Finish: Chrome.
  3. Shelves: Open-wire truss construction, chrome plated steel. Provide four (4) shelves.
  4. Posts: Numerically calibrated grooved posts with tapered split ABS plastic sleeves, chrome plated steel. Provide leveling feet.

## 2.7 CLEANROOM MIRROR

- A. Manufacturers: Products complying with this specification may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.
1. Terra Universal Inc., 700-T N. Harbor Blvd., Anaheim, CA 92805, USA; Tel: 1 800 767-0100.
  2. Innotech Products Inc., Minneapolis, MN 55414, USA.
  3. Approved equal.
- B. Description: Wall-mounted stainless steel frame plate-glass mirror.
- C. Product characteristics:
1. Dimensions:
    - a. 24-inch wide x 72-inch tall nominal.
    - b. 36-inch wide x 72-inch tall nominal.
  2. Frame: Low-profile electropolished stainless steel.

## 2.8 CLEANROOM INTERCOM SYSTEM

- A. Manufacturers: Products complying with this specification may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.
1. Aiphone Corporation, 1700 130<sup>th</sup> Ave NE, Bellevue, WA 98005, USA; Tel 800—692-0200; www.aiphone.com
  2. Approved equal.
- B. Basis of Design: Aiphone AN-8000 series.
- C. Description: IP network compatible communication system.

- D. General: The contractor shall furnish and install a network-based Intercommunication System. The system shall be microprocessor controlled, and the operating system (software) shall be stored in EPROM memory. All user-programmable functions shall be stored in nonvolatile memory. System programming shall be accessible by the contractor, or the end user, to allow restructuring of the system as necessary. System programming shall be accessible from a Windows PC computer on the same Ethernet network as the intercom exchange, running supplied dedicated setup software.
- E. Features:
1. Automatic Line Release: The system shall release the speech path if dialing is not completed within five seconds.
  2. Push to Talk; Release to Listen.
  3. Microphone Mute.
  4. Single Digit Dialing: A station shall have the ability to dial up to 20 digits by the touch of one button. The user shall be able to program these at each station.
  5. Redial.
  6. Recall: A station shall be able to redial the last unit it conversed with by pressing a designated key
  7. Ambient Noise Control: A station shall be able to automatically adjust its voice switching threshold to compensate for ambient noise.
  8. Paging and Response: The system programming shall allow stations to be grouped into paging zones.
  9. Programmable Station Numbers: Station dialing numbers shall be programmable. Any number having the pre-selected number of digits (26), and not duplicated in the system, shall be useable.
- F. Components:
1. Exchange Unit: The Exchange Unit shall store and execute the system operating instructions, perform all call routing and power distribution functions for the connected stations and shall include an Ethernet/IP interface for connection to a standard 10BASE-T/100BASE-TX LAN or WAN network. The Exchange Unit shall also provide two paging audio outputs and two paging control outputs. Connection of each station shall be via one twisted pair cable terminated with supplied mini-clamp connector. Connection to the network shall be via standard CAT5 cable terminated with RJ-45 connector. Connection of paging audio and paging control outputs shall be via standard audio (shielded) and control (unshielded) cabling terminated with 4-pin removable terminal blocks. Connection to 120V AC power source shall be via removable IEC type Universal Power Cord. The Exchange Unit shall mount in a standard 19" equipment rack and occupy one vertical rack space (1.75").
  2. Door Station: The IP Door Station shall incorporate a 10BASE-T/100BASE-TX network interface allowing intercom operation via a local area or wide area IP network and shall support Power-over-Ethernet (PoE) technology. The IP Door Station shall provide a call switch and an in-use LED, and shall be capable of hands-free full-duplex communication with other stations through a built-in speaker and condenser microphone. The IP Door Station shall provide an open collector output for use in controlling a door-opening relay or other external equipment. Power supply to the IP Door Station shall be via Power-over-Ethernet (PoE) -capable switching hub or external AC adaptor. The IP Door Station faceplate shall be brushed stainless steel, #11 gauge and shall mount to a standard three-gang enclosure. Pressing and releasing the call



- button shall initiate call-in to a pre-programmed Master Station or Master Station Group. Microphone sensitivity, speaker volume, calling tone volume, and open-collector output duration shall be software-adjustable
3. Master Station: The Flush-Mount Master Station shall connect to the exchange unit via one unshielded twisted pair (UTP) cable. The Flush-Mount Master Station shall mount in a standard 5-gang electrical box and shall be splash and dust resistant. This station shall be capable of hands-free full-duplex communication with all other intercom stations through a built-in speaker and condenser microphone. The Flush-Mount Master Station shall be equipped with an in-use LED, 20 operating keys, a 2.25" speaker, and remote control connections for keys 7, 8, 9, and C to enable one-touch dialing of pre-assigned stations and call cancellation using a remote momentary-contact switch. Microphone sensitivity, speaker volume, and calling tone volume shall be software-adjustable. Speaker volume shall also be adjustable at the station. The station shall incorporate a stainless steel front panel, with a splash-proof key pad and speaker.

G. Installation:

1. Communication Wiring: All communication wiring shall be UL listed and rated for plenum use. Wiring shall be in dedicated EMT conduit or shared cable tray.
2. Exchange Unit: Provide standard floor mounted, 4-post, 19-inch equipment rack, 84-inch height, black color.

## 2.9 CLEANROOM FIRE EXTINGUISHER

A. Fire Extinguisher Box:

1. Manufacturers: Products complying with this specification may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.
  - a. Amerex.
  - b. ANSUL
  - c. Badger
  - d. Larsen's Manufacturing Company
  - e. Approved equal.
2. Basis of Design: Larsen's Cameo series fire extinguisher cabinet.
3. Description: Recessed and surface mount fire extinguisher box with clear protruding bubble door for 180 degree visibility of extinguisher.
4. Box: Heavy gauge steel cabinet with white baked enamel finish.
  - a. Dimensions:
    - 1). Recessed: 32-inch height x 16-inch width x 3.5-inch depth.
    - 2). Surface Mount: 35.5-inch height x 19.5-inch width x 3-1/2-inch depth.
5. Door: Clear plastic bubble with 304 stainless steel door frame and trim with #4 finish, 1/2-inch thick, hollow-metal design. Stainless steel pull handle with self-adjusting roller catch and a continuous piano hinge. Provide vertical red lettering "FIRE EXTINGUISHER" on bubble.

B. Fire Extinguisher:

1. Manufacturers: Products complying with this specification may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.

- a. Amerex.
  - b. ANSUL
  - c. Badger
  - d. Larsen's Manufacturing Company
  - e. Approved equal.
2. Description: ANSI/UL listed 10-lb CO2 fire extinguisher, aluminum cylinder, 7-inch diameter, with mounting bracket. Sized to match box housing.

## **PART 3 EXECUTION**

### **3.1 JOB CONDITIONS**

- A. The General Contractor shall provide the shell space and an adjacent staging area in vacuum clean and wiped down condition and shall assist in maintaining the conditions necessary for the performance of the work in this area.
- B. Check project for conditions that affect work. Do not begin installation until unsatisfactory conditions are corrected. Defects caused by unsatisfactory conditions or untimely installation shall be corrected at no cost to University's Representative.
- C. The Cleanroom Contractor shall coordinate with sprinkler systems work for pipe penetrations and sprinkler head locations.
- D. The Cleanroom Contractor shall coordinate with cable tray, fire alarm communications, telephone, clock, and data systems, and other work for ceiling, wall, or floor penetrations.
- E. The Cleanroom Contractor shall coordinate other work performed within the cleanroom area as required to safeguard the cleanliness of the cleanroom area.

### **3.2 INSTALLATION PROCEDURE FOR HEPA FILTER MODULES**

- A. When installing HEPA filter modules, all airflow dampers shall be fully open prior to balancing. Airflow balancing shall then be initiated by first reducing flow (by use of damper) of filter module units having higher than normal flows. Throttling of these flows will cause an increase in flow through those units having lower than normal flows.
- B. Balancing of a complete room of HEPA Filter Modules shall be accomplished in the following manner:
  1. Set up designed fan speeds.
  2. Balance airflows through filter module units as described. It is recommended that airflow measurement from unit be taken in at least eight (8) points approximately 1 inch (25 mm) from filter face. Once these point positions are determined, each unit is to be measured in same manner. Because of local variations in velocities through filter media, a vane type unit is recommended. It covers a larger area, and hence, provides a more comprehensive reading. The intention is to gain relative balance between units at the point, not gain absolute data.

### **3.3 INSTALLATION OF UTILITIES**

- A. The Cleanroom Contractor shall supervise protocol compliance during the installation of all mechanical, electrical, furnishings, and equipment in space above floor in all rooms designated as clean spaces.
- B. The Cleanroom Contractor shall be responsible for making and sealing all penetrations to Cleanroom walls, ceilings, and floors. All electrical and utility wall or ceiling boxes at clean room boundaries shall be sealed back type.
- C. Division 11, 13, 22, 23 and 26 and the Cleanroom Contractor shall coordinate location of furnishings, equipment, mechanical, electrical, and cleanroom equipment prior to construction to eliminate any interferences.
- D. Panelboards, including circuit breakers, wireways, and pull boxes above cleanrooms shall be

**END OF SECTION 13 2100CR**



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## SECTION 13 2101CR – CLEANROOM PERFORMANCE TESTING

### PART 1 GENERAL

#### 1.1 SUMMARY

- A. This specification details the requirements for Cleanroom Performance Testing (CPT) by an NEBB certified Cleanroom certification agency to measure and record Cleanroom environmental conditions and document Testing, Adjusting, and Balancing (TAB) condition of primary and secondary HVAC air systems serving the Cleanroom facility.
- B. Drawings and general provisions of the Contract, and Division 1 Sections apply to work of this Section.

#### 1.2 REFERENCES

- A. International Standards Organization (ISO): Air cleanliness classification for cleanrooms and definition of terms for cleanroom work shall be in accordance with ISO 14644 Class 4, 5 and 6 (Formerly Class 10, 100 and 1,000).
- B. National Environmental Balancing Bureau (NEBB): Current edition of the NEBB *Procedural Standards for Certified Testing of Cleanrooms (NEBB-PSCPT)*. This specification section contains multiple references to this acronym. When used or referenced in this specification, NEBB-PSCPT, is meant to identify the current publication and /or various sections, tables, equations, charts from the current publication.

#### 1.3 RELATED DOCUMENTS

- A. General and Supplementary Conditions and Division 1
- B. Section 13 2100CR – Cleanroom Construction
- C. Section 13 2105CR – Cleanroom Construction Protocol
- D. Section 13 2110CR – Cleanroom Ceiling System
- E. Section 13 2120CR – Cleanroom Wall System
- F. Section 13 2130CR – Cleanroom Automatic Sliding Doors
- G. Section 13 2140CR – Cleanroom Chemical Fume Hood and Wet Processing Stations
- H. Division 21: Fire Suppression
- I. Division 22: Plumbing
- J. Division 23: HVAC

- K. Division 25: Cleanroom Controls
- L. Division 26: Electrical

#### 1.4 DEFINITIONS

- A. Clean Zone: A defined area, including the cleanroom and adjacent spaces that are exposed to the cleanroom supply and return airstreams.
- B. CPT: Cleanroom Performance Testing.
- C. HEPA Filter: High efficiency particulate air filter.
- D. NEBB: National Environmental Balancing Bureau.
- E. CPT Technician: The person(s) vested with authority by the CPT agency to perform all CPT testing and documentation within the Clean Zone.
- F. CPT Supervisor: The person vested with authority by the CPT agency to supervise all CPT testing and documentation within the Clean Zone and ensure requirements of the contract documents are met in completion of the CPT activities.
- G. ULPA Filter: Ultra-High efficiency particulate air filter.

#### 1.5 PERFORMANCE REQUIREMENTS

- A. Clean spaces are classified according to ISO 14644. Verification of room and air cleanliness shall be by measurement of the concentration of airborne particles at or above the size limits given below.
- B. Classified spaces shall be as follows:
  - 1. Refer to project drawings.
- C. Airborne particulate cleanliness classification:
  - 1. ISO Class 4 (formally Fed Std 209E Class 100); as-built; 0.1  $\mu\text{m}$  (10,000 particles/ $\text{m}^3$ ), 0.2  $\mu\text{m}$  (2,370 particles/ $\text{m}^3$ ), 0.3  $\mu\text{m}$  (1,020 particles/ $\text{m}^3$ ), 0.5  $\mu\text{m}$  (352 particles/ $\text{m}^3$ ), 1.0  $\mu\text{m}$  (83 particles/ $\text{m}^3$ ).
  - 2. ISO Class 5 (formally Fed Std 209E Class 100); as-built; 0.1  $\mu\text{m}$  (100,000 particles/ $\text{m}^3$ ), 0.2  $\mu\text{m}$  (23,700 particles/ $\text{m}^3$ ), 0.3  $\mu\text{m}$  (10,000 particles/ $\text{m}^3$ ), 0.5  $\mu\text{m}$  (3,520 particles/ $\text{m}^3$ ), 1.0  $\mu\text{m}$  (832 particles/ $\text{m}^3$ ), 5.0  $\mu\text{m}$  (29 particles/ $\text{m}^3$ ).
  - 3. ISO Class 6 (formally Fed Std 209E Class 1,000); as-built; 0.1  $\mu\text{m}$  (1,000,000 particles/ $\text{m}^3$ ), 0.2  $\mu\text{m}$  (237,000 particles/ $\text{m}^3$ ), 0.3  $\mu\text{m}$  (102,000 particles/ $\text{m}^3$ ), 0.5  $\mu\text{m}$  (35,200 particles/ $\text{m}^3$ ), 1.0  $\mu\text{m}$  (8,320 particles/ $\text{m}^3$ ), 5.0  $\mu\text{m}$  (293 particles/ $\text{m}^3$ ).
- D. Particle count within room space shall not exceed limits for above mentioned classifications as defined by ISO Class 4 – 6 throughout room at an elevation of 760 mm (30 inches) above floor level.
- E. Levels of cleanliness apply while Cleanroom is at an “At Rest” condition.

- F. Cleanroom spaces shall be tested and certified to one ISO Class lower than intended design classification for as-built conditions with all furnishings installed and equipment operational (i.e. hoods, etc...).

## 1.6 DESIGN REQUIREMENTS

- A. Environmental:
1. Clean Bays:
    - a. Room Temperature:  $68^{\circ}\text{F} \pm 0.18^{\circ}\text{F}$ .
    - b. Room Relative Humidity:  $45\% \pm 2\%$ .
  2. Gowning:
    - a. Room Temperature:  $68^{\circ}\text{F} \pm 1^{\circ}\text{F}$ .
    - b. Room Relative Humidity: not controlled – resultant of Clean Bay humidity control.
- B. Room Pressure and Leakage:
1. Overall leakage rate of entire room and air handling system should not exceed 3 percent of total air supply with all doors closed and room in occupied condition. Positive pressure shall be sustained in operational Cleanroom spaces in accordance with the Drawings and with all equipment operating at design capacity.

<u>Cleanliness Class</u>	<u>Positive Pressure (leakage)</u>
ISO 5 (FS Class 100)	0.5 percent to 1 percent
ISO 6 (FS Class 1,000)	1 percent to 2 percent
ISO 7 (FS Class 10,000)	2 percent to 3 percent
  2. When an entry door is opened, outward airflow shall be maintained. Special attention shall be directed to ensure an airtight enclosure by caulking, including fan housings, ductwork, etc., to minimize air leakage.
- C. Lighting Intensity:
1. Lighting installation shall be meet a minimum of 100 foot-candles sustained light intensity as measured at height of 760 mm (30 inches) above floor.
  2. Lighting fixtures shall be mounted so as to not disturb airflow patterns.
  3. Lighting fixtures shall be located so as to not conflict with equipment layout as shown on Cleanroom drawings.
- D. Sound Level:
1. Unoccupied Conditions: Sound level within the Cleanroom spaces shall not exceed (NC60) curve as determined by octave band analysis at height of 1830 mm (72 inches) above floor.

## 1.7 SUBMITTALS

- A. Submit the following prior to start of work:
1. Qualification of the NEBB certified Cleanroom Performance Testing firm.
  2. Qualification of the CPT agency project specific staff members.
  3. Testing procedures for certification of each performance parameters.
  4. Testing apparatus instrumentation and equipment including certificates of current calibration during the testing process.

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5. Samples of each test report.
- B. Submit the following certified items within ten (10) working days following completion of work:
1. Provide a single collated test report with all items.
  2. Preliminary test reports for each CPT parameter.
  3. Copy of working field notes or logs to document project specific tasks.
  4. Procedural instructions which may affect operational certification results.
- C. Submit the final NEBB Certified CTP Report within thirty (30) working days after completion of all field activities. Include the following (minimum requirements):
1. Typed, hand-written or computerized field reports, charts, and forms complete with measured data referenced to sample location.
  2. Written description of operating condition of each cleanroom.
  3. Reduced set of architectural floor plan drawings, maximum size 11-by-17 inches, made from the project CADD Contract Documents, obtained from the Owner, showing test and sample locations referred to on other field data sheets.
  4. Separate narrative section outlining any operating or anomalies at the end of the testing procedures.
  5. A list of instrumentation and test equipment used in the certifying process, including manufacturer, model and serial numbers, and NIST-traceable calibration certificate.
  6. Written description of tests performed, including the purpose, instrumentation, procedure, results, date tests were taken, names of field technicians performing the tests, and analysis of the data. Present data in tabular form and display graphically to permit full understanding of the tests.
  7. Electronic copies of the Final NEBB Certified CPT Report shall be submitted in PDF format.
  8. A narrative outline with recommendations relating to test results and operating conditions of each area tested.
  9. A statement that cleanroom testing was performed in accordance with the NEBB Procedural Standards for Certified Testing of Cleanrooms.
  10. Provide one hard-bound copy and one unbound reproducible copy of the Final NEBB Certified CPT Report for the Owner's use.

## 1.8 QUALITY ASSURANCE

- A. Cleanroom Performance Testing (CTP) Agency Qualifications:
1. In addition to the General Standards and as a condition of award, special standards must be met by the Cleanroom CPT agency to demonstrate that the bidder possesses certain expertise that has been determined essential for adequate contract performance.
  2. The following will be required of the bidding contractors prior to award: A list of at least five (5) projects, completed within the last five (5) years, which included construction, testing, and certification of ISO Class 5 (FS Class 1,000) or better certified Cleanroom spaces. These projects should be equal to or greater than this project's Cleanroom scope of work. Include documented experience for academic and research University Cleanroom projects of equal or greater scope.



3. Include a list of all ISO Class 6 (FS Class 1,000) or better certified Cleanroom spaces tested and certified within the last five (5) years or currently under construction. List should include size of filtered clean area, ISO classification, General Contractor, and Owner contact information. List should include the job title, place of performance, and the General Contractor's project manager's name, address and phone number; Owner's company name, address, name of person to be contacted and phone number.
- B. CPT Supervisor Qualifications:
    1. The supervisor shall be current, qualified and in good standing with the National Environmental Balancing Bureau (NEBB) and employed by the NEBB Certified CPT Firm.
  - C. CPT Technician Qualifications:
    1. Completed previous training in cleanroom operations and certifying procedures.
    2. Thorough, demonstrable knowledge of test procedures and equipment.
  - D. Equipment Calibration:
    1. Traceable by serial number to the National Institute for Standards and Technology (NIST) in accordance with the current edition of the NEBB CPT Procedural Standard.
    2. Calibrate test equipment that requires calibration within the project work schedule, prior to any testing with the instrument.
  - E. Testing Procedures:
    1. The reference standards for field tests and project record documents shall be in accordance with the current edition of the NEBB *Procedural Standards for Certified Testing of Cleanrooms*.
    2. Measurement sampling based upon accepted NEBB sampling and statistical procedures.

## 1.9 WARRANTY

- A. Provide warranties in accordance with Division 1 requirements.

## 1.10 COORDINATION

- A. Jobsite visits: Provide at least two (2) jobsite visits by the CPT Supervisor during strategic construction phases for the period that the finished cleanroom envelope is being constructed.
- B. Schedule work activities with the Owner and the General Contractor/Construction Manager. Schedule may require that crucial tests be completed in an alternate sequence to allow selective partial occupancy.

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## **PART 2 PRODUCTS**

### **2.1 CLEANROOM PERFORMANCE TESTING (CPT) AGENCY CONTRACTORS**

- A. Contractors: Subject to compliance with requirements, provide products and services by one of the following:
1. Air Filtration Management, Inc.; Tel: (610) 867-3869; [www.airfiltrationmgmt.com](http://www.airfiltrationmgmt.com)
  2. BTC Services; Tel: (801) 974-5911.
  3. CCS Inc.; Tel: (401) 765-5743; [www.cleanroomcerts.com](http://www.cleanroomcerts.com)
  4. ENV Services; Tel: (800) 345-6094; [www.envservices.com](http://www.envservices.com)
  5. Pentagon Technologies; Tel: (480) 497-6880; [www.pen-tec.com](http://www.pen-tec.com)
  6. Approved equal – Subject to approval by Owner's representative obtained during bidding submittal process and prior to project award.

## **PART 3 EXECUTION**

### **3.1 INSPECTION**

- A. NEBB CPT Firm and the NEBB CPT Supervisor shall be responsible to inspect the facility to verify that the construction of the cleanroom spaces shall be in a condition ready for the specified test occupancy state. Inspection should include, but not limited to, the following items:
1. Building perimeter walls, roof, and accessories installed to create a pressurized envelope around the cleanroom.
  2. Cleanroom perimeter walls, ceiling, raised floor panels, doors, and necessary interior partitions installed that are essential to successful system performance. If approved by the Construction Manager or Owner, use temporary barriers for area isolation.
  3. Permanent personnel gowning area in operation.
  4. Final wipe down cleaning procedures complete on:
    - a. Cleanroom finished surfaces.
    - b. HVAC system ducts, plenums, and air handler surfaces exposed to airflow.
    - c. Wall and floor cavities used as part of the cleanroom air handling strategy.
    - d. Building structural elements and utility systems in contact with the cleanroom airstream.
  5. Tool hookup or miscellaneous construction activities curtailed in the test area.
- B. NEBB CPT Firm and the NEBB CPT Supervisor shall be responsible to inspect the facility to verify that the building environmental systems shall be fully operational, under control and commissioned and shall be in a condition ready for the specified test occupancy state. Inspection should include, but not limited to, the following items:
1. Air-handling systems serving the cleanroom installed and operating under automatic controls and fully commissioned.
  2. Testing, adjusting and balancing complete for both the air and the hydronic systems serving the cleanroom air-handling systems.
  3. Process exhaust systems and pressurization control fans installed and operating to simulate cleanroom pressurization.
  4. Cleanroom lights, sprinklers, and safety devices installed and operational.

5. Housekeeping vacuum system operational.
6. support systems required to perform certification tests operating normally for a minimum stable period of 5 days.

### **3.2 PREPARATIONS**

- A. Confirm that activities within the facility comply with the requirements of the specified cleanroom occupancy test state.
- B. Inspect the entire cleanroom, accompanied by the Construction Manager or Owner, and note existing conditions that could jeopardize the certification results. Obtain the Construction Manager or Owner's written release before proceeding with certification steps.
- C. Coordinate field certification activities with the Construction Manager or Owner to permit observation of any test procedure.

### **3.3 TESTING GENERAL REQUIREMENTS**

- A. The testing, balancing, adjusting and performance verification of the air distribution in the Cleanrooms shall include, but is not limited to:
  1. As-Built Facility Test and Balance.
  2. At-Rest Facility Performance Acceptance tests.
- B. All tests shall be conducted by a NEBB certified and competent technician.
  1. The technician shall have a minimum of two (2) years of service devoted to the test, balance and performance verification of Cleanroom facilities.
  2. Provide all instruments, lubricants, test equipment, material and labor required for the tests.
  3. The tests shall be started only after the Cleanroom Contractor has completed the initial operating and balancing adjustments. The General Contractor shall review the pretest check list.
  4. The As-Built Facility testing shall be conducted under the direct supervision of the Cleanroom Contractor.
  5. The At-Rest Facility Performance Acceptance Test shall be conducted by the Cleanroom Contractor. Tests shall be performed and the results witnessed and confirmed by the Owner's representative prior to final acceptance of the Cleanroom systems.
- C. Instrumentation shall be in accordance with the description given in each test procedure, and shall have a demonstrated accuracy and sensitivity suitable for the test procedure. All instruments shall be calibrated according to the manufacturer's recommendation and/or accepted industry practice. Owner's representative may require the calibration of any instrument prior to test and balance.
- D. Instrumentation shall include, but is not limited to:
  1. Particle Counter (ASTM F50-68).
  2. Inclined manometer.
  3. Electronic direct reading anemometer.
  4. Direct reading flowhood.
  5. Alnor velometer.

6. Direct readout tachometer.
7. Clip-on ampmeter/voltmeter.
8. Thermometers (dry bulb and wet bulb).
9. Pressure gauges.
10. Pitot tubes.
11. Photo-electric illumination meter.
12. Sound level meter.
13. Accelerometers, transducers for vibration.
14. Vibration meter.
15. Magnetic field meter and sensor(s).

E. The following tests shall be performed:

CLEANROOM TEST & CERTIFICATION												
Room	Design Class	Test/Cert Class (As-Built)	Airflow Velocity, Volume, Uniformity (Filter Face & Room)	Filter / Grid Leak Test	Airborne Particle Counts / Class (.1 & .5 um Particles)	Pressure	Parallelism	Light Level	Sound Level	Temp / Humid	EMI	Floor Vibration
Gowning	ISO 7 (10,000)	ISO 6 (1,000)	X	X	X	X		X	X	X		
Nano-Bio	ISO 6 (1,000)	ISO 5 (100)	X	X	X	X		X	X	X	X	X
Etch	ISO 6 (1,000)	ISO 5 (100)	X	X	X	X		X	X	X	X	X
Thin Film	ISO 6 (1,000)	ISO 5 (100)	X	X	X	X		X	X	X	X	X
Optical Litho	ISO 5 (100)	ISO 4 (10)	X	X	X	X	X	X	X	X	X	X
Nano Litho	ISO 5 (100)	ISO 4 (10)	X	X	X	X	X	X	X	X	X	X
Service Chases	NA	NA				X		X				

### 3.4 BALANCING PRIMARY AIR SYSTEMS (BY DIVISION 23)

- A. Adjust and balance air handling systems for design quantities. Conduct balancing with filters in place and all automatic control devices and dampers operative and adjusted.
- B. Adjust fan speed within the limits of the adjustable sheaves and motor horsepower to the required output.
- C. Balance main and branch air quantities using a velocity traverse with pitot tube. Following balancing of duct system, take readings at each outlet and record.
- D. All required exhaust fans operational.

- E. Balance all systems to design values plus or minus 5 percent.

### **3.5 PRIMARY AIR SYSTEMS TEST DATA (BY DIVISION 23)**

- A. Fan Data:
1. Manufacturer name and model number.
  2. Design airflow rate.
  3. Actual airflow rate.
  4. Design speed.
  5. Actual speed.
  6. Motor name, rated amps, KW, RPM, voltage.
  7. Inlet and discharge static pressure.
  8. Motor amps.
  9. Motor starter heater size.
- B. Air Outlet Data:
1. Outlet size.
  2. Actual free area.
  3. Manufacturer's test factor.
  4. Measured average velocity.
  5. Design airflow rate.
  6. Measured airflow rate.
  7. Airflow rate percentage above or below design.
- C. Makeup Air Intake Data:
1. Size of inlet.
  2. Actual free area.
  3. Measured average velocity.
  4. Makeup air temperature.

### **3.6 AIR VELOCITY AND AIRFLOW UNIFORMITY (BY CPT AGENCY)**

- A. Apparatus
1. Electronic direct-reading anemometer or direct-reading airflow rate flowhood.
- B. Procedure:
1. Airflow through each individual HEPA filter shall be determined by either velocity or airflow rate measurement. Each measurement will be recorded.
  2. Velocity measurements will be an average of several readings taken 100 mm to 150 mm (4 inches to 6 inches) from filter face.
  3. Filter module dampers, return air registers and perforated floor panels will be adjusted to provide proper airflow and room pressure.
- C. Acceptance:
1. The measured airflows shall be within the range specified based on the projected floor area. A minimum of 80 percent of the measurements shall be within 20 percent of the average measurement, and the remaining measurements shall be within 30 percent of the average airflow requirements.
  2. ISO 5 Areas: Allowable deviation for all filters shall be <10% of the average measurement of the room.

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### **3.7 AIR CLEANLINESS LEVEL (BY CPT AGENCY)**

- A. Apparatus: Particle counter.
- B. Procedure:
  - 1. Air cleanliness will be tested according to the procedures established by ISO Class 5 and 6.
  - 2. A monitoring plan, described in ISO 14644-1 will be submitted for approval by Owner representative before air cleanliness testing is performed.
- C. Acceptance: The air cleanliness level must meet the acceptance criteria established by ISO Class 5 and 6.

### **3.8 LIGHT LEVELS (BY CPT AGENCY)**

- A. Apparatus: Photo-electric illumination meter.
- B. Procedure:
  - 1. This test shall be performed during the As-Built facility condition.
  - 2. Divide the work area into 1.5 m by 1.5 m (5 foot by 5 foot) grids. Measurements shall be taken at 760 mm (30 inches) above the floor through the work area.
  - 3. Light level measurements at each location shall be recorded.
- C. Acceptance: Average of all measurements shall be not less than the design requirements.

### **3.9 SOUND LEVEL TEST (BY CPT AGENCY)**

- A. Apparatus: Sound pressure level meter with A-weighted scale.
- B. Procedure:
  - 1. This test shall be performed during the As-Built facility condition.
  - 2. Divide the work area into 3 m by 3 m (10 foot by 10 foot) grids. The audio noise level shall be measured in the center of each grid at 910 mm (36 inches) above the floor throughout the work area.
  - 3. This test shall be performed with all air moving systems off, and then repeated with the entire system on.
  - 4. With the sound meter setting on the A-scale, record the amount of pressure and location of each measurement.
- C. Acceptance: No single measurement shall exceed the maximum level permitted in the design requirements.

### **3.10 ROOM PRESSURE (BY CPT AGENCY)**

- A. Apparatus: Inclined Manometer and Smoke Sticks.
- B. Procedure:
  - 1. With all Cleanroom doors closed, measure and record the pressure differential between the designated areas and the adjoining spaces or exterior ambient.

- C. Acceptance:
  - 1. Pressure differentials with all doors closed shall be maintained to the design conditions schedules.
  - 2. With the doors open, an inward airflow is unacceptable as evidenced by the airflow direction.

### **3.11 TEMPERATURE AND HUMIDITY (BY CPT AGENCY)**

- A. Apparatus:
  - 1. Dry-bulb thermometers.
  - 2. Either relative humidity indicator or wet-bulb thermometer, or electronic digital relative humidity meter.
- B. Procedure:
  - 1. Perform this test after completion of the initial test and balance and the system has been in full operation for at least 4 hours.
  - 2. Temperature and Humidity stability test duration shall be minimum 48-hours.
  - 3. Divide the work area into 3 m by 3 m (10 foot by 10 foot) grids and record each measurement.
  - 4. Each measurement shall utilize a 60 – 120 second sample rate.
  - 5. Electronic meter sensors to be calibrated with standard saturated salt solutions prior to testing, to ensure accuracy.
- C. Acceptance: Average temperature and humidity readings shall satisfy the operating conditions throughout the room as required by the design criteria.

### **3.12 FINAL FILTER/CEILING GRID LEAK TEST (BY CPT AGENCY)**

- A. Apparatus: Particle counter.
- B. Procedure: ISO 14644-3 Annex B6.
- C. Acceptance:
  - 1. Any detectable leak greater than one scale division on the logarithmic scale shall be either repaired or the filter replaced.
  - 2. The extent to which repairs may be made is limited to the area of patching material required. The maximum area of patch allowable shall not exceed 1 percent of filter face area. Any patch area in excess of 1 percent of filter face area shall be rejected and the filter shall be replaced.

### **3.13 AIRFLOW PARALLELISM TEST**

- A. Purpose: Verify parallel vertical flow paths of supply airflow.
- B. Test Procedure:
  - 1. Measure and record the parallel vertical flow path.
  - 2. Divide the cleanroom into equal area grids. The maximum grid spacing shall be 10 ft x 10ft. Perform the test in the middle of each grid.
  - 3. Secure the plumb line, spirit level or straight edge as required, mark the plumb line at 12 inch intervals, the distance from the plumb line to the streamer or vapor is determined at a distance of 36 inches and 60 inches above the floor,

introduce the test medium using a support stand at the specified height. Calculate the angle of deflection.

- C. Acceptance Criteria:
  - 1. The angle of deflection should not be greater than  $14^\circ$  from center when measured higher than 915 mm (36 inches) above the floor.

### 3.14 ELECTROMAGNETIC INTERFERENCE (EMI) TEST

- A. Purpose: To characterize the cleanroom magnetic field environment, specifically with respect to background DC magnetic field stability and nominal levels of AC magnetic fields from the building electric infrastructure (equipment, circuits, end-use devices). The focus of this testing is on Clean Bays 4 and 5 which are designated as low-field based on the e-beam lithography system planned for Clean Bay 5 and possible future use of Clean Bay 4 for additional sensitive instrumentation.
- B. Test Equipment: Instrumentation with three-axis magnetic field sensor that has the capability to record both DC and AC (with a focus on power-frequency and harmonic) magnetic fields, with resolution of 0.05 milligauss DC and 0.02 milligauss AC. Instrumentation should be able to record magnetic field levels over a time period of approximately two hours with sufficient resolution to capture transient events caused by operation of the building elevators, or movement of large vehicles along service roads (at a cadence of at least one reading per second).
- C. Implementation: DC magnetic field tests can be performed when the cleanroom structure/walls are complete, prior to installation of clean room equipment. Building elevators must be operational for the testing. DC measurements should attempt to capture the magnetic field background when large trucks are moving near the building on the north and south service roads. AC magnetic field tests should be performed once the building is operational and main service loading is at approximately 20-25% of design load. Load values from the service equipment metering should be noted during AC testing.
- D. DC Magnetic Field Test Plan: DC magnetic field readings should be recorded for a time period of approximately one hour at each of three locations in Clean Bay 4 and three locations in Clean Bay 5, generally west side, middle, east side. The magnetic field sensor should be set at a height of one meter above floor level and the sensor orientation should be kept consistent for comparison and analysis of changes in horizontal and vertical DC magnetic field levels. Readings should be recorded for a period of approximately one hour at each location and should include movement of large vehicles on the nearest service road and operation of both building elevators.
- E. AC Magnetic Field Test Plan: AC magnetic fields should be mapped over a one-meter grid in Clean Bays 4 and 5 at heights of one and two meters above floor level with lighting and air-handling equipment operating. For reference, spot readings of AC magnetic fields should be recorded at three general locations each in Clean Bays 1, 2, and 3 (west, center, east). Immediately preceding the cleanroom AC measurements, one set of AC readings should be recorded along a profile line from the west edge of the Nano-Physics Building, and passing over the west duct bank located beneath the sidewalk on the east side of Ackerman Hall. This profile is meant to provide an estimate of contribution to AC fields in the clean room.



- F. The above testing is general in nature, more detailed evaluation can be performed at the specific location planned for the e-beam lithography system, or any other identified sensitive instrumentation as required by the equipment manufacturer.
- G. All testing should be coordinate with building facilities personnel to ensure normal operation of elevators for DC magnetic field readings, and sufficient building electric load for AC magnetic field readings. Facilities personnel can assist in obtaining service load (amperes) during the AC testing.
- H. Magnetic field limits: From the installation guide, the e-beam lithography system planned for Clean Bay 5 has requirements of 0.5 mG (p-p) for AC magnetic fields, corresponding to 0.177 mG (rms), and requires a DC stability of 0.5mG as well. Thus, these are the target limits for both Clean Bays 4 and 5. Spot measurements in Clean Bays 1 to 3 are meant to establish a baseline for comparison, and help identify any dominant magnetic field sources, internal or external to the building.
- I. Documentation: Test reports should include a complete description of the measurement equipment, dates and times (recorded field levels are typically time-stamped), personnel performing the tests, all test results, and an evaluation with respect to specifications. Notes should include a description of elevator operation and timing, along with any note movement of large vehicles near the building during DC measurements. AC measurement notes should describe the status of lighting, air-handling, total loading of main service equipment, and status of any other pertinent electric equipment. If magnetic field limits are exceeded, the report should also provide an initial evaluation of the most likely source or sources of the exceedance, and address possible corrections or mitigation approaches.

### 3.15 VIBRATION TEST

- A. Purpose: The purpose of the Vibration Certification is to document the as-built clean room vibration levels to determine the vibration impact of building mechanical systems and other normal building functions on the clean room. The measurements procedures and reporting requirements are an important part of the certification.
- B. Design Intent: The Cleanroom design goal was the VC-E vibration level as defined in Institute of Environmental Sciences and Technology IEST-RP-CC012.2.
- C. Test Procedure:
  - 1. Measurements shall follow recommended practices given in Institute of Environmental Sciences and Technology IEST-RP-CC024.1 titled "Measuring and Reporting Vibration in Microelectronics Facilities."
  - 2. Measurements shall be made at location selected by the Owner in the specified occupancy state.
  - 3. The accelerometers shall be mounted to structural and building support members, floor slabs, equipment bases or other surfaces as directed by the Owner.
  - 4. Measurements shall be made as follows:
    - a. Units of velocity, micro inches per second rms.
    - b. Reported in 1/3rd Octave Bands between 1.25 Hz. and 80 Hz., although additional narrowband measurements may be necessary in some cases.

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- c. Linear averaging, although it may also be necessary to make additional measurements with peak hold averaging.
  - d. Minimum overlap of 75%.
  - e. If the 1/3rd Octave data is synthesized from a narrow band spectrum, the Hanning window shall be used.
5. Additional measurement requirements for specific equipment may be specified by the Owner.
- D. Documentation:
1. Reports shall be provided for the vibration measurements and shall follow the recommended practices given in section 6.4 of IEST-RP-CC024.1. In addition, reports should include the following:
    - a. Engineer's Name
    - b. Test Date(s)
    - c. Instrument Identification
    - d. Test Location Diagram
    - e. Test Data
  2. All performance data that exceeds the acceptance criteria specified by the Owner shall be clearly identified in the report.
  3. Calibration certificates for all test equipment shall be included in the final report.

### **3.16 AT-REST FACILITY PERFORMANCE ACCEPTANCE TEST (BY CPT AGENCY)**

- A. Upon completion of initial testing, balancing and adjusting, and with the Cleanroom complete with all environmental equipment in operation but empty of any production equipment, and with all operating personnel absent, the following tests shall be performed:
1. Light Level.
  2. Sound Level.
  3. Temperature and Humidity.
  4. Room Pressure.
  5. Airflow Uniformity.
  6. Airflow Parallelism.
  7. Air Cleanliness Level.
  8. Final Filter Leak Test.
  9. EMI Levels.
  10. Vibration Levels.

**END OF SECTION 13 2101CR**

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## SECTION 13 2105CR – CLEANROOM CONSTRUCTION PROTOCOL

### PART 1 GENERAL

#### 1.1 SUMMARY

- A. Drawings and general provisions of the Contract, and Division 1 Sections apply to work of this Section.
- B. This section specifies the general requirements for all personnel, components, materials, equipment, tools, and protocol requirements to be utilized in the construction, start-up, commissioning, and certification of the Cleanroom spaces.
- C. The Cleanroom Protocol procedures shall be developed and implemented by a contractor regularly engaged in the business of designing, manufacturing, installing, and certifying cleanrooms.
- D. The manufacturer/installation contractor shall guarantee that the performance of the complete cleanroom will meet all the performance criteria established by this specification.
- E. The cleanroom manufacturer/installation contractor shall provide certification listed herein from a third party source.

#### 1.2 REFERENCES

- A. Air cleanliness classification for cleanrooms and definition of terms for cleanroom work shall be in accordance with ISO Class 5 and 6 (Formerly Class 100 and 1,000). All cleanroom construction shall be in accordance International and Local building codes.

#### 1.3 RELATED DOCUMENTS

- A. Section 11 5343 – Laboratory Fittings and Fixtures
- B. Section 13 2100CR – Cleanroom Construction
- C. Section 13 2110CR – Cleanroom Ceiling System
- D. Section 13 2120CR – Cleanroom Wall System
- E. Section 13 2130CR – Cleanroom Automatic Sliding Doors
- F. Section 13 2140CR – Cleanroom Chemical Fume Hood and Wet Processing Stations
- G. Division 21: Fire Suppression
- H. Division 22: Plumbing
- I. Division 23: HVAC
- J. Division 25: Cleanroom Controls
- K. Division 26: Electrical

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## 1.4 DEFINITIONS

- A. Clean Zone: A defined area, including the cleanroom and adjacent spaces, that is exposed to the cleanroom supply and return airstreams.
- B. HEPA Filter: High efficiency particulate air filter, including ULPA (Ultra-High efficiency particulate air) filters.
- C. Protocol Level: The phase or degree of construction completion that mandates specified activities, training, security clearance, dress, work means and methods, cleaning procedures, and system performance to maintain the cleanliness of the clean zone.
- D. Protocol Manager: The person vested with authority by the Cleanroom Protocol Contractor to supervise all construction personnel working within the Clean Zone and ensure requirements of the contract documents are met in completion of the Clean Zone construction.

## 1.5 SUBMITTALS

- A. Cleanroom Protocol:
  - 1. Written performance and method protocol procedures shall be prepared and submitted by contractor performing tasks and services specified herein. Cleanroom protocol procedures shall include the following items used in the performance of services:
    - a. Manpower, organization, and responsibilities of all members performing work.
    - b. Procedures to be utilized.
    - c. Sequence of construction events and protocol levels.
    - d. Products to be utilized.
    - e. Equipment to be utilized.
  - 2. Written protocol procedures shall be developed for each of the construction protocol levels for the following activities and services:
    - a. Instruction and training material and procedures for clean construction workers.
    - b. Monitoring and enforcement of clean construction protocol.
    - c. Design and use of temporary construction and equipment to maintain clean construction boundary and entry/exit of personnel and equipment to the clean construction boundary.
    - d. Procedures and equipment for continuous and special cleaning.
    - e. Testing procedures and equipment including for air, water, and other cleanroom related activities.
- B. Submit manufacturer's product data for all supplies and equipment used in Cleanroom Protocol procedures.
- C. Submit MSDS information for all products used inside the Cleanroom for cleaning supplies, sealants, and other applicable products.

## 1.6 CLEANROOM PROTOCOL CONTRACTOR QUALIFICATIONS

- A. In addition to the General Standards and as a condition of award, special standards must be met by the Cleanroom Protocol contractor to demonstrate that the bidder possesses certain expertise that has been determined essential for adequate contract performance.
- B. The following will be required of the bidding contractors prior to award: A list of at least five (5) projects, completed within the last five (5) years, which included construction of Class 1,000 or

better clean spaces. These projects should be equal to this project's Cleanroom scope of work. Include documented experience for monitoring a cleanroom protocol program for all subcontractors working within the clean zone, including subcontractors not working directly for the cleanroom subcontractor.

## **PART 2 PRODUCTS**

### **2.1 INSTALLATION PROTOCOL**

- A. The Following guidelines shall be followed in order to establish procedures for dress, conduct, and activities inside the Clean Zone as necessary to maintain safety and contamination requirements:
1. The Cleanroom Contractor shall have full authority over all operations inside the Clean Zone.
  2. All persons entering the Clean Zone shall complete training respective of the protocol level incorporated.
  3. Construction personnel shall receive training on Clean Build Protocol, at regularly scheduled training sessions from the Cleanroom contractor. Manufacturer's representatives, service personnel, Owner representatives and end users to receive special training on clean protocol prior to entering the Clean Zone.
  4. There shall be one training session for protocol levels 2 and 3, and another for protocol level 4.
  5. Personnel access to the Clean Zone shall be through the designated personnel construction gowning entrance. Material and tool entry shall be through a material entry pass-through, and pre-clean area only.
  6. Any approved sub contractor shall use dedicated, clean construction tools in the clean zone inspected for each level of protocol. Tools which are used on a daily or regular basis are to remain in the Clean Zone until they are no longer needed.
  7. Any approved sub contractor shall clean as they work, always leaving the construction zone in at least the same or better condition than when the work began.
- B. The following activities are banned anywhere inside the Clean Zone and adjacent spaces during all construction protocol levels:
1. Eating or drinking foodstuffs.
  2. Chewing gum.
  3. Smoking or chewing tobacco.
  4. Spitting.
  5. Standing, walking or sitting on electrical conduits, and bus duct, HVAC ductwork, fire sprinkler piping, or other building utility piping, process high purity piping, specialty gas piping, HEPA filter modules, cleanroom light fixtures or any other cleanroom component.
  6. Breaking open any clean products specially sealed and wrapped for protection prior to the material entry airlock.
  7. Cutting, threading, grinding, or welding pipe, conduit, bus duct, or fittings.
  8. Operating any propane, acetylene, diesel, gas, air, or oil fueled tools, high-lift or other construction equipment.
  9. Installing or spilling oil, stain, paint, sealant, cleaning agent, caulking, or other diffusing product onto the structural floor before application of specified sealers and paints.
  10. Using chemicals and cleaners not previously approved by the Cleanroom Protocol contractor and site environmental health and safety representative.
  11. Entering or working inside the Clean Zone in garments and footwear that are not in compliance with the posted construction protocol level.

12. Entering or working inside the Clean Zone without clearance from the Cleanroom Protocol contractor and Protocol Manager.
- C. The following procedures and criteria shall be followed by all persons entering and working in the Clean Zone during all construction protocol levels:
1. Walk on sections of tacky walk-off mat provided at entry to the Clean Zone.
  2. Unpack, wipe down, and vacuum clean all construction material, tools, and accessories to remove grease and contamination in the material entry pass-through.
  3. Wipe up spills of caulking, sealant, paint and the like immediately.
  4. Dispose of all outer packaging materials including tie-straps, plastic seal wraps, product protecting devices and other debris in trash receptacles. Do not let debris accumulate on floor.
  5. Provide continuous HEPA filtered vacuum pick-up during drilling, coring, cutting, or similar particle generating work activities after beginning cleanroom protocol level.
  6. Provide all necessary construction tools that are cleaned, stored, and used only within the designated Clean Zone after beginning of protocol level.
  7. No wood, paper, foam, or cardboard containers or packing allowed in the Clean Zone after beginning of protocol level 2.
  8. Limit quantity of material inventory stored in the Clean Zone to a quantity that can be used during the current shift.

## 2.2 CLEAN / BUILD PROTOCOL TRAINING PROGRAM

- A. Prior to construction start, the Cleanroom Protocol contractor will provide a cleanroom protocol-training program. A draft protocol and training program shall be submitted during the proposal stage to confirm the requirements of the specifications. Its intent will be to expose each individual trade to the intricacies of a cleanroom and the “clean build” process. Attendance is mandatory for all workers involved with the cleanroom project. The primary goal of the protocol training is to:
1. Help contractors understand the reasons for various restrictions on activities within the cleanroom.
  2. Provide overall exposure to the sub-micron level of cleanliness required in the different cleanroom classifications.
  3. Inform them on specific cleanroom components such as the use of air locks, air showers, and gowning procedures.
  4. Emphasize the necessity for continuous daily clean-up programs.
  5. In conjunction with the pre-construction training activity the process will be monitored and adjusted at the weekly contractor coordination meeting. These meetings will further:
    - a. Gauge the level of compliance to these restrictions and allow the cleanroom contractor to adjust enforcement of same if necessary.
    - b. Ensure tradesman participation and involvement in an overall commitment to maintain the integrity of this facility.
    - c. Serve as a venue to present and post any and all weekly “restricted access” area(s) and help schedule clearance of the areas.

## 2.3 PRE-CLEANROOM CONSTRUCTION ACTIVITIES

- A. The following describes construction activities to be complete prior to the cleanroom construction
1. The building superstructure must be complete including slab floors, exterior walls, roof, exterior windows and doors, structural steel and welding.
  2. Fire protection mains, plumbing drains, and cleanroom perimeter walls (drywall) shall all be in place at this time.
  3. All interior surfaces (i.e., columns, joists, walls, etc.) shall be painted or coated to prevent future shedding of particulate into the cleanroom.

4. Temporary gowning room and a material entry pass-through will be constructed at the cleanroom entrances.
  - a. The material entry pass-through may be constructed of sheet plastic and a structural support as necessary.
5. All utilities required for the Clean Zone are brought through the perimeter Clean Zone boundary wall and capped for final distribution in Clean Zone. All penetrations through the Clean Zone boundary wall to be sealed airtight.

## 2.4 CLEAN ZONE CONSTRUCTION PROTOCOL LEVELS

- A. General milestones for clean construction protocol levels include (Note: levels may overlap):
  1. Level 1: Rough Construction Phase
  2. Level 2: Cleanroom Floor/Ceiling installation
  3. Level 3: Cleanroom Wall Installation
  4. Level 4: Start-up test and Certification

## 2.5 PROTOCOL LEVEL 1 (ROUGH CONSTRUCTION PHASE)

- A. Level 1 Activities:
  1. The building superstructure must be complete including slab floors, exterior walls, roof, exterior windows and doors, structural steel and welding.
  2. Fire protection mains, plumbing drains, and cleanroom perimeter walls (drywall) shall all be in place at this time.
  3. All interior surfaces (i.e., columns, joists, walls, etc.) shall be painted or coated to prevent future shedding of particulate into the cleanroom.
  4. Temporary gowning/material staging areas will be constructed at the cleanroom entrances.
  5. Staging areas may be constructed of sheet plastic and a structural support as necessary.
  6. Install air handling units and associated ductwork, including ductwork required for outdoor make-up air.
  7. Hang Cleanroom ceiling support system.
  8. Install MEP overhead rough in.
  9. Install plenum sensible cooling recirculating air-handling systems.
  10. Seal air tight all duct and fan openings.
  11. Initial gross clean up of the clean construction zone including overhead mechanical systems prior to entering Level 2 protocol.
  12. Provide start up of make-up air systems for room pressurization prior to moving to Level 2 protocol
- B. Cleanliness Level (Level 1):
  1. No smoking or chewing tobacco is allowed.
  2. No eating or drinking within the clean zone.
  3. No gasoline or diesel powered equipment allowed. All lifting equipment/power tools shall be electric powered.
  4. Grinding, cutting, drilling, or other operations (i.e. cutting drywall) which generate dust contamination must be controlled by means of daily vacuuming or cleanup.
  5. Substrates, over which succeeding work is to be installed, shall be carefully inspected and wiped clean to eliminate entrapment of any contamination in the finished work.
  6. Surfaces of material and equipment being installed shall be wiped clean using clean water and lint-free wipes. Oil and grease must be cleaned with a solution approved by the Protocol Manager. Dirty wipes must be replaced and disposed of.
  7. Floors must be vacuumed or wet mopped weekly.
  8. All trash and debris must be removed from building daily.

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## 2.6 PROTOCOL LEVEL 2 (FLOOR / CEILING INSTALLATION)

- A. Level 2 Activities:
1. This establishes the time at which major building construction activities within the clean zone should be completed and access limited.
  2. Cleanroom space shall be subject to daily cleaning.
  3. All material entering clean zone must be wiped down at established temporary material entry pass-through.
  4. Installation of secondary ceiling suspension (turnbuckle & threaded rod)
  5. All tools entering the clean zone shall be thoroughly cleaned with solution approved by the protocol manager.
  6. Contractors working within the cleanroom envelope shall wear booties and hairnets.
  7. Install Cleanroom piping systems.
  8. Install Cleanroom specialty gas systems.
  9. Install flooring and protective covering.
  10. Install Cleanroom ceiling grid.
  11. Install recirculating fan filter units.
- B. Cleanliness Level ( Level 2):
1. No smoking or chewing tobacco is allowed in clean zone or its perimeter.
  2. No eating or drinking at the clean zone levels.
  3. Immediate clean-up of debris created by construction activities.
  4. No grinding, cutting, welding or drilling is allowed within clean zone.
  5. No powder or air actuated tools allowed.
  6. No gasoline or diesel powered equipment allowed.
  7. Ladder, scaffold and/or gang box feet/wheels must have protective covers.
  8. All tools (including ladders, scaffolding, and gang boxes) entering the clean zone must be thoroughly cleaned of all dirt, grease and oil. If this is not possible then new tools must be utilized.
  9. All materials entering the clean zone shall be unwrapped/uncrated in an established material entry pass-through, and all surfaces thoroughly cleaned of all dirt, grease, oil, lint or other contaminants by means of non-shedding, lint-free wipes and approved cleaning solution. If vacuuming is required, vacuum must be HEPA filtered.
  10. Work shoes must be cleaned before entering clean zone (and donning of shoe covers) by use of shoe cleaners and/or tacky mats.
  11. All personnel entering the clean zone must wear clean work boots, shoe covers/booties, latex gloves, clean work clothes, and hairnets. Shoe covers that are torn or soiled must be replaced.
  12. Intermediate clean prior to moving to Level 3 Protocol.

## 2.7 PROTOCOL LEVEL 3 (CLEANROOM WALL INSTALLATION)

- A. Level 3 Activities:
1. Continuous daily clean-up procedures are accelerated.
  2. Cleanroom wall system is installed and tied into the ceiling.
  3. Cleanroom ceiling system and all overhead work complete.
  4. Install all wall mounted devices i.e.. Control sensors, fire alarm sensors, strobes, horns, pull stations, exit and emergency lighting.
  5. Install all wall mounted Cleanroom equipment.
  6. Remove airtight seal from all air handling units & blowers and perform final blow down.
  7. Final hook-up of the fire sprinkler system in the ceiling grid system.
  8. Final installation and hook-up of light fixtures in ceiling grid system.



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9. All overhead electrical, fire alarm, telecommunications, and controls work shall be completed.
- B. Cleanliness Level (Level 3):
1. No tobacco use allowed.
  2. No food of any kind is allowed.
  3. No powder or air actuated tools are allowed.
  4. No gasoline or diesel powered equipment allowed.
  5. No grinding, cutting, drilling or dust generating activities allowed in the clean zone.
  6. When it becomes necessary to change any work already installed by cutting or drilling, the material must be removed to the staging area. If this is not possible or timely, then temporary barriers must be installed to isolate the work from surrounding cleanroom materials and continuous vacuum removal must be incorporated.
  7. All personnel must wear clean work clothes at the start of each shift.
  8. All personnel must wear shoe cover/booties, gloves, hairnets, beard covers and lab coats.
  9. Any torn or soiled cleanroom garments must be replaced.
  10. Continuous cleaning, vacuuming and trash removal is required.
  11. All materials entering the clean zone shall be unwrapped/ uncrated in a designated material entry pass-through and all surfaces thoroughly cleaned of all dirt, grease, oil, lint or other contaminants by means of non-shedding, lint-free wipes and approved cleaning solution. If vacuuming is required, vacuum must be HEPA filtered.
  12. Superclean of cleanroom prior to Level 4 Protocol

## 2.8 PROTOCOL LEVEL 4 (START UP TEST)

- A. Level 4 Activities:
1. Install Hepa filters and blank pans.
  2. Install cleanroom ceiling screens.
  3. Cleanroom certification and testing.
  4. Perform final wipedown of cleanroom walls.
  5. Installation of base contract process equipment.
- B. Cleanliness level (Level 4):
1. All level 3 requirements in effect with the following additions:
    - a. Access to clean zones shall be limited only to personnel needing access to perform work and who have gone through a cleanroom construction indoctrination program (security badges issued).
    - b. Cleanroom badges are to be worn on the outside of the cleanroom gowns and be visible.
    - c. Signage installed at all clean zone access points which include a checklist for required cleaning to be performed prior to access.
    - d. Gowning to include cleanroom coveralls with hood and face masks, boot covers, hairnet, beard covers and gloves.
    - e. Material entry pass-through areas and gowning rooms to be strictly controlled by cleanroom monitor.

## **PART 3 EXECUTION**

### **3.1 JOB CONDITIONS**

- A. The General Contractor shall provide the shell space and an adjacent staging area in vacuum clean and wiped down condition and shall assist in maintaining the conditions necessary for the performance of the work in this area.
- B. Check project for conditions that affect work. Do not begin activities and services until unsatisfactory conditions are corrected. Defects caused by unsatisfactory conditions or untimely installation shall be corrected at no cost to Owner.
- C. The Cleanroom Protocol Contractor shall monitor and coordinate all work performed within the cleanroom area as required to safeguard the cleanliness of the cleanroom area.

**END OF SECTION 13 2105CR**

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## SECTION 13 2110CR – CLEANROOM CEILING SYSTEM

### PART 1 GENERAL

#### 1.1 SUMMARY

- A. Drawings and general provisions of the Contract, and Division 1 Sections apply to work of this Section.
- B. This specification details construction features, components, installation, performance capabilities and design requirements for a complete engineered field-fabricated environmental cleanroom.
- C. The cleanroom shall be the product of a manufacturer/installation contractor regularly engaged in the business of designing, manufacturing, installing, and certifying cleanrooms.
- D. The manufacturer/installation contractor shall guarantee that the performance of the complete cleanroom will meet all the performance criteria established by this specification.
- E. The cleanroom manufacturer/installation contractor shall provide certification listed herein from a third party source.

#### 1.2 REFERENCES

- A. Air cleanliness classification for cleanrooms and definition of terms for cleanroom work shall be in accordance with ISO Class 5 and 6 (Formerly Class 100 and 1,000). All cleanroom construction shall be in accordance International and Local building codes.

#### 1.3 RELATED DOCUMENTS

- A. General and Supplementary Conditions and Division 1
- B. Other Division 9 sections for floor finishes related to this section but not the work of this section.
- C. Division 3 Concrete; not the work of this section.
- D. Division 6 Wood and Plastics; not the work of this section.
- E. Division 7 Thermal and Moisture Protection; not the work of this section.
- F. Section 11 5343 – Laboratory Fittings and Fixtures
- G. Section 13 2100CR – Cleanroom Construction
- H. Section 13 2105CR – Cleanroom Construction Protocol
- I. Section 13 2120CR – Cleanroom Wall System
- J. Section 13 2130CR – Cleanroom Automatic Sliding Doors
- K. Section 13 2140CR – Cleanroom Chemical Fume Hood and Wet Processing Stations

- L. Division 21: Fire Suppression
- M. Division 22: Plumbing
- N. Division 23: HVAC
- O. Division 25: Cleanroom Controls
- P. Division 26: Electrical

#### **1.4 DEFINITIONS**

- A. Clean Zone: A defined area, including the cleanroom and adjacent spaces, that is exposed to the cleanroom supply and return airstreams.
- B. HEPA Filter: High efficiency particulate air filter, including ULPA (Ultra-High efficiency particulate air) filters.
- C. Protocol Level: The phase or degree of construction completion that mandates specified activities, training, security clearance, dress, work means and methods, cleaning procedures, and system performance to maintain the cleanliness of the clean zone.
- D. Protocol Manager: The person vested with authority by the Cleanroom Protocol Contractor to supervise all construction personnel working within the Clean Zone and ensure requirements of the contract documents are met in completion of the Clean Zone construction.

#### **1.5 WARRANTY**

- A. Provide warranties in accordance with Division 1 requirements.
- B. One (1) year limited standard warranty against defects including excessive fading, excessive nonuniformity of color or shade, cracking, peeling, pitting or corrosion.

#### **1.6 QUALITY ASSURANCE**

- A. Provide for travel, accommodations, and access expenses to accommodate up to Four (4) Owner's representatives to witness factory inspection of completed clean room ceiling grids, plenum modules, and fan filter units prior to product shipment. Provide notice in writing to the Architect a minimum of 30 days prior to scheduled factory testing to allow adequate time for Owner's representatives to arrange factory visit.

#### **1.7 SUBMITTALS**

- A. Provide samples of each type of product materials, support components, finishes, and accessories illustrating installed products, finishes, and color.
- B. Detailed manufacturer product data sheets, for each proposed product type, which provides the necessary information to describe and evaluate the product and its performance.
- C. Shop Drawings: Submit complete shop fabrication and installation drawings, including plans, elevations, sections, details, schedules, and 3-dimensional layouts (as necessary). Minimum scale shall be 1:50. Show relationship to adjoining materials and construction. Shop drawings shall

depict final product design and installation. Shop drawings shall be prepared electronically and submitted in the form of reproducible or photocopies, prepared in standard Architectural drawing formats and scaled to defined dimensions.

- D. Test reports, by an independent testing laboratory, certifying that component parts perform as specified.
- E. Upon completion of installation, operation and maintenance instructions will be furnished. Operation instructions shall include manufacturer's name, size, model, type, and serial numbers for the various elements of system; detailed drawings, wiring diagram, repair parts lists, lubrication manuals, and general maintenance instructions. Provide services necessary to properly instruct University personnel on operation and maintenance of all systems.
- F. Provide the following certified items:
  - 1. Operating and maintenance procedures.
  - 2. List of recommended spare parts.
  - 3. Approved shop drawings.
  - 4. Warranty certificates.
  - 5. As-built drawings.
  - 6. Test reports.
  - 7. Procedural instructions for future wall penetrations and proper sealant to be used.
- G. Upon completion of work, tests shall be completed, systems balanced and tested, and a qualified representative provided to instruct a representative of the Owner's maintenance department in proper operation and maintenance of all installed systems.

## **1.8 CLEANROOM MANUFACTURE QUALIFICATIONS**

- A. In addition to the General Standards and as a condition of award, special standards must be met by the Cleanroom Manufacturer/Installation Contractor to demonstrate that the bidder possesses certain expertise that has been determined essential for adequate contract performance.
- B. The following will be required of the bidding contractors prior to award: A list of at least five (5) projects, completed within the last five (5) years, which included construction of ISO Class 5 (Class 1,000) or better clean spaces. These projects should be equal to or greater than this project's Cleanroom scope of work and include materials and systems of similar design and installation. Include documented experience for academic and research University Cleanroom projects of equal or greater scope.
- C. Include a list of all ISO Class 6 (Class 1,000) or better Cleanrooms constructed within the last five (5) years or currently under construction. List should include size of clean area, class and Owner contact. List must include the job title, place of performance, cost of the project and the project manager's name, address and phone number; or, if non-government, company name, address, name of person to be contacted and phone number.

## **1.9 ENVIRONMENTAL CONDITIONS**

- A. Deliver materials in good condition to the jobsite in the manufacturer's original unopened containers that bear the name and brand of the manufacturer, project identification, and shipping and handling instructions.

- B. Store materials in a clean, dry, enclosed space off the ground, and protected from the weather and from extremes of heat and cold. Protect adhesive and gels from freezing. Store adhesives, gels, and accessories in the spaces where they will be installed for at least 48 hours before beginning installation.
- C. Maintain a minimum temperature in the spaces to receive the flooring and accessories of 65°F (18°C) and a maximum temperature of 100°F (38°C) for at least 48 hours before, during, and for not less than 48 hours after installation. Thereafter, maintain a minimum temperature of 55°F (13°C) in areas where work is completed. Protect all materials from the direct flow of heat from hot-air registers, radiators, or other heating fixtures and appliances.
- D. Install flooring and accessories after the other finishing operations, including painting, have been completed. Close spaces to traffic during the installation of the flooring. Do not install flooring over concrete slabs until they are sufficiently dry to achieve a bond with the adhesive, in accordance with the manufacturer's recommended bond and moisture tests.

## **PART 2 PRODUCTS**

### **2.1 CLEANROOM CEILING SYSTEM**

- A. Manufacturers: Subject to compliance with requirements, provide products and services by one of the following:
  - 1. Cleanpak International, 11241 SE Hwy 212, Clackamas, OR 97015, USA; Tel: 503-557-4500.
  - 2. Approved equal – Subject to approval by Owner's representative obtained during bidding submittal process and prior to project award.
- B. General Specifications Welded Flush "Top Load" Grid Style:
  - 1. Grid: The welded grid manufacturer shall furnish a complete assembly of integral flush aluminum grid, integrated plenum, sprinkler coupling, ULPA fan filter units, recessed lighting system with integral electronic ballast, blank pans, flush grid lens, face screens and all metal finished with a dry powder epoxy coating. The grid shall be "top load" style welded system. Filter and blank off panels shall load from top of grid and rest on field installed gel seal system.
  - 2. Accessories: In addition to the final product provide accessories that will adapt existing walls and ceiling systems to the plenum, provide an adapted lighting system for sensitive processes, and pre-punched holes for future wiring required for static control systems. Provide the following items:
    - a. Wall attachment kits.
    - b. Photo sensitive lighting as indicated on the drawings.
    - c. Fire protection pre-punched electrical holes.
    - d. Alarm and signage pre-punched electrical holes.
  - 3. Work Included: The work included refers to the work necessary to fabricate and furnish a complete cleanroom modular ceiling grid system.
- C. General Specifications Welded Flush "Top Load" Grid Style w/ Plenum:
  - 1. Grid: The welded grid manufacturer shall furnish a complete assembly of integral flush aluminum grid, integrated plenum, sprinkler coupling, filtration, ULPA filters, recessed lighting system with integral electronic ballast, blank pans, flush grid lens, face screens and all metal finished with a dry powder epoxy coating. The grid shall be "top load" style welded system. Filter and blank off panels shall load from top of grid and rest on field installed gel seal system.

2. Accessories: In addition to the final product provide accessories that will adapt existing walls and ceiling systems to the plenum, provide an adapted lighting system for sensitive processes, and pre-punched holes for future wiring required for static control systems. Provide the following items:
    - a. Wall attachment kits.
    - b. Photo sensitive lighting as indicated on the drawings.
    - c. Fire protection pre-punched electrical holes.
    - d. Alarm and signage pre-punched electrical holes.
  3. Work Included: The work included refers to the work necessary to fabricate and furnish a complete cleanroom modular ceiling grid system.
- D. Sizing the Grid:
1. Standard Grid Module Size: The grid system shall be nominal 112.5 mm (4.5 in.) in height and shall maintain a level face and overall squareness. The width and length of the grid shall be determined by the overall layout of the facility. The maximum grid module width shall 2400 mm (8 ft.) and maximum length shall be 6000 mm (20 ft.). All grids shall be designed to the overall nominal dimension and are to be undersized by 1.5 mm (1/16 in.) as a growth factor. Manufacturing allowable tolerance on detail parts shall be no greater than 0.75 mm (.030 in.).
- E. Construction of the Grid:
1. Perimeter Grid: The grid frame shall be a welded construction of extruded aluminum. As an assembly, the grid assembly shall allow to recess all lighting, wiring, gel, filters, fan filter units, blank pans, return air perforated pans, sprinklers and lenses in order to maintain a flush ceiling system. Attachment points such as grid to grid and suspension bracket holes shall be pre-punched into the perimeter grid.
    - a. Size: The width of the interior profile shall be 66mm (2.6 in.) outside dimension to allow for a greater filter coverage per area. The width of the perimeter profile shall be exactly half of the interior profile, 33 mm (1.3 in.) to allow the perimeter grid to mate to an adjacent grid assembly and create the 66 mm (2.6 in.) width profile. All components shall be removable from the upper or plenum side of the grid system.
  2. Welds: All exterior welds on the grid shall be ground smooth prior to coating.
  3. Penetration Holes:
    - a. Grid To Grid Holes: Requirement for an 8 mm (5/16 in.) diameter. Bolt: Standard Hole Size = 10 mm (0.375 in.).
    - b. Suspension Bracket Holes: Requirement for an 8 mm (5/16 in.) diameter. Bolt: Standard Hole Size = 10 mm (0.375 in.).
    - c. High Voltage Holes: Requirement for 12.5 mm (1/2 in.) grommet. Standard hole size = 15.6 mm (0.625 in.).
    - d. Low Voltage Holes: No grommet required. Standard hole size = 12.5 mm (0.500 in.).
- F. Structural and Exterior Attachments:
1. Attachment Accessories: The cleanroom contractor shall be responsible for the exterior attachment parts and hardware. Manufacturer shall provide sufficient attachment points and dimensional layouts for placement of the structural posts and attachment hardware. The attachment structures shall be mid-span and corner suspension brackets as required.
  2. Structural Calculation: The cleanroom grid manufacturer shall provide necessary structural calculations stamped by a licensed Professional Structural Engineer. The structural calculations shall include but are not limited to the cleanroom grid and support structure. The manufacture/installer shall also provide all necessary horizontal structure and calculation for sway bracing.

3. Structural Calculation Factor: All calculation shall meet seismic requirements for the project location in accordance with international and local building codes. All structural calculation shall include a minimum safety factory of 2.5.
  4. Suspension Rod: Threaded rod shall be used with anchor base plates attached to structure above, suspension brackets, turnbuckle levelers, and accessories.
    - a. Placement of Suspension Attach Points: For a typical grid, the suspension attachment points shall be placed at each corner of the grid and at mid-span of the long sides. The contracted Structural Engineer must review and certify the quantity and placement of suspension points.
- G. Plenum Integrated to Ceiling Grid
1. Provide a plenum attached to the ceiling grid as an integral part of the ceiling grid plenum system. Modules shall be supplied completely pre-assembled with the grid and plenum as one piece.
  2. The system shall utilize suspension rods supported from the overhead structure.
  3. Plenums will be welded style construction using formed steel roof panels welded to formed steel side panels. Side and top panel thickness shall be sized so as to meet structural load requirements. The roof panels shall be formed such that the panel brakes are towards the outside of the plenum so as to form a smooth inside surface. The side panels shall be riveted to the flush ceiling grid system. Holes will be provided at the perimeter of the plenum roof for suspension. The entire plenum ceiling grid module shall be coated with a baked on powder coating.
  4. Units shall be manufactured to dimensional tolerance of +/- 3mm (1/8 inch) on width and length and diagonal dimensions or squareness of +/- 3mm (1/8 inch).
  5. Supply a flexible membrane diffuser to provide uniform air distribution of +/- 0.102 m/s (20 fpm) from the unit average at 150mm (6 inch) beyond the filter face when plenums are individually fed from the top with 3.81 to 5.08 m/s (750 to 1,000 fpm) air supply.
  6. In order to accommodate service personnel and equipment, the top panels, support frame, and walking surface shall be designed for either a uniform loading of 146 kg per square meter (30 pounds per square foot), or a point load of 75 kg (200 pounds) anywhere on the top surface. Under this added live load, the deflection of the bottom surface shall not exceed 3mm (1/8 inch) at the midspan of the module length. Plenums shall be capable of fully supporting the weight and seismic loading of air handling equipment that is to be directly attached to and directly supported by the plenums.
  7. Provide pre-drilled bolt holes in the sides of modules for field connection of one module to another where applicable.
  8. Provide pre-cut airflow openings in the sides of modules for transfer of air from one module to another where applicable.
- H. Blank Panels:
1. Construction: Blank panels shall be constructed of cold rolled steel and have welded corners designed to effectively create an airtight seal and a 19 mm (3/4 in.) knife edge for sealing in urethane gel. All surfaces shall have a powder coated epoxy finish. Provide hold-down clips to secure pan to ceiling grid.
  2. The height of the pan shall be sufficient to provide an elevation change no greater than 175mm (7 inch) to the adjacent ceiling plenum modules and/or provide a flush height elevation to installed fan filter units.
  3. The blank panels shall be structurally constructed for walking on.
- I. Filter Units:
1. Manufacturers: Filters to be manufactured by Camfil Farr model Megalam or approved equal.



2. Construction: Pleated 70mm ULPA filter media pack consisting of micro-glass fiber with acrylic resin binder, anodized aluminum frame with center divider and knife-edge for insertion into ceiling system gel seal, thermoplastic resin separator, 24-gauge white powder coated steel downstream grille, fire retardant polyurethane sealant. Filters shall be manufactured in an ISO Class 7 environment and provided with design and testing labeling and bar code serial number for individual unit identification.
3. Accessories: Provide room side adjustable equalizer airflow balancing damper at filter inlet with adjustment port at centerline of filter grille.
4. Filter Testing: ULPA Filters shall be individually factory tested and certified in accordance with the latest applicable standards of the Institute of Environmental Sciences and Technology (IEST). The filters shall meet a minimum efficiency of 99.9995% vs. MPPS (Most Penetrating Particle Size). Filters shall be tested in an ISO Class 6 environment.
  - a. Media supplier shall provide certification that media meets performance specification.
  - b. Each filter shall be certified to have a minimum efficiency of 99.9995% on the removal of vs. MPPS (Most Penetrating Particle Size).
  - c. Each ULPA filter shall be individually factory tested for overall efficiency in accordance with IEST-RP-CC007 and leak tested in accordance with IEST-RP-CC034. All filters shall also be scanned for pinhole leaks following installation.
  - d. All ULPA filters shall be factory tested for air flow resistance with a measured air volume. The mean initial pack resistance, with a range of plus/minus 15 percent, shall be 0.44 inch w.c. for 70mm pack when tested on a volumetric basis of 100 CFM per square foot of active filter face area.

J. Fire Suppression Systems:

1. The grid system shall have the ability to place fire protection piping through the grid channel itself. Provide sprinkler port penetrations in the ceiling grid channel at all sprinkler head locations, as indicated on the drawings.
2. The ceiling grid/plenum shall incorporate a rigid or flexible fire protection piping system. Flexible fire protection hose system shall consist of the flexible hoses attached to a common rigid pipe header in the plenum. The hose shall be Clean-Flex Welded Flexible hose or Clean-Flex WeldFree Flexible hose as manufactured by HUNTAIR or approved equal. Flexible hoses shall have a live length of minimum or 900mm (36 inches). The grid channel shall be capable of accepting a true flush sprinkler head within the width of the extrusion.
3. Sprinkler Piping: provide fire sprinkler piping in accordance with contract fire protection system's drawings. The fire sprinkler system will consist of pipe and fittings in accordance with NFPA 13. Fire protection system shall be approved by authority having jurisdiction. The cleanroom side sprinkler end will terminate above the flush lens and be located in center of filter support grid to accept a true flush sprinkler head. Provide ¾-inch or 1-inch female fittings for sprinkler heads coordinated with fire protection design.
4. Sprinkler Pressure Testing: All installed piping shall be pressure tested in accordance with NFPA 13 requirements.
5. Grid/Plenum Sprinkler Pipe Connection: A single male threaded pipe stud shall be provided for each inlet sprinkler pipe connection to a grid/plenum module.
6. Fire sprinkler piping within the ceiling grid/plenum module shall be factory-installed, sealed, and painted by the manufacturer. Manufacturer shall provide flexible sprinkler piping, sleeves and sprinkler heads that forms an airtight seal to the grid.
7. The sprinkler pipe spool connections between modules shall be furnished and installed by others (sprinkler contractor).

K. Lighting Systems

1. General:
    - a. Luminaires: Including lamp ballast and wiring between ballast and lamps, luminaires shall be integral and recessed with cleanroom ceiling grid. The furnished lighting system shall consist of lamps, lamp holders, lenses, wiring, ballasts and terminal boxes. All components provided shall be installed as part of the cleanroom modular grid system. Lighting system provided shall be 277 volts unless otherwise specified.
    - b. Locations: Lamp and lamp bar assemblies shall be designed and installed as required per the light levels specified. Locations shall be determined by the quality of lighting required by specified light levels. The Owner shall mandate the number of lux required depending on the process to determine the specification. Foot candles shall be measured throughout the cleanroom at the working plane, 750 mm (30 in.) above the finished floor.
    - c. All lighting work shall comply with International Electrical Code, NEC, applicable local codes, and standards for Safety of 'Underwriter' Laboratories, Inc. (UL). All electrical components shall be UL listed and labeled.
    - d. Yellow and red lighting lenses where required shall eliminate 99.999% of UV light between 250 – 550nm wavelengths (yellow) or 250 – 575nm wavelengths (red).
  2. Wiring:
    - a. Light Bar Assemblies: Light bar assemblies shall contain full wiring from lamp holder to ballast and have a wire pigtail at each end. All wire shall consist of copper braided wire. The light bar assembly installed in the ceiling grid shall function as a sheet metal enclosure to prevent exposure and to eliminate chaffing of wire installation.
    - b. Wire Diagram: Lead wires from ballasts shall terminate at J-Box locations or pigtails at the ends of a grid section for grid-section to grid-section hookups.
    - c. Ground Wire: A ground wire shall be provided between ballast/grid and ground terminal in terminal J-box.
  3. Power Lead-in Nipples: Nipples shall be provided at each power lead-in.
  4. Lamps: Lamps shall be T5, 28 watt, 3500 K color temperature, 85 CRI, rapid start.
  5. Lens: Diffuser lens mounts flush with ceiling grid without external fasteners.
    - a. Color: Lens shall be clear for lighted areas and white for non-lighted areas.
    - b. Packaging: All shipped loose lenses shall be wrapped per grid section and shipped attached to the adjacent grid section.
  6. Ballast: Integrated circuit electronic fluorescent ballast. Ballast shall meet the following criteria:
    - a. ANSI C82.1, minimum power factor of 0.99, UL listed, Class P, Type 1, and internally thermal protected. Lamps will operate at a frequency of 20 - 35 kHz without a detectable flicker. Ballast meet the requirements of FCC (CFR47 part #18) for electromagnetic and radio frequency interference.
    - b. Distortion: Less than 10% total harmonic distortion, less than 6% third harmonic distortion.
    - c. Sound: Rated "A".
    - d. Connection: Poke-in wire trap connection.
- L. Walkable Return Air Grating:
1. General: Walkable return air grates shall be constructed of molded fiberglass reinforced plastic (FRP) grating supported by strut members spans and angles welded to the plenum modules.
  2. Grating:
    - a. Description: Grating shall be of a one piece molded construction with tops and bottoms of bearing bars and cross bars in the same plane. Grating shall have a

square mesh pattern providing bidirectional strength. Grating shall be reinforced with continuous rovings of equal number of layers in each direction. The top layer of reinforcement shall be no more than 1/8-inch below the top surface of the grating so as to provide maximum stiffness and prevent resin chipping of unreinforced surfaces. Percentage of glass (by weight) shall not exceed 35% so as to achieve maximum corrosion resistance, and as required to maintain the structural requirements. After molding, no dry glass fibers shall be visible on any surface of bearing bars or cross bars. All bars shall be smooth and uniform with no evidence of fiber orientation irregularities, interlaminar voids, porosity, resin rich or resin starved areas.

- b. Basis of Design: Fibergrate Composite Structures Inc. molded Fibergrate or approved equal.
  - c. Non-slip Surfacing: Grating shall be manufactured with a concave, meniscus profile on the top of each bar providing maximum slip resistance.
  - d. Grating bar intersections are to be filleted to a minimum radius of 1/16" to eliminate local stress concentrations and the possibility of resin cracking at these locations.
  - e. Fire rating: Grating shall be fire retardant with a tested flame spread rating of 25 or less when tested in accordance with ASTM E 84. Data performed only on the resin shall not be acceptable.
  - f. Color: Selected by Architect.
  - g. Depth: 2-inch.
  - h. Mesh Configuration: 2-inch x 2-inch.
  - i. Load/Deflection: Grating design loads shall be less than manufacturers published maximum recommended loads. Maximum recommended loads shall be determined by acoustic emission testing. Grating shall be designed for a uniform load of 100 psf or concentrated load of 300 lb. Deflection is not to exceed 0.375" or L/D = 120, whichever is less.
  - j. Hardware: Type 316 stainless steel hold-down clips shall be provided and spaced at maximum of four feet apart with a minimum of four per piece of grating, or as recommended by the manufacturer.
  - k. Layout: Each grating section shall be readily removable, except where indicated on drawings. Manufacturer to provide openings and holes where located on the contract drawings. Grating openings which fit around protrusions (pipes, cables, machinery, etc.) shall be discontinuous at approximately the centerline of opening so each section of grating is readily removable.
  - l. Sealing: All shop fabricated grating cuts shall be coated with vinyl ester resin to provide maximum corrosion resistance. All field fabricated grating cuts shall be coated similarly by the contractor in accordance with the manufacturer's instructions.
3. Strut Supports: Galvanized steel channel strut with white baked on powder coated finish to match ceiling plenums. Nominal 1-5/8 inch width and thickness required for structural span.
  4. The height of the grates shall be flush with the top of the plenum modules.

M. Packaging

1. Cleanroom Provisions for Final Cleaning: All grids are cleaned inside a controlled area for purpose of final cleaning and packaging. The area shall meet the requirements of ISO Class 7 or Class 10,000 per Federal Standard 209.
2. Clean: By "Clean" it is meant that all housing and equipment components will be thoroughly cleaned of all oils, grease, lubricants, dirt, and dust before final packaging.
3. Prepping the Grid: After final installation of lamp assembly and wiring, apply caulking, RTV 162, GM 802 by GE or equal. Caulking shall be applied to all seams at mating

- surfaces. All surfaces shall be vacuumed and wiped down using only isopropyl alcohol (IPA) or IPA/DI water 50% mixture prior to applying any wrapping material.
4. Wrapping the Grid: The packaging that is applied to the grid is for protection and is crucial to the value of the shipment. Grid modules shall be double-bagged and protected from handling damage for shipment.
    - a. Protrusion Prepping: All protruding parts from the grid shall be protected by bubble wrap and tape.
    - b. First Bag: Fitted and sealed with heat strip or tape.
    - c. Second Bag: Fitted and sealed with heat strip or tape. Identification and handling instruction labels applied.
    - d. Shipment Protection: Weatherproof tarp to protect grid modules from the exterior elements during transportation.

## 2.2 FAN FILTER UNITS (FFU)

- A. Manufacturers: Products, which comply with this specification section as evaluated and approved by the Owner's representative, may be provided by the following manufacturers. All products within a product category specified in this section shall be provided by a single manufacturer.
  1. Cleanpak International.
  2. Approved equal – Subject to approval by Owner's representative obtained during bidding submittal process and prior to project award.
- B. General: The nominal 2x4 foot fan filter unit shall be capable of producing a minimum of 720 cfm of true airflow (not a velocity based reading) at 1-inch w.c. of fan static pressure. The fan shall consist of an integrated motor and centrifugal plug fan. The impeller shall have single-sided suction with backward-curved blades made of aluminum and be mounted directly to the rotor of the motor. Motor shall be single phase external rotor motor with permanently lubricated ball bearings. The fan assembly shall be statically and dynamically balanced as per ISO 1940, class G 6.3.
- C. Basis of Design: Cleanpak International model CPFFU-AC1-2x4 or approved equal.
- D. Housing: Fan housing shall be powder-coated steel or galvalume. Unit shall incorporate a sound baffle with sound absorbent insulation. Unit shall carry an ETL listing per UL 1995. The fan housing shall sit directly on the final filter with a gasket seal between. Housing shall incorporate a finger guard on the inlet side of the fan that requires tooled removal.
- E. Electrical: Provide a triac type manual speed controller and on/off switch located on the top of the FFU housing. Power input to the unit shall be 115VAC / 60 Hz. Provide a 6-foot flexible cord with plug for 115VAC units.
- F. Filter Unit:
  1. Manufacturers: Filters to be manufactured by Camfil Farr model Megalam or approved equal.
  2. Construction: Pleated 70mm ULPA filter media pack consisting of micro-glass fiber with acrylic resin binder, anodized aluminum frame with center divider and knife-edge for insertion into ceiling system gel seal, thermoplastic resin separator, 24-gauge white powder coated steel downstream grille, fire retardant polyurethane sealant. Filters shall be manufactured in an ISO Class 7 environment and provided with design and testing labeling and bar code serial number for individual unit identification.
  3. Filter Testing: ULPA Filters shall be individually factory tested and certified in accordance with the latest applicable standards of the Institute of Environmental Sciences and Technology (IEST). The filters shall meet a minimum efficiency of 99.9995% vs.

MPPS (Most Penetrating Particle Size). Filters shall be tested in an ISO Class 6 environment.

- a. Media supplier shall provide certification that media meets performance specification.
- b. Each filter shall be certified to have a minimum efficiency of 99.9995% on the removal of vs. MPPS (Most Penetrating Particle Size).
- c. Each ULPA filter shall be individually factory tested for overall efficiency in accordance with IEST-RP-CC007 and leak tested in accordance with IEST-RP-CC034. All filters shall also be scanned for pinhole leaks following installation.
- d. All ULPA filters shall be factory tested for air flow resistance with a measured air volume. The mean initial pack resistance, with a range of plus/minus 15 percent, shall be 0.44 inch w.c. for 70mm pack when tested on a volumetric basis of 100 CFM per square foot of active filter face area.

### **PART 3 EXECUTION**

#### **3.1 JOB CONDITIONS**

- A. Check project for conditions that affect work. Do not begin installation until unsatisfactory conditions are corrected. Defects caused by unsatisfactory conditions or untimely installation shall be corrected at no cost to University's Representative.
- B. The Cleanroom Contractor shall coordinate with sprinkler systems work for pipe penetrations and sprinkler head locations.
- C. The Cleanroom Contractor shall coordinate with cable tray, fire alarm communications, telephone, clock, and data systems, and other work for ceiling penetrations.

#### **3.2 INSTALLATION**

- A. The nature of the completed facility demands special attention to maintaining an overall cleanliness in the project area.
- B. All installation methods shall be in accordance with the latest recommendations of the component manufacturer and in conformance with this specification. Accurately align and securely anchor assemblies and suspension members in accordance with drawings. Position suspension systems vertically, spaced as required. Support ceiling systems horizontally securely in place, flush with adjacent components.
- C. Assemble ceiling components into a rigid structure with tight, straight-line joints. Completed installation shall be free of exposed bolts, nuts, rivets, and fasteners within the cleanroom area, and shall interface with all mechanical and electrical work in a clearly pre-planned and craftsman-like installation.

#### **3.3 CONDITIONS OF SURFACES**

- A. Examine adjoining construction and conditions adjacent to which work is to be installed. Do not proceed with the work until unsatisfactory conditions have been corrected.

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### 3.4 ERECTION

- A. Verify dimensions of supporting structure by field measurements to insure cleanroom ceiling will be accurately designed, fabricated, and fitted to the structure.
- B. Coordinate cleanroom ceiling work with the work of related sections. Provide items to be placed during the installation of other work at the proper time to avoid delays in the work. Place such items, including inserts and anchors, accurately in relation to the final location of the cleanroom ceiling system components using locking type devices at all connections.
- C. Erect all component parts of the cleanroom ceiling in accordance with the manufacturers written instructions and recommendations.
- D. Erection Tolerances - erect all component parts within the following tolerances: Variations from plumb or angle shown: 3.175 mm (1/8 in.) maximum variation in height on 3000 mm (10 ft.) run, noncumulative.
- E. Cutting and Trimming of Component Parts:
  - 1. Cutting and trimming of cleanroom ceiling modules should be avoided. Where deemed essential, restore finish completely to protect material and remove all evidence of cutting and trimming.
  - 2. All cutting and trimming to be done outside the cleanroom area or in approved cleanroom fabrication shop located within cleanroom envelope.
- F. Do not erect components which are observed to be warped, bowed, deformed, or otherwise damaged or defaced to such extent as to impair strength or appearance. Remove and replace components damaged in the process of erection.
- G. Set units level, plumb, and true to line, with uniform joints. Support and secure in place by bolting to angles and similar supports anchored to supporting structure.

### 3.5 CLEANING

- A. Provide cleaning in accordance with Project Specifications.
- B. Provide cleaning methods required for each component part as recommended by the manufacturer.
- C. The nature of the project requires special attention to minimizing potential contamination of the fully developed cleanroom environment. All construction dust and contaminants left on surfaces or in recesses that will be exposed to cleanroom air will have the effect of unduly loading up the filter system. Daily cleanup and vacuuming of the work area is essential for an ongoing control of contaminants, especially as the cleanroom fit-up progresses.

### 3.6 PROTECTION

- A. Protect the cleanroom ceiling system throughout the construction period in a clean and properly protected condition so it will be without any indication of use or damage at the time of Substantial Completion.
- B. Protect the work during shipment, storage, erection and construction so as to avoid development of non-uniformity of appearance or other deleterious effects in the Work.

- C. Protection shall consist of factory applied protection or 10 mm (3/8 in.) coroplast attached with cleanroom tape for high traffic areas.
- D. Remove protection when no longer required.
- E. Materials found to be defective or improperly installed shall be replaced.

**END OF SECTION 13 2110CR**





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## SECTION 13 2120CR – CLEANROOM WALL SYSTEM

### PART 1 GENERAL

#### 1.1 SUMMARY

- A. This Section specifies the requirements necessary to furnish and install, complete, cleanroom wall system (CRW) including, but not limited to the following:
  - 1. Cleanroom wall systems, both structural and non-loadbearing, completely demountable, non-progressive, including all installation attachments.
  - 2. Wall panel material including paint, coating, or finish.
  - 3. Reinforcing and bracing as necessary to maintain wall system structural integrity.
  - 4. Trim closure strips and non-outgassing type gasketing.
  - 5. Glazed wall panels.
  - 6. Cleanroom swinging aluminum doors and frames.
  - 7. All labor, supervision and equipment for the cleanroom wall installation.
  - 8. Related work specified elsewhere.
  
- B. Inspect all building areas prior to installation, where cleanroom wall will be installed, for any job condition that will alter the layout or details shown on the drawings. Coordinate installation with other trades to avoid conflicts.

#### 1.2 RELATED DOCUMENTS

- A. General and Supplementary Conditions and Division 1
- B. Section 13 2100CR – Cleanroom Construction
- C. Section 13 2105CR – Cleanroom Protocol
- D. Section 13 2110CR – Cleanroom Ceiling System
- E. Section 13 2130CR – Cleanroom Automatic Sliding Doors
- F. Section 13 2140CR – Cleanroom Chemical Fume Hood and Wet Processing Stations
- G. Division 21: Fire Suppression
- H. Division 22: Plumbing
- I. Division 23: HVAC
- J. Division 25: Cleanroom Controls
- K. Division 26: Electrical

#### 1.3 WARRANTY

- A. Provide warranties in accordance with Division 1 requirements.

- B. One (1) year limited standard warranty against defects including excessive fading, excessive nonuniformity of color or shade, cracking, peeling, pitting or corrosion.

#### **1.4 QUALITY ASSURANCE**

- A. Quality Assurance Responsibilities: Cleanroom Contractor is solely responsible for quality control of the work.
- B. Manufacturer's Qualifications: Manufacturer shall have been engaged in the fabrication of clean room walls of types and sizes required and whose products have been in satisfactory use in similar service for not less than 10 years. Like items of material provided herein, shall be the products of one manufacturer in order to achieve standardization for appearance, maintenance and replacement.
- C. Installing Contractor: Cleanroom wall system installer shall be trained and approved by the manufacturer and shall be experienced in the installation of this cleanroom wall system.
- D. Field Samples: Prior to the Pre-Construction Conference, provide a field sample of clean room wall system, not less than 20 lineal feet in an area designated by the Architect. Utilize the same materials and installation methods in the sample as required for the final work. Sample areas shall serve as the standard for materials, workmanship and appearance for such work throughout the project and shall remain a part of the final work.

#### **1.5 DELIVERY, STORAGE AND HANDLING**

- A. Wall system panels shall be delivered with an approved protective coating and packaged to prevent transit and construction dust from contaminating surfaces. Stripping of packaging, except protective coatings on wall panels, to be done in a material entry airlock.
- B. Deliver materials in their original, unopened packages.
- C. Exercise extreme care in handling all cleanroom wall system components to prevent damage.
- D. Store materials in such manner as to prevent damage or intrusion of foreign matter.
- E. Conspicuously mark "Rejected" on materials which have been damaged, and remove from the jobsite.

#### **1.6 SUBMITTALS**

- A. Provide samples of each type of product materials, support components, finishes, and accessories illustrating installed products, finishes, and color.
- B. Detailed manufacturer product data sheets, for each proposed product type, which provides the necessary information to describe and evaluate the product and its performance.
- C. Shop Drawings: Submit complete shop fabrication and installation drawings, including plans, elevations, sections, details, schedules, and 3-dimensional layouts (as necessary). Minimum scale shall be 1:50. Show relationship to adjoining materials and construction. Shop drawings shall depict final product design and installation. Shop drawings shall be prepared electronically and submitted in the form of reproducible or photocopies, prepared in standard Architectural drawing formats and scaled to defined dimensions.

- D. Test reports, by an independent testing laboratory, certifying that component parts perform as specified.

## PART 2 PRODUCTS

### 2.1 CLEANROOM WALL PANEL

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Plascore, Inc.
  2. PortaFab Modular Building Systems.
  3. Approved equal – Subject to approval by Owner’s representative obtained during bidding submittal process and prior to project award.
- B. Wall Panel Characteristics:
1. Shall consist of two layers of sheet aluminum with two glue lines bonding a non-faced honeycomb aluminum core. Components can vary due to make-up of panel thickness and over all size.
  2. Overall panel thickness: Total bonded panel including core, glue lines and face sheets shall be 6.35 mm (1/4 in.) for single wall or 47.8 mm (1.88 in.) for double wall.
  3. All aluminum face skins shall conform to the following general standard: 3000 series aluminum sheet, half hard, 8.13 mm (0.032 in.) thick, specified with by various levered lengths.
  4. Finish: The finished sides of the panels shall have a mil applied paint finish per the following paint schedule:
    - a. The paint application method shall be by reverse roll coat and shall be smooth with a dry film thickness of 0.70 - 0.80 mils. The substrate (aluminum sheet) shall be pre-treated to allow for a superior bond.
    - b. All finishes will comply with required specifications:
      - 1). Coating type: Epoxy
      - 2). Color: No Restrictions
      - 3). Gloss: (60 Degrees): 70% maximum, no minimum
      - 4). Dry film thickness: 0.4 - 1.0 mils
      - 5). Pencil Hardness: 2H (NCAA IT-12)
      - 6). Adhesion: No paint removal (NCCA IT-5)
      - 7). Tabor Abrador: <10mg (CS 10,1000 GM 100 cycles)
      - 8). Surface Resistivity:  $10^6 - 10^9$  Ohms/Sq
      - 9). Outgassing: 0.15 PPM/mg of sample
      - 10). Electrostatic Decay: <10% IN, 0.5/sec
- C. Design Criteria: Vertical loading: Dead Load = Component weight
1. Stiffness: 1/120 at 240 Pa (5 psf).
- D. Support of Ancillary Systems: The batten system will allow the connection of workstations or other attachments at any point along the batten. This system allows for a 225 kg (500 lbf.) pull-out load using 3 connection points over a 175 mm (7 in.) length on a 1200 mm (48 in.) horizontal member.
- E. Deflection Capability: Can accommodate deflection requirements up to 19 mm (3/4 in).

## 2.2 CLEANROOM WALL FRAMING SYSTEM

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Plascore, Inc.
  2. PortaFab Modular Building Systems.
  3. Approved equal – Subject to approval by Owner’s representative obtained during bidding submittal process and prior to project award.
- B. Aluminum Wall Framing System:
1. Basis of Design:
    - a. Wall Type D: Flush finish on both sides of wall. Plascore F2550 Wall System with all hardware including headtrack, floor track, corner details, and associated appurtenances.
    - b. Wall Type L: Liner wall applied to walls or structure. Plascore L2550 Wall System with all hardware including headtrack, floor track, corner details, and associated appurtenances.
    - c. Wall Type S: Flush finish on single side with strut framing system. Plascore S5050 Wall System with all hardware including headtrack, corner details, and associated appurtenances.
  2. Construction:
    - a. Headtrack: Extruded aluminum for connection to the ceiling grid. Headtrack to provide vibration isolation between CRW and ceiling system. Allow 19 mm (3/4 in.) minimum vertical movement, in addition to wall system support and removal. Overall width shall not exceed 50 mm (2 in.) wide.
    - b. Studs: Standard intermediate stud and standard corner stud shall be common components of all framed wall systems, maintaining a nominal 50mm (2 in.) thickness.
      - 1). For single wall (6.35 mm (1/4 in.) panel on one side): Extruded aluminum with continuous threaded screw boss on one side for attachment of panel batten, and continuous open slot on other side to accept standard strut pipe-clamps and fittings or vinyl closure.
      - 2). For double flush wall (nominal (50 mm (2 in.) panel): Standard aluminum stud with a continuous threaded screw boss on one side for attachment of panel batten.
      - 3). For liner wall (6.35 mm (1/4 in.) panel): Same standard panel batten as used on single or double wall. Secures 6.35 mm (1/4 in.) panel to existing wall or framing.
    - c. Corner Studs: A common one-piece corner stud with standard 62.5 mm (2.5 in.) removable battens shall be utilized on all framed wall systems.
    - d. Connectors: Framing members are fastened together with an aluminum block fastened to the end of the stud with standard sheet metal screws. The assembly can then be fastened to the vertical studs with screws and mini-channel nuts by using a common Allen wrench. The framing members can be fastened together with 90-deg fittings as an option.
    - e. Floor Track: Extruded aluminum prepunched at 150 mm (6 in.) for connection to cleanroom floor at 25 mm (6 in.) on center.
    - f. Panel Batten: 50 mm (2 in.) wide extruded aluminum, pre-punched for connection to framing studs at 100 mm (4 in.) on center. Accepts standard mini-channel nuts for attachment of a workstation bracket. A continuous vinyl closure covers fasteners.

- g. Miscellaneous Components: Corners, door frames, bulkhead frames, glazing frames shall be aluminum with similar dimensions compatible with panel thickness.
- 3. Finish:
  - a. Aluminum Head Tracks, Studs, Battens, Floor Tracks, Door Frames, and Miscellaneous Components: Clear anodized aluminum.
  - b. Vinyl Closures: White.

### 2.3 CLEANROOM SWINGING DOORS AND FRAMES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - 1. Kawneer Company Inc.
  - 2. Plascore, Inc.
  - 3. PortaFab Modular Building Systems.
  - 4. United States Aluminum Corporation.
  - 5. Approved equal – Subject to approval by Owner’s representative obtained during bidding submittal process and prior to project award.
- B. Description: Door and frames shall be pivot aluminum type and shall be provided as an integral part of the Cleanroom wall system.
- C. Stile and Rail Doors: Glazed or paneled doors with tubular extruded aluminum frame members.
  - 1. Frame Joints: Concealed mechanically fastened, using tie rods or j-bolts and reinforcing plates.
  - 2. Thickness: 45 mm (1-3/4 in).
  - 3. Stile Width: Nominal 150 mm (6 in.).
  - 4. Top and Intermediate Rail: Nominal 150 mm (6 in.).
  - 5. Bottom Rail: Nominal 300 mm (12 in.).
  - 6. Glazing: 6.35 mm (1/4 in) laminated glass.
  - 7. Glazing Stops: Sloped design, snap-on extruded aluminum, designed to allow replacement of glazing without disassembly of door frame. Provide non-removable stops on clean bay side.
  - 8. Glazing Gasket: Santoprene thermoplastic rubber.
  - 9. Yellow and red lighting window film covering where indicated are to eliminate 99.999% of UV light between 250 – 550nm wavelengths (yellow) or 250 – 575nm wavelengths (red).
  - 10. Solid Panels: 6.35 mm (1/4 in.) solid aluminum panels with one (1) intermediate horizontal rail.
  - 11. Undercut: 50 mm (1/2 in.).
  - 12. Hardware:
    - a. Pivot Hinges: Doors shall have full ball bearing pivot.
    - b. Door Closers: Closers shall be concealed with heavy duty arms and through bolts; Plascore LCN 3130 or approved equal.
    - c. Exit Device: Push-to-exit rim exit device with door latch and strike. Anodized aluminum finish, UL listed for panic exit hardware.
      - 1). Trim: Keyed lock cylinder to retract latchbolt from pull side. All lock cylinders shall be keyed alike. Provide one key per cylinder.
    - d. Handle Grips:
      - 1). Vertical: 1-inch round tube; radius bend; 10-inch center-to-center; 2-inch clearance.
      - 2). Horizontal: 1-inch round tube; radius bend; center-to-center specific for door width; 2-3/4-inch projection.

13. Finish:
  - a. Aluminum: Class 1 natural anodized finish.
  - b. Hardware: Satin Stainless Steel.
14. Accessories:
  - a. Thresholds: ¼-inch high, 0.125-inch wall, aluminum mill finish, width as required.
  - b. Door stop: Universal dome stop, ¼-inch high base plate, rubber stop material, satin stainless steel or nickel finish.

## 2.4 CLEANROOM GLAZING

- A. Glazing for Cleanroom Walls:
  1. Glazing: 6.35 mm (1/4 in) tempered glass.
  2. Glazing Stops: Sloped design, snap-on extruded aluminum, designed to allow replacement of glazing without disassembly of door frame. Provide non-removable stops on clean bay side.
  3. Glazing Gasket: Santoprene thermoplastic rubber.
  4. Wall panels below center mutton to be ¼-inch honeycomb cleanroom panel to match wall system
  5. Yellow and red lighting window film covering where indicated are to eliminate 99.999% of UV light between 250 – 550nm wavelengths (yellow) or 250 – 575nm wavelengths (red).

## PART 3 EXECUTION

### 3.1 INSTALLATION

- A. The nature of the completed facility demands special attention to maintaining an overall cleanliness in the project area.
- B. All installation methods shall be in accordance with the latest recommendations of the component manufacturer and in conformance with this specification. Accurately align and securely anchor framing and finish members in accordance with drawings. Position framing vertically, spaced as required. Locate framing adjacent to door frames, openings, door pockets, partition intersections, and comers. Lock wall panels securely in place, flush with adjacent panels.
- C. Assemble partition components into a rigid structure with tight, straight-line joints. Completed installation shall be free of exposed bolts, nuts, rivets, and fasteners within the cleanroom area, and shall interface with all mechanical and electrical work in a clearly pre-planned and craftsman-like installation.

### 3.2 CONDITIONS OF SURFACES

- A. Examine substrates and adjoining construction and conditions under which work is to be installed. Do not proceed with the work until unsatisfactory conditions have been corrected.

### 3.3 ERECTION

- A. Verify dimensions of supporting structure by field measurements to insure cleanroom wall will be accurately designed, fabricated, and fitted to the structure.

- B. Coordinate cleanroom wall work with the work of related sections. Provide items to be placed during the installation of other work at the proper time to avoid delays in the work. Place such items, including inserts and anchors, accurately in relation to the final location of the cleanroom wall system components using locking type devices at all connections.
- C. Erect all component parts of the cleanroom wall in accordance with the manufacturers written instructions and recommendations.
- D. Erection Tolerances - erect all component parts within the following tolerances: Variations from plumb or angle shown: 3.175 mm (1/8 in.) maximum variation in height on 3000 mm (10 ft.) run, noncumulative.
- E. Cutting and Trimming of Component Parts:
  - 1. Cut and trim component parts of the cleanroom wall during erection in accordance with manufacturer's recommendations. Restore finish completely to protect material and remove all evidence of cutting and trimming.
  - 2. All cutting and trimming to be done outside the cleanroom area or in approved cleanroom fabrication shop located within cleanroom envelope.
  - 3. Field cutting shall conform to fire safety requirements.
  - 4. Field cut and drill panels for installation of electrical and telephone device box blockouts and conduit at locations indicated.
- F. Do not erect members which are observed to be warped, bowed, deformed, or otherwise damaged or defaced to such extent as to impair strength or appearance. Remove and replace members damaged in the process of erection.
- G. Set units level, plumb, and true to line, with uniform joints. Support and secure in place by bolting to clip angles and similar supports anchored to supporting structure.

### **3.4 CLEANING**

- A. Provide cleaning in accordance with Project Specifications.
- B. Provide cleaning methods required for each component part as recommended by the manufacturer.
- C. The nature of the project requires special attention to minimizing potential contamination of the fully developed cleanroom environment. All construction dust and contaminants left on surfaces or in recesses that will be exposed to cleanroom air will have the effect of unduly loading up the filter system. Daily cleanup and vacuuming of the work area is essential for an ongoing control of contaminants, especially as the cleanroom fit-up progresses.

### **3.5 PROTECTION**

- A. Protect the cleanroom wall system throughout the construction period in a clean and properly protected condition so it will be without any indication of use or damage at the time of Substantial Completion.
- B. Protect the work during shipment, storage, erection and construction so as to avoid development of non-uniformity of appearance or other deleterious effects in the Work.
- C. Protection shall consist of factory applied protection or 10 mm (3/8 in.) coroplast attached with cleanroom tape for high traffic areas.

- D. Remove protection when no longer required.
- E. Materials found to be defective or improperly installed shall be replaced.

**END OF SECTION 13 2120CR**



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## SECTION 13 2130CR – CLEANROOM AUTOMATIC SLIDING DOORS

### PART 1 GENERAL

#### 1.1 SUMMARY

- A. Automatic Sliding Doors shall consist of aluminum framing and glass, with operators rated and sealed for cleanroom use. System installation shall include wiring from electrical j-box to the operator and the door operating switches (infrared, push-button, etc.).

#### 1.2 RELATED DOCUMENTS

- A. General and Supplementary Conditions and Division 1
- B. Other Division 9 sections for floor finishes related to this section but not the work of this section.
- C. Section 13 2100CR – Cleanroom Construction
- D. Section 13 2105CR – Cleanroom Construction Protocol
- E. Section 13 2110CR – Cleanroom Ceiling System
- F. Section 13 2120CR – Cleanroom Wall System
- G. Division 25: Cleanroom Controls
- H. Division 26: Electrical

#### 1.3 WARRANTY

- A. Provide warranties in accordance with Division 1 requirements.
- B. In addition to Division 1 requirements, automatic doors capable of operating without failure of any component, for not less than 300,000 open-and-close cycles, with normal maintenance as defined in manufacturer's standard operating manual.
  - 1. Provide a minimum 5 year warranty against defects in materials and workmanship for the controller and drives.

#### 1.4 QUALITY ASSURANCE

- A. BHMA Standard: Provide automatic entrance doors complying with applicable requirements or ANSI/SHMA A156.10. "Power Operated Pedestrian Doors."
- B. UL Standard: Provide powered door operators complying with UL 325, Electric Door, Drapery, Gate, Louver and Window Operators and Systems.
- C. Emergency Exit Doors: Provide automatic entrance doors complying with requirements for doors serving as exit components in the means of egress as defined by IBC, 2003 Edition, and NFPA 101 and as certified by the manufacturer for the application shown.

- D. The sliding door package shall be installed by factory-authorized and factory-trained personnel. The work shall be done in strict compliance with the manufacturer's recommendations and according to approved shop drawings.
- E. ISO Class 5 Rating: Certify that the automatic entrance door meets the required cleanroom classification rating.

## 1.5 DELIVERY, STORAGE AND HANDLING

- A. Deliver doors and frames, cardboard-wrapped or crated to provide protection during transit and Project Site storage. Provide additional protection to prevent damage to finish of factory finished doors and frames.
- B. Inspect doors and frames upon delivery for damage. Minor damages may be repaired provided refinished items are equal in all respects to new work and acceptable to Architect; otherwise, remove and replace damaged items as directed.
- C. Store doors and frames in an environmentally controlled area at building site under cover. Place units on minimum 4 inches high blocking, provide 1/4-inch spaces between stacked doors to promote air circulation. Ensure that the stacking and storage of the units does not induce warping or racking of the door units. If cardboard wrapper on door becomes wet, torn or damaged remove carton immediately and provide same amount of surface protection to prevent damage to surfaces etc.

## 1.6 DEFINITIONS

- A. NAAMM - National Association of Architectural Metal Manufacturers.
- B. ANSI - American National Standard Institute.
- C. ASTM - American Society of Testing and Materials.
- D. IBC - International Building Code
- E. NFPA - National Fire Protection Association.
- F. UL - Underwriters Laboratories Inc.

## 1.7 SUBMITTALS

- A. General: Submit in accordance with Division 1 Specifications.
- B. Product Data: Submit manufacturer's product data and standard details for automatic entrance doors, including fabrication, finishing, hardware, operators, accessories and other components of the work. Include roughing-in diagrams, wiring diagrams, parts lists, and maintenance instructions, as well as certified test data, where required.
  - 1. Certification by manufacturer that sliding door operators have been designed for, and will meet, the requirements for the cleanliness classification specified for each door operator location.
- C. Shop Drawings: Submit shop drawings for the fabrication and installation of automatic entrance doors and associated components of the work. Indicate anchors, joint system, expansion

provisions, hardware, and other components not included in manufacturers standard data. Include glazing details.

- D. Closeout Submittals
  - 1. Submit under provisions of Division 1 Specifications.
  - 2. Operation and Maintenance Data: Submit manufacturer's printed, recommended operation and maintenance data.
  - 3. Warranty: Submit specified product warranty in accordance with Section 01780.

## 1.8 COORDINATION

- A. General
  - 1. Furnish and install of complete Automatic Cleanroom Sliding Doors with Electric Operators.
- B. Work included;
  - 1. Coordination of door opening with Architectural and Cleanroom floor and wall elements.
  - 2. Door installation.
  - 3. Electrical connection of door from local power j-box.

## PART 2 PRODUCTS

### 2.1 CLEAN ROOM AUTOMATIC SLIDING DOORS

- A. MANUFACTURERS
  - 1. Acceptable Manufacturers:
    - a. Stanley Access Technologies.
    - b. Besam, Inc.
    - c. Horton Automatic Doors.
    - d. Approved Equal
- B. MATERIALS
  - 1. Aluminum Extrusions: Alloy and temper as recommended by manufacturer for strength, corrosion resistance, application of required finish and control of color, but not less than 22,000 psi ultimate tensile strength. Provide main extrusions of not less than 0.125 inch wall thickness, except as otherwise indicated.
    - a. Provide extruded glazing stops and other applied trim extrusions with minimum wall thickness 0.062 inch.
  - 2. Aluminum Sheets: Alloy and temper as recommended by manufacturer for strength, corrosion resistance, abrasion resistance, and application of required finish and control of color. Provide sheets of not less than 0.062-inch thickness, except as otherwise indicated.
  - 3. Aluminum Fasteners: nonmagnetic stainless steel, or other non-corrosive metal compatible with the items being fastened.
    - a. Do not use exposed fasteners except where unavoidable for the assembly of units, and unavoidable for the application of hardware.
  - 4. Steel Reinforcement and Brackets: Manufacturer's standard units with 2.0-oz. hot-dip zinc coating, ASTM A123, applied after fabrication. Steel reinforcements shall be limited such as to not cause stray magnetic fields during operation.
  - 5. Compression Weather-stripping Manufacturer's standard replaceable stripping; either molded neoprene gaskets or molded PVC gaskets. Compression gaskets include collapsible finger guards at pivot jambs as well as bumper-type gaskets at doorstops and laps.

6. Sealants and Gaskets: Use sealants and gaskets in the fabrication, assembly and installation of the work, which are recommended and guaranteed by the manufacturer to remain permanently elastic, non-shrinking, non-migrating, and without effect of outgassing.
7. Glazing
  - a. PVC base material
  - b. Conductivity: 106 to 108 ohms grounded with wall system
  - c. Color:
    - 1). Clear Transparent
    - 2). Orange Transparent
  - d. Transmittance: no measurable transmittance <500 nm wave length at locations requiring Orange Transparent glazing
  - e. Thickness: ¼" unless noted otherwise on Drawings.

## 2.2 CLEANROOM AUTOMATIC SLIDING DOOR COMPONENTS

- A. General
  1. Aluminum frames including top and bottom pivots.
  2. All Door hardware:
    - a. Passage hardware
    - b. Breakaway / Panic hardware
  3. Floating head and aluminum tube at door head. (See drawings for details).
  4. Door operator with electronic controller and push-plate switches.
  5. Directional motion sensor on each side of door.
  6. Control options for door operator or motion sensor operations.
  7. Operators housing guide rollers, door carrier.
  8. Glazing.
  9. Interlock controls (door switch and relay) for interlock with outer doors where shown on Drawings.
  10. Overhead safety threshold sensor(s) for obstructions.
  11. Dimensions: Doors shall be 7-foot total width with a 3.5-foot active door and 3.5-foot inactive door. Doors shall be 8-foot tall.
- B. Automatic sliding doors shall be overhead concealed, Electro-mechanical operator as manufactured by the listed manufactures.
- C. Operator Capacity: Size as recommended by manufacturer's published data for the door size, weight, movement, and condition of exposure, for long-term maintenance-free operation under normal traffic load.
- D. Exposed Housing for Operators: Extruded or formed aluminum, 0.062 inch minimum thickness, with provisions for maintenance access, with fasteners concealed when door is in closed position.
- E. Adjustment Features: Provide operators with fully adjustable opening speeds, closing speeds, and checking speeds and length of time door remains open.
- F. Manufacturer's standard electric-mechanical drive unit, self-contained with connections for power and control wiring, power opening and either power or spring closing with safety release clutch for obstructed closing; and with checking for both opening and closing cycles. Provide for manual sliding/opening when power is off.
  1. Operator Action: Single-slide/Double slide.
  2. Provide overhead-concealed operators with angled cover for airflow.

3. Provide emergency breakaway swing feature (ANSI Standard 156.10 and BHMA 1601 Protection Standards).
  4. Provide power disconnect switch.
- G. Openings and seams in the electric motor housing shall be sealed with closed cell gasketed, non-VOC material or with non-VOC sealant.

## 2.3 ACCESSORIES

- A. Operators
1. General
    - a. Sizes and Profiles: The required sizes for door and frame units, and the profile requirements are shown on the drawings.
    - b. Prefabrication: Except as otherwise indicated, provide each continuous unit of framework, door sidelights, transom panels, hardware, and accessory items, as a “packaged entrance” unit. Complete the fabrication, assembly, finishing, application of hardware and other work, before shipment to the project site, to the greatest extent possible. Disassemble only to the extent necessary for shipment and installation.
    - c. Complete the cutting, fitting, forming, drilling, and grinding of metal work prior to cleaning and finishing. Cut material square and remove all burrs from all exposed edges, with no chamfer. Ease edges and corners to a radius of approximately 1/64th of an inch.
    - d. Weld by methods recommended by AWS to avoid discoloration at welds. Grind exposed welds smooth and restore mechanical finish.
    - e. Conceal fasteners, wherever possible.
    - f. Maintain continuity of line and accurate relation of planes and angles. Provide secure attachment and support at mechanical joints, with hairline fit of contacting members.
- B. Touchless Door Switch:
1. Basis of Design: BEA Inc. model MS-08 or approved equal.
  2. Touchless switch with Doppler radar for use in Cleanroom environments.
  3. Dimensions: 4.5-inch high x 2.75-inch wide x 2-inch deep.
  4. Single gang box wall mounting with full perimeter gasket.
  5. Engraved face plate with symbol of a waving hand and lettering “WAVE TO OPEN”.
  6. Control is to be hard wired to door actuator. No wireless or remote button operators are allowed.
  7. Variable adjustment of pattern from 2-inch to 20-inch.
  8. Variable relay-hold time from 0.5 to 10 seconds.
  9. Electrical: 12 to 24vac/vdc.

## 2.4 FABRICATION

- A. General
1. Reinforce the work as necessary for performance requirements, and for support to the structure. Separate dissimilar metals with bituminous paint or preformed separators, which will prevent corrosion. Separate metal surfaces at moving joints with nonmetallic separators to prevent “freeze-up” of joints.

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## **2.5 FINISHES**

- A. Aluminum Finishes: Clear Anodized Finish: NAAMM AA-M21C22A32. 0.4 mils minimum thickness.
- B. Hardware Finishes:
  - 1. Door Hardware: Clear Anodized Aluminum Finish
  - 2. Trim Plates: Satin Stainless Steel

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Comply with manufacturer's instructions and recommendations.
- B. Set units plumb, level and true to line, without warp or rack of frames or doors. Anchor securely in place. Separate aluminum and other corrodible metal surfaces from sources of corrosion or electrolytic action at points of contact with other materials.
- C. Install complete door operator system in accordance with manufacturer's instructions, including controls and controls wiring.
- D. Set tracks, header assemblies, operating brackets, rails and guides level and true to location with adequate anchorage for permanent support.
- E. Install thin metal foil conductor at each corner of glazing panel to make electrical connection between face of glazing and metal doorframe. Foil shall be sandwiched between the glazing and the glazing stop material. Cut excess foil exposed to view.

### **3.2 ADJUSTING**

- A. After repeated operation of completed installation equivalent to 3 days' use by normal traffic (100 to 300 cycles), readjust door operators and controls for optimum operating condition and safety. Clean exposed surfaces.

### **3.3 CLEANING**

- A. Clean aluminum surfaces promptly after installation, exercising care to avoid damage of the protective coating (if any). Remove excess glazing and sealant compounds, dirt and other substances. Exercise extreme care in cleaning glazing. Follow manufacturer's recommendations.

**END OF SECTION 13 2130CR**

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## **SECTION 13 2140CR – CLEANROOM CHEMICAL FUMEHOODS AND WET PROCESSING STATIONS**

### **PART 1 GENERAL**

#### **1.1 SUMMARY**

- A. This Section includes the following equipment and related accessories for use in Cleanroom environments.
  - 1. Polypropylene chemical fume hoods.
  - 2. Stainless steel chemical fume hoods.
  - 3. Polypropylene chemical wet processing stations.
  - 4. Stainless steel chemical wet processing stations.

#### **1.2 RELATED DOCUMENTS**

- A. General and Supplementary Conditions and Division 1
- B. Section 13 2100CR – Cleanroom Construction
- C. Section 13 2105CR – Cleanroom Construction Protocol
- D. Section 13 2120CR – Cleanroom Wall System
- E. Division 21: Fire Suppression
- F. Division 22: Plumbing
- G. Division 23: HVAC
- H. Division 25: Cleanroom Controls
- I. Division 26: Electrical

#### **1.3 REFERENCES (LATEST EDITION)**

- A. NFPA 70 - National Electric Code
- B. NFPA 318 - Protection of Cleanrooms
- C. UL/FM 4910 Material Standards
- D. ISO Standard 14644-1 - Classification of Cleanliness for Cleanrooms
- E. IES-RP-CC-002.2 - IES Standard for Unidirectional Flow Clean Air Devices
- F. American Council of Industrial Hygienist - Latest edition
- G. ASHRAE - 110 - Method of Laboratory Fume Hood Testing
- H. NSF 49 - Latest Edition

- I. ISO Standard 14644-2 Specification of Testing and Monitoring for Compliance w/ 14644-1
- J. IES-RP-CCO 34.1 HEPA and ULPA Filter Leak Testing
- K. NFPA 45 - Standard on Fire Protection for Laboratories Using Chemicals
- L. NFPA 496 – Standard for Purged and Pressurized Enclosures for Electrical Equipment
- M. Underwriters Laboratories 6-1010-1 International Standard for Laboratory Hoods and Cabinets

#### **1.4 DEFINITIONS**

- A. OEM: Original Equipment Manufacturer- A company who produces hardware to be marketed under another company's brand or be included as an integral part of another company's product.

#### **1.5 EQUIPMENT DESCRIPTIONS**

- A. Design Requirements:
  - 1. Fume hoods and wet processing stations shall be purpose – designed specifically for ISO classified Cleanroom use. Materials of construction or finishes that may shed particles or may off-gas shall not be used. Additionally, a thorough review of all end-user chemicals to be used in each station per tank, with indicated temperatures and concentrations shall be made prior to fabrication. Construction materials for all tanks, work decks, process piping, waste carboys, and containment plenums shall be matched specifically based on the end-user chemical review. All construction materials shall meet FM-4910 flame retardant standards.
- B. Performance Requirements:
  - 1. Fume hoods and wet processing stations shall meet all OSHA exhaust requirements and shall maintain a design exhaust velocity across the front access opening with less than 125 Pa (0.50 inch wg) pressure drop.
  - 2. Fume hoods and wet processing stations shall be evaluated “AM” (As Manufactured) under the Modified ANS/AHRAE 110-1999 testing procedures and shall meet a minimum performance rating:
    - a. Static Tests: 4.0 AM 0.05 ppm
    - b. Walk-by: 4.0 AM 0.10 ppm maximum and must return to 0.05 ppm within 15 seconds.
  - 3. Electrical wiring shall comply with the National Electrical Code.
  - 4. Static pressure loss not more than 125 Pa (0.5 inch wg) at 0.5 m/s (100 fpm) face velocity per SEFA 1.2, “Laboratory Fume Hoods - Recommended Practices”

#### **1.6 SUBMITTALS**

- A. Product Data:
  - 1. Provide manufacturers description, materials of construction, finish, itemized features, and operating characteristics for each hood and processing station. Include original equipment manufacturers' (OEM's) documentation for furnished specialties and accessories.
  - 2. Submit testing and quality assurance procedures.
  - 3. Describe finishing and cleaning for materials to be used in the Cleanroom.
  - 4. Describe packaging and shipping procedures.
  - 5. Provide on-site product inspection procedures.



- B. Shop Drawings: For each fume hood and processing station provide:
  - 1. Fabrication drawings, including dimensions, weights, required clearances, method of field assembly, location and size of each field connection, and access features.
  - 2. OEM equipment installation details.
  - 3. Wiring Diagrams: Power, signal, and control wiring.
  - 4. Plumbing Diagrams.
- C. Quality Control Submittals:
  - 1. Factory As-Manufactured (AM) test results in accordance with Modified ANSI/ASHRAE 110-1999.
  - 2. Field As-Installed (AI) test results in accordance with Modified ANSI/ASHRAE 110-1999.

## 1.7 QUALITY ASSURANCE

- A. Installer Qualifications: An authorized representative of the manufacturer shall install units and equipment required for this Project.
- B. Product Options: As fabricated, drawings for each unit, which indicate size, profiles, and dimensional requirements of hoods, and processing stations, and show location and installation details of OEM equipment.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- D. Comply with NFPA 70, "National Electrical Code."

## 1.8 DELIVERY, STORAGE AND HANDLING

- A. Delivery, storage and handling shall be in accordance with the submitted detail procedures as approved by Owner.
- B. High purity OEM components shall be shipped to site in OEM's original protective packaging and only opened for installation in the Cleanroom.
- C. Installed piping shall be protected with both end caps and bagged ends. Exposed ends or projections shall be encased and protected from shipping and handling damage.
- D. Manufactured units shall be sealed and packaged in a Class 100 Cleanroom before shipping, to maintain the highest level of factory cleanliness through the shipping and handling process.

## 1.9 EXTRA MATERIALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
  - 1. Portable waste containers constructed of appropriately matched materials for chemistries.
  - 2. Quick disconnects for portable waste containers.

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## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Air Control, Inc. P.O. Box 1738, Henderson, North Carolina 27536, USA; Phone: 252.492.2300
  2. ReynoldsTech, 6895 Kinne Street, East Syracuse, New York, 13057, USA; Phone: (315) 437-0532
  3. JST Manufacturing, 219 E. 50<sup>th</sup> St., Boise, ID 83713, USA; Phone (800) 872-0391.
  4. Or approved equal.

### **2.2 MANUFACTURED UNITS**

- A. Fume Hoods and Wet Process Stations as described in Part 1 of this Section shall be factory-assembled, pre-wired, pre-plumbed, and factory-tested.
- B. Cleanliness critical fabrications and component installations shall be performed under clean conditions as submitted by the Manufacturer and approved by Owner.
- C. During the fabrication process and after testing is complete, the manufactured units shall be cleaned of all dust, dirt, grease, oils, stains and fabrication markings as a preparation for Cleanroom installation prior to sealing and packaging for shipment.

### **2.3 MATERIALS**

- A. Non-metallic fume hoods and wet processing stations shall be fabricated from the following:
1. "Wetted" inside hood surfaces: white stress-relieved polypropylene sheet stock plastics conforming to FM approved fire retardant plastics.
  2. Non-wetted hood components: white stress-relieved polypropylene sheet stock plastics.
  3. Carboys: white stress-relieved polypropylene sheet stock plastics conforming to FM approved fire retardant plastics.
  4. Raw sheet stock materials shall be inspected prior to fabrication and shall be certified to be free of any visual or structural defects.
  5. All joints shall be thermally welded to make leak tight, structurally sound, flush joints.
  6. Tanks, decks, piping to be other plastic material as dictated by specific chemistries, temperatures, and concentrations. Materials include Teflon, PVDF, quartz, and polycarbonate.
  7. Fasteners: Fasteners in the air stream of the polypropylene units shall be non-metallic or have protective plastic caps
- B. Metallic fume hoods and wet process stations shall be fabricated from the following:
1. "Wetted" inside hood surfaces: 16-gauge, 316L stainless steel with a #4 finish.
  2. Non-wetted hood components: 16-gauge, 304 stainless steel with a #4 finish.
  3. Carboys: 16-gauge, 316L stainless steel with a #4 finish.
  4. Fasteners: Fasteners in the air stream of the stainless steel processing stations shall be 316L stainless steel.

### **2.4 COMPONENTS**

- A. The following features are common to fume hoods and wet processing stations:

1. Units shall have an instrument compartment-mounted "Low Face Velocity Alarm" which provides audible and visual warnings when the exhaust volume drops below a safe level as detected by a face velocity airflow monitor. For fume hood monitoring devices provided by Control Contractor, coordinated location and cutout for mounting monitor.
2. Work surface or processing deck shall be recessed for spinner containment.
3. Exhaust louver above rear work surface shall be adjustable and set at the factory for design conditions.
4. Unit shall be configured for bulkhead mounting through the Cleanroom wall panels to allow rear service access from the service chase. The exhaust plenum, exhaust connections, and utility connections shall be accessible from the chase.
5. Base cabinets shall be vented to accommodate chemical storage beneath the work surface or processing deck. Base cabinet storage areas shall have access doors on both the Cleanroom side and the service chase side.
6. Rollout trays shall be installed in the base cabinet storage area of each unit – for supply chemical bottles and for waste receptacles. Trays shall be fully welded leaktight.
7. External piping utility connections include nitrogen gas, specialty gases, compressed air, process vacuum, UHP water supply, UHP water return, non-potable water, wastewater drain and plenum drain. Refer to contract documents for required utilities.
8. Piping utilities shall connect in the service chase to the rear of the units.
9. Sink and plenum drains shall be polypropylene, DWV pipe that terminates with Schedule 80 pipe stub extending from the rear of the unit. The installer of the Cleanroom drain piping shall install P-traps on the exterior when connecting the unit to the wastewater drains system.
10. All other internal utility piping shall be Teflon PFA tubing which terminates at the rear of the unit with an extended, male-female, flare, straight union, panel mount fitting.
11. General-purpose sinks shall have a formed bottom sloping to a 25 mm (1 in.) center drain and shall be plumbed to drain. PVDF gooseneck for High-purity DI water shall be installed at the general purpose sink.
12. DI water spray gun with 10 mm (3/8 in.) coiled PFA tubing shall be installed adjacent to general-purpose sink.
13. High-purity DI piping design shall provide supply and return piping connections for a recirculating flow system.
14. Nitrogen spray gun shall have 0.5 mm PTFE membrane filter and 6.35 mm (1/4 in.) PFA tubing.
15. Electrical items shall be wired to a single point of connection at a junction box on the rear of the unit.
16. Fluorescent lighting shall provide 100 foot-candles minimum at the work surface. Provide yellow lighting sleeves for hoods located in Lithography Clean Bays.
17. Light switch shall be mounted on the instrument panel.
18. Duplex electrical GFI-type receptacles shall be mounted at each end of the instrument panel.
19. Two digital timers with membrane keypad, buzzer and alarm light shall be mounted on the instrument panel.
20. One emergency off switch shall be mounted on the instrument panel.
21. Units shall have leveling feet with a minimum of 25 mm (1 in.) adjustment. A minimum of six levelers shall be used to support casework on a variety of surfaces. The cabinets shall be reinforced to support loads without distortion.
22. Exhaust plenum shall transition to a standard ANSI duct flange for connection to the exhaust duct system by the Mechanical Contractor.

**B. Fume Hood:**

1. Fabricate fume hoods with a front canted at 7 degrees away from operator for ergonomic comfort.

2. Provide a full view, vertically rising safety sash with encapsulated counter weights for ease of operation. Sash shall close within one inch of the work surface. Provide sash stop with manual override at normal operating height as indicated in the drawings. Provide labeling with arrow at normal sash operating height.
  3. Air by-pass louvers shall be located in the upper front of the hood to provide a near constant exhaust volume.
  4. Fume hoods shall have flat work decks without the underneath wash-down tubs.
  5. Work decks shall be either one-inch thick polypropylene or reinforced stainless steel in hoods of the same material.
- C. Wet Processing Stations:
1. A full-length, leak-proof, drip tub shall be installed underneath a segmented work deck. The tub shall have a leak-tight bottom, which is sloped to 37.5 mm (1 ½ in) drains. Ports shall connect tub to the exhaust plenum. A continuous front lip exhaust shall be provided at the work surface level.
  2. An instrument compartment, which allows HEPA filtered air from the ceiling to reach the work surface, shall be located forward-mounted above the work surface.
  3. 28W T5 Fluorescent lights shall be mounted at rear of instrument panel in a fume-tight, sealed compartment.
  4. A top-hinged, full-length, transparent eye shield shall provide 500 mm (20-inches) of access above the work surface.
- D. Plumbing
1. PFA Tubing System: Except for the general service sink drains and for plenum drains, all process utilities (both high-purity and non-rated services) shall be distributed from point-of-service connection to point-of-use in 100% virgin, high purity, high molecular weight, Teflon PFA (perfluoroalkoxy resin) tubing, fittings and connectors, which conform to ASTM D3307.
    - a. Tubing:
      - 1). High purity PFA tubing shall have standard wall ratings in compliance with ASTM D2837.
      - 2). Products and Acceptable manufacturers:
        - a). Fluoroline 4200 tubing by Entegris, Inc.
        - b). Furon 400 Series tubing by Saint-Gobain Performance Plastics, Inc.
        - c). Or Owner approved equal.
    - b. Fittings:
      - 1). Heat flared tubing fittings with PFA bodies and PFA nuts.
      - 2). Products and Acceptable Manufacturers:
        - a). Flaretek fittings by Entegris, Inc.
        - b). Flare Grip fitting by Furon/Saint Gobain Performance Plastics, Inc.
        - c). Or Owner approved equal.
  2. Polypropylene Piping Systems:
    - a. General service sink drains and plenum drains shall be Schedule 80, polypropylene pipe and fittings conforming to ASTM D4101, ASTM D3311 and ASTM D1785. Joints may be either electro-fused or heat fused.
    - b. Acceptable Manufacturers:
      - 1). George Fischer
      - 2). Approved equal
  3. Gooseneck Faucet in PVDF: Deck mounted non-recirculating laboratory faucet manufactured from Virgin unpigmented PVDF resin per ASTM D 3222. Inlet and Outlet

to be 19 mm (1/2 in.) female pipe thread, and molded into base. Unit to be activated by needle valve of same resin, mounted at point of release of fluid.

- a. Available Manufacturers:
  - 1). WaterSaver
  - 2). Orion Fittings, Inc.
  - 3). Approved equal
4. DI water spray gun with 10 mm (3/8 in.) coiled PFA tubing. Non-recirculating design.
  - a. Available Manufacturers:
    - 1). Entegris Fluid Handling Products
    - 2). Approved equal.

#### E. Electrical

1. This section will describe the main electrical wiring methods and protocols to be used in the hood fabrication. The design basis for the hood is for general classification usage as outlined in NFPA 70. All wiring methods are to be in compliance with U/L 6-1010-1. All hoods must receive an Underwriters Laboratory Field Inspection Label. A copy of this report will be provided to the "AHJ" of South Bend In. All cost burdens for this label are the responsibility of the hood manufacturer. All specialty equipment including but not limited to spinners, hot plates, Sonics, temperature controllers etc. must also be U/L approved or bare a U/L Product Field Evaluation Label.
2. Service Entrance: Any low voltage 24VDC power needed by the hoods is provided via transformer that is supplied with the hood. The service entrance shall be located on the rear of the hood in a NEMA 12 rated enclosure.
3. Main Electrical Enclosure: The main electrical enclosure on each hood shall be sealed for corrosion resistance purposes. The enclosure shall have space available for up to 5 additional single pole circuit breakers to be installed at a later date.
4. Control Power: All instrument and control power shall be low voltage 24VDC. Wiring to be color coded to distinguish control power from main power distribution. All hoods to have a low-voltage emergency power-off control circuit.
5. Receptacles: GFIC duplex receptacles with NEMA 3R weatherproof covers. The receptacles will be located as indicated on the drawings.

#### F. Controls and Interlocks

1. All electrical control power shall be 24vdc low voltage. All low voltage wiring to be color coded for clarity throughout the hood. All heated tanks shall be designed and compliant with NFPA 318. The following is a list of control interlocks required within each tool:
  - a. Tank drain-heat interrupt
  - b. Low-exhaust / power interrupt
  - c. Waste collection tanks full / drainage interrupt
  - d. Waste collection area leakage / drain interrupt – visual alert -
  - e. Tank level / sonic operation interrupt
  - f. Low Nitrogen Pressure – Less than 15psi
  - g. 5-gallon waste carboy present / drain inhibit
  - h. Waste solvent collection 5 gallon carboy full / drainage interrupt
  - i. Disposable 1-gallon spinner waste carboy present
2. Leak Detection Devices: Leak detection sensors shall be light defractive style, low voltage and Teflon coated and shielded for use in chemical areas.
3. Building Management System Interface: Sets of form "C" dry contacts to be available within each hood. This set of contacts will be activated upon a fault condition occurring within the unit. The controls contractor may then use this relay to interface with the building management system.

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- G. Hood Controller
1. Hoods shall use a touchscreen PLC for overseeing major hood functions. This controller shall be fully programmable with graphics and provide for flexibility and 20% expansion for input/output for future upgrades.
- H. Hood Process Equipment: Refer to hood deck plan drawings for process equipment requirements.
1. Spinners: Where noted on drawings laboratory spinners will be provided.
    - a. Spinner chucks are not included. They are to be provided by the owner. Spinners will be facilitated and installed per the manufacturers recommendations. The spinners will drain to a waste jug located in the storage area.
  2. Quartz Tanks:
    - a. Quartz tanks that are heated and stagnate are to be provided as noted. Tanks are sized for (1) 150mm cassette. The tanks will be provided with UL/FM 4910 exterior insulation jackets. The tanks will be drained to the on-board waste collection holding tank. Tank temperature is controlled via PID style controller using RTD probe. Tank drainage will be inhibited above a 60C temperature. The heating control circuit will be interlocked and in compliance with NFPA 318. The tank will be supplied with a reflux-condensing collar fabricated from ECTFE material and flush hinged cover. Note: Quartz tanks will be mfg. by Imtecc Inc. for compliance with U/L.
  3. Automatic Quick Dump Rinse (QCR) System:
    - a. Quick dump rinse systems will be provided per the locations on the deck layout drawings. Rinsers will be fabricated from natural polypropylene material. The unit will have the capability to be programmed based upon fill time, cascade, spray sequence; dump and fill count cycle etc. All program and recipe control is handle via a user interface. Needle valves will be provided for controlling the spray and bottom fill water pressure. Dump door drain will be pneumatically operated. All water valves will be PFA Teflon.
  4. Ultrasonic Tanks:
    - a. Ultrasonic tanks are stagnant and are to be provided as noted. Dependent upon location tanks may be heated or non-heated. Please refer to deck layout drawings for specific requirements. Tanks are sized at approximately 10" square. The tanks will be provided with a stainless steel insulation jacket. The tank jacket area is N2 purged. The tank ultrasonics operate at 40Khz. This frequency is adjustable. The sonic intensity is adjustable. Tank temperature is controlled via PID style controller using RTD probe. The heating circuit will be interlocked and in compliance with NFPA 318. The tank will be supplied with a flush cover. The sonic tanks will have dual drain capability where-by the liquid may be routed to either house waste or solvent collection. Solvent waste collection mode will allow the liquid drain to the on-board waste holding tank as detailed in the plumbing section of this specification. Operation and control of the solvent collection mode will be under manual control.
  5. Hot Plates:
    - a. Where shown on the drawings hot plates will be provided. The hot plates will be located in wells and the wells will be provided with flush covers. The hot plate wells will be of the same material as the base tool construction. Hot plate wells will be Teflon coated. Hot plates will be 9" square in size. Hot plates will be as manufactured by Torrey Pines Scientific Inc. or owner approved equal and will bear the U/L label. The unit will have over temperature and walk-away timer for safety purposes. Controls shall be visible and accessible from a safe and comfortable user position.
  6. Stirring Hot Plates:

- a. Where shown on the drawings stirring hot plates will be provided. The stirring hot plates will be located in wells and the wells will be provided with flush covers. The hot plate wells will be of the same material as the base tool construction. Stirring hot plates will be 9" square in size. Stir plates will be as manufactured by Torrey Pines Scientific Inc. or equal as approved by owner and will bear the U/L label. The unit will have over temperature and walk-away timer for safety purposes.
7. Ambient Temperature Process Tanks:
  - a. Where shown on the deck layout drawings, process tanks ambient temperature tanks will be provided. Tanks will have air operated drains and flush fitting covers. The tanks will be fabricated from natural polypropylene material and will drain to the respective holding tank based upon the chemistry being processed with the tank. The tank will be supplied with a product standoff plate that is perforated so the product does not rest directly on the bottom of the tank. The tank will be pitched to drain.

## **PART 3 EXECUTION**

### **3.1 SOURCE QUALITY CONTROL:**

- A. Test:
  1. General: One of each type of hood manufactured according to the approved shop drawing shall be factory tested in accordance with Modified ASNI/ASHRAE 110-1999. Owner reserves the right to attend the hood testing. Hood Manufacturer shall provide all testing facility and all equipment necessary for the test. At least two weeks notice of proposed test date shall be provided to Owner.
  2. Test Room: The hood to be tested shall be set up in a test room of sufficient size so that a minimum on 1500 mm (5 ft.) of clear space is available in front of and on both sides of the hood for viewing of performance tests.
  3. Exhaust System: A hood exhaust system, properly calibrated so that known exhaust air volumes can be easily attained, shall be provided. The exhaust capacity shall be sufficient to exhaust the hood with a face velocity of 0.5 m/s (100 fpm).

### **3.2 INSTALLATION**

- A. For the purposes of this specification installation is broken down into two (2) work events. The setting of the individual hoods and the facility connection hook-ups to each hood.
- B. Equipment Setting:
  1. Equipment supplier will set and level hoods and benches into location. Setting of equipment will not take place until cleanroom work is such that all hoods can be set in their entirety and equipment will not be subject to damage from other trades.
  2. Facility Connections:
    - a. All facility connections to hoods to be performed by others. All equipment is to be installed in accordance with manufacturer's documentation. Owners designated personnel will be responsible for all facility connections.
- C. Start-up and Testing
  1. A representative from the manufacturer's factory will be present to perform start-up and commissioning services for the systems. They will also provide a written report verifying that the unit has been installed properly and to factory specifications. The factory person will also provide training on the operation and care of the unit to the owner and/or his

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authorized representative. Airside testing will not be performed until final supply and exhaust air balance is complete. Owners' representative will be present to conduct final field evaluation and compliance report for U/L Field Product Labeling.

### **3.3 FIELD TESTING**

- A. Chemical Fume Hoods and Wet Processing Stations:
1. Balance, test and certify each exhausted fume hood and wet processing stations in accordance with ASHRAE 110-1995 (AI) for Flow Visualization, Face Velocity, and Tracer Gas Containment Testing Requirements.
  2. Field tests shall be performed by a qualified independent testing company on each unit to determine face velocity and air flow patterns.
  3. Exhausted fume hoods and wet processing stations shall achieve an AI performance rating equal or better than 0.10 ppm with 4.0 Lpm tracer gas release rate when tested in accordance with ASHRAE 110-1995.
  4. Balancing of the system is in the scope of work of Division 23.

**END OF SECTION 13 2140CR**



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## SECTION 13 2160CR

### CLEANROOM SPECIALTY GAS DELIVERY SYSTEMS

#### PART 1 GENERAL

##### 1.1 WORK INCLUDED

- A. Specialty gas delivery systems for Cleanroom Hazardous Production Material (HPM) gas systems including:
  - 1. Gas Safety Cabinets.
  - 2. Automatic / Autopurge Process and Purge Panels.
  - 3. Automatic Programmable Logic Controller (PLC) Touch-Screen Controllers.
- B. Work NOT included under this section is as follows:
  - 1. Specialty gas piping distribution inside Cleanroom facility outside of gas safety cabinets. This piping will be installed by the Owner as part of Cleanroom tool installation.

##### 1.2 RELATED WORK DESCRIBED ELSEWHERE

- A. General and Supplementary Conditions and Division 1
- B. Section 13 2000CR – Cleanroom Construction
- C. Section 13 2001CR – Cleanroom Performance Testing
- D. Division 22 – Plumbing
- E. Division 23 – Heating Ventilating and Air Conditioning
- F. Division 26 – Electrical

##### 1.3 DEFINITIONS

- A. Clean Zone: A defined area, including the cleanroom and adjacent spaces that are exposed to the cleanroom supply and return airstreams.
- B. Protocol Level: The phase or degree of construction completion that mandates specified activities, training, security clearance, dress, work means and methods, cleaning procedures, and system performance to maintain the cleanliness of the clean zone.
- C. Protocol Manager: The person vested with authority by the Cleanroom Protocol Contractor to supervise all construction personnel working within the Clean Zone and ensure requirements of the contract documents are met in completion of the Clean Zone construction.

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#### **1.4 CLOSING IN UNINSPECTED WORK**

- A. Do not cover or enclose work prior to testing, inspection, and approval. All work covered or enclosed prior to approval and acceptance shall be re-opened. All finishes shall be restored.

#### **1.5 SUBMITTALS**

- A. Submit as specified herein and under provisions of Division 1 “Submittal Requirements”.
- B. Submittal shall be complete with all product data specified herein and organized by specification section in one binder. All submitted product data shall be referenced to the applicable paragraph number contained within this specification section.
- C. Manufacturer’s Data: Submit complete materials list, including catalog data, of all materials, equipment, and products for work in this section.
- D. Shop Drawings: Submit coordinated shop drawings depicting the work specified herein for actual fabrication and installation. Work shall be coordinated with other trades and building structural and architectural elements. Shop drawings shall include plans, elevations, and sections as required depicting the intended installation and final product. Drawings shall be electronically prepared in AutoCAD or similar software and submitted in a complete package with minimum ¼ inch = 1 ft scale format and maximum sheet size of Architectural “E” (30” x 42”).

#### **1.6 RECORD DRAWINGS**

- A. The Contractor shall maintain an up-to-date set of “red-line” prints, marked to indicate progress of the Project and all as-built conditions. Prints shall be updated on a daily basis, and shall be available for review at all times on the job site.
- B. Record Drawings shall indicate locations of all equipment and pipe rerouting, as well as any changes in locations or positions of equipment.
- C. Comply with Division 1 “Project Closeout” for Record Drawings requirements.

#### **1.7 SUBSTITUTIONS**

- A. Approved Substitution/Approved Equal: In addition to the items required in Division 1, all substitution requests shall include item-by-item comparison of the proposed substitution to this project specification. A copy of the project specification shall be submitted, with each item and subsection of the project specification marked as “Comply” or “Not Comply.” In any cases where “Not Comply” is indicated, an explanation of the relative advantages of the proposed design shall be provided.
- B. Substitution shall not affect dimensions shown on Drawings.
- C. The Contractor shall pay for changes to the building design, including engineering design, detailing, utility and service requirements, and construction costs caused by the requested substitution.

- D. Substitutions shall have no adverse affect on other trades, the construction schedule, or specified warranty requirements.
- E. Maintenance and service parts shall be locally available for the proposed substitution.

## **PART 2 PRODUCTS**

### **2.1 PIPING AND FITTINGS**

- A. Ultra-Pure Specialty Gases (Electropolished Stainless Steel):
  - 1. Piping: Provide ultra-high purity (UHP), electropolished, seamless, ASTM A269 Grade 316L stainless steel tubing. Tubing shall meet UHP low sulfur content range of 0.005% - 0.010% by weight maximum sulfur content. Tube and fittings shall meet the following dimensional tolerance: O.D. 1/4" – 3/8", wall thickness 0.035" ( $\pm 5\%$ ); O.D 1/2", wall thickness 0.049" ( $\pm 5\%$ ); O.D. 3/4" or larger, wall thickness 0.065" ( $\pm 5\%$ ). Electropolish internal surface finish shall be 10  $\mu$ m Ra maximum. Tube ends shall be prepared for orbital welding. Products shall be cleaned and passivated. Finished products shall be packaged and boxed for protection during shipment and storage and marked for identification by the manufacturer. Cleaning and Packaging shall be per Swagelok Specification SC-01 (Rev C) titled "Ultra-High Purity Process Specification" or similar specification. Manufacturer: Cardinal, Haynes, Swagelok or approved equal.
  - 2. Fittings:
    - a. Piping Joints: Automatic orbital welded tube butt joints with Type 316L stainless steel CAJON weld fittings.
    - b. Valve Joints: Type 316L stainless steel VCR metal gasket face seal fittings with nickel gasket.
    - c. Radius bends are allowed in accordance with piping manufacturer's approved procedures. Minimum radius bend shall be 10 times the pipe diameter.
    - d. Products shall be cleaned and purged to remove loose particles and cutting oils that typically remain on products and components following industrial manufacturing processes by the manufacturer. Finished products shall be packaged and boxed for protection during shipment and storage, and marked for identification by the manufacturer. Cleaning and Packaging shall be per Swagelok Specification SC-01 (Rev C) titled "Ultra-High Purity Process Specification" or similar specification.
    - e. Manufacturer: Cardinal, Haynes, Swagelok, or approved equal.
  - 3. All tubing, fittings, and valves shall be delivered to the site cleaned, capped, and protected. If contamination occurs, the item shall be re-cleaned in accordance with manufacturer's cleaning specification or replaced at no additional cost to the Owner.

### **2.2 VALVES**

- A. Ultra-Pure Specialty Gases:
  - 1. Shutoff Valves: Provide Type 316L stainless steel springless diaphragm valve with nylon directional rotary handle or pneumatic actuator suitable for ultra-high purity applications. Cleaning and Packaging shall be per Swagelok

- Specification SC-01 (Rev C) titled "Ultra-High Purity Process Specification".  
Manufacturers: Swagelok DP series with VCR fitting or equal.
2. Excess Flow Control Valve: Provide excess flow shut-off valve designed to automatically shut off the delivery of gas if the flow exceeds the preset limit. The shutoff mechanism shall be incorporated within the valve with an actuating knob to manually operate the valve and clearly indicate the relative operating conditions as OPEN (RESET) or AUTO (SHUT OFF).
    - a. Supply Pressure: 10 – 3500 psig (sized for gas specific application)
    - b. Differential Pressure: 5 or 12 psig (sized for gas specific application)
    - c. Body: 316L stainless steel
    - d. Seal: Metal to metal
    - e. Seat: PCTFE
    - f. Diaphragm: Elgiloy or equivalent
    - g. Spring: Hastelloy C-22
    - h. Poppet: 316L stainless steel
    - i. Knob: Anodized aluminum (red)
    - j. Stem: stainless steel
    - k. Cap: 316L stainless steel
    - l. Leak Rate (He):  $2 \times 10^{-10}$  scc/sec
    - m. Surface Finish (Ra): 15 – 20 micro-inch.
  3. Check Valves: Ultra-high purity all-welded design, 316L electropolished stainless steel designed for use with semiconductor process gases, VCR face seal end connection fittings

### 2.3 PIPING ACCESSORIES

- A. Ultra-Pure Specialty Gases:
  1. Gauges: Bourdon tube type, type 316 stainless steel, 2-inch face. Accuracy  $\pm 2\%$  of full scale. Pressure range sized for gas specific application approximately 1.25 times system operating pressure.
  2. Pressure Switch: Industrial pressure switch for monitoring process gas piping pressure. Adjustable range 3 to 100 psig. NEMA 4x die-cast aluminum enclosure with epoxy painted finish, hermetically sealed DPDT switch, setpoint repeatability – 1% or adjustable range, electrical input (max) – 11 amps 120/250 vac, electrical connection – 1/2-inch NPT, pressure connection – 1/4-inch FNPT.
  3. Gas Filters: Ultra-high purity in-line gas filter designed for use with semiconductor process gases. 316L electropolished stainless steel housing, high-purity alumina ceramic filter element, all-welded in-line construction, VCR face seal end connection fittings.

### 2.4 GAS SAFETY CABINET

- A. Manufacturers: Products, which comply with this specification section as judged and approved by the Owner's representative, may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.
  1. Spectra Gases, Inc., <http://www.spectragases.com>
  2. Applied Energy Systems, Inc., <http://www.appliedenergysystems.com>
  3. Praxair, Inc., <http://www.praxair.com>
  4. Scott Specialty Gases, Inc., <http://www.scottgas.com>

5. Or approved equal
- B. Gas Safety Cabinet:
1. Purpose-designed cylinder gas system cabinet with space for systems that provide precise control and purge gas cylinder for total purging capability.
  2. Construction: The gas cabinet shall be constructed of not less than 0.097-inch (12 gauge) steel. Provide powder-coated or epoxy enamel finish.
  3. Fire protection:
    - a. UL approved sprinkler system components.
    - b. UV/IR detector for automatic shutdown controller (Flammable and Pyrophoric gases only).
  4. Door: Full-height, self-closing and self-latching door with louvered air intake located at bottom.
  5. Window: Self-closing, non-combustible, 1-hour fire rated approved, ¼-inch wire reinforced safety glass access window for access to equipment controls. Cabinet shall be designed such that the average ventilation velocity at the face of the gas cabinet access ports or windows shall not be less than 200 fpm with a minimum of 150 fpm at any point of the access port or window.
  6. Cabinet shall be securely braced to permanent structure. Individual cylinders shall be braced to cabinet.
  7. Door lock: Cabinet shall be equipped with a keyed lock. All gas safety cabinets shall be keyed alike. Furnish two sets of keys for each cabinet.
  8. Codes and standards: Cabinet shall comply with national and local building and fire codes and OSHA, NFPA, and SEMI standard requirements for the safe handling of hazardous gases.
  9. Venting: Provide 6-inch diameter duct exhaust collar for connection to exhaust duct system. Connection to exhaust duct system shall be by Division 23.

## 2.5 AUTOMATIC / AUTOPURGE PROCESS AND PURGE PANELS

- A. Manufacturers: Products, which comply with this specification section as judged and approved by the Owner's representative, may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.
1. Spectra Gases, Inc., <http://www.spectragases.com>
  2. Advanced Specialty Gas Equipment, <http://www.asge-online.com>
  3. Applied Energy Systems, Inc., <http://www.appliedenergysystems.com>
  4. Or approved equal
- B. Specialty Gas Cabinet Application (Toxic; Highly Toxic; Pyrophoric; Corrosive):
1. Ammonia (NH<sub>3</sub>)
  2. Boron Trichloride (BCl<sub>3</sub>)
  3. Chlorine (Cl<sub>2</sub>)
  4. Diborane (B<sub>2</sub>H<sub>6</sub>)
  5. Phosphine (PH<sub>3</sub>)
  6. Silane (SiH<sub>4</sub>)
- C. Basis of Design: Spectra Gases, Inc. 1950 UHP Series Automatic Process Panel and 1750 UHP Series Automatic Purge Panel.

- D. Description: Assembly shall consist of separate process and purge panels to provide a simple means of cylinder exchange and hook up of process gas and purge gas cylinders, minimizing manual intervention with automatic process control and auto purge capability.
1. Assembly shall be stainless steel, including all valves, piping, fittings, regulators, and associated components. All joints shall be orbitally welded. Stainless steel shall be Type 316L, electropolished. Valves shall be packless, diaphragm construction with conveniently replaceable seat assemblies, and shall be pneumatically actuated. Fittings shall be seamless Type 316L stainless steel VCR, and automatic butt welded tube fitted joints. Regulators for halogenated corrosive gases shall have Hastelloy internal components.
  2. Process panel shall include rigid pigtail with pneumatic isolation valve, panel inlet isolation valve, single stage tied seat process gas regulator (0-100 psig) with inlet and outlet pressure gauges, high and low pressure vents, venturi vacuum purge assist from outside nitrogen supply source, purge gas inlet valve(s), excess flow valve switch (explosion proof), relief/vent valve, process gas outlet connection, vent outlet connection, purge gas inlet connection, and pressure transducers (explosion proof) for cylinder storage and process delivery pressures.
  3. Purge panel shall be of similar mechanical design to process panel and shall include rigid pigtail with pneumatic isolation valve, single stage tied seat purge gas regulator (0-100 psig) with inlet and outlet pressure gauges, low pressure vent, relief/vent valve, purge gas outlet to process panel, purge gas outlet to tool, and pressure transducers for cylinder storage and purge gas delivery pressures.
  4. Pressure Transducer: Class 1 Division 2 transducer to sense cylinder storage and process delivery pressures to provide a 4-20 mA signal to touch screen controller. For liquefied gases that rely on weight rather than pressure for net cylinder content, provide a low profile platform electronic scale. Scale shall have 300 Lbs capacity and rated for Class I Division 2 requirements. Route signal(s) from pressure transducer(s) or electronic scale to touch screen controller. Provide required conduit, power and wiring for system operation.
  5. Provide normally closed emergency shut-off valves installed on the pneumatic pigtails. Valves shall be actuated by building compressed air (nitrogen) 80-120 psig. Provide separate supply connections for pneumatic valve actuation and venturi vacuum purge assist.
  6. Entire assembly helium leak checked to  $1 \times 10^{-6}$  scc/sec out-board with a mass spectrometer. Dead end pressure tested for 12 hours creep test.

## 2.6 AUTOMATIC PROGRAMMABLE LOGIC CONTROLLER (PLC) TOUCH-SCREEN CONTROLLER UNIT

- A. Manufacturers: Products, which comply with this specification section as judged and approved by the Owner's representative, may be provided by the following manufacturers. All products specified in this section shall be the provided by a single manufacturer.
1. Spectra Gases, Inc., <http://www.spectragases.com>
  2. Advanced Specialty Gas Equipment, <http://www.asge-online.com>
  3. Applied Energy Systems, Inc., <http://www.appliedenergysystems.com>
  4. Or approved equal.

- B. Specialty Gas Cabinet Application (Toxic; Highly Toxic; Pyrophoric; Corrosive):
1. Ammonia ( $\text{NH}_3$ )
  2. Boron Trichloride ( $\text{BCl}_3$ )
  3. Chlorine ( $\text{Cl}_2$ )
  4. Diborane ( $\text{B}_2\text{H}_6$ )
  5. Phosphine ( $\text{PH}_3$ )
  6. Silane ( $\text{SiH}_4$ )
- C. Basis of Design: Spectra Gases Model 207 installed on the top of the gas cabinet.
- D. Description:
1. General: Microprocessor based Programmable Logic Controller (PLC) with touch-screen graphical user interface (GUI) for control and display of system operation and status. The PLC and touch-screen GUI together shall control and display the various functions of the automatic control unit and perform critical valve manipulations through programmed algorithms and sequence of operations based on automatic safety routines and user prompted actions. Solenoids located inside of the control unit shall control pneumatic valves on the process and purge panels or the gas delivery system with instrument compressed air or nitrogen supplied at 80-110 psig. The touch-screen GUI shall provide the man-machine interface to command the operational functions of the auto purge gas delivery cabinet systems. Panel layouts and components shall be represented graphically on various screens. Depending on the mode of operation, valves shall be manipulated individually or actuated automatically based on the operation being requested. The primary purpose of the controller is to perform complex sequences of valve operations (i.e. purging) while minimizing the chance of gas release or equipment damage from human error.
  2. Programmable Logic Controller (PLC): Standard product offering from PLC manufacturer with analog and digital input and outputs sized for quantity required for automatic controller design. Manufacturers: Allen-Bradley, Siemens, Honeywell, or equal.
  3. Graphical User Interface (GUI): The GUI shall be a bright color TFT touch panel, 10.4 inch (minimum) viewable screen, 256 colors, 640 x 480 pixel resolution (minimum), wide viewing angle, and high contrast to ensure that data is easily seen.
  4. Modes of operation:
    - a. Auto.
    - b. Manual (password protected).
    - c. Set up (password protected).
  5. Mushroom style push/pull illuminated EMO (E-stop) button. Provide remote EMO switch on door of gas safety cabinet at 48-inch height. Provide permanently affixed (screws) engraved label with white 1-inch lettering on red label reading "EMERGENCY OFF".
  6. Alarm/Warning Indication:
    - a. Audible: Provide warning/shutdown audible alarm horn (97 dBA minimum).
    - b. Provide stack light for visual indication of gas cabinet overall status (normal – green; fault – amber; emergency – red). In addition, GUI screen shall indicate alarm/warning with color change and/or prominent display text.

7. Pressure Monitoring: Transducers for cylinder pressure and gas delivery pressure shall be connected to the automatic controller for local display at the GUI.
8. Gas Monitoring Shutdown: Provide gas leak detection shutdown input signal to provide emergency shutdown of gas delivery system in the event of gas detection. Gas detectors shall be located inside the gas cabinet, adjacent to the gas cabinet in the room, and at each point of use (future – Owner installed at tool installation).
9. Additional Alarms:
  - a. Excess gas flow sensor with optional time delay on alarm – digital input signal from flow switch.
  - b. Loss of cabinet exhaust air flow ventilation – digital input signal from air flow switch.
  - c. Coaxial line pressurization low – digital input signal from pressure switch.
  - d. Equipment shutdown interlock – digital input signal from equipment.
10. Spare Capacity: Provide the following minimum spare I/O capacity:
  - a. Two (2) additional digital inputs.
  - b. Two (2) additional digital outputs.
  - c. Two (2) additional analog input signals.
  - d. Two (2) additional analog output signals.
11. Provide retransmit capability for analog signals and alarm status.

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Specialty Gases:
  1. Comply with NFPA 45-2000.
  2. Stainless Steel Tubing Welding Procedures:
    - a. Systems shall be welded with an automatic orbital TIG welding machine with a fully enclosed weld head. Welding process shall utilize Gas Tungsten Arc (GTA). Tungsten electrodes shall be replaced at regular intervals by procedure to produce high quality welds. An Argon back purge is required inside the tubing during welding and an Argon purge is required around the weld head during the welding process. Argon quality shall meet or exceed 100 ppb moisture, 100 ppb oxygen, and 100 ppb total hydrocarbons (TOC).
    - b. Welding shall be performed by qualified welder's certified on the welding machine being used. Submit welder's qualification and current certifications.
    - c. At completion of work day, all uncompleted tubing runs shall be capped and sealed with stainless steel compression fittings with nylon ferrules.
    - d. All welds shall be performed in a clean environment (Class 100 or better) located in a welding enclosure.
    - e. Each weld shall be given a unique identification number indicating weld date, machine used, and welder's identification recorded on the piping and as-built project drawings.



- f. Daily pipe segment coupon welds shall be performed at the start of each work day and immediately following electrode replacement for each pipe size welded. The coupons shall be cut open and inspected for satisfactory welding machine performance by a qualified welding inspector.
- 3. Cleaning:
  - a. Ultra-Pure Specialty Gases: Items shall be cleaned and purged by the supplier in strict compliance with the provisions of the manufacturer's ultra-pure cleanliness standards.

### 3.2 TESTS

- A. Contractor shall thoroughly test all Work prior to operation in the presence of Owner's Representative. Any Work showing faults under test shall be replaced. Contractor shall maintain an accurate written record of all tests and test results, and shall submit three copies of all final tests to the Owner's Representative.
- B. Ultra-Pure Specialty Gases:
  - 1. General:
    - a. The Owner's Representative has the option to cut out several brazed or welded joints of each system to visually inspect the cleanliness and workmanship of the joint. For any joint section that is unacceptable, the replacement cost will be borne by the Contractor.
    - b. Prior to testing operation, open valves and blow out pipelines to remove foreign matter.
    - c. Perform testing in presence of the Owner's Representative.
    - d. Use 99.999% purity Helium for purging and pressure testing.
    - e. Observe safety procedures at all times.
    - f. Use gauges cleaned for Ultra-High Purity (UHP) service.
  - 2. Pressure Tests:
    - a. Helium Pressure Test: The line shall be pressure-tested at 200psig or 1-1/2 times the operating pressure (whichever is higher) for 24 hours. The line pressure shall be monitored and corrected for ambient temperature. A pressure drop that cannot be temperature compensated shall require corrective action and retesting.
    - b. Helium Leak Test (Out-Board): The line pressure shall be brought up to test pressure using filtered helium.
      - 1). A helium leak detector will be used to externally check each joint for leakage using the procedures prescribed by the leak detection manufacturer.
      - 2). Helium leak testing shall be performed by a qualified quality control technician, using a portable leak detector.
      - 3). All leaks exceeding a  $1 \times 10^{-6}$  scc/sec found in the line shall be repaired and retested as described above.
    - c. Helium Leak Test (In-Board):
      - 1). Adequately purge piping system with UHP argon or approved equal inert gas to remove residual Helium on interior of system prior to in-board leak testing.
      - 2). A helium leak detector will be used to check each joint for leakage using the procedures prescribed by the leak detection manufacturer.

- 3). Helium leak testing shall be performed by a qualified quality control technician, using a fixed mass spectrometer Helium detector with vacuum pump.
- 4). All leaks exceeding a  $1 \times 10^{-9}$  scc/sec found in the line shall be repaired and retested as described above.

**END OF SECTION 13 2160**

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**SECTION 22 0000CR**  
**GENERAL PLUMBING REQUIREMENTS**

**PART 1 GENERAL**

**1.1 DESCRIPTION**

- A. Specification requirements defined in Division 20 of this Specification apply to, and are in addition to the work associated with equipment, systems, materials, and installation requirements specified in Division 22. Contractor shall provide the requirements specified in Division 20 to obtain complete systems, tested, adjusted, and ready for operation.

**1.2 RELATED WORK**

- A. Section 20 0000 - General Mechanical Requirements
- B. Section 20 0520 - Excavation and Backfill
- C. Section 20 0529 - Mechanical Supporting Devices
- D. Section 20 0553 - Mechanical Systems Identification
- E. Section 20 0573 - Mechanical Systems Firestopping
- F. Section 20 0700 - Mechanical Systems Insulation

**PART 2 PRODUCTS**

- 2.1 Not Applicable to this Section.**

**PART 3 EXECUTION**

- 3.1 Not Applicable to this Section.**

**END OF SECTION**



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**SECTION 22 0594CR**

**DOMESTIC WATER SYSTEMS BALANCE**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 22 1118 –Water Distribution System
- B. Section 22 2114 – Material Specialties

**1.2 REFERENCE**

- A. The Work under this Section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and sections under Division 1 General Requirements.

**1.3 DESCRIPTION**

- A. Plumbing Contractor shall be responsible for providing complete testing and balancing work of liquid fluid handling systems, such as domestic hot water return, laboratory hot water return, water mixing valves, and other processes included in this Project.
- B. Work required shall consist of setting volume flow rates and adjusting speed controls, recording data, making tests, and preparing reports as specified herein.
- C. Scope of work includes new work specified herein and includes all equipment, distribution systems, and terminal units connected.
- D. Procedures shall be in accordance with the latest edition of AABC or NEBB and as per detailed herein.
- E. TAB work shall be performed by persons trained in TAB work and certified by Associated Air Balance Council (AABC) or National Environmental Balancing Bureau (NEBB). Contractors who are members of AABC or NEBB and who have qualified personnel available to perform work may submit Quality Assurance Submittal for approval.
- F. Contractors who are members of AABC or NEBB and who have qualified personnel available to perform Work may submit Quality Assurance Submittal for approval. Contractors who cannot meet these requirements shall subcontract with independent TAB Contractor. TAB subcontractor shall prepare Quality Assurance Submittal for Contractor who will submit it for approval.

- G. Upon direction of Architect/Engineer or TAB subcontractor, Contractor shall provide (at no additional cost to Owner) any additional work and/or devices necessary to properly balance the system, including calibrated balancing valves, gauge tappings, flow sensors, and thermometer wells. Contractor shall be responsible for trimming and balancing pump impellers as necessary to obtain design pump flow rates at minimum pressure differential.
- H. TAB work shall not proceed until all assigned personnel have been approved by, Engineer via Quality Assurance Submittal. Coordinate each phase of TAB work with overall project schedule. Each phase of TAB work shall be done in timely manner as detailed herein. Fieldwork must be complete before occupancy. Certificate of Substantial Completion shall not be issued until after Final Report is accepted by, Engineer.

#### 1.4 SUBMITTALS

- A. General:
  - 1. Make submittals in accordance with Section 01340 – Submittals. Unless Submit minimum of 5 copies of all submittals unless otherwise directed.
  - 2. Reports shall be assembled using a 3-ring hard cover binder with Project Name and location on the cover and the side panel. Information sheets shall be 8-1/2" x 11" white bond paper. Use pre-printed forms of NEBB or AABC wherever possible. Assemble report in the following order.
    - a. Transmittal letter.
    - b. Cover sheet with Project title, location, submittal date, and names and addresses of Owner, Contractor, TAB subcontractor, Architect, and Engineer.
    - c. Index of numbered tabs listing major systems.
    - d. Data organized by system in the following order:
      - 1) Equipment data and measurement summary
      - 2) Equipment measurement data
      - 3) Branch main measurement data
      - 4) Terminal device measurement data
    - e. Provide numbered tabs for each system.
- B. Quality Assurance Submittal:
  - 1. Within 30 days of signing Contract, Contractor shall submit the following information:
    - a. Firm resume
      - 1) AABC or NEBB active membership required
      - 2) Names of 3 recent relevant completed projects along with the project address, Owner's contact person, supervising design professional.
    - b. Supervisor resume.
    - c. Balance technician(s) resume.
  - 2. Architect/Engineer and Owner reserve the right to contact previous project representatives and to reject persons whom Architect/Engineer and/or Owner feel are not qualified for this Project due to lack of relevant experience or problems on previous projects.

- C. Planning Report:
  - 1. Submit Planning Report as detailed in Part 3-EXECUTION of this Section to demonstrate to Engineer and Owner that proper procedures are being followed. Planning Report shall be submitted after Quality Assurance submittal and 30 days before fieldwork starts.
- D. Initial Test Report:
  - 1. Prior to starting Final Balance Phase, submit Initial Test Report as detailed in Part 3 of this Section to indicate to A/E and Contractor incomplete work or problem areas to be resolved before final balance is completed.
- E. Final Report:
  - 1. Within 30 days after fieldwork is completed, submit Final Report as detailed in Part 3 of this Section to assure design objectives are met and to assist Owner in future maintenance.

## 1.5 REFERENCE STANDARDS

- A. Refer to the latest publications of the NEBB, the American Society of Plumbing Engineers (ASPE) and the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) for establishing required procedures.

## PART 2 PRODUCTS

### 2.1 INSTRUMENTATION

- A. Provide required instrumentation to obtain proper measurements. Application of instruments and accuracy of instruments and measurements shall be in accordance with requirements of NEBB or AABC Standards and instrument manufacturer's specifications.
- B. Instruments used for measurements shall be accurate, and calibration histories for each instrument shall be available for examination by Architect/Engineer upon request. Calibration and maintenance of all instruments to be in accordance with requirements of NEBB or AABC Standards.

## PART 3 EXECUTION

### 3.1 GENERAL

- A. TAB work shall be done in separate phases as outlined herein. Project schedule shall allow ample time to complete TAB work before occupancy. Follow procedures outlined herein and as described in Planning Phase narratives.
- B. Set point for individual branch balancing valves in domestic hot water return and tempered water systems shall be 0.5 gpm unless otherwise noted on drawings or schedules.

- C. Set point for domestic hot water return circulating pump shall be the flow rate defined in Pump Schedule on drawings.

### 3.2 PLANNING PHASE

- A. Procedure:
1. Obtain latest contract documents including addenda and change orders. Obtain shop drawings and performance curves from Contractor for pumps, flow measuring devices, and terminal devices. Prepare Planning Report as detailed herein. Make adjustments in Planning Report and/or measuring instrument calibration.
- B. Planning Report:
1. Planning Report shall contain the following minimum requirements.
    - a. Narratives:
      - 1) Provide written narratives of procedures used. Provide separate narratives for each pump and liquid fluid handling system.
      - 2) Identify flow-measuring devices to be used at each pump and terminal device. Provide different narratives for constant and variable flow systems.
      - 3) For non-standard water systems, include narratives on how to measure and adjust for different viscosities.
      - 4) Narratives shall include references to published standards of NEBB or AABC. Narratives shall include measuring instruments to be used and ranges required for each procedure. Narratives shall include specified adjustment tolerances. For this Project, minimum acceptable is  $\pm 10\%$  of design flow.
    - b. Prebalance Checklist: include, but not limited to:
      - 1) Check for completeness or work
      - 2) System cleaning
      - 3) System fill and air venting
      - 4) Place system into operation
      - 5) Check expansion tanks and fill pressures
      - 6) Pump bearings, alignment, starters, vibration isolators, rotation
      - 7) Setting valves to proper position including shutoff and bypass valves
      - 8) Set up of controls and control devices
    - c. Measuring Instrument List: list measuring instruments to be used for each procedure. Indicate ranges required for each procedure. Provide data on each measuring instrument to be used. This data shall include:
      - 1) Manufacturer name and model number
      - 2) Measurement range
      - 3) Pressure/temperature limits
      - 4) Date put into service
      - 5) Date of last calibration
      - 6) Include certificate from calibration firm



2. Architect/Engineer reserves the right to request adjustments in any procedure and/or ask for recalibration of any measuring instrument, which has not been recalibrated within the past year.
3. Samples: Submit copies of TAB forms to be used.
4. Branch circuit and terminal measurements: indicate on pre-printed forms of AABC or NEBB measurements to be taken in the field. Include branch circuit or terminal identification, system, space served, location, design flows (include zone and system summaries), and flow measuring device size, type, Cv, and manufacturer. Indicate initial setpoint on forms.

### **3.3 SET-UP PHASE**

- A. Procedure:
  1. Perform prebalance checkout as per Planning Phase narrative.
- B. Initial Test:
  1. Measure pump data and flows in "as found" condition after initial valve settings are made.
- C. Initial Test Report:
  1. Submit report to Architect/Engineer and Contractor indicating measurements made and make notes of items, which are not complete or are not within design tolerance.

### **3.4 FINAL BALANCE PHASE**

- A. Procedure:
  1. Perform procedures as per Planning Phase narrative. Correct deficiencies and redo procedures as required before submitting Final Report.
- B. Final Report:
  1. Submit report to Engineer and to Contractor indicating data and measurements as per requirements herein and per Planning Phase narrative. Do not submit partial or incomplete reports.
- C. Final Report Adjustments:
  1. Architect/Engineer reserves the right to check any measurement made and to reject any portion of work not within the design tolerance of  $\pm 10\%$  of design flow. Contractor shall resubmit all or portions of Final Report as directed by Engineer.

**END OF SECTION**



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## SECTION 22 1118CR

### WATER DISTRIBUTION SYSTEM

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section covers interior domestic cold water, domestic hot water (115°F), domestic hot water return, clean cold water, tempered water, nonpotable cold water and trap filler lines to a point 5 ft outside building wall.

##### 1.2 RELATED WORK

- A. Section 20 0513 - Motors
- B. Section 20 0529 - Mechanical Supporting Devices
- C. Section 20 0700 - Mechanical Systems Insulation
- D. Section 22 0594 - Domestic Water Systems Balance

##### 1.3 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.4 QUALITY ASSURANCE

- A. Order pipe with each length marked with manufacturer's name or trademark and type of pipe; with each shipping unit marked with purchase order number, metal or alloy designation, temper, size, and supplier's name.
- B. Installed material not meeting specification requirements must be replaced with material that meets these Specifications without additional cost to Owner.

##### 1.5 DELIVERY, STORAGE, AND HANDLING

- A. Promptly inspect shipments to ensure material is undamaged and complies with specifications.
- B. Cover pipe to prevent corrosion or deterioration while allowing sufficient ventilation to avoid condensation. Do not store materials directly on grade. Protect pipe, tube, and fitting ends from damage. End caps shall remain in place. Protect fittings, flanges, and unions by storage inside or by durable, waterproof, above ground packaging.
- C. Offsite storage agreements will not relieve Contractor from using proper storage techniques.

- D. Storage and protection methods must allow inspection to verify products.
- E. Before shipping, piping shall be cleaned, free of rust and scale, and chemically treated to protect inside of pipe from rusting, and furnished with end caps.

## 1.6 SUBMITTALS

- A. Manufacturer's technical data for the following:
  - 1. Pipe
  - 2. Fittings
  - 3. Joints
  - 4. Valves
  - 5. Unions and Flanges
  - 6. Dielectric fittings
  - 7. Water hammer arrestors
- B. Shop Drawings on items specified herein.

## PART 2 PRODUCTS

### 2.1 MATERIALS

- A. Materials as specified shall be new unless otherwise noted.

### 2.2 PIPE, FITTINGS, AND JOINTS

- A. Above Ground:
  - 1. Copper (2-1/2" and Smaller):
    - a. Pipe: Copper tube, Type L, hard drawn, ASTM B88
    - b. Fittings:
      - 1) Cast bronze, solder joint, pressure rated, ANSI B16.18
      - 2) Wrought copper, solder joint, pressure rated, ANSI B16.22
    - c. Joints:
      - 1) Lead free (<0.2%) solder, ASTM B32, flux, ASTM B813
    - d. Nipples: Red brass pipe, threaded
    - e. Exposed tubing and fittings in kitchen and areas subject to chemical cleaning shall have chrome plated finish.
  - 2. CPVC (2" and Smaller):
    - a. Pipe: CPVC, NSF certified for potable water, SDR 11, ASTM D2846
    - b. Fittings: CPVC, NSF certified for potable water, pressure rated, socket pattern, ASTM D2846
    - c. Joints: Solvent cement, ASTM F493, NSF certified for potable water
  - 3. CPVC (2-1/2" and Larger):
    - a. Pipe: CPVC, NSF certified for potable water, Schedule 80, ASTM D1784
    - b. Fittings: CPVC, NSF certified for potable water, pressure rated, socket pattern, ASTM D2846
    - c. Joints: Solvent cement, ASTM F493, NSF certified for potable water

## 2.3 UNIONS AND FLANGES

- A. General:
  - 1. Unions, flanges and gasket materials to have pressure rating of not less than 150 psig at 180°F.
- B. Copper (3" and Smaller):
  - 1. Wrought copper union, Nibco Figure 733. Mueller Brass equal.

## 2.4 VALVES

- A. Shutoff Valves:
  - 1. Ball Valves:
    - a. Acceptable manufacturers: Apollo, Crane, Hammond, Milwaukee, Nibco, Stockham and Watts with indicated features and equal to model listed. Note that not all manufacturers make all sizes.
    - b. Full Port, 3 Piece: Bronze body, ASTM B584, stainless steel ball and stem, teflon seats, stem extension, 600 psi WOG pressure rating, Nibco 595-Y-66.
    - c. Insulated Handle: For insulated systems to prevent condensation on valve body with thermal and vapor seal, equal to Nibco Nib Seal.
    - d. Valves 2" and smaller shall have screwed ends. Valves 2-1/2" and larger shall have flanged ends.
    - e. 2-1/2" and larger: American Valve model 4000, flanged end or university approved equal.
- B. Balancing Valves:
  - 1. Circuit Setter:
    - a. Acceptable Manufacturers: Armstrong, Bell and Gossett, Griswold or Taco
    - b. 2" and Smaller: Shall be of bronze construction with glass and carbon-filled TFE seat rings and have differential pressure read-out ports across valve seat area. Read-out ports to be filled with internal EPT insert and better connection with check valve. Valve bodies to have 1/4" NPT tapped drain/purge port. Valves to have memory stop feature and calibrated nameplate to assure specific valve setting. Valve to be leak-tight at full-rated working pressure and temperature (300 psi/250°F). B&G Circuit Setter Model CB, Griswold Speedsetter or approved equal.
  - 2. Globe Style Balancing Valve:
    - a. Acceptable Manufacturers: Nibco or Victaulic/Tour and Anderson
    - b. Size 2" and Smaller: Valve shall be for precise regulation and control and rated 240 psi at 250°F. Valve shall be constructed of dezincification resistant brass (DZR) or bronze alloy. Valve shall be Straight Pattern Globe having 2 metering/test ports with internal check valves. Two 1/4" drain plugs and protective caps. Valve must be equipped with visual position readout and concealed memory stops for repeatable regulation and control. Nibco T or S1710, Tour and Anderson STAD or STAF, or approved equal.

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## 2.5 WATER HAMMER ARRESTORS

- A. Mechanical Water Hammer Arrestors:
  - 1. Piston-compressed air column type, with sealed air chamber.
  - 2. Manufacturers: Watts, Sioux-Chief, and Precision Plumbing Products (PPP), Inc., equal to size shown. Provide access panels when mechanical shockstops are installed in non-accessible concealed locations.

## PART 3 EXECUTION

### 3.1 INSTALLATION

- A. Install pipe and fittings in accordance with reference standards, manufacturer's recommendations and recognized industry practices.
- B. Maintain piping system in clean condition during installation. Remove dirt and debris from assembly of piping as work progresses. Cap open pipe ends where left unattended or subject to contamination.
- C. Include connections to plumbing fixtures, to equipment by others, and to equipment requiring water. Provide proper backflow and back siphonage protection to safeguard potable water system from contamination.
- D. Lay out water system so as to conform to intent of drawings. Coordinate piping with building features and work of other trades. Plans indicate, general routing, provide additional offsets as required. Install piping with necessary swing joints and offsets to allow for expansion. Install shut-off valves on branch lines near mains to avoid long dead-leg branches when valves are closed. Install water piping plumb and square with building. Pitch water pipe to drain with drain valves at low points.
- E. Install shut-off valves where indicated and at base of risers to allow isolation of portions of system for repair. Do not install water piping within exterior walls.
- F. Provide protective sleeve covering of elastomeric pipe insulation where copper or steel piping is embedded in masonry or concrete.
- G. Do not route piping through transformer vaults or above transformers, panelboards, or switchboards, including required service space for this equipment, unless piping is serving this equipment.
- H. Install valves and piping specialties, including items furnished by others, as specified and/or detailed. Provide access to valves and specialties for maintenance. Make connections to equipment, fixtures and systems installed by others where same requires piping services indicated in this Section.
- I. Install water pipe using proper pipe and fittings. Use reducing fittings for changes in pipe size.
- J. Provide a valve lock on ball valves dedicated to emergency shower or eyewash equipment to lock valves in place.

- K. Provide CPVC pipe in all locations within the clean-room with the exception of trap primer piping. Piping within the clean-room shall not be insulated.
- L. Soldered Copper Pipe Joints:
  - 1. Use non-acidic and lead free flux on cleaned pipe and fittings for soldered joints.
  - 2. Cut pipe square and ream before assembly.
  - 3. Fill joints with solder by capillary action. Solder shall cover joint periphery. Wipe joint clean.
  - 4. Apply heat carefully to prevent damage to pipe, fittings and valves.
  - 5. Follow manufacturer's recommendations when heating valves and equipment for soldered connections.
- M. CPVC pipe
  - 1. Solvent Cement Pipe Joints:
    - a. Use solvent cement certified for use in potable water applications on cleaned socket pattern pipe and fittings.
    - b. Cut pipe square and ream before assembly.
    - c. Follow manufacturer's recommendations when joints pipe, fittings and valves with solvent cement connections.

### **3.2 WATER HAMMER ARRESTORS**

- A. Use water hammer arrestors to control water hammer. Installed devices shall be sized and located according to manufacturer's recommendations, PDI Standards, or as shown on drawings.
- B. Use water hammer arrestors with quick-closing valves, and at branch main risers serving more than 1 fixture.
- C. Provide access panels when water hammer arrestors are installed in non-accessible concealed locations.

### **3.3 DIELECTRIC UNIONS AND FLANGES**

- A. Install dielectric unions or flanges at points where copper-to-steel pipe connection is required in domestic water systems.
- B. Install unions on equipment side of shutoff valves for items such as: water heaters, water softeners, pumps, filters, and similar equipment requiring periodic replacement.

### **3.4 CLEANING**

- A. Flush and clean piping prior to testing. Remove corrosion by mechanical or chemical means. Use chemicals that are non-toxic.

### **3.5 TESTING**

- A. Refer to Testing paragraph of Section 20 0000 - General Mechanical Requirements.
- B. Water test system may be applied to system in its entirety or in sections. Test piping with water to pressure of 150 psi for 2 hrs. No decrease in pressure allowed. Provide pressure gauge with shutoff and bleeder valve at highest point of system tested. Inspect joints in system under test.
- C. Defective work or material shall be replaced or repaired as necessary and inspection and test repeated. Repairs shall be made with new materials. No caulking of threaded joints or holes will be allowed.
- D. Do not conceal pipe until satisfactorily tested.
- E. Testing with air will not be allowed.

### **3.6 BALANCING**

- A. Balance water distribution system. Adjust control valves for proper operation. Set balancing valves to maintain hot water in hot water system.
- B. Balance flush valves, flow control valves and mixing valves for adequate flow and temperature to plumbing fixtures and equipment.

### **3.7 DISINFECTION**

- A. Disinfect water piping in the following manner:
  - 1. Clean and flush water pipe with water until water at remote tap is clear.
  - 2. Fill water systems with solution containing 50 ppm of chlorine (minimum concentration). Allow solution to stay in water system for 24 hrs. Alternately use solution of 200 ppm of chlorine (minimum concentration) for 3 hrs.
  - 3. Flush water system of chlorine solution.
  - 4. Allow clean water to stand in system for 24 hrs. Take sample from remote tap for bacteriological test.
- B. Do not use water system for potable water supply until safe bacteriological test is obtained. Repeat steps 1 through 4 until safe water system is obtained.

### **3.8 BACTERIOLOGICAL TESTS**

- A. Take representative water samples and test to ensure bacteriologically safe water supply system. Include HPC (Heterotrophic Plate Count) test and test for presence of *Pseudomonas aeruginosa* as well as regular coliform bacteria test. HPC test maximum containment level of 500 organisms/ml. Perform bacteriological tests shortly before Owner's acceptance of building. If tests fail, make corrections and retest.

**END OF SECTION**



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## SECTION 22 2114

### MATERIAL SPECIALTIES

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section covers material specialties for piping systems.

##### 1.2 RELATED WORK

- A. Section 22 1118CR - Water Distribution System
- B. Section 22 6114CR - Laboratory Compressed Air System
- C. Section 22 6214CR - Laboratory Vacuum Piping System
- D. Section 22 6653CR - Corrosion Resistant Waste and Vent System

##### 1.3 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.4 SUBMITTALS

- A. Manufacturer's technical data for the following:
  - 1. Trap primers
  - 2. Safings
- B. Shop drawings on items specified herein.
- C. Certificates: Submit performance testing certificates for reduced pressure backflow preventers and double check backflow preventers.

#### PART 2 PRODUCTS

##### 2.1 MATERIALS

- A. Materials herein specified shall be new unless otherwise noted.

## 2.2 TRAP PRIMERS

- A. Manufacturers: Precision Plumbing Products, Portland, OR.
- B. Trap primer body shall be of machined brass with air inlet ports and backflow valve. Trap primer shall be activated an electronic timer. Precision Plumbing Products "Prime-time".
- C. TP-1: Surface mounted with number of outlets selected to match drawings. Model PTS-4 through PTS-2130. 120V electrical connection.

## 2.3 SAFINGS

- A. 4 lb sheet lead, to 18" beyond edge of drain on all sides.
- B. Chlorinated polyethylene (CPE) as manufactured by Noble Company under trade name Chloraloy 240.

## PART 3 EXECUTION

### 3.1 INSTALLATION

- A. Install trap primer units as recommended by manufacturer and as indicated for priming drain traps. Insure positive air gap to protect against backflow.
- B. Install air vents at high points in water systems where air may collect.
- C. Safing:
  - 1. Install safing for floor drains. Extend safing to 18" from edge of drain. Safing shall be clamped to floor drain body and pitched to drain to weep holes. Floor drains installed in unexcavated areas do not require safing.
  - 2. Where core drilled floor drain installation into existing floor slab has been approved by A/E, drain strainer inlet shall be grouted in place with non-shrink epoxy concrete approved by Structural Engineer.
  - 3. Install safings for showers. Concrete floor shall be smooth and free of dirt. Seal joints per manufacturer's recommendations and turn up sides minimum of 6" above curb or maximum water level. Safing shall clamp into drip pan of floor drain and be secured by flashing clamp to assure drainage into weep holes of drain body. Inside vertical corners of showers shall have 12" strips 6 ft above floor, extend 6" in each direction and bottom to overlap pan 3".
  - 4. Membrane roofing material, preformed elastomer pipe pots, and flashing seams are provided by Roofing Contractor for pipe penetrations and drain flashing. Plumbing Contractor shall provide drain flashing clamps and stainless steel strap clamps for piping penetrations. Coordinate with General Contractor to facilitate sealing drain flashing and pipe penetrations.

### **3.2 TESTING**

- A. Safings shall be subject to standing water test to detect leaks and proper drainage to weep holes of floor drain.

**END OF SECTION**



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**SECTION 22 4014CR**

**EQUIPMENT BY OTHERS**

**PART 1 GENERAL**

**1.1 DESCRIPTION**

- A. Items specified herein shall be provided by Plumbing Contractor to make equipment provided by others and the owner functional.

**1.2 RELATED WORK**

- A. Section 22 1118 - Water Distribution System
- B. Section 22 6114 - Laboratory Compressed Air System
- C. Section 22 6214 - Laboratory Vacuum Piping System
- D. Section 22 6314 - Nitrogen, Carbon Dioxide and Special Gas Piping Systems
- E. Section 22 6653 - Corrosion Resistant Waste and Vent System

**1.3 REFERENCE**

- A. The Work under this Section is subject to requirements of the Contract Documents including the General Conditions of the Contract, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.4 SUBMITTALS**

- A. One package of manufacturer's technical data for all items. Submittal shall be assembled brochure, showing cuts and full detailed descriptions for each item.
- B. Shop drawings on items specified herein.

**PART 2 PRODUCTS**

**2.1 MATERIALS**

- A. Materials specified herein shall be new unless otherwise noted.

**2.2 WET BENCH SINKS**

- A. Where sinks occur in the wet benches:
  - 1. Route a waste pipe from the bench sink to discharge into the adjacent floor sink.

## **2.3 EMERGENCY SHOWER AND EYEWASHES**

- A. ES-1, ES-2 Barrier-free, combination emergency shower/eyewash units are furnished by others and installed by this contractor. This Contractor shall provide the following:
  - 1. All rough-in piping to a point of emergency shower connection.
  - 2. Final water connections to fixture.
  - 3. Install pipe supports as recommended by emergency shower and eyewash manufacturer.

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Plumbing Contractor shall install items specified herein as recommended by respective manufacturers. Final connections of waste, water, etc., shall be installed by, Plumbing Contractor as directed by equipment manufacturer. Incidental items, such as, adapters and unions required to make final connection shall be provided by Plumbing Contractor.
- B. Coordinate rough-in sizes and elevations with equipment supplier before proceeding with work.

**END OF SECTION**

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## SECTION 22 6114CR

### LABORATORY COMPRESSED AIR SYSTEM

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section covers piping and equipment required to provide laboratory grade compressed air at  $-40^{\circ}\text{F}$  dew point at 100 psi as shown on the plans and details.

##### 1.2 RELATED WORK

- A. Section 20 0513 - Motors
- B. Section 20 0529 - Mechanical Supporting Devices
- C. Section 22 4014 - Plumbing Fixtures by Others
- D. Section 23 0550 - Vibration Isolation
- E. Section 26 2913 - Enclosed Controllers

##### 1.3 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.4 SUBMITTALS

- A. Shop drawings on items specified herein.

##### 1.5 PRODUCT DELIVERY

- A. Deliver pipe and equipment properly packaged to protect against shipping and handling damage.
- B. Installed pipe shall be sealed during construction to prevent construction debris from entering piping system.

#### PART 2 PRODUCTS

##### 2.1 MATERIALS

- A. Materials herein specified shall be new unless otherwise noted.

## 2.2 PIPE AND FITTINGS

- A. Above Ground
  - 1. Copper
    - a. Pipe:
      - 1) Copper tube, Type L hard temper, cleaned and capped, ASTM B280, marked "ACR" or similar in accordance with ASTM.
      - 2) Copper tube, Type L hard temper, cleaned and capped, ASTM B819, marked "MED" or similar in accordance with ASTM.
    - b. Fittings:
      - 1) Wrought copper, solder joint, pressure rated, cleaned and bagged, ANSI B16.22.
    - c. Joints: Brazed, silver solder, BCuP-5 type, AWS A5.8, 1250°F melting point minimum.

## 2.3 UNIONS

- A. Copper 3" and smaller:
  - 1. Wrought copper union, Nibco 733

## 2.4 VALVES

- A. Manufacturers:
  - 1. The following list of valve manufacturers are acceptable subject to providing valves equal to item specified: Nibco, Apollo and Watts.
- B. Ball Valves:
  - 1. 3" and Smaller:
    - a. Full port, 3-piece, bronze body, stainless steel ball, teflon seats, stainless steel trim, blow-out proof stem, 6" tube extension, oxygen cleaned and bagged, 600 psi WOG; Nibco CS-595-YX-66-EC Series through 2".

## 2.5 CHECK VALVES

- A. Copper Pipe:
  - 1. Spring loaded, bronze or bronze/stainless steel body, 316 stainless steel spring, straight through flow, shipped bagged and oxygen clean. Apollo Ball-Cone Model 62-100-57.

## PART 3 EXECUTION

### 3.1 INSTALLATION

- A. Install compressed air piping as shown on drawings and details. Slope piping to drain to low point.
- B. Provide flexible connections at compressor inlet and outlet connection points as shown on details.



- C. Cut copper tube square and ream before assembly. Keep piping capped during construction to prevent intrusion of construction debris.
- D. Support piping drops through finished ceiling from structure above to prevent any lateral or up/down movement. Other outlet drops shall be supported from walls, columns, or workbenches using appropriate hangers, anchors, or Unistrut.
- E. Install unions on equipment side of shutoff valves for items such as: air dryers, receiver, compressors, filters, and similar equipment requiring periodic replacement or maintenance.
- F. Install vented valve for lock-out/tag-out at connection to equipment. Vented valve shall meet OSHA requirements for disabling power source and bleeding downstream energy.
- G. Install temporary plugs and caps on openings during construction phase.

### **3.2 BRAZED JOINTS**

- A. Tubing shall be new and delivered to job site with original mill caps in place.
- B. Joints shall be cleaned and polished before brazing.
- C. Flux of any type shall not be used.
- D. Avoid prolonged heating and burning during brazing.
- E. Purge lines with dry nitrogen during brazing.
- F. Provide manual shut-off and check valves required for nitrogen purge.

### **3.3 TESTING**

- A. Refer to testing paragraph of Section 20 0000 - General Mechanical Requirements.
- B. Air piping shall be tested at 150 psi for 2 hr prior to connection of laboratory fixtures. Soap test each joint to detect leaks during test period. No loss of pressure allowed during test period. Defective joints shall be cut out and replaced. Air piping shall be re-tested at 100 psig for 8 h after final connection of laboratory fixtures.
- C. Air compressor equipment shall be delivered pre-assembled and tested by equipment manufacturer.
- D. Verify proper signal transmission for each condition specified to Building Automation Controller.

### **3.4 CLEANING**

- A. All pipe, fittings and valves will be cleaned by manufacturer. On- or off-site cleaning of any components by Contractor is not allowed. Any components, which have become

contaminated, will not be used on any clean systems. They may be used in laboratory vacuum or any water system using copper pipe or fittings.

- B. Before system is placed into use, flush piping with product air to remove foreign particles.

### **3.5 WARRANTY**

- A. Manufacturer shall warrant air compressor package and components complete, for period of 2 yrs from date of start-up.

**END OF SECTION**

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## SECTION 22 6214CR

### LABORATORY VACUUM PIPING SYSTEM

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section covers piping required to provide laboratory vacuum at 26" Hg (26" of mercury) to lab outlets (28" Hg at pump outlet.) as shown on drawings and details for general laboratory vacuum outlets in.

##### 1.2 RELATED WORK

- A. Section 20 0529 - Mechanical Supporting Devices
- B. Section 22 2114 - Material Specialties
- C. Section 22 4014 - Plumbing Fixtures by Others

##### 1.3 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.4 SUBMITTALS

- A. Shop Drawings on items specified herein

##### 1.5 PRODUCT DELIVERY

- A. Deliver pipe and equipment properly packaged to protect against shipping and handling damage.
- B. Installed pipe shall be sealed during construction to prevent construction debris from entering piping system.

#### PART 2 PRODUCTS

##### 2.1 MATERIALS

- A. Materials as specified shall be new unless otherwise noted.

##### 2.2 PIPE AND FITTINGS

- A. Above Ground

1. Copper
  - a. Pipe: Copper tube, Type L, hard temper, ASTM Specification B88
  - b. Fittings:
    - 1) Cast bronze, solder joint, pressure rated, ANSI B16.18
    - 2) Wrought copper or bronze, solder joint, pressure rated, ANSI B16.22
  - c. Joints: Lead free (<0.2%) solder, Bridgit or Silvabrite, ASTM B32; flux, ASTM B813

## 2.3 FLANGES

- A. Copper:
  1. Cast red brass, Alloy 844, ASTM B584, Class 150, Standard bolt pattern, ANSI Standard B16.24 with neoprene gasket

## 2.4 VALVES

- A. Copper Piping Systems:
  1. Manufacturers: The following list of valve manufacturers is acceptable unless otherwise noted subject to providing valves equal to items specified: Nibco, Apollo and Watts.
  2. Size 4" and Smaller:
    - a. Ball Valves: Full port, 3-piece bronze body, quarter turn, stainless steel ball and stem, Teflon seats, blowout-proof stem, 600 psi WOG rated, screwed or soldered joint. Apollo 82-140 Series or Apollo 92-240 Series.

## PART 3 EXECUTION

### 3.1 INSTALLATION

- A. Install vacuum piping as shown on drawings and details. Slope piping to drain to low point.
- B. Provide line size cleanout plug at end of corridor distribution mains for flushing out piping.
- C. Provide vibration isolators for base or skid-mounted pumps.
- D. Provide wiring necessary for float control switches, safety switches, solenoid valves, and controls interface required. Coordinate power requirements with Electrical Contractor.
- E. Flexible connections shall be provided as shown on drawings.
- F. Installation shall be inspected and approved by manufacturer's field representative. Equipment start-up shall be by manufacturer's representative in presence of Owner's representative.

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### **3.2 PIPING SYSTEMS**

- A. Piping for Laboratory Vacuum system shall be copper.
- B. Copper Piping:
  - 1. Joints for copper tube will be made with approved non-acidic flux on cleaned pipe and fittings. Solder will fill joints by capillary action. Solder will cover joints by capillary action. Solder will cover joint periphery. Wipe joints clean.
  - 2. Cut copper tube square and ream before assembly. Keep piping capped during construction to prevent intrusion of construction debris.
- C. Mechanical formed Tees
  - 1. Copper pipe may utilize mechanically formed tee fittings by use of T-drill machine, UL Listed method, ANSI B31.
  - 2. Joints for mechanically formed tees in copper system shall be brazed in accordance with American Welding Society lap joint weld, and Copper Development Association Copper Tube Handbook using BCup Series filler metal (Note: Soft soldered joints are not permitted.)

### **3.3 CLEANING**

- A. Before system is in use, flush piping with dry compressed air to remove foreign particles.

### **3.4 TESTING**

- A. Refer to testing paragraph of Section 20 0000 - General Mechanical Requirements.
- B. Vacuum piping shall be tested at 200 psi for 2 hrs prior to connection of laboratory fixtures. Soap test each joint to detect leaks during test period. No loss of pressure allowed during test period. Vacuum piping shall be re-tested at 100 psig for 8 hrs after final connection of laboratory fixtures.
- C. Verify proper signal transmission for each condition specified to Building Automation Controller.

**END OF SECTION**



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**SECTION 22 6254CR**

**{PRIVATE }HOUSEKEEPING VACUUM SYSTEM**

**PART 1 GENERAL**

**1.1 DESCRIPTION**

- A. This Section covers piping and inlets as shown on the plans for the housekeeping dry vacuum system in the vivarium.

**1.2 RELATED WORK**

- A. Refer to Section 20 0529 - Mechanical Supporting Devices.
- B. Refer to Section 23 0550 - Vibration Isolation

**1.3 REFERENCE**

- A. The Work under this section is subject to requirements of the Contract Documents including the GENERAL CONDITIONS FOR TRADE CONTRACTOR UNDER CONSTRUCTION MANAGEMENT.

**1.4 SUBMITTALS**

- A. Submit shop drawings on all items specified herein.

**1.5 PRODUCT DELIVERY**

- A. Deliver pipe and equipment properly packaged to protect against shipping and handling damage.
- B. All installed pipe shall be sealed during construction to prevent construction debris from entering the piping system.

**PART 2 PRODUCTS**

**2.1 MANUFACTURERS**

- A. Spencer Turbine Co., Ross Cook Co. or approved equal.

**2.2 MATERIALS**

- A. All materials here in specified shall be new unless noted otherwise.

**2.3 TUBING AND FITTINGS**

- A. Tubing and fittings shall be 16 gauge zinc coated steel. Fittings to be long sweep type.

## **2.4 JOINTS**

- A. Slip joint connections with heat shrink sleeves.

## **2.5 INLET VALVE (VCV-1)**

- A. Spencer Turbine VLV-90082, 1-1/2" male thread-exposed inlet.

## **2.6 INLET VALVE (VCV-2)**

- A. Spencer Turbine VLV-90089, 1-1/2" male thread-exposed inlet.

## **2.7 HOSE RACK (VCH-1)**

- A. Spencer Turbine RKV-90000, wall mount, cast aluminum hose rack.
- B. Spencer Turbine HOS-90168, 1-1/2" light duty, PVC vacuum hose.

## **2.8 VACUUM PRODUCER (VCP-1)**

- A. 24" diameter SOH vacuum producer rated at 220 SCFM at 7.8" Hg, 70 degrees F inlet temperature, 14.7 PSIA discharge pressure. 4" tube inlet and 4" tube outlet. Motor to be 10 HP, 460 V, 3-phase, 60 Hz, 3500 RPM open drop proof, long shaft with cork-mounting pads include electronic modulating bleed control with current sensing device (NEMA 12 #5260). Current transformer, bleed valve and adapter/reducer with orifice plate, bleed silencer and main line tee. The vacuum producer shall be electrically grounded in accordance with NFPA 77 and NFPA 70.
- B. NEMA 4 across the line starter with reset, start/stop push buttons in cover and three overload relays. Spencer Turbine Industravac Model #SA-510-A or approved equal.

## **2.9 DRY SEPARATOR**

- A. 30" diameter bag separator, shaker type, 4" tube inlet, 40 sq. ft. filter area, external manual bag shaker, grounded filter bags, hinged inspection door, cam actuated removable dirt can with 2.25 cu. ft. capacity, 99.9% filtration at 3 microns. Dry separator to be integral with vacuum producer equipment skid.
- B. System shall have an electronic control panel with lights for power supply indication, circuit continuity, system actuation, no/low charge indication, and alarm contacts to building automation system for any abnormal condition.

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Install vacuum piping as shown on the drawings and details per manufacturer's recommendations. Slope piping to drain to low point.



- 
- B. Ensure metal to metal contact is maintained in piping system installation and operation by means of overlapping type fittings, butt welds.
  - C. Provide a line size cleanout plug at the end of corridor distribution mains for flushing out piping.
  - D. Provide plugs or caps for all openings during the construction phase. The temporary plug shall be plastic cap or equivalent.
  - E. Support piping drops from structure above to prevent any lateral or up/down movement. All other outlet drops shall be supported from walls, columns, or work benches using appropriate hangers, anchors, or unistrut.

### **3.2 TESTING**

- A. Refer to testing paragraph of Section 20 0000, General Mechanical Requirements.

### **3.3 CLEANING**

- A. Before the system is in use flush all piping with dry compressed air to remove foreign particles.

**END OF SECTION**



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## SECTION 22 6314CR

### NITROGEN AND SPECIAL GAS PIPING SYSTEMS

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section specifies nitrogen, and special gases, piping and related accessories. Nitrogen piping system shall include distribution from an exterior bulk liquid nitrogen storage tank and associated vaporizer. Special gas piping system shall include distribution of gases from localized point-of-use gas cylinder manifolds to terminal devices at individual points of use throughout the building.

##### 1.2 RELATED WORK

- A. Section 20 0529 - Mechanical Supporting Devices.
- B. Section 22 4014CR - Equipment by Others.
- C. Section 22 6214CR - Laboratory Vacuum Piping System.
- D. Section 22 6114CR - Laboratory Compressed Air System.

##### 1.3 REFERENCE

- A. The Work under this Section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.4 SUBMITTALS

- A. Shop drawings on items specified herein.

#### PART 2 PRODUCTS

##### 2.1 PIPE

- A. Above Ground:
  - 1. Stainless Steel Tubing
    - a. Electropolished 316 L stainless steel seamless tubing, ASTM A269, fully annealed, free of all scratches, burrs, and surface defects, superior visual characteristics. Hardness shall not exceed Rb 80, Surface finish 10 Ra micro inches maximum. Tubing shall be cleaned and passivated for ultra high-purity piping.

- b. Tubing shall be cleaned with deionized water and nitric acid, rinsed with deionized water, dried with high purity (99.999%) nitrogen and packaged under class 100 conditions prior to shipment. Package shall have ends faced and protected with polyimide nylon film and polyethylene caps; packed in double polyethylene bags.
- c. Minimum tube wall thickness shall meet the following requirements:

Tube size (inches)	Minimum wall thickness (inches)	Working Pressure (psi)
1/8	.028	7,800
1/4	.039	4,500
3/8	.039	3,300
1/2	.024	3,100
- 2. Fittings:
  - a. Electropolished 316L stainless steel fittings with weld glands.
  - b. VCR fittings where required for equipment connections only.
  - c. Piping used for each system shall be from the same lot number.

## 2.2 VALVES

- A. Stainless Steel
  - 1. Acceptable Manufacturers: AP Tech, Carten Controls, Parker UHP, Swagelok, TESOM, Veriflo
  - 2. 1/2" and smaller
    - a. 316 stainless steel diaphragm valves with weld ends, helium leak tested to  $1 \times 10^{-9}$  standard cc/sec, electronic position sensor, solenoid pilot. Swagelok ALD series or engineer approved equal.
    - b. Valves shall be cleaned and passivated from manufacturer for ultra high-purity piping.

## 2.3 FLOW METER

- A. Nitrogen mass flow meter
  - 1. Acceptable Manufacturers: Alicat Scientific
  - 2. Digital Mass flow meter rated for 0 to 40 scfm flow rate set for nitrogen gas. Flow meter shall provide:
    - a. Mass flow
    - b. Volumetric flow
    - c. Gas pressure
  - 3. Unit shall be provided with 4-20mA signal for each parameter indicated above to clean-room control system.

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Piping shall be installed above ground in buildings. Protect pipe openings during construction to prevent introduction of dirt and debris.
- B. Shutoff valves shall be accessible in case of emergency; installed minimum of 5 ft from each piece of equipment.
- C. Identify gas services during installation so that the chance for crossover of one gas service to a different terminal unit is avoided. Do not depend on test procedure listed herein to identify cross connections.

### **3.2 TESTING**

- A. Refer to testing paragraph of Section 20 0000 - General Mechanical Requirements.
- B. Pressurize piping system prior to connection of laboratory fixtures and check for leakage by examining each joint.
  - 1. Gaseous nitrogen system shall be pressurized with dry nitrogen at 150 psig.
- C. Test pressure shall remain in piping for at least 2 hrs. Source pressure shall be shut off and pipe temperature at beginning and end of test shall be recorded. Pressure changes, other than that caused by temperature change, will not be permitted.

**END OF SECTION**



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**SECTION 22 6653CR**

**CORROSION RESISTANT WASTE AND VENT SYSTEM**

**PART 1 GENERAL**

**1.1 DESCRIPTION**

- A. This Section specifies pipe, fittings, equipment and methods for corrosion resistant waste and vent piping system installed to 5 ft outside the building wall.

**1.2 RELATED WORK**

- A. Section 20 0520 - Excavation and Backfill
- B. Section 20 0529 - Mechanical Supporting Devices
- C. Section 22 2114 - Material Specialties

**1.3 REFERENCE**

- A. The Work under this Section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.4 SUBMITTALS**

- A. Shop drawings on items specified herein.
- B. Submit Manufacturer's technical data for the following:
  - 1. Pipe and fittings
  - 2. Joints
  - 3. Floor drains
  - 4. Cleanouts

**PART 2 PRODUCTS**

**2.1 MATERIALS**

- A. Use new materials unless otherwise noted.

**2.2 PIPE**

- A. Underground:
  - 1. Polypropylene (PP)

- a. Pipe: PP, Schedule 80, non-flame retardant, ASTM D4101, plain end.
  - b. Fittings: PP, Schedule 40, non-flame retardant, drainage pattern, socket fusion.
  - c. Joints: Socket fusion.
  - d. Manufacturers: Enfield "Enfusion", George Fischer "Fuseal", Orion "Rionfuse"
2. Polyvinylidene Fluoride (PVDF) – traps only
- a. Pipe: PVDF, Schedule 40, ASTM D3222, UL listed 94-VO noncombustible, plain end.
  - b. Fittings: PVDF, Schedule 40, drainage pattern, socket fusion.
  - c. Joints: Socket fusion.
  - d. Manufacturers: Orion "Superblue".
- B. Above Ground:
1. Polypropylene (PP)
- a. Pipe: PP, Schedule 40, ASTM D4101, flame retardant in conformance with ASTM D635, plain end.
  - b. Fittings: PP, Schedule 40, flame retardant in conformance with ASTM D635, drainage pattern, socket fusion.
  - c. Joints: Socket Fusion
  - d. Manufacturers: Enfield "Enfusion", George Fischer "Fuseal", Orion "Rionfuse", Zurn.
2. Polypropylene (PP)
- a. Pipe: PP, Schedule 40, ASTM D4101, flame retardant in conformance with ASTM D635, grooved end.
  - b. Fittings: PP, Schedule 40, flame retardant in conformance with ASTM D635, drainage pattern, mechanical joint.
  - c. Joints: Mechanical.
  - d. Manufacturers: Enfield, George Fischer "Fuseal MJ", Orion "Riontite", Zurn.

### 2.3 ADAPTERS

- A. Provide where indicated and as necessary; glass to plastic compression coupling, plastic to metal mechanical joint, or glass to metal mechanical joint and/or compression coupling.
- B. Plastic to plastic 1" through 4": Fernco Proflex 3000 Series shielded coupling with neoprene gasket, stainless steel shield, and stainless steel clamping bands.
- C. Submit adapter fittings for approval prior to installation.

### 2.4 CLEANOUTS

- A. Corrosion resistant materials similar to piping materials. Refer to Cleanout and Drain Schedule on drawings.

### 2.5 FLOOR DRAINS

- A. Corrosion resistant materials similar to piping materials. Refer to Drain and Cleanout Schedule on drawings.



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## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Install piping neat and orderly; accomplish changes of direction using proper pipe fittings. Connect to sinks, cup sinks, floor drains, and other devices as shown on drawings. Conceal piping unless noted to be exposed in reagent rack. Piping within casework shall be coordinated with casework supplier.
- B. Pitch vent piping to waste line. Install horizontal waste piping with minimum pitch of 1" in 4 ft; except piping 3" and larger may pitch 1" in 8 ft. Make changes in direction of flow by use of drainage pattern fittings.
- C. Set floor drains level and at low points. Protect weep holes from filling with concrete. Clamp safing to drain body for proper drainage.
- D. Install cleanouts as shown on drawings. Locate cleanout access cover so that snake of 100 ft can be properly used.
- E. Provide caps and plugs on open pipe ends during construction phase to prevent construction debris from entering pipe.
- F. Provide necessary transition fitting and couplings required when changing from one piping material to dissimilar material.
- G. Install PVDF waste piping on the traps at the clean-room floor sinks only. All other waste and vent shall be polypropylene.

### **3.2 PLASTIC PIPING**

- A. Install plastic pipe and fittings as recommended by respective manufacturer. Fuse plastic pipe joints with surrounding temperature above freezing using equipment supplied by pipe manufacturer. Adhere to instructions for fusing as published by manufacturer. Instructions for fusing shall be kept on site.
- B. Install mechanical joints in accordance with instructions from pipe/fitting manufacturer. Use materials of same manufacturer, especially made for mechanical jointing. Use pipe and fittings with factory cut groove, except pipe may be grooved in field using equipment and methods as recommended by manufacturer of pipe. Use hangers on each side of mechanical couplings.

- C. Manufacturer's representative shall instruct workmen in proper installation techniques required for polypropylene piping with fusion joints, high silicon cast iron with mechanical joints, and borosilicate glass piping with mechanical joints and provide certification to Owner that instruction has been given and proficiency demonstrated by Contractor in execution of installation of piping system.
- D. Do not install PP material in plenum space. Refer to HVAC drawings to determine plenum spaces.
- E. Use special precautions and approved/listed systems when PP material penetrates fire resistive or smoke barrier. Refer to Section 20 0573 - Mechanical Systems Firestopping.
- F. Do not use plastic pipe when high temperature (above 100°F) water (at autoclaves, sterilizers, glasswashers, and similar devices) is discharged to receptor or drain. Provide minimum of 25 ft of glass or high silicon cast iron piping material downstream of high temperature drain discharge point.

### **3.3 TESTING**

- A. Hydrostatically test to 5-psi pressure. Maintain 5-psi hydrostatic pressure for 2 hrs without leakage.
- B. Replace or repair piping system until satisfactory test is obtained. No piping shall be concealed until satisfactorily tested.

### **3.4 CLEANING**

- A. After successful pressure test, clean and flush piping system to eliminate debris in drainage system.

**END OF SECTION**

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## SECTION 22 6714.13CR

### PLASTIC PIPING FOR RO SERVICE

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section specifies Polypropylene (PP) piping, fittings, valves, and specialties for the “RO Water” to the humidification system for the clean room. This section covers the requirements for procurement, installation, inspection, and sanitization.
- B. This system is defined by:
  - 1. This Section
  - 2. Sections listed under Related Work below,
  - 3. Flow Diagram
  - 4. Piping plan drawings

##### 1.2 RELATED WORK

- A. Section 20 0529 - Mechanical Supporting Devices
- B. Section 20 0573 - Mechanical Systems Firestopping
- C. Section 22 6720.13CR – Cleanroom Humidification Water System

##### 1.3 REFERENCE

- A. Work under this section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and sections under Division 1 General Requirements.

##### 1.4 SCOPE OF WORK

- A. Contractor shall be responsible for procurement, installation, inspection, and sanitization of piping system.
- B. Contractor shall provide personnel trained and experienced in installation of selected manufacturer's piping system. If personnel are not experienced at start of installation, piping manufacturer's representative shall train Contractor prior to installation. Training certification and experience record is required.
- C. Contractor shall submit documentation on components proposed for system and shall obtain approval prior to purchase or fabrication of those components.
- D. Contractor shall inspect system and provide documentation to demonstrate that system is installed according to specification, is leak free, and has been sanitized according to procedure.

## 1.5 BASIS OF DESIGN

- A. Service: RO Water
  - 1. Process Fluids: RO water; 5% hydrogen peroxide solution
  - 2. Operating Pressure/Temp. 70 psig at 80°F
  - 3. Piping System
    - a. Required Pressure Rating: 144 psig at 68°F for all components
    - b. Material: PP as specified below.
      - 1) Joining method: socket fusion
      - 2) Elastomer: EPDM

## 1.6 SUBMITTALS

- A. The following items must be submitted for review, and approved prior to purchase of item.
  - 1. Training certification and experience record for installation personnel.
  - 2. Specifications for pipe, fittings, valves, and other components
  - 3. Description of joining method and identification of specific fusion and cutting equipment.
  - 4. Detailed Sanitization Procedure (see part 3.1)
- B. The following documentation is required to be delivered with system:
  - 1. Manufacturer's material certifications
  - 2. Joint inspection records
  - 3. Pressure Test Report
  - 4. Sanitization Records

## 1.7 DELIVERY

- A. Pipe, fitting, and components shall be furnished with plastic end-caps/plugs to prevent contamination and damage.
- B. Pipe, fitting, and components shall be furnished in individually sealed bags to prevent contamination.
- C. Pipe, fittings, and components shall be handled and shipped so as to protect from contamination and damage.

## PART 2 PRODUCTS

### 2.1 MANUFACTURERS:

- A. George Fischer , Asahi

### 2.2 GENERAL

- A. Piping, fittings, and valves for each service that are to be heat fused shall be products of same manufacturer.

- B. Piping, fittings, valves, gaskets and accessories shall be compatible with Design Conditions in Part 1.5 as stated above.
- C. Dimensions of end connections for valves shall be compatible with pipe and fittings.
- D. Materials in contact with water shall have approval by FDA for sanitary product contact surfaces.
- E. Pipe and fittings shall be permanently identified with production lot and wall thickness or pressure rating.
- F. Piping, fittings, valves, and components shall be manufactured in dedicated equipment in clean environments and bagged.
- G. Material certification documentation shall be furnished for piping, fittings, valves, and components.

### **2.3 PIPE, FITTINGS, & JOINTS**

- A. Polypropylene (PP)
  - 1. Pipe and fittings: Polypropylene manufactured from natural polypropylene compound conforming to standards of ASTM D-4101.
  - 2. Piping shall be George Fisher "PP-n" or Asahi/America "PolyPure"
    - a. Fused joints
      - 1) Socket fusion
    - b. Mechanical Joints
      - 1) Tri-Clamp with Sanitary gasket or sanitary union
      - 2) Mechanical joints to be used only where indicated on P&ID. Use in other locations requires prior approval.
    - c. Connections at equipment (only)
      - 1) Flange adapter with George Fisher V-Flange ring with boltholes per ANSI B16.5, Class 150 pattern.
      - 2) For mating with plastic tank flange, flat gasket shall be Garlock "Stress Saver", PTFE, or approved equal.
      - 3) For mating with stainless steel flange, flat gasket shall be Garlock Gylon 3545 or George Fisher Sygef HP Gasket.

### **2.4 VALVES**

- A. General
  - 1. Valve type shall be as indicated on flow diagram.
  - 2. Valves shall be same material and manufacturer as the piping.
  - 3. Valves shall conform to Basis of Design in Part 1.5 above.
  - 4. End Connections shall be spigot ends for socket fusion or, if indicated or required, Triclamp or flanged ends.

- B. PP Valves
  - 1. Diaphragm Valves
    - a. Weir type, self-draining, PTFE diaphragm backed by EPDM, non-rising stem, position indicator, stroke limit stops.
    - b. Size 2" and smaller: George Fischer Type 315, ASAHI Type 342.
    - c. Size 2-1/2" and larger: George Fischer Type 317, ASAHI Type 14.
    - d. Zero static valve: George Fischer Type 319, ASAHI Type 343.
  - 2. Sampling valves
    - a. diaphragm valves, 1/2"
  - 3. Self Contained Pressure Regulating Valves
    - a. PTFE, EPDM backed, diaphragm and Viton O-rings.
    - b. Relief valves to be George Fisher V85 or equal.
    - c. Retaining (back pressure) valves to be Plast-O-matic RVDT
  - 4. Check Valves
    - a. Ball check valves, Viton seals, PP ball.
    - b. George Fisher Type 360, or approved equal.
- C. Actuators
  - 1. Valve actuators for on/off control to be provided integral to valve by manufacturer of valve.
  - 2. Actuator type (pneumatic/electric) shall be as indicated on P&ID. Position switches shall be provided if indicated on P&ID.

## 2.5 SPECIALTY ITEMS

- A. Orifice Plates
  - 1. Manufacturers: Rubber Fab Mold and Rubber Co., Newman Gasket Co.
  - 2. Flow restriction orifice plates shall be 316L stainless steel with minimum finish of 25 Ra, for installation in Tri-clamp.
  - 3. Orifice plates shall be tagged with instrument number and orifice bore size.
  - 4. Orifice plates shall be concentric or eccentric depending upon installation orientation
  - 5. Orifice specification and preliminary sizing information is shown in Equipment Schedule. Sizing information shall be verified by Engineer after Contractor submits isometric drawings.

## 2.6 INSTRUMENTATION

- A. Instrumentation specifications are covered in Section 22 6720.13CR.

## PART 3 EXECUTION

### 3.1 GENERAL

- A. Install and inspect piping and accessories as per contract documents and recommendations of equipment manufacturers.

- B. Provide installation personnel who are trained and experienced with assembly of selected piping in high purity systems.
- C. Provide installation personnel who are certified by piping manufacturer for specified joining method.
- D. Provide diaphragm valves.
- E. Inspect all delivered components to verify conformance to specification and to check for evidence of damage or contamination.
  - 1. Individually inspect minimum of 20% of items from each lot of items.
  - 2. Perform additional sampling if non-compliant items are identified.
  - 3. Do not use suspect materials.
  - 4. Document inspection.
- F. Maintain high level of cleanliness during handling and installation.
  - 1. Prior to starting work, identify areas that will be used for storage and fabrication, and take measures to prevent contamination from adjoining areas.
  - 2. Handle and store tubing, fitting, and components in a manner that prevents impact damage, excessive stress, and contamination.
  - 3. Maintain manufacturer's protective packaging in place until immediately prior to use.
  - 4. Keep openings on assemblies sealed during fabrication to prevent contamination prior to final installation.
- G. Monitor and inspect the installation process to ensure:
  - 1. Conformance with this specification.
  - 2. Compliance with the manufacturer's requirements.
  - 3. Piping is supported as specified.

### 3.2 INSTALLATION

- A. PP Joint Fabrication
  - 1. Perform joining in strict accordance with manufacturer's recommended procedures with manufacturer's specified equipment.
  - 2. Fabricate in clean area. Provide ventilation to room isolated from areas where grinding or welding of metals is occurring.
  - 3. Cut piping in strict accordance with manufacturer's recommended procedures.
  - 4. Clean components prior to fusion conscientiously and in strict compliance with manufacturer's recommendations for high purity services.
  - 5. Form joints using socket fusion with equipment made specifically for this use by manufacturer of this material.
  - 6. Use sanitary union or Tri-clamp joints only where indicated on drawings or where necessary to connect to accessories and equipment. Verify that gasket is correctly indexed prior to tightening. Tighten hand tight only; do not use tools.
  - 7. Provide ANSI flanged joints for connecting to equipment that does not have Tri-Clamp fittings available. Tighten flanged connections in strict accordance with manufacturer's recommendations. Threaded joints are not acceptable.

B. Configuration

1. Horizontal runs shall be continuously supported by an equal leg aluminum, stainless steel, or galvanized steel "V" channel under pipe.
2. Install tubing so that there are no undrainable pockets.
3. Provide adequate support of pipe at pump discharge.
4. Orient diaphragm valves per manufacturer's instructions to ensure complete drainage.
5. Install check valves and orifice plates in vertical sections. If installation in horizontal is required, provide eccentric valve or plate and orientate properly.
6. Provide low point drains and high point vents in compliance with drawings and engineering review of isometric drawings.
7. Rough or sharp edges must not be in contact with pipe.
8. Erect tubing without spring or force. Connect to equipment such that stress is not transferred to equipment.
9. Install all tee connections so as to minimize dead leg. Distance from sealing point on the branch to inside of main line wall shall be less than six (6) branch line diameters.
10. Route lines so as to accommodate thermal expansion where required. Provide supports appropriate for thermal expansion. Install supports so that movement of piping due to thermal expansion is not impeded.

C. In-Line Devices

1. Locate and orient in-line specialty items and instrumentation so as to allow for access after insulation is installed, including:
  - a. Access for maintenance and calibration.
  - b. Viewing of gauges by operating personnel.
  - c. Clearance for removal of regularly replaced components (filter elements, UV lamps, etc.)
  - d. Convenient operator access to sample valves and insertion of sampling container.
2. Install in-line specialty items and instruments such that they are free draining.
  - a. Install restriction orifices in vertical section of pipe unless. If orifice must be in horizontal run, use an orifice that is eccentric drilled and orientate with hole at low point.
3. Install in-line specialty items and instruments in strict accordance with manufacturer's instructions.
  - a. Install sensors for conductivity and resistivity in run of a horizontal tee with flow exiting the upward branch.
  - b. Provide length of straight pipe upstream and downstream of flowmeters. As specified by manufacturer
  - c. Install pressure regulators and backpressure regulators with at least 10 pipe diameters of straight pipe upstream and downstream of regulator.
  - d. Install sanitary orifice plates in sanitary unions or in Tri-clamp joints as indicated on drawings. Clearly tag orifice location.
  - e. Securely support relief valves and relief discharge lines.

D. Pipe Sleeves

1. Provide sleeves on piping penetrations through floor slabs one pipe size larger than service piping, and extend sleeve 2" above finished floor.



### 3.3 HYDROSTATIC TESTING

- A. Execute all pressure testing safely.
  - 1. Do not pressurize plastic piping with gas.
  - 2. Isolate equipment or instrumentation that cannot be exposed to pressure.
  - 3. Notify personnel with access to system that testing is to take place. Tag each use point to indicate that valve is not to be used.
  - 4. Ensure that air is completely vented from system to avoid a hazardous condition.
  - 5. Pressurize system gradually.
  - 6. Provide controls to prevent pressure from exceeding specified test pressure.
  
- B. Ensure that cleanliness of system is not compromised.
  - 1. Provide water for testing and flushing that has quality equal to or better than service water.
  - 2. When performing preliminary testing of sections of system, after test is complete flush all water out of system and ensure that it drains completely. Close all openings in system after draining.
  
- C. Execute final acceptance test on completed piping system.
  - 1. Do not insulate or conceal piping until testing is complete.
  - 2. Test system in sections or as a whole, but all joints need to be covered in test.
  - 3. Ensure that air is completely vented from system.
  - 4. Pressurize gradually and hold system at 100 psig for 4 hours. An initial pressure decrease will occur due to pipe elongation after pressurization. After 4 hours, pressure loss will stabilize, and pressure must then hold at test pressure without a loss of 1% over period of one hour to pass test.
  - 5. Monitor pressure with gauge located near bottom of system that is readable to at least plus or minus 1 psi.
  - 6. Note if pressure drops more than 1% over test period and determine source of leakage.
    - a. Cut out and reinstall defective joints.
    - b. Hand tighten wing nuts on sanitary clamps if required. If leakage continues, install new gasket. Do not tighten using tools.
    - c. Retest
  
- D. Provide written certification that includes identification of portion of system tested, date, time, test criteria, test medium and pressure, duration, and name and title of person responsible for test.

### 3.4 SANITIZING/FLUSHING

- A. General
  - 1. Perform sanitization after inspection, documentation, and acceptance of system. If chemical sanitation is not required then this procedure will be used for flushing, without addition of sanitant.
  - 2. Prior to sanitization, slowly fill system with water while venting air from system. Continue to check that all air has been vented after water is recirculating.
  - 3. Adjust any pressure regulators to their preliminary setpoints.
  - 4. Perform sanitization immediately prior to placing the system in operation and coordinate with Owner's representative.

5. Ensure that proper chemicals are used and that they are handled safely.
  6. Provide all equipment, fittings, and supplies necessary to execute the sanitization.
  7. Prepare a procedure which identifies the:
    - a. Recirculation circuit(s) and sampling points
    - b. Measures required to confine the sanitizing solution
    - c. Step-by-step procedure (including any modifications to the piping or controls)
    - d. Sign-off matrix
  8. Record execution of procedure including Owner sign-off.
- B. Procedure
1. Sanitize using peracetic acid solution: Minncare or approved equal.
  2. Safety:
    - a. Follow manufacturer's safety recommendations for handling of chemicals.
    - b. Disconnect power to UV lights prior to sanitization.
    - c. Provide controls to ensure that system remains within pre-established sanitization conditions and that system pressure does not exceed Design Conditions in Part 1.5 above.
  3. Notify personnel with access to system that is being. Prior to cleaning, tag each use point to indicate that valve is not to be used.
  4. Isolate equipment or instrumentation that is not to be exposed to sanitant. Bypass ion exchange beds. Replace any sub-micron filter elements with 5-micron cartridge filter elements. Record all changes made to system that are required to execute test.
  5. Makeup solution of 1% Minncare with water that is less than 70°F. Water shall be equivalent to service water quality as per Part 1.5 above or deionized water that has passed through a 1.0-micron filter.
  6. Fill entire system with solution. All gas must be vented, and system set up for recirculation so that all parts will be exposed to solution.
  7. Recirculate at flow rate of at least 3 fps. Draw samples at points of use and at other key sample points to confirm presence and concentration of peracetic acid solution using test strips. Monitor system temperature to ensure that it does not rise above 75°F.
  8. Confirm that there is solution throughout the system, and then continue to recirculate for at least 3 hours. Draw off water for at least one minute at each use point.
  9. After recirculation with peracetic acid solution flush system with product quality water for at least 45 minutes, rotating draw off from all use points.
  10. Test water with peracetic acid solution residual test strips at key sample points to ensure less than 1 ppm is achieved.
  11. Continue to flush for 30 minutes. Draw off water for at least 1 minute at each use point.
  12. Return system to its original configuration. Verify that all modifications that were made to piping or controls were restored. Prepare system for normal operation.

**END OF SECTION**

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## SECTION 22 6714.15CR

### PIPING FOR ULTRA PURE WATER

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section specifies piping, fittings, valves, and specialties for Ultra Pure Water (UPW) Cleanroom service and the requirements for procurement, installation, and inspection.

##### 1.2 REQUIREMENTS

- A. This system is defined by:
  - 1. This specification
  - 2. Specifications listed under Related Work below
  - 3. UPW Flow Diagrams
  - 4. Piping plan drawings

##### 1.3 RELATED WORK

- A. Section 22 6720.15 - Ultrapure Water System

##### 1.4 SCOPE OF WORK

- A. The UPW equipment Vendor is responsible for providing piping on the equipment skids. Vendor is responsible for identification of any piping that is to be field installed by Contractor to interconnect Vendor's equipment.
- B. Contractor is responsible for procurement, installation, inspection of distribution system piping outside of Vendor's skids.
- C. Contractor shall submit isometric drawing for piping within Cleanroom.
- D. Contractor and Vendor shall provide personnel trained and experienced in installation of selected manufacturer's piping system.
- E. Contractor shall coordinate with the UPW Equipment Vendor to obtain water for hydrotesting, and for execution of sanitization.
- F. Contractor shall provide documentation to demonstrate that system is installed according to specification is leak free and has been inspected.

##### 1.5 SUBMITTALS

- A. The following items must be submitted for review, and approval:
  - 1. Training certification and experience record for installation personnel.
  - 2. Specifications for pipe, fittings, valves, and other components
  - 3. Description of joining method.

- B. The following documentation is required shall be delivered with system:
  - 1. Manufacturer's material certification
  - 2. Record of fusion machine operating parameters for every joint
  - 3. Joint inspection records
  - 4. Pressure Test Report

## 1.6 DELIVERY

- A. Pipe, fitting, and components shall be furnished with plastic end-caps/plugs to prevent contamination and damage.
- B. Fitting and components shall be furnished in sealed packaging.
- C. Pipe, fittings, and components shall be handled and shipped so as to protect from contamination and damage.

## 1.7 REFERENCE

- A. Work under this section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and sections under Division 1 General Requirements.

## 1.8 WARRANTY

- A. Piping components shall be warranted for period of one year from date of startup or 18 months from date of shipment, whichever is longer.

## PART 2 PRODUCTS

### 2.1 PIPE, FITTINGS, & JOINTS

- A. Polyvinylidene Fluoride (PVDF)
- B. Manufacturer: George Fischer (GF) SYGEF Plus polyvinylidene fluoride (PVDF).
- C. Pipe and fittings shall be permanently identified with production lot and wall thickness or pressure rating.
- D. Piping, fittings, valves, and components shall be manufactured in dedicated equipment in clean environments and bagged.
- E. Material certification documentation shall be furnished for piping, fittings, valves, and components.
- F. Sizes indicated on drawings as "2 inch" correspond to the 63 mm size; "2.5 inch" correspond to the 75 mm size.
- G. End Connections
  - 1. Suitable for Bead and Crevice Free (BCF) butt fusion

2. Mechanical joints: TriClamp [for only where necessary to connect to equipment or instrumentation.]
  3. Flanges: 150" ASI [ if only flange connections are available on equipment]
  4. O-rings for Triclamps: Tuf-Flex Teflon manufactured by Rubber Fab Mold and Rubber Co.
- H. Valves
1. Shutoff valves shall be GF Type 315 diaphragm valves; weir type, self-draining, position indicator, stroke limit stops.
  2. GF Type 319 zero static tee valves shall be used where shown on the P&IDs and for:
    - a. Drop valves in Clean Room with ½" port.
    - b. Sampling valves with ½" port.
    - c. Drain and vent valves with ½" port.
  3. Sample, drain, vent, and drop valves shall be capped.

## 2.2 SPECIALTY ITEMS

- A. Hoses
1. Platinum cured silicon wire reinforced hose, PVDF end fittings; manufactured by Rubber Fab Mold and Rubber Co, type RF-SV.
    - a. For the DI beds: 1" [Vendor to confirm], PVDF Triclamp fittings
    - b. For jumpers at use points: ¾", PVDF Triclamp fitting on one end and male NPT on other.
- B. Constant Flow Valves
1. Plastomatic Flow Control Valves, PVDF with EPDM diaphragm
    - a. End of line: ¾", 3 gpm.
    - b. Return from wet bench: ½" 2 gpm
- C. Pressure Gauges
1. All gauges and pressure transmitters on UPW shall have isolators.
    - a. In the distribution system, all isolators shall be Plastomatic Ultrapure Gauge Guard; PVDF body, Viton diaphragm, spigot ends for GF pipe.
  2. Ranges
    - a. In Clean Room: 0 to 60 psig
    - b. At distribution equipment: 0 to 100 psig
    - c. Return of distribution loop: 0 to 60 psig
    - d. Retaining (back pressure) valves to be Plast-O-matic RVDT

## PART 3 EXECUTION

### 3.1 GENERAL

- A. Install system in strict accordance with:
1. This specification and those listed under Related Work
  2. Flow Diagrams
  3. Plan Drawings
  4. Approved Isometric Drawings.

## 3.2 INSTALLATION

### A. General

1. Prior to starting work, identify areas that will be used for storage, and take measures to prevent contamination from adjoining areas.
  - a. Store materials and components in an area that is segregated from other piping materials and is maintained clean.
2. Handle tubing, fitting, and components in a manner that prevents impact damage, excessive stress, and contamination.
3. Provide installation personnel who are certified by piping manufacturer for specified joining method. If personnel are not certified, Contractor shall provide for manufacturer's representative to train prior to installation.
4. Install and piping and accessories as per contract documents, recommendations of equipment manufacturers, and drawings.
5. Note that piping to drain, or vent that is downstream of the final PVDF isolation valve may be schedule 80 PVC.

### B. Fabrication

1. Join pipe using Bead and Crevice Free (BCF) butt fusion.
2. Provide mechanical joints only where necessary to connect to equipment or instrumentation, or where specifically indicated on drawings. Mechanical joints shall be TriClamp unless equipment connection is flanged.
3. Perform fabrication under ISO Class 7 Clean Room conditions.
4. Perform joining in strict accordance with manufacturer's recommended procedures, with manufacturer's specified equipment, by personnel trained in the joining this specific material.
5. Maintain manufacturer's protective packaging in place until immediately prior to use.
6. Keep openings on assemblies sealed during fabrication to prevent contamination prior to final installation.
7. Inspect fittings and pipe prior to use. Do not install piping if it is scratched.
8. Cut piping in strict accordance with manufacturer's recommended procedures.
9. Clean components prior to fusion conscientiously and in strict compliance with manufacturer's recommendations for high purity services.
10. Form joints using equipment made specifically for this use by manufacturer of this material.
11. Provide a record of operating conditions for each joint.
12. Label each joint for traceability.
13. Do not use Tri-clamp joints except if indicated on drawings or where necessary to connect to accessories and equipment.

### C. Configuration

1. Provide support for lines as follows:
  - a. Continuous support of horizontal lines using a stainless steel V channel. The intent is to prevent sagging over time; sections that are less than a foot long do not require support.
  - b. Install channel along piping only. Do not extend under valves or any other fittings that have a larger diameter
2. Install pipe to enable complete drainage of system:
  - a. Route pipe so as to prevent any pockets.

- b. Provide a slight slope or ensure that pipe is exactly level.
  - c. Orientate diaphragm valves per manufacturer instructions
  - d. Use eccentric reducers when appropriate
  - e. Provide low point drains.
3. Drop Valves
- a. The drop valves on lines that are overhead in the Clean Room chase shall be oriented such that the use port is downward, and at an angle [to ensure handle is free from adjoining pipe] and to ensure that the distribution line will drain completely.
  - b. Install with adequate space to allow access to handle and access to outlet port to allow for connection of branch lines.
4. Verify that rough or sharp edges are not in contact with pipe.
5. Erect tubing without spring or force. Connect to equipment such that stress is not transferred to equipment.
6. Install all tee connections so as to minimize dead leg. Distance from sealing point on the branch to inside of main line wall shall be less than six (2) branch line diameters.
7. Install in-line instruments in strict accordance with manufacturer's instructions.
- a. Install sensors for conductivity/resistivity in run of a horizontal tee with flow exiting the upward branch.
  - b. Provide length of straight pipe upstream and downstream of flowmeters as specified by manufacturer
  - c. Install pressure regulators and backpressure regulators with at least 10 pipe diameters of straight pipe upstream and downstream of regulator.
  - d. Install sanitary orifice plates in Tri-clamp joints as indicated on drawings. Provide tags.
  - e. Orient in-line devices and instrumentation so as to allow for viewing.
  - f. Provide caps [blinds] on all drop, drain, and sample valves.

### 3.3 INSPECTION

- A. Contractor is responsible for final system inspection, and documentation of the inspection, including:
- 1. Visual inspection of each joint
    - a. Verify that appearance of joint conforms to manufacturer's standard.
    - b. Verify joint has fusion record label.
  - 2. Verification that fusion records are complete.
  - 3. Confirm conformance with final drawings, and proper support.

### 3.4 HYDROTESTING

- A. Execute all pressure testing safely.
- 1. Do not pressurize plastic piping with gas.
  - 2. Isolate equipment or instrumentation that cannot be exposed to test pressure.
  - 3. Notify personnel with access to system that testing is to take place. Tag each use point to indicate that valve is not shall be used.
  - 4. Ensure that air is completely vented from system to avoid a hazardous condition.
  - 5. Pressurize system gradually.

6. Provide controls to prevent pressure from exceeding specified test pressure.
- B. Ensure that cleanliness of system is not compromised.
    1. Coordinate testing with UPW Equipment Vendor to obtain water that has appropriate quality.
    2. When test is complete, flush all water out of system and ensure that it drains completely. Close all openings in system after draining.
  - C. Execute final acceptance test on completed piping system.
    1. Do not insulate or conceal piping until testing is complete.
    2. Ensure that air is completely vented from system.
    3. Pressurize gradually and hold system at 100 psig for 4 hours. An initial pressure decrease will occur due to pipe elongation after pressurization. After 4 hours, pressure loss will stabilize, and pressure must then hold at test pressure without a loss of 1% over period of one hour to pass test.
    4. Monitor pressure with gauge readable to at least plus or minus 1 psi.
    5. Note if pressure drops more than 1% over test period and determine source of leakage.
      - a. Cut out and reinstall defective joints.
      - b. Hand tighten sanitary clamps if required. If leakage continues, install new gasket.
      - c. Retest
  - D. Provide written certification that includes identification of portion of system tested, date, time, test criteria, test medium and pressure, duration, and name and title of person responsible for test.
  - E. Coordinate the sanitization procedure with the UPW Equipment Vendor.

**END OF SECTION**



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## SECTION 22 6720.13CR

### CLEANROOM HUMIDIFICATION WATER SYSTEM

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section specifies the distribution equipment system for the water to the cleanroom humidification system.
- B. This system is defined by:
  - 1. This Section
  - 2. Sections listed under Related Work below,
  - 3. Flow Diagram
  - 4. Plan drawings

##### 1.2 SCOPE

- A. Contractor's Scope of Work includes:
  - 1. Subcontracting with an acceptable water treatment equipment vendor (Vendor). A common Vendor shall be selected to supply this system and the UPW system per Section 22 6720.15.
  - 2. Managing Vendor's scope of work and performance. Coordinating:
    - a. Production of drawing showing layout of equipment positioned in Owner's area.
    - b. Identification of all field installation of piping and wiring interconnections required between Vendor's equipment.
  - 3. Installation of Vendor's equipment and providing utilities to equipment.
    - a. Providing piping and wiring interconnections between Vendor equipment as required.
  - 4. Providing distribution piping.
  - 5. Coordination of startup and system Turnover with Owner to ensure system is always actively managed.
- B. Vendor's Scope of Work includes furnishing:
  - 1. A complete system, as defined in this document.
  - 2. Detailed drawings and instructions to Contractor for installation for field piping and wiring interconnections required between Vendor's equipment and components.
  - 3. Documentation
  - 4. Sanitization of system
  - 5. On-site support checkout, startup, and testing
  - 6. Demonstration that system meets quality and operational requirements
  - 7. On-site training
  - 8. Operation of system until turnover to Owner

##### 1.3 RELATED WORK

- A. PW system shall meet requirements of following Sections:

1. Section 20 0513 - Motors
2. Section 22 6714.13CR - Plastic Piping for RO Service
3. Section 22 6720.15CR - Ultra Pure Water System

**1.4 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.5 VERIBASIS OF DESIGN**

- A. Quality
1. "RO Water" shall be produced by other under Section 22 6720.15CR for supply to this system. Contractor shall provide piping from Ultra Pure Water production system to this storage tank.
- B. Supply
1. The supply water to this system will be produced by the UPW Treatment system as per Section 22 6720.15.
- C. Size Requirements
1. Equipment shall be located in area shown on the plan drawing. Location and sizes of equipment shown in those areas are preliminary.
  2. Contractor shall work with Vendor to determine equipment layout and submit an accurate drawing indicating positions of equipment in the area.
  3. Layout shall ensure:
    - a. Selected equipment and skid sizes will be able to pass through available building opening and passageways, or must be delivered prior to completion of that area of building.
    - b. Proper access to PW equipment and instrumentation for operations and maintenance.
    - c. Compatibility with floor drains shown on drawings.
    - d. Clearance for removal of regularly replaced components (filter elements, UV lamps, etc.)
    - e. Access to tank manway and components on top of tank.

**1.6 SUBMITTALS & DOCUMENTATION**

- A. The following documents shall be furnished as follows:

	Submit For Approval	Upon Delivery	Turn Over Package
Piping and Instrumentation Diagram (P&ID)	X	X	As built
Pump Curves with Operating Points	X		X
Drawing of system in facility space	X		
Instructions for Rigging, Storage, and Anchoring		X	
Detailed Equipment drawings	X	X	X

	Submit For Approval	Upon Delivery	Turn Over Package
Descriptions of equipment and components.	X		X
Instrument Cut sheets	X		X
I/O List	X	X	X
Calibration Certifications		X	X
Functional Specification	X	X	As built
Loop Diagrams		X	X
Panel wiring drawings		X	As built
Component Cut Sheets	X		X
Electrical single line diagrams	X	X	X
Schematic wiring diagrams		X	X
Sanitization Procedure	X	X	
Acceptance Test Procedures		X	
Acceptance Test Report			X
Water sampling results			X
O & M Manuals		X	As built
Training Program Outline		X	
Service Agreement Proposal		X	

**1.7 WATER TREATMENT EQUIPMENT VENDORS**

- A. Acceptable Vendors: Smith Engineering Inc, Siemens Water Technologies, Mar Cor Purification, GE Water Technologies.

**1.8 DELIVERY**

- A. Vendor shall provide complete instructions on handling, rigging, anchoring, and on-site reassembly with unit.
- B. Vendor is responsible for packaging to ensure unit arrives undamaged and uncontaminated.
  - 1. Nozzles shall have covers which protect the face from damage and seal system from contamination.
  - 2. Parts shipped loose shall be boxed and properly identified with durable, waterproof shipping tags attached with stainless steel wire or plastic tie strips. Parts shall be match marked for easy reassembly at site.

**1.9 WARRANTY**

- A. System components shall be warranted from defects in materials and workmanship by respective manufacturer for period of 1 yr from date of start-up or 18 months from date of shipment, whichever occurs first. Start-up shall be considered to begin from date system is producing water quality as stated above, and approved by Owner.

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## **PART 2 PRODUCTS**

### **2.1 GENERAL**

- A. For equipment that is skid mounted:
  - 1. Size of skid must be compatible with building dimensions and/or delivery must be coordinated with construction schedule to ensure that skid can be moved into building and set in place.
  - 2. Skid size and dimension must be compatible with room layout.
  - 3. Skids shall conform to AISC Manual of Steel Construction.
  - 4. Skid construction shall comply with local and state code seismic requirements.
  - 5. Single connection for each utility and for drain shall be provided.
  - 6. Frame to be stainless steel or carbon steel with 2 coats epoxy paint.
  - 7. Frame shall adequately support system components at their operating weights.
  - 8. Surfaces that allow water to pool on part of frame are not permitted.
  - 9. Skids shall be designed so that they may be lifted by both forklift truck and overhead crane.
  - 10. Vendor shall inform contractor of field work required to assemble and interconnect skids.

### **2.2 ULTRAVIOLET LIGHTS**

- A. Description: In-line Ultraviolet Lights
- B. Acceptable Manufacturers: Aquionics, Aquafine, Ideal Horizons
- C. Service: Bacterial Reduction
- D. Wavelength: 254 nm
- E. Dosage: 30,000 microwatt-sec/cm<sup>2</sup> after 9,000 hours
- F. Microbacterial (E-coli) reduction: 99.9%
- G. Design Flow Rate: 8 gpm
- H. Materials
  - 1. Wetted surfaces: 316L stainless steel electropolished to a surface finish of 15 Ra and passivated.
- I. Connections shall be flange
- J. Accessories: 2 "S" pattern light traps, 1 on inlet and 1 on outlet.
- K. Instrumentation
  - 1. Temperature sensor with shut down interlock, local alarm, dry contacts.
  - 2. UV intensity meter with local alarm and dry contacts.
  - 3. LED operating indicators for each UV lamp.
  - 4. Elapsed running time meter.

5. Remote start/stop capability.

L. Electrical: 120 VAC; single phase, 60 Hz

**2.3 STORAGE TANK**

A. Description: polyethylene, cylindrical, atmospheric, closed top tank with flanged and covered manway.

B. Capacity: 600 gallons nominal

C. Tank to be one piece, seamless construction of high density linear polyethylene.

D. Polyethylene to be FDA approved for food contact as per 21 CFR 177.1520. Resin complies with ASTM D-1998.

E. Design for at least 1.9 specific gravity. Temperature is 60 to 80°F.

F. Tank shall be water-tight

G. Cone or dish bottom to be totally drainable.

H. Indoor location

I. Dished top head

J. Epoxy coated (2 coats) steel, or plastic support, so that bottom tank nozzle is at least 18" off of floor.

- K. Nozzles:
1. Nozzles shall be welded inside and outside.
  2. Nozzles shall all be flanged and gusseted.
  3. Manway shall be flanged with gasketed, bolted cover. A standard lid is unacceptable.
  4. Minimum size of nozzles is as per following schedule. Vendor is responsible to ensure adequate number and size of nozzles
  5. Schedule

LOCATION	SERVICE	SIZE	CONNECTION	NOTES
Top	Manway	16" min.	flange	Replace standard access port with a flanged nozzle
Top	Inlet	1"	flange	
Top	Vent	1.5"	flange	
Top	Breather	2"	flange	
Top, center	Sprayball	2"	flange	
Top	Level transmitter	By Vendor	flange	[top or bottom depending on level transmitter]
Bottom center	Outlet	2"	flange	Provide Vortex Breaker

- L. Quality Control :
  - 1. Vendor shall have active quality control program.
  - 2. Tank fabrication and all welds shall be inspected, and inspection shall be documented.
  - 3. Testing shall conform to ASTM D-1998.
  - 4. Tank shall be kept clean during and after fabrication consistent with use for high purity service.

## 2.4 STORAGE TANK PRESSURE/VACUUM RELIEF

- A. Protectoseal vacuum and pressure breather valve

## 2.5 STORAGE TANK SPRAY BALL ASSEMBLY

- A. Description: Static spray ball with connecting piping
- B. Sprayball
  - 1. Acceptable Manufacturers: Sanimatic or approved equal
  - 2. Design Conditions: 8 gpm at 20 psi
  - 3. Material: 316L stainless steel with 25 Ra finish; Teflon
  - 4. Connection: Slip joint with stainless steel pin
  - 5. Pattern: 180 degrees upward; uniform coverage
  - 6. Features: Self draining
  - 7. Piping
    - a. Specification: Polypropylene
    - b. Configuration: Piping to suspend ball at location that provide complete and uniform coverage spray to top of tank. Piping to attach to tank flange.

## 2.6 LOOP COOLER

- A. Description: Sanitary, double tube sheet, shell and tube heat exchanger.
  - 1. Unit shall be installed on slip steam off water loop as shown on Flow Diagram.
  - 2. Shell side shall be chilled water.
  - 3. Rate of chilled water flow will be set to constant value.
- B. Acceptable manufacturer: Exergy Series 35, double tubesheet, Model 01095-5, or approved equal
- C. Following shall be provided:
  - 1. Temperature gauge on chilled water return line.
  - 2. Pressure relief valve (1/2") on chilled water line at exchanger for thermal expansion relief.
  - 3. Globe valve on outlet of chilled water.
  - 4. Needle valve on recirc line

## 2.7 DISTRIBUTION PUMPS

- A. Vertical, multistage, stainless steel centrifugal, Grundfos CRN or approved equal
- B. Grundfos model CRN for 10 gpm at 150 feet head

- C. Surfaces in contact with water shall be 316 stainless steel.
- D. Nozzles shall be 150# ANSI flanges.
- E. Seal shall be a single bellows mechanical seal with a carbon stationary face and a tungsten carbide rotation face.
- F. Motor shall be TEFC, 460 V, 3 phase, VFD compatible
- G. Each pump will have motor starter
- H. One pump will run continuously, the other will be installed standby, and will be isolated and dry. Switchover will be manual.

## 2.8 INSTRUMENTATION

- A. General
  - 1. Instrumentation shall be provided to enable reliable, safe, and efficient operation of the system, and to meet the functional requirements of this specification.
  - 2. Instrumentation shown on the drawings identified in Part 1.1 and in this specification shall be provided.
  - 3. Instruments shall be of sanitary design. Pressure sensors shall have diaphragm seals.
  - 4. Vendor shall ensure instruments are properly calibrated.
  - 5. Resistivity transmitters shall be Thornton or approved equal.
    - a. Vendor shall provide calibration certification of installed unit.
    - b. Sensors for conductivity/resistivity shall be installed in run of a horizontal tee with flow exiting the upward branch.
  - 6. Tank level transmitter shall provide continuous measurement of water level.
  - 7. Diaphragm seals shall be provided for all gauges and pressure transmitters on piping and equipment in distribution system. Alternatively, pressure gauges with 3A rating can be used.
  - 8. Pressure regulators and backpressure regulators shall be installed with at least 10 pipe diameters of straight pipe upstream and downstream of regulator.
  - 9. Self contained backpressure regulator and gauge shall be provided on the end of the return line of the distribution loop.
    - a. Specification as per referenced piping section
    - b. Adjustable pressure range 40 to 60 psig.
  - 10. Pressure Gauges shall have minimum 3.5" face.

## 2.9 CONTROLS

- A. General
  - 1. Controls shall be provided to enable reliable, safe, and efficient operation of the system, and to meet the functional requirements of this specification.
  - 2. Control function shall be provided by the UPW PLC system as per Section 226720.15CR.

- B. **Functionality**
1. System shall continuously monitor and provide alarms for:
    - a. Tank level
    - b. Distribution loop:
      - 1) Resistivity, on supply line.
    - c. Status of distribution pump.
  2. Alarms
    - a. Alarm for the distribution system and preliminary setpoints shall be as follows:
      - 1) Storage Tank Level
        - a) High High - Approx. 95% capacity: Provide Alarm.
        - b) Full - Approx. 90% capacity, stop signal to UPW system
        - c) Add - Approx. 75% capacity, send signal to UPW system for makeup
        - d) Low Low alarm - Approx. 50% capacity: Provide Advisory message. This level indicates that makeup is inadequate.
        - e) Low - Approx. 5% capacity: Shut down distribution pumps and provide alarm. Pumps shall not start under Low Low level conditions.
      - 2) Resistivity
        - a) Low: 0.1 megohm
- C. **Panels**
1. NEMA 12 panel(s) shall be provided to contain controllers, solenoids, VFDs, step down transformers, and other devices required for system.
  2. Panels shall be designed and listed in accordance with UL 508A.
  3. Transmitters to be mounted in panels where feasible.
  4. Power for transmitters and instrumentation shall be provided from panel.
  5. Panels shall provide 20% minimum spare capacity of space, PLC chassis space, wireway space, and terminal blocks to allow for future expansion by adding I/O cards and associated cabling.

## 2.10 ELECTRICAL POWER

- A. Vendor shall provide all panels, devices, wiring, local disconnects, VFDs and motor controls for the system.
1. Panels shall be designed and listed in accordance with UL 508A.
  2. Electrical components and installation shall conform to the NEC.
  3. Equipment and installation shall conform to the latest requirements or state and local authorities having jurisdiction.
  4. UL labeled equipment shall be provided to the full extent that UL labels are applicable.
  5. Wiring shall comply with methods approved in NFPA 79.
- B. **Motors**
1. NEMA Premier efficiency as per NEMA MG. 1-2003.
  2. Service factor of 1.2 [Shall not operate in service factor]
  3. TEFC



4. Conform to requirements of NEMA, IEEE, NSI, and NEC standards and shall be listed by UL for service specified.
- C. One 480 VAC/3 ph/60 Hz drop will be provided [under the electrical contractor's scope of work] for this system
  1. Vendor shall provide for distribution of power from these panels to accommodate all of Vendor's needs.
    - a. Vendor will be responsible for transforming power as required.
    - b. Vendor shall provide detailed instructions to Contractor covering any field wiring between Vendor equipment.
    - c. Vendor shall provide local disconnect.

### **PART 3 EXECUTION**

#### **3.1 CONTRACTOR RESPONSIBILITIES**

- A. Inspect delivered equipment and components for evidence of damage or contamination
- B. Rig, handle, store, set, and anchor equipment as per Vendor's recommendations and in manner that prevents impact damage and excessive stress.
- C. Maintain a high level of cleanliness during handling and installation.
  1. Prior to starting work, identify areas that will be used for storage and fabrication, and take measures to prevent contamination from adjoining areas.
  2. Keep openings on assemblies sealed during fabrication to prevent contamination prior to final installation.
- D. Provide housekeeping pads as indicated on the drawings identified in Part 1.1.
  1. Determine final size of pads based on approved Vendor submittal drawings.
- E. Install equipment level and plumb.
- F. Interconnect Vendor equipment as required
  1. Install PW piping in compliance with specification in "Related Work"
  2. Connect utilities.
- G. Ensure that the system is ready for safe startup.
- H. Provide tagging for equipment, piping, and valves.
- I. Coordinate startup, balancing, testing and turnover of system with Owner and Vendor.
  1. After the system is fully operational, oversight is required to maintain acceptable water conditions.
  2. Make arrangements to enable Vendor to monitor and manage the operation until the Owner is able to take full responsibility for the system.

#### **3.2 VENDOR RESPONSIBILITIES**

- A. Provide a representative responsible for on-site activities:

1. Verify that system is ready for startup.
  - a. Inspect installation, interconnections, utility connections, vents, etc
  - b. Conduct pre-startup check-out.
2. Startup and test system.
  - a. Verify proper operation in all operating modes.
  - b. Adjust operation of equipment and controls to meet operational, water quality, and safety requirements, and update documentation as required.
  - c. Test and balance distribution system and achieve stable operation at specified flow and pressure conditions.
  - d. Adjust self contained backpressure regulator at end of distribution loop to maintain pressure at its upstream pressure gauge at the design setpoint value.
    - 1) Verify system flows are as per design values
3. Sanitize system as per procedure.
4. Demonstrate to the Owner or to the Commissioning Agent that system operates in accordance with requirements of this specification and per approved submittal documentation.
  - a. Provide procedures that systematically verify that system operates as designed.
    - 1) Identification of acceptable ranges for all operating parameters.
5. Maintain operational oversight of system until Owner's organization is able to assume responsibility for operation.
6. Provide Turn Over documentation as identified in Part 1.
  - a. Documents shall include the final operational setpoints and information.
7. Provide training for Owner
  - a. Provide a program that covers overview, operator training, and maintenance training.
  - b. Operations training shall include:
    - 1) Start-up procedure.
    - 2) Shutdown procedure.
    - 3) Emergency operations.
    - 4) Safety procedures and hazards.
    - 5) Alarm conditions and actions,
    - 6) Parameter adjustments
    - 7) Security

**END OF SECTION**

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## SECTION 22 6720.15CR

### ULTRA PURE WATER SYSTEM

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section specifies the system for production and distribution of Ultra Pure Water (UPW) for use in the Cleanroom, and requirements for installation and start-up.

##### 1.2 REQUIREMENTS

- A. The complete requirements for this system are defined by:
1. This specification
  2. Specifications listed under Related Work below
  3. Flow Diagrams
  4. Plan Drawings

##### 1.3 SCOPE

- A. Contractor's Scope of Work includes:
1. Subcontracting with water treatment equipment vendor (Vendor) and managing Vendor's scope of work, performance, and schedule. A common Vendor shall be selected to supply this UPW system and the Humidification RO Water system per Section 22 6720.13.
  2. Managing Vendor's scope of work and performance. Coordinating:
    - a. Production of drawing showing layout of equipment positioned in Owner's area.
    - b. Identification of all field installation of piping and wiring interconnections required between Vendor's equipment.
  3. Installation of Vendor's equipment and providing utilities to the equipment.
  4. Providing distribution piping.
  5. Coordination of submittals to ensure that all requirements stated below are fulfilled.
  6. Providing tagging for equipment, piping, and valves.
- B. Vendor's Scope of Work includes furnishing:
1. All components required for a complete system that meets the requirements of this specification.
  2. Detailed drawings and complete instructions to Contractor to enable installation of Vendor's equipment, components, and any field piping and wiring interconnections that are required between Vendor's equipment and components.
  3. Documentation as identified herein.
  4. On-site checkout, startup, and testing of system.
  5. Sanitization of system, including the distribution piping system.
  6. Demonstrating to the Owner that system meets the quality and operational requirements for a three month period, including sampling and analyzing for bacteria and TOC.

7. On-site training.
8. Providing a proposal for ongoing system monitoring and maintenance program.

**1.4 RELATED WORK**

- A. System shall meet the requirement of the following sections:
1. Section 20 0514 Variable Frequency Drive (VFD) System
  2. Section 22 6714.15 Piping for Ultra Pure Water Service
  3. Section 22 6720.13CR – Cleanroom Humidification Water System

**1.5 WATER TREATMENT EQUIPMENT VENDORS**

- A. Acceptable Vendors: Smith Engineering Inc, Siemens Water Technologies, Mar Cor Purification, GE Water Technologies.

**1.6 PROPOSALS**

- A. Vendor’s proposal shall include:
1. Documentation indicated herein
  2. Documents shall clearly distinguish between items which are provided skid built [prewired, prepiped] and those that are furnished loose and required field piping and wiring.
  3. Total cost of furnishing complete system.
    - a. Additional cost based on a specification of a maximum of 10 ug/L of oxygen in the delivered UPW versus 1 ug/L.
  4. Pricing for an annual Service Agreement.
- B. Proposal shall reflect a holdback on the final 10% payment until the three month acceptance testing period is completed.

**1.7 SUBMITTALS & DOCUMENTATION**

- A. Documents shall be furnished as follows:

	<b>With Proposal</b>	<b>Submit For Approval</b>	<b>Upon Delivery</b>	<b>Turn Over Package</b>
<b>MECHANICAL</b>				
Production flow rates; flows to drain; utility loads	X	X		X
Piping and Instrumentation Diagrams (P&IDs)	Preliminary	X	X	As built
Equipment Layout drawing within facility space		X		
Distribution Pump Curves		X		X
Material certs for components in contact with UPW in distribution system to Cleanroom			X	X
Instructions for Rigging, Storage, and Anchoring			X	
Instructions for extended storage of system			X	

	<b>With Proposal</b>	<b>Submit For Approval</b>	<b>Upon Delivery</b>	<b>Turn Over Package</b>
Equipment Data	basic	X		X
Equipment List	basic	X		X
Overpressure protection components data		X		X
Pressure Test results				X
Detailed Equipment Drawings		X		X
Tank Drawing; detail of vortex breaker		X		X
<b>INSTRUMENTS &amp; CONTROLS</b>				
Instrument List		X	X	X
Instrument Cut sheets		X		X
I/O List		X	X	X
Calibration Certifications			X	X
Operational and controls description and functions		X		
Functional Specification			X	As built
Loop Diagrams			X	X
Control Schematics			X	X
Control Panel wiring drawings				As built
Component Cut Sheets		X		X
PLC Program Printout and Disk File				As built
OIT Configuration			X	As built
<b>ELECTRICAL</b>				
Single line diagrams		X	X	X
Schematic wiring diagrams		X		X
Electrical panel drawings			X	X
<b>OTHER</b>				
Sanitization Procedures	outline		X	X
Acceptance Testing Plan	program	X	X	
Acceptance Testing Report				X
O & M Manuals			X	As built
Training Program			X	
Service Agreement	proposal			X

- B. Content of the documents shall include the information listed below.
1. P&IDs:
    - a. Scope of Vendor's supply
    - b. Size and pipe spec on every line
    - c. Sampling valves
    - d. All field connections [utilities, vents, drains] with:
      - 1) Design flow; and pressure and temperature if pertinent.
      - 2) Type & size of connections.
    - e. Equipment and instrumentation shall be identified with tags assigned by the Owner.

- f. All I/O identified
  - g. Critical details for water quality: slopes, analytical sampling circuits, minimum dimensions, etc
  - h. Details of side streams for analyzers
  - i. Set points for pressure relief and self contained pressure control devices [regulators].
  - j. As-built P&IDs shall incorporate changes made during startup and testing.
2. Loop Diagrams shall be prepared in accordance with ISA 5.4
  3. Utility Requirements:
    - a. Peak domestic water flow rate
    - b. Discharges to drains: peak and steady state flows at equipment rating.
    - c. Electrical power
    - d. Chilled Water flow rates
  4. Equipment Data
    - a. Dimensions
    - b. Pressure and vacuum rating
    - c. Sizes and types of nozzles
    - d. Materials and surface finish for all components in contact with water
    - e. Pump curves with operating point[s]
    - f. Seal detail drawing and materials of construction, accessories
  5. Overpressure protection components
    - a. For all components on tank vents [vent filters, breather valves, check valves, relief valves, rupture disk]:
      - 1) Flow capacity with corresponding pressure drop
      - 2) Set pressure
      - 3) Pressure and vacuum rating of protected equipment
  6. O and M Manuals: Complete instructions on operation and maintenance including:
    - a. List of all operating and water quality parameters, normal operating ranges, and acceptable ranges.
      - 1) All parameters and setpoints that were established during startup and testing shall be included.
    - b. Procedures for Start-up, Shutdown, and Emergency operations.
    - c. Operation of controls, control sequences, alarm conditions and actions.
    - d. PM schedule.
    - e. Complete Bill of Materials with part numbers.
    - f. Recommended spare parts list.
    - g. Bulletins for all components.
    - h. Troubleshooting guide.
    - i. Manufacturer's contact information.
  7. Control system Functional Specification:
    - a. Control System Description
      - 1) Architecture
      - 2) Hardware
      - 3) Software configuration
      - 4) Communication
    - b. Detailed description of each:
      - 1) Operator Interface screen
      - 2) Operator inputs

- 3) Sequential operations [startup, shutdown, emergency shutdown, etc.]
      - 4) Active alarms and Interlocks
      - 5) Messages
    - c. Functionality
      - 1) Modes
      - 2) Security levels, access
      - 3) Alarms and setpoint values
      - 4) interlocks
      - 5) Analog and Discrete Loops
      - 6) Backup/restore
      - 7) Operator Interface
8. Wiring schematics
  - a. Drawings shall be in ladder format.
  - b. Rungs shall be numbered.
  - c. Relay function shall be fully described to right of relay right rung.
  - d. Relay contact location shall be referenced at coil location.
  - e. Contacts shall have associated coil reference and short description of function.
  - f. Contacts shall have relay pin-out identifiers.
  - g. Wire colors and designators shall be identified.
  - h. Terminal blocks shall be uniquely identified.
  - i. Field and panel wiring shall be differentiated by solid line for panel and dashed line for field.
  - j. Connections to field device or other remote panel shall be identified.
9. Sanitization Procedures
  - a. Identification of subsystems requiring regular sanitization and cleaning.
    - 1) Procedure for the initial sanitization
  - b. Ozonation system
    - 1) Operation of system
    - 2) Safety Procedures
10. Acceptance Testing Plan
  - a. System functionality
    - 1) Functional testing forms [check lists] covering:
      - a) all operating modes
      - b) Acceptable ranges for operating parameters.
      - c) Alarm challenges
      - d) Power loss and Recovery
  - b. Water quality monitoring and testing plan [three month]
    - 1) Sampling Points
    - 2) Acceptable ranges for quality parameters
    - 3) Analytical methods
    - 4) Frequency of sampling, trending
  - c. Ozonation system
    - 1) List of operating parameters and acceptable values
    - 2) Procedures for verification of parameter values.
11. Acceptance Testing Report
  - a. Results of pressure testing of equipment and piping.
  - b. Completed Functional testing forms [check lists]

- c. Complete testing and monitoring of ozone system
- d. Water testing results

## 1.8 REFERENCE

- A. The Work under this section is subject to requirements of Contract Documents including. General Conditions, Supplementary Conditions, and sections under Division 1 General Requirements.

## 1.9 PRODUCT DELIVERY

- A. Equipment shall be properly packaged to protect against shipping and handling damage.
- B. Manufacturer's instructions on rigging, installation, and anchoring of equipment shall be provided.
- C. Equipment shall be furnished with protective covering to prevent contamination during shipping, storage and handling.

## 1.10 WARRANTY

- A. System components shall be warranted from defects in materials and workmanship by respective manufacturer for period of 1 year from date of start-up or 18 months from date of shipment, whichever occurs first. Start-up shall be considered to begin from date system is producing water quality approved by Owner.

## PART 2 PRODUCTS

### 2.1 BASIS OF DESIGN

- A. Scope
  - 1. The system is comprised as follows:
    - a. Pretreatment: comprised of coarse filtration and softening. This subsystem is specified in detail by this specification.
    - b. Production: generation of "DI" water as supply to the UPW distribution system. This subsystem is defined by performance criteria, and the Vendor shall provide the detailed design. This system provides water to both the UPW system and RO water for the Cleanroom humidification system.
    - c. UPW Distribution Equipment: Storage, pumping, and final treatment to produce UPW.
    - d. RO Water feed to humidification.
- B. General
  - 1. Vendor is responsible for providing a system that consistently and reliably meets the quality and capacity requirements of this specification.
  - 2. UPW Water shall meet the following requirements:



PARAMETER	LIMIT
Resistivity on-line @ 25°C	≥18.1 Megohm-cm
TOC on-line	1 ug/L
Bacteria 100 mL Sample	< 3 cfu
Dissolved Oxygen on-line	1 ug/L *

\* Vendor shall provide alternative pricing based on a specification of a maximum of 10 ug/L of oxygen versus 1 ug/L.

a. Water supplied from the Production system to the humidification tank shall be RO water with a resistivity greater than 0.2 Megohm cm.

C. Capacity

1. Production Rates

- a. UPW: 12 gpm
- b. RO: 2.1 gpm

2. Distribution: Continuously deliver 60 gpm at 55 psig to the Cleanroom distribution loop. [55 psig at the point where water leaves the Vendor's skid]

D. Size

1. Equipment shall be located in the area shown on the lower level Plan Drawing.

a. The equipment arrangement shown on drawing is for reference only. Vendor shall provide arrangement best suited for equipment.

- 1) Note that on Flow Diagram, package lines indicate equipment and components provided by UPW system Vendor, but are not intended to define skids. Also, some piping shown within package lines may need to be field installed by contractor, and these shall be identified by Vendor.

2. Vendor shall determine layout of UPW equipment within the designated space and submit an accurate layout drawing

a. Layout shall ensure:

- 1) Equipment and skid sizes are suitable to pass through available building opening and passageways, or must be delivered prior to completion of that area of building.
- 2) Proper access to equipment and instrumentation for operations and maintenance.

E. Site Conditions

1. Available utilities

a. Supply Water

- 1) Pressure at connection to Vendor's system: 35 to 40 psig under flow conditions.
- 2) Temperature at connection to Vendor's system: 65 F nominal, provided by temperature control unit [by others]. Temperature can be adjusted to suit Vendor's requirements.
- 3) Source is City of Minneapolis.
  - a) City water may have either chlorine or chloramines as disinfectant. Chlorine levels can, on occasion, be significantly higher than typical levels.

- b) Vendor shall be responsible for verification of water quality.
- c) Quality parameters:

CONSTITUENT	AVERAGE
Residual chlorine, Total, average	1.3 mg/L
pH	9
Silt Density Index	2 to 3.6
Total Alkalinity	47.2 mg/L
Total Hardness	43.3 mg/L
Turbidity	0.016 NTU
Sodium	7.5 mg/L
Chloride	2.6 mg/L
Fluoride	1.19 mg/L
Nitrate	0.18 mg/L
Sulfate (SO <sub>4</sub> )	8.8 mg/L
Iron	.015 mg/L
Aluminum	0.033 mg/L

- b. Chilled water at 60 F, and 40 psig.
- c. Nitrogen at 55 psig
- d. Instrument air at 90 psig.

**2.2 SKIDS**

- A. Equipment shall be mounted on common frames and delivered assembled on skids where feasible.
  - 1. Skid construction shall conform to AISC Manual of Steel Construction.
  - 2. Single connection for each utility and for drain shall be provided whenever feasible.
  - 3. Frame shall be stainless steel or carbon steel with two coats of epoxy paint.
  - 4. Frame shall adequately support system components at their operating weights.
  - 5. Surfaces that allow water to pool on part of frame are not permitted.
  - 6. Skids shall be designed so that they may be lifted by both forklift truck and overhead crane.
- B. Arrangement of equipment and piping shall enable proper access for operations and maintenance, including:
  - 1. Maintenance and calibration of instrumentation
  - 2. Clearance for removal of regularly replaced components (filter elements, UV lamps, etc.)
  - 3. Convenient operator access to sample valves and for insertion of sampling container.

**2.3 MATERIALS AND FABRICATION**

- A. Vendor is responsible for selection of materials and surface finishes that will ensure that water quality will be maintained.

- B. Materials in contact with water downstream of the RO unit shall comply with the following:
  - 1. Piping shall be George Fischer SYGEF Plus polyvinylidene fluoride (PVDF) with Bead and Crevice Free (BCF) butt fusion joints as per Section 22 6714.14.
    - a. Material certification shall be provided
  - 2. Stainless steel in equipment shall be type 316, polished to 25 Ra. Equipment in the distribution system shall be electropolished.
  - 3. RO water sent to the Humidification Water storage tank may be polypropylene or PVC.
- C. System shall be fabricated and assembled in cleanroom with a high degree of emphasis on maintaining cleanliness throughout the assembly process.
  - 1. Assembly that involves open piping or equipment shall be performed in an area that has an HVAC system that is isolated from other work areas. Metalwork shall not be performed in the same area.
  - 2. Stainless steel fabrication shall be performed in an area that is isolated from areas where carbon steel is being worked.

## 2.4 PRETREATMENT

- A. Booster Pumps
  - 1. Vendor shall provide booster pumps if required by Vendor's system.
  - 2. Two Booster Pump Units shall be provided, piped in parallel, with one operating at a time. Controls shall be provided to switch operation between pumps at preset intervals.
  - 3. Vendor shall specify pumps
- B. Multimedia Filter
  - 1. Duplex parallel multi-media filters shall be provided; each consisting of fiberglass vessel with internal distributors, piping, fully automatic brass multi-port control valve, pressure gauges, sample valves and media. Unit shall be preassembled, prewired, and hydrostatically tested. Media shall be packaged separately.
  - 2. Design flow: as required to meet service and regeneration flows of downstream equipment
  - 3. Both units will normally be in service.
  - 4. Each unit shall be capable of handling the service flow rate at the following criteria:
    - a. Sizing criteria: less than 5 gpm/ft<sup>2</sup> at design flow
    - b. Backwash Flow Rate: 15 gpm/ft<sup>2</sup>
    - c. Fast Rinse Flow Rate: at service flow rate
    - d. Suspended Solids Removal: down to 10 micron
    - e. Clean Bed Pressure Drop: less than 5 psig at service flow rate
  - 5. Media: 3 support layers and 3 active filtration layers. Active filtration layers shall be anthracite, sand and fine garnet (top to bottom). Support layers are medium garnet, medium gravel, and coarse gravel.
  - 6. Piping: PVC
  - 7. Controls: Backwash automatically initiated based on pressure differential, or frequency controlled by seven-day time clock. Operator shall have option to select day-of-week and time-of-day for backwash to occur.

8. Electrical: 120 VAC, single phase, 60 Hz
  9. Sample valve shall be provided after unit.
- C. Water Softener
- D. A duplex parallel water softener system shall be provided: fiberglass vessels with internal distributors, piping, automatic brass control valves, alternating controller, pressure gauges, sample valves, resin, gravel, outlet "Y" strainer, dry-brine tank and brine eductor. Unit shall be preassembled, prewired, and hydrostatically tested. Media shall be packaged separately.
1. Design flow: as required to meet service and regeneration flows of downstream equipment.
  2. Both units will normally be in service.
  3. Each unit shall be capable of handling the service flow rate at the following criteria:
    - a. Volumetric Flow Rate: less than 3 gpm/ft<sup>3</sup> at design flow rate
    - b. Velocity: greater than 2.5 gpm/ft<sup>2</sup>
    - c. Backwash Flow Rate: 4-6 gpm/ft<sup>2</sup>
    - d. Brine Dosage: 4.5-5.7 gal/ft<sup>3</sup> for 15-25 minutes
    - e. Slow Rinse: Brine dilution rate for 40-45 minutes
    - f. Fast Rinse: Service flow rate for 5-15 minutes
    - g. Resin Capacity: 30,000 grains/ft<sup>3</sup> at 15 lb. salt dosage
    - h. Brine Tank, Salt Dose: 6-15 lb/ft<sup>3</sup> of softener resin
    - i. Normal hardness leakage: 5 ppm
  4. Controls: Motor-driven control valve shall stage each softener through regeneration steps. Regeneration intervals based on throughput. After regeneration, a rinse to drain cycle shall be provided prior to placing unit in service.
  5. Power: 120VAC, 1ph, 60HZ
  6. Piping: PVC

## 2.5 PRODUCTION

- A. Vendor shall be responsible for the detailed design of the Production system as needed to ensure water will reliably attain the requirements for water delivered by the UPW distribution system.
- B. Water from the pretreatment system will supply the Production system. Water from the Production system will supply the UPW storage tank. Water from the RO unit in the Production System will supply the Humidification RO Water storage tank.
- C. At a minimum, treatment shall consist of carbon, RO, UV TOC reduction, and electro-dionization.
- D. Pumps on the system shall be duplex [except for RO]
- E. Water supply to the UPW tank shall not have dead legs.

- 
- F. System shall provide:
1. Sampling points and analytical instrumentation that will enable the appropriate level of monitoring required to ensure that water quality is maintained.
  2. Automatic control, monitoring, and alarming required to ensure that system performance and efficiency is maintained.
  3. Features required to enable charging of cleaning and sanitization chemicals.
  4. Features and procedures necessary to enable verification that water quality is being maintained, including:
    - a. Identification of points within the production and distribution system where water quality needs to be monitored to assure proper equipment performance.
    - b. Identification of quality parameters and the frequency of sampling required to properly access operation.
    - c. Providing sampling valves and apparatus that enable representative samples to be taken.
    - d. Specification of acceptable ranges for quality parameters.
- G. Chlorine Removal
1. Chlorine and chloramines shall be removed using activated carbon .
  2. Duplex parallel unit with automatic backwash cycles shall be provided. Both units will normally be in service. Each unit shall be capable of handling the service flow rate.
  3. System shall be designed to consistently and reliably protect the RO membranes and quality of the RO permeate.
- H. Reverse Osmosis
1. Unit shall be designed by Vendor and shall include pH adjustment for CO<sub>2</sub> removal.
  2. Supply temperature can be specified by Vendor, to optimize the performance of the production system.
  3. Performance requirements are:
    - a. 16 gpm minimum normal permeate with 65 deg F supply water
    - b. 75 percent minimum recovery.
    - c. 97 percent minimum rejection
  4. Instrumentation and controls shall ensure safe, efficient operation, and shall include:
    - a. Supply and permeate conductivity, with alarm points. [TDS monitor is not acceptable]
    - b. pH of feed water
    - c. Flow transmitter on permeate
    - d. Low pressure supply shutdown
    - e. Flowmeter on reject
    - f. Pressure transmitters on stage inlet and outlet
    - g. VFD for pump
    - h. Elapsed run timer
- I. UV lights
1. Units shall be selected by Vendor. Medium pressure lights are preferred.
  2. A unit shall be installed prior to the EDI unit.

3. Lights shall be provided so as to ensure the TOC in UPW system is well below specification.
  4. Metal surfaces in contact with water shall be 316 ss, electropolished.
  5. Connections shall be Triclamp
  6. Lights shall have:
    - a. An optical sensor that reads UV light intensity with analog output and display and adjustable alarm setpoints. Alarm signal shall be wired to the control system.
    - b. High temperature sensor with shut down interlock.
    - c. Operating indicators for each UV lamp.
  7. Accessories: Two "S" pattern light traps, 1 on inlet and 1 on outlet, 316 stainless, electropolished.
  8. Acceptable Vendors: Aquionics, Aquafine, Ideal Horizons
- J. Electro Deionization
1. Unit shall be designed by Vendor.
  2. 12 gpm minimum continuous capacity.
  3. Minimum recovery of 90%
  4. Concentrate recycle is not permitted
  5. Resistivity of product shall be monitored.

## 2.6 DISTRIBUTION SYSTEM

- A. General
1. Design of system is per this spec and drawing
  2. Vendor is responsible for ensuring system will meet quality requirements.
- B. Distribution Pumps
1. Two, redundant, pumps, piped in parallel, shall be provided.
  2. Distribution pumps shall be Grundfos CRN 15-3 with:
    - a. Triclamp connections, 316 stainless wetted parts, which have been electropolished, passivated, cleaned, rinsed with DI water, and dried.
    - b. Balanced cartridge seal, silicon carbide by tungsten carbide,
    - c. FXM o-rings
    - d. TEFC, VFD compatible, motor
    - e. Plastic wrapped for shipment.
  3. A VFD shall be provided for each pump.
    - a. Manufacturers: ABB, Danfoss Graham, Yaskawa (MagneTek), or Grundfos.
    - b. VFD will be used to set up pump for optimum performance. Pump speed will not be automatically controlled.
  4. Both pumps will run continuously at exactly the same speed. Under normal conditions they will each provide half of the flow rate. If one pump fails, the other will provide a flow rate which will be adequate.
    - a. VFD shall be set up to ramp up when pump is started and ramp down when shut off.
- C. Storage Tanks
1. Two identical tanks are required as per Section 226720.28.
  2. The tanks will operate as a single reservoir.

D. Nitrogen Blanket

1. Tank shall have a static nitrogen blanket as per Flow Diagram
  - a. Filter housing
  - b. Filter shall be a Pall KleenPak Emflon II membrane Assembly KA3V002PV1, or approved equal.
  - c. Pressure regulator shall be a Fisher Ace 95Jr stainless steel or approved equal.
    - 1) Set point shall be 4 inches w.c.
  - d. Backpressure shall be held on tank using a Protectoseal 2" x 2" PVC Pipe-Away breather PVD17802B2 on the vent line, with opening set pressure 6 inches w.c.
    - 1) Breather shall be offset from tank nozzle by at least 2 pipe elbows.
    - 2) Vent piping downstream of breather may be schedule 80 PVC, shall be vented to outside of building through roof, terminating in a gooseneck with a "bird" screen on outlet.
    - 3) An overflow line shall be provided off of a tee from the vent line downstream of the breather. This line shall be routed to near the floor and at the end shall be a check valve, Check all FIV PTFE with a cracking pressure of 1/2 psi.

E. Degassing

1. Membrana Liqui-Cel membrane contactors on the distribution supply line shall be used to remove oxygen. Unit shall operate in Combo mode: sweep nitrogen with vacuum. Operation shall be fully automatic to maintain quality levels within range.
2. UPW design flow rate is 60 gpm
3. Providing membrane contactors on the Production system to remove oxygen may be considered in order to reduce the number of contactors on the distribution line.
4. Nitrogen supply shall have isolation valve, pressure regulator, pressure gauge, and flowmeter with needle valve.
5. Vacuum line shall have a pressure switch, a pressure gauge, a check valve, and an isolation valve.
6. Vendor shall provide vacuum pump system.

F. UV light

1. Units shall be selected by Vendor. Medium pressure lights are preferred.
2. A unit shall be located prior to DI cylinders.
3. Lights shall be provided so as to ensure complete destruction of ozone and reduction of the TOC in UPW system to below specification.
4. Metal surfaces in contact with water shall be 316 SS electropolished.
5. Connections shall be Triclamp
6. Lights shall have:
  - a. An optical sensor that reads UV light intensity with analog output and display and adjustable alarm setpoints. Alarm signal shall be wired to the control system.
  - b. High temperature sensor with shut down interlock.
  - c. Operating indicators for each UV lamp.
7. Accessories: Two "S" pattern light traps, 1 on inlet and 1 on outlet, 316 stainless, electropolished.

- G. Deionization beds
1. Vendor shall determine the number of sets of beds/cylinders required.
  2. UPW design flow rate is 60 gpm
  3. Resin shall be virgin Low TOC mixed resins, Resintech MBD-10 Ultra Grade or approved equal. TOC < 2 ppb at rinse up of 100 bed volumes.
  4. Beds shall be fitted with Tri-Clamp connections.
  5. A conductivity monitor shall be provided downstream of one of the 1<sup>st</sup> sets of beds. When the conductivity falls to 17 meg, the control system shall provide an Advisory alarm indicating the beds should be replaced.
  6. Hoses shall be platinum cured silicon wire reinforced hose with PVDF Triclamp ends; one inch inside diameter, manufactured by Rubber Fab Mold and Rubber Co.
- H. UltraFilter
1. Ultrafilter shall be comprised of filter cartridge housings piped in parallel.
    - a. Filter cartridges shall be MarCor Fiberflo Hollow cartridge filters, 0.05 micron absolute, 30" long, style 4; or approved equal.
    - b. Housings shall be PVDF Series HD Serfilco, with Viton o-ring, or approved equal, sized for flow rate and pressure drop < 10 psi.
  2. UPW design flow rate is 60 gpm
  3. Vendor shall determine the number of filters required.
- I. Ozone System
1. An ozonation system shall be provided to maintain a constant level of ozone within the UPW storage tanks and to enable ozonation of the distribution loop at predesignated times.
  2. System shall be capable of providing 1 ppm of ozone in the distribution system.
  3. System shall be comprise of:
    - a. Ozone generator and injection system. Ozone shall be generated from purified water.
    - b. UV lights which will provide ozone destruction
    - c. Ozone destruct unit on common vent from storage tanks.
    - d. Ozone monitors that will verify that:
      - 1) proper level of ozone is maintained in tank,
      - 2) ozone is completely destroyed by UV light on supply to loop
      - 3) monitoring of ozone level in return loop when loop is being ozonated
    - e. Automatic bypass around DI beds for loop ozonation.
    - f. Monitor for gaseous ozone in area around ozone generator and injection point.
  4. Vendor is responsible for design of system that automatically control, monitor, and provide interlocks and shutdowns to:
    - a. Provide a high level of safety that will prevent ozone from exceeding acceptable ranges in the water, or from release into the atmosphere.
    - b. Provide ozone levels that assure that TOC and bacterial specification are reliably and consistently maintained.
  5. Vendor shall ensure materials of construction are compatible with ozone, and that any components that are not compatible are effectively and reliably isolated from ozonated water.



J. LOOP COOLER

1. Description: Sanitary, double tube sheet, shell and tube heat exchanger.
  - a. Unit shall be installed on properly designed slip steam
  - b. Shell side shall be chilled water.
  - c. Chilled water flow will be set at a constant rate.
2. Acceptable manufacturer: Exergy Series 35, double tubesheet, Model 01095-5, or approved equal.
3. Following instrumentation shall be provided:
  - a. Temperature gauge on chilled water return line.
  - b. Pressure relief valve (1/2") on chilled water line at exchanger for thermal expansion relief.
  - c. Globe valve on outlet of chilled water.

2.7 CONTROL SYSTEM

A. Vendor shall provide:

1. A single control system to monitor and control the entire UPW system and the Cleanroom Humidification Water system. Refer to Section 22 6720.13.
  - a. PLC shall be an Allen Bradley MicroLogix or CompactLogix.
  - b. HMI shall be Allen Bradley Color Panelview Plus 1000 Plus
  - c. System shall have 20% spare processing capacity and space for an additional 20% I/O.
2. Design of entire control system, hardware, and software.
3. Identification of the quality and operating parameters that must be automatically monitored to ensure safe, efficient operation of the system, and to consistently and reliably produce and maintain the required water quality.
4. Documentation establishing the acceptable operating ranges for the parameters.
5. Specification of sensors and transmitters.
6. Programming to accomplish the required functions. Programming shall be systematically tested, including challenge testing, and testing shall be documented.

B. System shall provide monitoring, control, and alarming to ensure that system operates within the established operating ranges and conditions

1. Monitoring of the following shall be included:
  - a. Hardness and chlorine concentration of water prior to the RO.
  - b. Resistivity of water to RO, from RO, and from EDI.
  - c. Tank level
  - d. Faults from distribution pump VFDs.
  - e. Status of each distribution pump.
  - f. Discrete alarm signals from RO, EDI, UV lights, degass and other equipment to ensure safe and proper operation of those units.
  - g. Resistivity after 1<sup>st</sup> set of DI beds.
  - h. Supply to Cleanroom distribution loop: Resistivity, TOC, dissolved oxygen, pressure, and ozone concentration.
  - i. Return from Cleanroom distribution loop: Resistivity, TOC, flow, pressure and ozone concentration..

- j. Operation of the ozonation equipment, including safety shutdown interlocks.
- k. Detection of ozone in air around generator.
2. Automatic control of the following shall be included:
  - a. Water levels in UPW Tank and Humidification Tank
  - b. Prevention of flow into the storage tank if water quality or operating parameters in the Production system are out of range.
  - c. Ramp up speed on distribution pump to a preset level if one pump fails or if flow rate falls below a preset minimum.
  - d. Continuous ozonation of the tank and regular ozonation of the distribution system.
3. Control system shall provide:
  - a. For each analog parameter, an alarm shall be provided that indicates that the value is outside of expected range [Advisory: low and high setpoints], and one when the value is outside of the acceptable range [Critical: low low and high high setpoints].
  - b. Data transfer to Owner's Clean Room control system [Honeywell PLC]; including all alarm conditions, conductivity, resistivity and ozone levels in the distribution system.
  - c. Adjustable timers for alarms.
  - d. An Alarm List.
  - e. Password protected security to prevent change of primary operating parameters by unauthorized personnel.
  - f. Monitoring any fault signals from analytical equipment and from process equipment [RO, EDI, etc]
4. Alarms Setpoints
  - a. Vendor shall specify appropriate operating ranges and alarm setpoints
  - b. Storage tank level actions and alarming shall include:
    - 1) High High - Approx. 98% capacity: Provide critical alarm.
    - 2) Full - Approx. 90% capacity: stop flow to tank
    - 3) Add - Approx. 75% capacity: start flow to tank provided that other tank is not being filled.
    - 4) Low level- Approx. 45% capacity. Prioritize flow to this tank.
    - 5) Low Low - Approx. 5% capacity: Shut down distribution pumps and provide critical alarm. Pumps shall not start under Low Low level conditions.
  - c. Preliminary alarm setpoints for the distribution system shall be as follows:
    - 1) Pressure at supply to Cleanroom
      - a) High: 65 psig Advisory alarm.
      - b) High High: 100 psig Critical alarm and shutdown pumps
      - c) Low : 45 psig Advisory alarm.
      - d) Low Low: 20 psig Critical alarm and shutdown pumps
    - 2) Pressure at return from Cleanroom
      - a) High: 55 psig Advisory alarm.
      - b) High High: 100 psig Critical alarm and shutdown pumps
      - c) Low: 35 psig Advisory alarm.
      - d) Low Low: 10 psig Critical alarm

- 3) Flow in Cleanroom return:
  - a) High: 70 gpm Critical alarm and shutdown pumps
  - b) Low: 22 gpm Advisory alarm
  - c) Low Low: 15 gpm Critical alarm.
- 4) Resistivity in supply to Cleanroom
  - a) Low: 18.1 Advisory alarm
  - b) Low Low: 18.0 Critical alarm.
- 5) TOC and Oxygen in supply to Cleanroom shall have High and High High alarm setpoints

C. Panels

1. NEMA 4 panel(s) shall be provided to contain controls, solenoids, operator interface, motor starters, step down transformers, and other devices required for system.
2. Panels shall be designed and listed in accordance with UL 508A.
3. Transmitters to be mounted in panels where feasible.
4. Power for transmitters and instrumentation shall be provided from panel.
5. Provide 20% minimum spare capacity of panel space, PLC chassis space, wireway space, and terminal blocks to allow for future expansion by adding I/O cards and associated cabling.

## 2.8 INSTRUMENTATION

A. Instrumentation shall be provided to enable monitoring of operating and quality parameters.

1. Vendor shall specify instruments for the UPW system.
2. On-line instruments that have range and accuracy appropriate for the water quality levels that they monitor.
3. Vendor shall ensure instruments are properly calibrated.

B. Manufacturers:

1. Hardness monitor: Hach SP510 or approved equal
2. Chlorine monitor: Hach CL17 or approved equal.
3. Flowmeters: Thornton PVDF vortex flowmeter; GE Aquatrans UTX878; or approved equal.
4. Resistivity and temperature: Thornton or approved equal
5. Dissolved oxygen – Thornton or approved equal
6. TOC monitor: Anatel A-1000 or approved equal
7. Vendor may provide alternatives in proposal
8. Self contained back pressure regulators at ends of distribution loops shall be George Fischer V786, same size as line size.
9. Isolators shall be provided for all gauges and pressure transmitters where bacteria is being controlled to low levels.
  - a. Isolators on piping within the distribution system equipment system shall be Plastomatic UltraPure Gauge Guards with Viton elastomers, and GF “metric” end connections. The part number for the gauge without a gauge is GGMU-V-001-PF-line size-5; with the line size stated in inches.

## **2.9 ELECTRICAL**

- A. Vendor shall provide all panels, devices, wiring, VFDs and motor controls for the system.
  - 1. A separate low voltage panel shall be provided for the PLC and HMI.
  - 2. Panels shall be designed and listed in accordance with UL 508A.
  - 3. An E-stop shall be provided.
  - 4. Electrical components and installation shall conform to the NEC.
  
- B. Motors shall:
  - 1. Have NEMA Premier efficiency as per NEMA MG. 1-2003,
  - 2. Service factor of 1.2
  - 3. Shall not operate in service factor
  - 4. Be TEFC
  - 5. Conform to requirements of NEMA, IEEE, NSI, and NEC standards and shall be listed by UL for service specified.
  
- C. Drops will be [under the Electrical contractor's scope of work] at the following locations:
  - 1. At the booster pumps, a 3 phase 480 volt drop.
  - 2. At the multimedia filter: one 120 volt, single phase drop
  - 3. At the softener system: one 120 volt, single phase drop. A 3 phase 480 volt drop for the UPW Treatment system
  - 4. A 3 phase 480 volt drop for the UPW Distribution system
  - 5. Verification of drop requirement and locations will be adjusted during submittal process.
  - 6. Vendor will be responsible for transforming this power and for distributing power as needed.
  - 7. For field connection of power wiring between equipment, Vendor shall provide detailed instructions to Contractor.

## **PART 3 EXECUTION**

### **3.1 CONTRACTOR**

- A. Inspect delivered equipment and components for evidence of damage or contamination
  
- B. Rig, handle, store, set, and anchor equipment as per Vendor's recommendations and in manner that prevents impact damage and excessive stress.
  
- C. Maintain a high level of cleanliness during handling and installation.
  - 1. Prior to starting work, identify areas that will be used for storage and fabrication, and take measures to prevent contamination from adjoining areas.
  - 2. Keep openings on assemblies sealed during fabrication to prevent contamination prior to final installation.
  
- D. Install equipment level and plumb.
  
- E. Interconnect Vendor equipment as required

- F. Install piping in compliance with Section 22 6714.15.
- G. Connect utilities.
- H. Ensure that the system is ready for safe startup.
- I. Coordinate testing and startup with Owner and Vendor.
- J. Coordinate sanitization of the piping system with the Vendor.
- K. Coordinate and submit the Turn-Over Package.
- L. Obtain acceptance signature from Owner

### **3.2 VENDOR**

- A. Provide a representative responsible for the following on-site activities:
  - 1. Inspect installation [interconnections, utility connections, vents, etc]
  - 2. Conduct pre-startup testing [continuity, motor rotation, etc]
  - 3. Conduct startup and testing.
    - a. Perform tests per Test Procedures and document results
    - b. Adjust operation of equipment and controls to meet operational, water quality, and safety requirements. Set up distribution system as per below
    - c. Update documentation as required.
    - d. Execute system sanitizations.
  - 4. Demonstrate to Owner or Owner's representative that the operation of the system is stable, meets the requirements of this specification, and attains required water quality.
  - 5. Provide training for Owner personnel or representatives.
  - 6. Establish the activities, monitoring, and testing for the three month acceptance period.
  - 7. Complete the three month acceptance program, and provide Turn Over documentation

### **3.3 DISTRIBUTION SYSTEM SETUP**

- A. Adjust pump speed and backpressure valve on loop so that:
  - 1. The pressure to supply to Cleanroom is approximately 55 psig.
  - 2. The pressure at the end of the Cleanroom return header [prior to the backpressure valve] is approximately 35 psig.

### **3.4 SERVICE AGREEMENT**

- A. Vendor shall provide a proposal for monitoring and maintenance program. Program will provide:
  - 1. Monitoring and testing procedures that will verify water quality compliance.
  - 2. Preventative maintenance procedures that will ensure efficient operation and suitable life of system components
- B. Proposal shall clearly define of the responsibilities of the Vendor and of the Owner.

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- C. Vendor services shall include:
1. Preventive Maintenance
    - a. Remote alarm monitoring
    - b. Inspection of equipment performance and establishing logs
    - c. Monitoring of operating parameters and adjusting as required
    - d. Regular replacement of filters, resin, membranes, UV lights, etc
  2. Water quality monitoring
    - a. Quality Control plan
    - b. Execution of sampling and laboratory testing
    - c. Execution of sanitizations
    - d. Calibration of instrumentation, documentation
  3. Support
    - a. Responsibility and communication matrix clearly outlining responsibilities of Vendor and Owner.
    - b. On-call support system
    - c. Stocking of critical spare parts
  4. Overall responsibility for the program
    - a. Defining a responsibility and communication matrix detailing responsibilities of Vendor and Owner.
    - b. Training of Owner personnel in the execution of daily monitoring, inspection, logging, notification and action tasks.

### 3.5 TRAINING

- A. Representative shall furnish on-site instruction and training.
- B. Representative shall coordinate training schedule with Owner.
- C. Training shall cover system overview and operator training.
- D. Scope of operations training shall include:
1. Start-up procedure.
  2. Shutdown procedure.
  3. Emergency operations.
  4. Safety procedures and hazards.
  5. Alarm conditions and actions.
  6. Security.
  7. Logging.
  8. Communication with Vendor.

**END OF SECTION**

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## SECTION 22 6720.28CR

### DUAL LAMINATE TANK

#### PART 1 GENERAL

##### 1.1 DESCRIPTION

- A. This Section describes the requirements for design, fabrication, testing, documentation, and installation of dual laminate storage tank for Ultra Pure Water (UPW).
- B. Two identical tanks are required.

##### 1.2 SUBMITTALS

- A. Manufacturer shall submit the following, and obtain approval, prior to fabrication:
  - 1. Fabrication drawings which include:
    - a. Manufacturer and material specification for the lining materials, FRP shell, and gaskets.
    - b. Details of wall, joints, overlays, manway, and nozzles.
    - c. Connection sizes, exact locations
    - d. MAWP of vessel at ambient temperature, and maximum allowable operating temperature.
  - 2. Quality Control and inspection procedures specific to this vessel.
- B. Manufacturer shall provide the following documentation upon delivery:
  - 1. Hydrotest Report
  - 2. Inspection and Test report
  - 3. Instructions for:
    - a. Rigging, installation, and anchoring.
    - b. Recommendation for post installation inspection and testing prior to placing tank in service.
    - c. Recommended, detailed inspection and care procedures for preventative maintenance.

#### PART 2 PRODUCTS

##### 2.1 MANUFACTURERS

- A. AC Plastiques, Canada; Composites USA, MD; Fisher Company, Utah.

##### 2.2 Design Criteria

- A. Service: Electronics Grade water with a resistivity of 18.2 megohm-cm
  - 1. Design details and material selection shall reflect the criticality of maintaining the quality of UPW by preventing opportunity for bacterial growth and by preventing contamination from tank materials or from outside of tank.

- B. Materials:
1. All product contact surfaces shall be Kynar.
  2. Liner shall have a minimum thickness of 2.2 mm PVDF.
  3. Metal hardware shall be stainless steel.
- C. Mechanical
1. Type: vertical, cylindrical tank with dished bottom and top heads.
  2. Operating pressure/temperature: 0.25 psig; 65-80 degrees F
  3. Design Pressure Rating: 3 psig minimum
  4. Design Vacuum Rating: minus 3 psig
  5. Location: indoors
  6. Seismic design: not required
  7. Dish shall be completely self draining
- D. Dimensions
1. Nominal diameter: 66 inches
  2. Straight Side: 96 inches
  3. Height off floor: approximately 18 inches from face of discharge nozzle to bottom of leg pad. Exact dimension to be finalized on Approval Drawings review.
- E. Nozzles
1. Nozzles shall be full face; bolt holes to straddle radial centerlines, with bolt holes conforming to ANSI 150#.
  2. Nozzles shall be gusseted.
  3. Vendor shall provide protective blinds with temporary gaskets on each nozzle for protection of face and to keep tank clean during shipping and storage.
    - a. Gaskets shall be Garlock "Stress Saver" PTFE, or Teflon envelope, or a gasket recommended by the Manufacturer for these nozzles and UPW service.
    - b. In addition to the gaskets provided for shipping, Manufacturer shall provide 2 gaskets for each nozzle. The gaskets shall be provided in sealed bags.
  4. Nozzle schedule:

SERVICE	SIZE	LOCATION	NOTES
Return	4"	Top, center	
Outlet	3"	Bottom, center	Vortex breaker required
Inlet	1"	top	
Vent	2"	top	
Level transmitter	3"	top	
Pressure gauge	1"	top	
Nitrogen	1"	top	
Nitrogen pilot	1"	top	
Manway	20 inch	top	



### **2.3 INSPECTION**

- A. Manufacturer shall be diligent in maintaining the inside of the tank clean during inspection and handling.
- B. Inspection and testing shall be performed as per manufacturers established procedures and shall be documented.
- C. Instruments used for testing shall be calibrated.
- D. Inspection and testing shall be performed that ensures that:
  - 1. FRP shell was fabricated as specified.
  - 2. Materials used were those specified.
  - 3. Tank was fabricated according to the manufacturer's stated standards.
- E. Liner shall be thoroughly spark tested as per established procedures.
- F. Hydrostatic test shall be performed using filtered, DI water. After test, tank was completely drained and dried using clean, filtered air
- G. Internal and external visual inspection for defects, conforming with ASTM D-2563 shall be performed by qualified personnel.

### **2.4 QUALITY CONTROL**

- A. Manufacturer shall have a Quality Assurance program in place that ensures proper materials and procedures throughout the fabrication process.
- B. Manufacturer shall verify that inspection and testing was performed and documented according to procedure.

### **2.5 NAMEPLATE**

- A. FRP encapsulated nameplate shall include:
  - 1. Equipment Number
  - 2. Materials of construction
  - 3. MAWP and vacuum rating
  - 4. Fabricator, fabrication date
  - 5. Purchase order number

### **2.6 SHIPPING**

- A. Tank openings shall be sealed with bolted, gasketed blinds, with the exception of one nozzle that will be provided with a filter to allow the tank to breath.
- B. Exterior shall be covered to keep tank clean during shipping.
- C. Tanks shipped in horizontal position shall be mounted on padded cradles. Tanks shipped in vertical position shall be secured to pallet or skid. All tank and blocking must be padded and bear upon knuckle radius of heads.

### **PART 3 EXECUTION**

#### **3.1 Contractor is responsible for receiving, inspection, installation, and inspection of tank in strict accordance with manufacturer's instructions and contract documents.**

- A. Inspect tank upon delivery for evidence of damage or contamination.
- B. Handle and install tank so as to prevent impact damage, excessive stress, and contamination.
  - 1. Lift tank by lifting lugs only. Protect from impact or point stress.
  - 2. Maintain a high level of cleanliness during handling and installation.
  - 3. Keep manufacturer's protective packaging in place until immediately prior to installation.
  - 4. Install tank so as to prevent stress on shell.
  - 5. Install tank level and anchored.
- C. Inspect and test tank after installation as specified by manufacturer.
- D. Follow Manufacturer' instructions for connections to flanges
  - 1. Discard gaskets on blinds and install new gaskets provided by Manufacturer.
  - 2. Torque bolts as directed.
  - 3. Support piping independently of tank nozzles.

**END OF SECTION**

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## **SECTION 23 0000CR**

### **GENERAL HVAC REQUIREMENTS**

#### **PART 1 GENERAL**

##### **1.1 DESCRIPTION**

- A. Specification requirements defined in Division 20 of this Specification apply to, and are in addition to the work associated with equipment, systems, materials, and installation requirements specified in Division 23CR. Contractor shall provide the requirements specified in Division 20 to obtain complete systems, tested, adjusted, and ready for operation.

##### **1.2 RELATED WORK**

- A. Section 20 0000 - General Mechanical Requirements
- B. Section 20 0513 - Motors
- C. Section 20 0514 - Variable Frequency Drives
- D. Section 20 0520 - Excavation and Backfill
- E. Section 20 0529 - Mechanical Supporting Devices
- F. Section 20 0553 - Mechanical Systems Identification
- G. Section 20 0573 - Mechanical Systems Firestopping
- H. Section 20 0700 - Mechanical Systems Insulation

#### **PART 2 PRODUCTS**

##### **2.1 Not Applicable to this Section.**

#### **PART 3 EXECUTION**

##### **3.1 Not Applicable to this Section.**

**END OF SECTION**



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**SECTION 23 0550CR**

**VIBRATION ISOLATION**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 20 0529 - Mechanical Supporting Devices
- B. Section 23 3314CR - Ductwork Specialties (Duct Flexible Connections)

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESIGN CRITERIA**

- A. Isolate all motor driven mechanical equipment, unless otherwise noted, from building structure, and from systems that they serve, to prevent equipment vibrations from being transmitted to structure. Unless specifically indicated, follow the latest edition of ASHRAE Application Handbook - Sound and Vibration Control, or manufacturer's recommendations for isolator selection whichever is more stringent.
- B. Select and locate isolators to produce uniform loading and deflection. Use minimum of 4 isolators to support each piece of equipment.
- C. Select vibration isolation devices based on the lowest operating speed of equipment.
- D. Vibration Criteria:
  - 1. All rotating equipment shall operate at speeds less than 80% of their true critical speed. Unless otherwise required, equipment shall be balanced according to recommendations given in the following schedules.
  - 2. Vertical vibration of rotating equipment shall not be greater than levels indicated. Vibration shall be measured on equipment. If equipment has inertia base, allowable vibration level is reduced by ratio of equipment weight alone to equipment weight plus inertia base weight.

<u>Equipment Speed</u> rpm	<u>Maximum Allowable</u> <u>Vibration Displacement</u> <u>Peak-to-Peak (mil)</u>
100 to 200	10
200 to 300	6
300 to 600	4
600 to 1000	3
1000 or 2000	2
over 2000	1

- E. Following field installation, each fan and pump over 25 hp shall be balanced in accordance with the following maximum rms velocity levels:
1. Fans: 0.15 inch.
  2. Pumps:  

0.16 inch/sec	for 30 hp and smaller
0.18 inch/sec	for 40 through 60 hp
0.20 inch/sec	for 75 through 100 hp
- F. Final in-field balance shall be measured with each fan over 25 hp installed on springs specified for unit. Fans shall be loaded with design static pressure. Measurement shall be carried out in vertical, horizontal and axis planes at impeller shaft bearing location.

#### 1.4 SUBMITTALS

- A. Submit Shop Drawings including, but not limited to, the following:
1. Manufacturer's name
  2. Isolator type and model number
  3. Materials of construction and finish
  4. Dimensional data
  5. Load ratings (lbs)
  6. Isolator free and operating heights
  7. Static deflections
  8. Isolation efficiency based on lowest operating speed
  9. All other appropriate data

#### 1.5 SUPERVISION, INSPECTION AND CERTIFICATION

- A. Vibration isolation manufacturer or qualified representative shall provide supervision to assure correct installation and adjustment of isolators. Upon completion of installation and after system is put into operation, manufacturer or manufacturer's representative, shall make final inspection, adjustment, and submit report to Engineer in writing, certifying correctness of installation and compliance with Specifications.

### PART 2 PRODUCTS

#### 2.1 MATERIALS

- A. Materials used shall retain their isolation characteristics for life of equipment served. Elastomeric materials shall comply with ASTM D2240 and shall be oil-resistant industrial grade neoprene.
- B. Isolators shall be treated to resist corrosion.
- C. Isolation devices subject to weather shall have either hot-dip or cold-dip galvanized, cadmium plated, or neoprene coated finish after fabrication and be furnished with limit stops to resist wind.

- D. Vibration isolator springs shall have minimum additional travel to solid equal to 50% of rated deflection.
- E. Ratio of lateral to vertical stiffness of vibration isolators shall not be less than 0.8 or greater than 2.0.
- F. Coordinate selection of devices with isolator and equipment manufacturer.

## **2.2 MANUFACTURERS**

- A. Mason Industries, Amber/Booth Co., Aeroflex-VMC-Korfund. Vibration Eliminator, Vibro-Acoustics, or Kinetics equal to manufacturer's model listed, except flexible pipe connections.
- B. Mason, Metraflex, Proco, Twin City Hose or Engineered Flexible Products (EFP) for flexible pipe connections.

## **2.3 TYPE 1 MOUNTS (NEOPRENE PAD)**

- A. Mason Type Super W, neoprene waffle pads, 50 durometer. Select number and size of pads as required to accept equipment operating weight evenly.

## **2.4 TYPE 2 MOUNTS (NEOPRENE PAD)**

- A. Mason Type ND or rails Type DNR, double deflection neoprene mounts with cast-in metal inserts for bolting to equipment.
- B. Both surfaces shall be rib molded for skid resistance. On equipment such as small vent sets and close coupled pumps, steel rails shall be used above mountings to compensate for overhang.

## **2.5 TYPE 3 MOUNTS (UNHOUSED SPRING WITH NEOPRENE)**

- A. Mason Type SLF, combination spring and neoprene with rib molded base. Spring type isolators shall be free standing and laterally stable without any housing and complete with 1/4" neoprene acoustical friction pads between baseplate and support.
- B. Mountings shall have leveling bolts rigidly bolted to the equipment. Spring diameters shall be no less than 0.8 of compressed height of spring at rated load.

## **2.6 TYPE 4 MOUNTS (RESTRAINED SPRING WITH NEOPRENE)**

- A. Mason Type SLR, combination spring and neoprene with rib molded base similar to Type 3 above, but shall have housing that includes vertical limit stops to prevent spring extension when weight is removed.
- B. Installed and operating heights shall be the same. Maintain minimum clearance of 1/2" around restraining bolts and between housing and spring so as not to interfere with spring action. Limit stops shall be out of contact during normal operations. Use height saving brackets.

## **2.7 TYPE S BASES (STEEL BASE)**

- A. Mason Type WF, structural steel bases, rectangular in shape for all equipment other than centrifugal refrigeration machines and pump bases which may be "T" or "L" shaped. Pump bases for split case pumps shall include supports for suction and discharge base ells. Perimeter members shall be beams with minimum depth equal to 1/10 of longest base dimension, but not less than 4". Beam depth need not exceed 14" provided that deflection and misalignment is kept within acceptable limits as determined by manufacturer. Employ height saving brackets in all mounting locations to provide base clearance of at least 1" above floor or housekeeping pad.

## **2.8 TYPE I BASES (INERTIA BASE)**

- A. Mason Type K, or BMK rectangular or T shaped structural beam or channel concrete forms for floating foundations. Bases for split case pumps shall be large enough to provide support for suction and discharge base ells. Base depth need not exceed 12" unless specifically recommended by base manufacturer for mass, rigidity or component alignment. Base depth shall be a minimum of 1/10 of longest base dimension, but not less than 6". Forms shall include concrete reinforcement bars welded in place running both ways. Furnish forms with drilled steel members with sleeves welded below holes to receive equipment anchor bolts where anchor bolts fall in concrete locations. Employ height saving brackets in all mounting locations to maintain base clearance of at least 1" above floor or housekeeping pad.

## **2.9 TYPE 5 HANGERS (SPRING HANGER WITH NEOPRENE)**

- A. Mason Type 30N, vibration hangers with steel spring and neoprene element in series. Neoprene element shall be molded with rod isolation bushing that passes through hanger box. Spring diameters and hanger box lower hole sizes shall be large enough to permit hanger rod to swing through 30 ° arc before contacting hole and short circuiting spring.
- B. Mason Type DNHS may be used where load rating and specified deflection cannot be accommodated by Type 30N.

## **2.10 TYPE 6 HANGERS (PRECOMPRESSED SPRING HANGER WITH NEOPRENE)**

- A. Mason Type PC30N, vibration hangers similar to Type 5, but precompressed to rated deflection so as to keep piping or equipment at fixed elevation during installation. Design hangers with release mechanism to free spring after installation complete and hanger is subjected to its full load.

## **2.11 TYPE 7 HANGERS (SPRING HANGER WITH DEFLECTION INDICATOR)**

- A. Mason Type HES, steel spring in steel housing including deflection indicator scale. Hangers shall be preset at factory for required load. Select hangers so that actual loads do not exceed rated capacities (lbs).



- B. Submittals shall include isolator rated deflection, required deflection and supporting calculation. Calculations shall be made by registered mechanical or civil engineer demonstrating structural adequacy of hanger and that hanger connections to building and pipe are adequate for live and dead loads encountered.

## **2.12 TYPE AG PIPE ANCHORS/GUIDES**

- A. Mason Type ADA all-directional acoustical pipe anchors and Type VSG guides for vertical piping consisting of telescopic arrangement of 2 sizes of steel tubing separated by minimum 1/2" thickness of heavy duty neoprene and neoprene isolation material. Vertical restraints shall prevent vertical travel in either direction. Allowable loads on isolation materials shall not exceed 500 psi and design shall be balanced for equal resistance in any direction.
- B. Submittals shall include supporting calculations by registered mechanical or civil engineer indicating anchor/guide loads and isolator selection.

## **2.13 TYPE T THRUST RESTRAINTS**

- A. Mason Type WB, horizontal thrust restraint consisting of spring element in series with neoprene pad as described for Type 3 mounts with the same deflection as specified for mountings or hangers. Spring element shall be contained within steel frame and designed so it can be preset for thrust at factory and adjusted in field for maximum of 1/4" movement at start and stop. Furnish thrust restraints complete with rods and angle brackets for attachment to both equipment and ductwork or equipment and structure. Attach horizontal restraints at centerline of thrust and symmetrically on either side of unit.

## **2.14 FLEXIBLE PIPING CONNECTIONS**

- A. Flexible connection shall be suitable for pressure, temperature and fluid involved, but not less than 215 psig working pressure at 250°F for 14" and smaller and 150 psi working pressure at 250°F for 16" and larger.
- B. Unless otherwise specified, minimum live length of metal flexible hose shall be length required to absorb 3/4" lateral movement, but not less than 12".
- C. Piping connected to steam heating coils in floor mounted air handling units where coils are supported without vibration isolation shall have flexible piping connections and piping vibration hangers to prevent thermal stress in piping system from damaging the coils.
- D. Water System:
  - 1. All water system flexible pipe connectors shall have control rods.
  - 2. Connections shall consist of Kevlar or Nylon tire cord fabric reinforced with EPDM cover and liner. Solid steel rings shall be used within raised face rubber flanged ends to prevent pullout. Flexible cable bead wire is not allowed. Furnish connections with control rod or cable assemblies as recommended by manufacturer.

3. 2" and Smaller: Threaded connections, single sphere design similar to Mason SAFEFLEX SFU.
  4. 2-1/2" and Larger: Floating steel flange connections, two sphere design with ductile iron or plated carbon steel reinforcing rings, similar to Mason SAFEFLEX SFDEJ. Single sphere design similar to Mason SAFEFLEX SFEJ, may be used for 14" and larger.
  5. Connection to Cooling Towers and Non-rotating Equipment Mounted on Vibration Isolators - Seamless corrugated bronze or stainless steel flexible hose with braided cover for 2" and smaller with threaded or flanged connections; seamless corrugated stainless steel flexible connector with braided cover for 2-1/2" and larger with flanged connections.
- E. Steam and Condensate Including Pumped Condensate System:
1. Seamless corrugated stainless steel flexible hose with braided cover for 2" and smaller with threaded or flanged connections; seamless corrugated stainless steel flexible connector with braided cover for 2-1/2" and larger with flanged connections.

## 2.15 PERFORMANCE

- A. Select vibration isolation devices to achieve either minimum 95% isolation efficiency or minimum static deflection and mounting requirements listed below, whichever is greater. Minimum static deflections listed below are not nominal but certifiable minimums with actual installed load. Unless otherwise indicated, apply requirements listed for floor mount for roof-mounted equipment.

Type of Equipment	Ground Supported Slab		Floor Span							
			20 Feet		30 Feet		40 Feet		50 Feet	
	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)
<u>Refrigeration Machines:</u>										
Air Cooled Chillers	-	-	4	0.75	4	1.75	4	1.75	4	2.5
<u>Pumps:</u>										
<u>Flexible Coupled</u>										
Thru 40 hp	3-I	0.75	3-I	0.75	3-I	1.75	3-I	1.75	3-I	2.5
50 - 125 hp	3-I	0.75	3-I	0.75	3-I	1.75	3-I	2.5	3-I	3.5
<u>Packaged Air Handling Units:</u>										
<u>Suspended</u>										
Thru 5 hp	-	-	5	1.0	5	1.0	5	1.0	5	1.0
7-1/2 hp and over Thru 400 rpm	-	-	5	3.5	5	3.5	5	3.5	5	3.5

<u>Type of Equipment</u>	<u>Ground Supported Slab</u>		<u>Floor Span</u>							
			<u>20 Feet</u>		<u>30 Feet</u>		<u>40 Feet</u>		<u>50 Feet</u>	
	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)
401 rpm and over	-	-	5	1.5	5	1.5	5	1.5	5	2.5

Centrifugal Blowers:

Suspended Use Type 5-T hangers with deflection from blower minimum deflection guide.

Floor Mounted

Thru 40 hp with operating static pressure less than 4" Use Type 3-S mount with deflection from blower minimum deflection guide. Provide Type T thrust restraint for fans operating at 2" or more static pressure.

50 hp and over and all fans operating at 4" or more static pressure Use Type 3-I mount with deflection from blower minimum deflection guide.

Mixed Flow and In Line Fans:

Suspended Use Type 5 hangers with deflection from blower minimum deflection guide. Use Type 5-T for over 4" static pressure.

Floor mounted with motor on or in fan casing Use Type 2 for 0.35" deflection, Type 3 for 0.75" deflection and Type 3-S for over 0.75" deflection from blower minimum deflection guide. Use Type 3-S-T for over 4" static pressure.

Floor mounted arrangement 1 or any separately mounted motor Use 2-I for 0.35" deflection and 3-I for 0.75" and over with deflection from blower minimum deflection guide.

Cabinet Fans and Fan Sections of Air Handling Units:

Suspended Type 5-T supports with deflection from blower minimum deflection guide.

Floor mounted Use Type 2-T for 0.35" deflection, Type 3-T for 0.75" deflections and 3-S-T for deflections over 0.75" with deflection from blower minimum deflection guide.

Blower Coil Units Type 5 with minimum deflection of 0.75".

Piping Connected to Rotating or Reciprocating Equipment: Use flexible piping connections and Type 6 hangers for first four hangers from connected equipment or 50 feet from equipment, whichever is greater. Hangers shall have deflection equal to connected equipment, Where piping is floor-supported, above requirements shall apply, but use Type 3 mounts instead of hangers. Flexible piping connection shall not be used for unit heaters and in-line pumps that are supported by connected pipes. Type 6 hangers with 1.0" minimum deflection shall be applied within one foot of both sides of in-line pump and for distance of 100 pipe diameters or 50 ft away from first hanger at in-line pump, whichever is greater.

Piping 2.5" and Larger Supported from Under-side of Second Floor: Use Type 5 hangers with 0.75" minimum deflection.

<u>Type of Equipment</u>	<u>Ground Supported Slab</u>		<u>Floor Span</u>							
			<u>20 Feet</u>		<u>30 Feet</u>		<u>40 Feet</u>		<u>50 Feet</u>	
	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)	Type	Min. Defl. (in.)
<u>Vertical Pipe Risers:</u>	Use Type 6 hangers, Type AG anchors and guides as stated in Section 20 0529 - Mechanical Supporting Devices.									

Ductwork connected to Rotating or Reciprocating Equipment ; All air ducts with a cross section of 2 sq ft or greater shall be isolated from the building structure by Type 6 hangers within 50 feet of the equipment. Hangers to have a minimum of .75" deflection.

**BLOWER MINIMUM DEFLECTION GUIDE**

When blowers are 60 hp or larger, select deflection requirements for next larger span, but not less than 2.5".

<u>Fan Speed (rpm)</u>	<u>On Grade</u>	<u>Required Deflection (Inches)</u>			
		<u>20 ft Floor Span</u>	<u>30 ft Floor Span</u>	<u>40 ft Floor Span</u>	<u>50 ft Floor Span</u>
175-224	.35	3.5	4.5	4.5	4.5
225-299	.35	3.5	3.5	3.5	3.5
300-374	.35	2.5	2.5	3.5	3.5
375-499	.35	1.5	2.5	3.5	3.5
500 and over	.35	0.75	1.5	2.5	3.5

**PART 3 EXECUTION**

**3.1 INSTALLATION**

- A. Install and adjust vibration isolation devices as specified, as shown on drawings and according to manufacturer's recommendations.
- B. In no case shall installation short circuit isolation devices. Install flexible piping connections on equipment side of shut-off valves.

**3.2 INERTIA BASES (TYPE I BASES)**

- A. Provide required concrete for inertia bases. Refer to Section 20 0000 - General Mechanical Requirements for concrete work.
- B. Raise inertia bases to final elevation with temporary blocking prior to making piping connections to pumps or ductwork connections to fans. After connections are complete, install vibration isolators in accordance with manufacturer's installation instructions.

**3.3 PACKAGED AIR HANDLING UNITS**

- A. Install Type T thrust restraints at fan sections when fan section is isolated from remainder of air handling unit.

### **3.4 FLEXIBLE PIPING CONNECTIONS**

- A. Provide flexible connections for piping connected to rotating or reciprocating equipment, equipment mounted on vibration isolators, and as indicated on plans and details.
- B. For non-metallic flexible piping connections, 2-1/2" and larger, use flange type recommended by manufacturer. Flanges for mechanical grooved connections are not allowed.

**END OF SECTION**



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**SECTION 23 0594CR**

**WATER SYSTEMS TEST ADJUST BALANCE**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 25 0901CR - Process Control Systems Integration
- B. Section 25 0993CR – Process Control Sequences
- C. Section 23 2118CR - Valves (balancing valves)
- D. Section 23 2120CR- Piping Specialties (flow measure devices)

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. TAB Contractor shall be responsible for providing complete testing, adjusting and balancing (TAB) work for HVAC hydronic systems, such as chillers, pumps, convertors and other processes included in this project.
- B. Work required shall consist of setting volume flow rates and adjusting speed controls, recording data, making tests, and preparing reports, as specified herein.
- C. Scope of work includes TAB of new work specified herein and includes all equipment, distribution systems, and terminal units connected.
- D. TAB work shall be performed by persons trained in TAB work and certified by Associated Air Balance Council (AABC) or National Environmental Balancing Bureau (NEBB). Procedures shall be in accordance with the latest edition of AABC or NEBB Standards, ASHRAE - 1999 HVAC Applications Chapter 36, and as detailed herein.
- E. Upon direction of Architect/Engineer or TAB subcontractor, Mechanical Contractor shall provide at no additional cost to Owner, any additional work and/or devices necessary to properly balance system, including calibrated balancing valves, gauge tappings, flow sensors, and thermometer wells. Mechanical Contractor shall be responsible for trimming and balancing pump impellers as necessary to obtain design pump flow rates at the minimum pressure differential.

- F. TAB work shall not proceed until all assigned personnel have been approved by Architect/Engineer via Quality Assurance Submittal. Coordinate each phase of TAB work with overall project schedule. Each phase of TAB work shall be done in timely manner as detailed herein. Fieldwork must be completed before occupancy. Certificate of Substantial Completion shall not be issued until after Final Report is accepted by Architect/Engineer.

#### 1.4 SUBMITTALS

- A. General:
1. Make submittals in accordance with project submittal procedure. Submit minimum of 5 copies of submittals unless otherwise directed (3 for O&M Manuals, 1 for A/E, 1 for Contractor).
  2. Reports shall be assembled using 3-ring hard cover binder with project name and location on cover and side panel. Information sheets shall be 8-1/2" x 11" white bond paper. Use pre-printed forms of NEBB or AABC wherever possible. Provide sortable electronic version as well as hard copy. Provide numbered tabs for each system. Assemble report in the following order:
    - a. Transmittal letter
    - b. Cover sheet with project title, location, submittal date, and name and addresses of Owner, Mechanical Contractor, TAB subcontractor, Architect, and Engineer
    - c. Index of numbered tabs listing major systems
    - d. Data organized by system in the following order:
      - 1) Equipment data and measurement summary
      - 2) Equipment measurement data
      - 3) Branch main measurement data
      - 4) Terminal device measurement data arranged by room or zone
- B. Quality Assurance Submittal:
1. Within 30 days of signing contract, Contractor shall submit the following information:
    - a. Firm resume
      - 1) AABC or NEBB active membership certificate
      - 2) Names of 3 recent relevant completed projects along with project address, Owner's contact person, supervising design professional
    - b. Supervisor resume
    - c. Balance technicians resumes
  2. Architect/Engineer and/or Owner reserves the right to contact previous project representatives and to reject persons whom Architect/Engineer and/or Owner feel are not qualified for this project due to lack of relevant experience or problems on previous projects.
- C. Planning Report:
1. Submit Planning Report as detailed in Part 3 of this Section to demonstrate to Architect/Engineer and Owner that proper procedures are being followed. Submit Planning Report after Quality Assurance submittal and 30 days before any fieldwork starts.



- D. Initial Test Report:
  - 1. Prior to starting Final Balance Phase, submit Initial Test Report as detailed in Part 3 of this Section to indicate to Architect/Engineer and Contractor incomplete work or problem areas to be resolved before final balance is completed.
- E. Final Report:
  - 1. Within 30 days after fieldwork is completed, submit Final Report as detailed in Part 3 of this Section to assure design objectives are met and to assist Owner in future maintenance.

## 1.5 REFERENCE STANDARDS

- A. Refer to the latest publications of NEBB, AABC and ASHRAE publications for establishing required procedures.

## PART 2 PRODUCTS

### 2.1 INSTRUMENTATION

- A. Provide required instrumentation to obtain proper measurements. Application of instruments and accuracy of instruments and measurements shall be in accordance with requirements of NEBB or AABC Standards and instrument manufacturer's specifications.
- B. Instruments used for measurements shall be accurate, and calibration histories for each instrument shall be available for examination by Architect/Engineer upon request. Calibration and maintenance of all instruments to be in accordance with requirements of NEBB or AABC Standards.

## PART 3 EXECUTION

### 3.1 GENERAL

- A. TAB work shall be done in separate phases as outlined herein. TAB schedule shall allow ample time to complete TAB work before occupancy. Follow procedures outlined herein and as described in Planning Phase narratives.
- B. Unless otherwise specified, maximum acceptable offset tolerance shall be  $\pm 10\%$  of design flow rates indicated on drawings and schedules.

### 3.2 PLANNING PHASE

- A. Procedure:
  - 1. Obtain the latest Contract Documents including addenda, construction bulletins and change orders. Obtain shop drawings and performance curves from Mechanical Contractor for pumps, flow measuring devices, and terminal devices. Prepare Planning Report as detailed herein. Make adjustments in Planning Report and/or measuring instrument calibration.

- B. Planning Report:
1. Planning Report shall contain the following minimum requirements.
  2. Narratives: Furnish written narratives of procedures to be used. Include separate narratives for each pump and liquid fluid handling system. Identify flow-measuring devices to be used at each pump and terminal device. Include different narratives for constant and variable flow systems. For non-standard water systems, include narratives on how to measure and adjust for different viscosities. Narratives shall include references to published standards of NEBB or AABC. Narratives shall include measuring instruments to be used and ranges required for each procedure. Narratives shall include specified adjustment tolerances.
  3. Prebalance Checklist: shall include, but not be limited to:
    - a. Check for completeness of work
    - b. System cleaning
    - c. System fill and air venting
    - d. Place system into operation
    - e. Check expansion tanks and fill pressures
    - f. Pump bearings, alignment, starters, vibration isolators, rotation
    - g. Setting valves to proper position including shut-off and bypass valves
    - h. Set up of controls and control devices
  4. Measuring Instrument List: List that measuring instruments will be used for each procedure. Indicate ranges required for each procedure. Provide data on each measuring instrument to be used. This data shall include:
    - a. Manufacturer name and model number
    - b. Measurement range
    - c. Pressure/temperature limits
    - d. Date put into service
    - e. Date of last calibration
    - f. Certificate from calibration firm
  5. Architect/Engineer reserves the right to request adjustments in any procedure and/or ask for recalibration of any measuring instrument that has not been recalibrated within past year.
  6. Samples: Submit copies of TAB forms to be used.
  7. Branch circuit and terminal measurements and adjustments: Indicate on pre-printed forms all measurements to be taken and adjustments to be made in field. Include branch circuit or terminal identification, system, space served, location, design flow rates (including zone and system summaries), and flow measuring device size, type, Cv, and manufacturer. Indicate the initial set points on forms.

### 3.3 SET-UP PHASE

- A. Procedure:
1. Perform prebalance checkout as per Planning Phase narrative.
- B. Initial Test:
1. Measure pump data and flow rates in "as found" condition after initial valve settings are made.

- C. Initial Test Report:
  - 1. Submit report to Architect/Engineer and Mechanical Contractor indicating measurements made and including notes of items that are not complete or are not within design tolerance.

### **3.4 FINAL BALANCE PHASE**

- A. Procedure:
  - 1. Perform procedures as per Planning Phase narrative. Correct deficiencies and redo procedures as required prior to submitting Final Report.
- B. Final Report:
  - 1. Submit report to Architect/Engineer and to Mechanical Contractor indicating all data, measurements and adjustments as per requirements herein and per Planning Phase narrative. Do not submit partial or incomplete reports.
- C. Final Report Adjustments:
  - 1. Architect/Engineer reserves the right to check any measurement or adjustment made and to reject any portion of work not within specified tolerance. Contractor shall resubmit all or portions of Final Report as directed by Architect/Engineer.

**END OF SECTION**



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**SECTION 23 0595CR**

**AIR SYSTEMS TEST ADJUST BALANCE**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 25 0901 - Process Control Systems Integration
- B. Section 25 0993 - Process Control Sequences
- C. Section 23 3314CR - Ductwork Specialties

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. This Contractor shall be responsible for providing complete testing, adjusting and balancing (TAB) work for air systems, such as air handling units, return fans, exhaust fans, air terminal devices, diffusers, grilles and other air moving processes included in this project.
- B. Work required shall consist of setting volume flow rates and adjusting speed controls, recording data, making tests, and preparing reports, as specified herein.
- C. Scope of work includes TAB of new work specified herein and includes all equipment, distribution systems, and terminal units connected.
- D. TAB work shall be performed by persons trained in TAB work and certified by Associated Air Balance Council (AABC) or National Environmental Balancing Bureau (NEBB). Procedures shall be in accordance with the latest edition of AABC or NEBB Standards, ASHRAE - 1999 HVAC Application Chapter 36, and as detailed herein.
- E. TAB Contractor shall perform ductwork leakage tests. Refer to Section 23 3114 - Ductwork. Test equipment will be provided by Mechanical Contractor.
- F. Upon direction of Architect/Engineer or TAB subcontractor, Mechanical Contractor shall provide at no additional cost to Owner, any additional work and/or devices necessary to properly balance system, including fan sheaves, motor sheaves and/or drive belts.

- G. TAB work shall not proceed until assigned personnel have been approved by Architect/Engineer via Quality Assurance Submittal. Coordinate each phase of TAB work with overall project schedule. Each phase of TAB work shall be done in timely manner as detailed herein. Fieldwork must be completed before occupancy. Certificate of Substantial Completion shall not be issued until after Final Report is accepted by Architect/Engineer.

#### 1.4 SUBMITTALS

A. General:

1. Make submittals in accordance with project submittal procedure. Submit minimum of 5 copies of submittals unless more directed (3 for O&M Manuals, 1 for A/E, 1 for Contractor).
2. Reports shall be assembled using 3-ring hard cover binder with Project Name and location on cover and side panel. All information sheets shall be 8-1/2" x 11" white bond paper. Use preprinted forms of NEBB or AABC wherever possible. Provide sortable electronic version as well as hard copy. Provide numbered tabs for each system. Assemble report in the following order:
  - a. Transmittal letter
  - b. Cover sheet with Project title, location, submittal date, and name and addresses of Owner, Mechanical Contractor, TAB subcontractor, Architect, and Engineer.
  - c. Index of numbered tabs listing major systems
  - d. Data organized by system in the following order:
    - 1) Equipment data and measurement summary
    - 2) Equipment measurement data
    - 3) Branch main measurement data
    - 4) Terminal device measurement data arranged by room or zone

B. Quality Assurance Submittal:

1. Within 30 days of signing contract, Contractor shall submit the following information:
  - a. Firm resume
    - 1) AABC or NEBB active membership certificate
    - 2) Names of 3 recent relevant completed projects along with project address, Owner's contact person, supervising design professional
  - b. Supervisor resume
  - c. Balance technician(s) resume
2. Architect/Engineer and/or Owner reserves the right to contact previous project representatives and to reject persons whom Architect/Engineer and/or Owner feel are not qualified for this project due to lack of relevant experience or problems on previous projects.

- C. Planning Report:
  - 1. Submit Planning Report as detailed in Part 3 of this Section to demonstrate to Architect/Engineer and Owner that proper procedures are being followed. Planning Report shall be submitted after Quality Assurance submittal and 30 days before any fieldwork starts.
- D. Initial Test Report:
  - 1. Prior to starting Final Balance Phase, submit Initial Test Report as detailed in Part 3 of this Section to indicate to Architect/Engineer and Contractor incomplete work or problem areas to be resolved before final balance is completed.
- E. Final Report:
  - 1. Within 30 days after fieldwork is completed, submit Final Report as detailed in Part 3 of this Section to assure design objectives are met and to assist Owner in future maintenance.

## 1.5 REFERENCE STANDARDS

- A. Refer to the latest publications of NEBB, AABC, ASHRAE, and Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) publications for establishing required procedures.

## PART 2 PRODUCTS

### 2.1 INSTRUMENTATION

- A. Provide all required instrumentation to obtain proper measurements. Application of instruments and accuracy of instruments and measurements shall be in accordance with requirements of NEBB or AABC Standards and instrument manufacturer's specifications.
- B. Instruments used for measurements shall be accurate, and calibration histories for each instrument to be available for examination by A/E upon request. Calibration and maintenance of instruments to be in accordance with requirements of NEBB or AABC Standards.

### 2.2 INSTRUMENT TEST HOLE PLUGS

- A. Center-pull plugs similar to Alliance Plastics CP Series. Plug material shall be Grade 1 virgin polyethylene.

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## **PART 3 EXECUTION**

### **3.1 GENERAL**

- A. TAB work shall be done in separate phases as outlined herein. TAB schedule shall allow ample time to complete TAB work before occupancy. Follow procedures outlined herein and as described in Planning Phase narratives.
- B. Unless otherwise specified, maximum acceptable offset tolerance is plus or minus 10% of the design flow rates as indicated on drawings and/or as scheduled.
- C. For spaces where a differential pressure is required to be maintained such as clean rooms, the maximum tolerance is +/- .01" WC. Associated exhaust air flow rate shall be balanced to provide indicated differential between supply air and exhaust air after supply air system has been balanced.

### **3.2 PLANNING PHASE**

- A. Procedure:
  - 1. Obtain the latest Contract Documents including addenda, applicable construction bulletins and change orders. Obtain shop drawings and performance curves from Mechanical Contractor for fans, flow measuring devices, and all terminal devices. Prepare Planning Report as detailed herein. Make adjustments in Planning Report and/or measuring instrument calibration.
- B. Planning Report:
  - 1. Planning Report shall contain the following minimum requirements.
    - a. Samples: Provide copies of all forms to be used.
    - b. General narratives: Furnish written narratives of all procedures used. Include separate narratives for each fan and air handling system. Identify flow-measuring devices to be used at each fan, air terminal device, and air outlet. Narrative shall include statement that every air outlet shall be measured and adjusted. Provide different narratives for constant and variable flow systems. Narratives shall include references to published standards of NEBB or AABC. Narratives shall include measuring instruments to be used and ranges required for each procedure. Narratives shall include specified adjustment tolerances.
    - c. Air system narratives: Provide narratives for each air system which shall include procedures for measuring static pressures at each component of air handling system to generate a static pressure profile. Measurements shall be made to measure performance of system in all operating modes including economizer mode using 100% outside air where applicable. Differentiate between constant and variable flow systems.
    - d. Air terminal narratives: Narratives shall describe procedures for measuring flows and adjusting controls to meet specified minimum and maximum flow rates based on actual field installed conditions.



- e. Branch duct and air outlet measurements: Indicate on preprinted forms all measurements to be taken in field. Include branch duct or air outlet identification, system, space served, location, and design flow rates (include zone and system summaries). Indicate duct or air outlet neck size, make, model number, Ak factor, and design velocities.
  - f. Pressure relationship test narrative: Narratives shall describe how to obtain and measure pressure relationships between spaces as per schedule or as listed below.
    - 1) Clean Room
  - g. Fume Hood Certification: Narrative shall include procedures as described in Scientific Equipment and Furniture Association (SEFA) Standard SEFA 1-2006. Each hood shall be labeled with:
    - 1) Test date
    - 2) Name of tester
    - 3) Sash position at 100 fpm and 125 fpm
    - 4) Hood Classification
  - h. Refer to fume hood specification for sash type of each hood, design exhaust rate and sash design opening size. Design airflows are based on design operating sash opening and 100 fpm face velocity at the sash opening.
2. Prebalance Checklist - to include, but not limited to:
- a. Check for completeness of work.
  - b. System cleaning if required.
  - c. Check fire, smoke and balancing damper positions.
  - d. Place system into normal operation without economizers.
  - e. Install test openings where required.
  - f. Indicate type of test holes to be used and installation procedure.
  - g. Note condition of filters.
  - h. Provide temporary blankoffs to simulate design pressure drops of filters.
  - i. Chisel holes and duct tape are not allowed.
  - j. Wet cooling coils.
  - k. Fan wheels, blades, bearings, alignment, starters, vibration isolators, and rotation.
  - l. Drive belt tension and alignment.
  - m. Setting of automatic dampers to proper position including shutoff and Bypass dampers.
  - n. For hoods and ovens indicate temperature and humidity. Correct for density changes.
  - o. Set up of controls and control devices
3. Measuring Instrument List - list what measuring instruments will be used for each procedure. Indicate ranges required for each procedure. Provide data on each measuring instrument to be used. This data shall include:
- a. Manufacturer name and model number
  - b. Measurement range
  - c. Pressure/temperature limits
  - d. Date put into service
  - e. Date of last calibration
  - f. Include certificate from calibration firm

4. Architect/Engineer reserves the right to request adjustments in any procedure and/or ask for recalibration of any measuring instrument, which has not been recalibrated within past year.

### **3.3 SET-UP PHASE**

- A. Procedure:
  1. Perform prebalance checkout as per Planning Phase narrative.
- B. Initial Test:
  1. Measure fan data and flows in "as found" condition after initial damper settings are made.
- C. Initial Test Report:
  1. Submit report to Architect/Engineer and Mechanical Contractor indicating all measurements made and make notes of all items, which are not complete or are not within design tolerance.

### **3.4 FINAL BALANCE PHASE**

- A. Procedure:
  1. Perform all procedures as per Planning Phase narrative. Correct all deficiencies and redo procedures as required before submitting Final Report.
- B. Final Report:
  1. Submit report to Architect/Engineer and Mechanical Contractor indicating all data and measurements as per requirements herein and per Planning Phase narrative. Do not submit partial or incomplete reports.
- C. Final Report Adjustments:
  1. Architect/Engineer reserves the right to check any measurement made and to reject any portion of work not within required tolerance of design flow. TAB Contractor shall resubmit all or portions of Final Report as directed by Architect/Engineer.

**END OF SECTION**

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## SECTION 23 0598CR

### ACCEPTANCE TESTING OF ROTATING EQUIPMENT

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 23 2123CR - Pumps

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 SCOPE

- A. The scope of this section is to set minimum standards for acceptance testing of rotating equipment. This testing involves checking machine alignment and vibration characteristics.
- B. Equipment covered by this Section includes the following:
  - 1. All pump-motor assemblies 5 hp and larger.

##### 1.4 QUALIFICATIONS

- A. Acceptance Testing Contractor (ATC) shall be independent of Mechanical Contractor.
- B. Described testing procedures shall be performed by well established company with at least 5 yrs of machinery installation, alignment and vibration testing experience. Technicians used by ATC shall have at least 3 yrs experience in installation, alignment and vibration measurement of rotating equipment.
- C. ATC shall submit list of personnel who will be utilized during acceptance testing, and their qualifications. Certificates or diplomas of completion of any manufacturer's vibration analysis training are required.
- D. ATC's personnel shall have ability to identify and pinpoint mechanical problems found during acceptance testing and recommend appropriate corrective measure, including dynamic balancing, in-depth vibration analysis and bearing checks.

##### 1.5 VIBRATION ANALYZER TESTING EQUIPMENT REQUIREMENTS

- A. ATC shall utilize instrument that is microprocessor based FFT analyzer and has swept filter, and which is designed for measuring vibration on rotating equipment. Test equipment shall have the following on-site capabilities:
  - 1. To collect and display overall vibration values from each bearing point on machines.
  - 2. To collect and display FFT data from each bearing point on machines.

3. To store vibration readings within analyzer for download to suitable software program for reporting and documenting purposes.
4. To measure phase with either photo-tach and/or strobe light, on site.
5. To measure start-up or coast-down vibration data, as well as to display and print collected data on-site.
6. To provide hard copy printout of measurements, including overall vibration measurement, FFT measurements, phase readings and start-up and coast-down data, on site from on-board printer.

## **1.6 ACCEPTANCE TESTING REPORT REQUIREMENTS**

- A. Documenting report shall contain the following sections:
  1. Summary of installation, alignment and vibration results fully documenting all aspects of installation and acceptance testing procedures.
  2. Alignment tolerances achieved on each piece of equipment including final alignment readings, shim placements and soft foot condition of any aligned unit.
  3. Documenting report of vibration readings including overall values and FFTs collected from each bearing point and measured in horizontal, vertical and axial direction. Preferred method of documentation is by utilizing appropriate software program for printout and display of collected vibration values.
  4. Final condition of each mechanical unit including indications of mechanical trouble and recommendations for corrective action.
  5. Other items as required.

## **PART 2 PRODUCTS**

### **2.1 Not Applicable to this Section**

## **PART 3 EXECUTION**

### **3.1 MACHINERY ALIGNMENT EXECUTION AND ACCEPTANCE STANDARDS**

- A. The following guidelines shall be used for establishing alignment procedures and tolerances for direct coupled machinery, regardless of speed.
- B. Rough alignment shall be used to bring machines into measurable range.
- C. Side-to-side alignment of direct coupled machinery shall be brought into tolerance first.
- D. Top-to-bottom alignment of direct coupled machinery shall be brought into tolerance next.
- E. Soft foot condition of each machine shall be checked and verified in documenting report. Machines found to exhibit soft foot condition shall be identified and documented in report along with corresponding shim amount used for correction.

- F. Final corrected alignment readings for direct coupled machines shall be as follows:
1. Angular alignment within .002".
  2. Radial alignment within .002".

### **3.2 MACHINERY VIBRATION EXECUTION AND ACCEPTANCE STANDARDS**

- A. The following guidelines shall be used to determine whether or not machine's operation is acceptable based on measured vibration levels and characteristics.
- B. Each machine train shall have vibration readings obtained from each bearing point in horizontal, vertical and axial direction.
- C. Data collected and displayed shall be clearly identified as to machine ID, bearing number and direction in which measured. This data shall be displayed in Velocity, Peak (in/sec. pk.) Frequency data reported shall be displayed in cpm (cycles per minute). Measured frequency ranges shall be large enough so as to fully measure bearing, gear and harmonics of above, but not so large so as to make displayed data unreadable on low end of frequency range.
- D. Each machine measured and in each measurement direction shall not exceed the following vibration levels:
1. Pumps 0.200 in/sec peak
- E. No machine which exceeds overall vibration values listed will be accepted for operation.
- F. No singular vibration peak, within measured frequency range, shall exceed 75% of overall value measured or machine will not be accepted for operation.
- G. Machines, which do not meet vibration acceptance levels, shall, in documenting report, contain sufficient data and comments to identify the cause of vibration as well as suggest corrective action to reduce vibration levels to acceptance criteria.
- H. Procedures used to reduce vibration levels of each machine to acceptance level shall be documented in accompanying report, including balancing results, additional alignment, phase analysis results, machine inspection procedures, and additional vibration analysis test results.

### **3.3 OWNER'S OBSERVER**

- A. Representative of utilities department wishes to be present during acceptance testing. Notify Engineer one week in advance of testing. Failure to provide this notification may result in non-acceptance of testing report.

**END OF SECTION**



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## **SECTION 23 2116CR**

### **PIPE AND PIPE FITTINGS**

#### **PART 1 GENERAL**

##### **1.1 RELATED WORK**

- A. Section 20 0529 - Mechanical Supporting Devices
- B. Section 23 0594CR - Water Systems Test Adjust Balance
- C. Section 25 3002 CR- Process Control Valves and Damper (Valves)
- D. Section 25 0903 CR- Process Control Instrumentation (Wells, Taps or In-line Devices)
- E. Section 23 2118CR - Valves
- F. Section 23 2120CR - Piping Specialties
- G. Section 23 2514CR - Chemical Treatment Systems (Pipe Cleaning)

##### **1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### **1.3 DESCRIPTION**

- A. This Section includes pipe and pipe fitting specifications and installation requirements for heating and cooling systems.
- B. Specification of an item in this or any other sections shall not relieve Contractor from providing all items, articles, materials, operations, methods, labor, equipment and incidentals necessary for a complete and functional system.
- C. Use only new material, free of defects, rust and scale, and guarantee for services intended.
- D. Use material meeting the latest revision of ASTM specifications as listed in this specification.
- E. Follow local codes if they require other types of pipe or joints.
- F. Use only long radius elbows having centerline radius of 1.5 pipe diameters unless otherwise indicated.
- G. Manufacturer, pressure class, size and heat code of each fitting and flange shall be permanently identified on its body in accordance with MSS SP-25.

- H. Where size for a pipe segment is not indicated, the pipe segment size shall be equal to the largest pipe segment to which it is connected. Transition to smaller size shall occur on the side of fitting where smaller size is indicated.
- I. Unless otherwise indicated, fittings and accessories connected to pipe shall be of the same material as the pipe.
- J. Unless otherwise indicated, construct piping for highest pressures and temperatures in respective system in accordance with the latest revision of the applicable Sections of ASME Code for pressure piping, ASME B31 including the following:
  - 1. B31.9 Building Services Piping
  - 2. B31.3 Process Piping
- K. Steam and steam condensate piping shall be constructed in accordance with the State of Minnesota code for High Pressure Piping, Chapter 5230, and ANSI B31.1 for high pressure steam piping and shall be in accordance with the Minnesota Department of Administration State Building Code, Mechanical Systems, Chapter 1346 for low pressure piping.
- L. Non-metallic piping is acceptable only for services indicated. It is not acceptable in occupied spaces and ventilation plenum spaces.

#### 1.4 SUBMITTALS

- A. Shop Drawings for each piping system for all pipe sizes including, but not limited to, the following:
  - 1. Name of system
  - 2. Pipe; ASTM number, grade if known, type, wall thickness, material
  - 3. Fittings; ASME number, grade if known, class, type, wall thickness, material
  - 4. Joint type
  - 5. Flanges; ASTM number, grade, class, type, material
  - 6. Bolts and nuts; material
  - 7. Thread joint sealants; material
  - 8. Flange gaskets; material, rating
  - 9. Unions; ASTM number, type, material, rating
  - 10. Type of welding
  - 11. Welding Quality Control Program
  - 12. Test pressure and media
  - 13. Pipe flushing procedures
  - 14. Pipe cleaning method
  - 15. All other appropriate data
- B. Submit pipe certification as specified under Pipe Certification in this Section.
- C. Submit required documents as specified under Pipe Welding in this Section.

#### 1.5 PRODUCT DELIVERY, STORAGE AND HANDLING

- A. Furnish pipe with plastic end-caps/plugs on each end of pipe. Maintain end-caps/plugs through shipping, storage and handling to prevent pipe-end damage and eliminate dirt and construction debris from accumulating inside of pipe.



- B. Where possible, store materials inside and protect from weather. Where necessary to store outside, elevate well above grade and enclose with durable, waterproof wrapping.
- C. Before shipping, all carbon steel piping shall be free of rust and scale, and furnished with plastic end caps/plugs on each end of pipe.

## 1.6 PIPE WELDING

- A. Procedure and Welding Qualification Records:
  - 1. Submit Welding Procedure Specifications (WPSs) and their supporting Procedure Qualification Records (PQRs) to be used on the work to Engineer for review and approval prior to performing any welding. These documents shall meet requirements of ASME B31.1 and B31.9, as applicable.
  - 2. Unless otherwise indicated, welding shall be done using only the following processes:
    - a. Shielded Metal Arc Welding (SMAW), also known as "stick" welding
    - b. Gas Tungsten Arc Welding (GTAW), also known as TIG and Heliarc welding
    - c. Gas Metal Arc Welding (GMAW), also known as MIG welding
    - d. Flux-Cored Arc Welding (FCAW), a variation of GMAW
    - e. Submerged Arc Welding (SAW)
  - 3. Unless otherwise stated, fabrication, installation, inspection, examination and testing shall be in accordance with ASME B31.1 or B31.9, as applicable.
  - 4. Backing rings (chill rings) or consumable inserts are not allowed, unless specifically requested by Owner or Engineer.
- B. Quality Control Program:
  - 1. Submit written quality control program for review and approval prior to implementing any welding on this project. Quality control program shall include the following as minimum:
    - a. Explanation of how Contractor will assure proper fitup for each weld.
    - b. Explanation of how Contractor will document welds performed by individual welding operators for systems under ASME B31.1.
    - c. Explanation of how Contractor will assure that proper welding procedure is being followed.
    - d. Credentials of personnel responsible for required weld examinations.
- C. Weld Inspection and Examination:
  - 1. Provide examination services for all welding for this Project. Examination shall be in accordance with requirements of ASME B31.1, Table 136.4 or B31.9, as applicable. Personnel performing examinations shall comply with requirements stipulated in 136.1 (A) through (E) or shall be AWS QC1 Certified.
  - 2. Periodically, as welding progresses, submit report, signed by weld examiner, indicating status of project welding quality.
  - 3. Arrange with Owner's Inspector for observation of fitup and welding methods prior to implementing any welds, including shop welds, on this Project.
  - 4. In addition, Owner's Inspector will perform any additional observations deemed necessary before, during, or after fabrication to assure, to Owner's satisfaction, that proper welding is provided. Owner reserves the right to perform independent examination of welds. If Owner has any concern as a

result of such examination Owner reserves the right to stop in progress welding work, without any cost to Owner, until resolution satisfactory to Owner is reached.

5. Owner will examine selected welds utilizing radiography to confirm quality of welding work.

D. Welder Qualifications:

1. Each welder and welding operator must qualify by passing required procedure test before performing any project welds. Submit copy of Manufacturer's Record of Welder or Welding Operator Qualification Tests (WPQS) as required by Section IX of ASME Boiler and Pressure Vessel Code for all welding procedures to be performed by welding operator.
2. Welder qualifications must be current. If qualification test is more than 6 months old, provide record of welding continuity for each welder.
3. Record of welding continuity is intended to show that welder has performed welding at least every 6 months since the date that welder qualification test was passed for the submitted welding procedure specification.
4. Record of welding continuity shall include, at minimum, the following:
  - a. Welder's employer name and address
  - b. Date Welder Qualification Test was passed
  - c. Dates indicating welding continuity
5. Welders shall be qualified as required by ASME B31.1 or B31.9, as applicable. In addition, there shall be an independent witness of welder tests. That witness shall be representative of independent testing laboratory, Authorized (Code) Inspector, Owner's or Engineer's Inspector or consultant approved by National Certified Pipe Welding Bureau.
6. Welder qualifications must cover all pipe sizes and wall thickness used on this project. Test segments or coupons shall be appropriately selected for qualification. Test position shall be arranged in "6G position."

E. Weld Record:

1. For welding within the scope of ASME B31.1 Power Piping, submit to Engineer for approval an administrative procedure for recording, locating, monitoring and maintaining quality of welds to be performed on the project. This quality control document record shall include but not be limited to:
  - a. Drawings and schedules identifying location of each weld by individual number, identification of welder who performed each weld by individual welder's name, stamp number, date, and WPS used.

## 1.7 PIPE CERTIFICATION

- A. Certification is required for all pipe within scope of ASME B31.1. Submit certification papers, as outlined below, within 30 days of delivery of pipe to project site.
- B. Type E or S Pipe:
  1. Furnish manufacturer's mill certificates (material test report) including dimensions, heat numbers, chemical analysis and tensile test results for pipe shipped to project site.

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## **PART 2 PRODUCTS**

### **2.1 ULTRA LOW PRESSURE STEAM (STEAM-TO-STEAM HUMIDIFIER)**

- A. 6" and Smaller:
1. Pipe: ASTM B88 seamless, Type L, hard temper copper tube
  2. Fittings: ASME B16.22, wrought copper solder joint
  3. Joint: ASTM B32, lead free solder, Bridgit, Silvabrite, Silverflow or Canfield
  4. Unions: ASME B16.18 cast copper alloy or ASME B16.22 wrought copper solder joint, Class 125
  5. Flanges: ASME B16.24, Class 150, cast copper alloy
  6. Use solder joints for valves and piping specialties in copper piping

### **2.2 LOW PRESSURE STEAM (15 PSIG AND LOWER)**

- A. 2" and Smaller:
1. Pipe: ASTM A53, Grade B, Type E or S, standard weight, carbon steel
  2. Fittings: Class 150 malleable iron, threaded
  3. Unions: ASME B16.39, malleable iron, Class 300. Refer to Unions and Flanges in this Section
- B. 2-1/2" and Larger:
1. Pipe: ASTM A53, Grade B, Type E or S, standard weight, carbon steel
  2. Fittings: ASTM A234 Grade WPB/ASME B16.9, standard weight, seamless, carbon steel weld
  3. Flanges: Class 150. Refer to Unions and Flanges in this Section
- C. ASTM A53, Type F, standard weight, carbon steel pipe may be used through 4" size

### **2.3 LOW PRESSURE STEAM CONDENSATE (15 PSIG AND LOWER)**

- A. 2" and Smaller:
1. Pipe: ASTM A53, Type F, extra strong, carbon steel
  2. Fittings: ASME B16.3, Class 150 malleable iron, threaded
  3. Unions: ASME B16.39, malleable iron, Class 300. Refer to Unions and Flanges in this Section
- B. 2-1/2" and Larger:
1. Pipe: ASTM A53, Grade B, Type E or S, extra strong, carbon steel
  2. Fittings: ASTM A234 Grade WPB/ASME B16.9, extra strong, seamless, carbon steel weld
  3. Flanges: Class 150. Refer to Unions and Flanges in this Section
- C. Type F pipe may be used for 2-1/2" through 4" size

### **2.4 HEATING HOT WATER**

- A. 2" and Smaller:
1. Pipe: ASTM B88 seamless, Type L, hard temper copper tube
  2. Fittings: ASME B16.22, wrought copper solder joint
  3. Joint: ASTM B32, lead free solder, Bridgit, Silvabrite, Silverflow or Canfield

4. Unions: ASME B16.18 cast copper alloy or ASME B16.22 wrought copper solder joint, Class 125
  5. Flanges: ASME B16.24, Class 150, cast copper alloy
  6. Use solder joints for valves and piping specialties in copper piping
  7. Press Joint Option:
    - a. Contractor may use press copper fittings as manufactured by Viega. Other acceptable manufacturers are Nibco and Elkhart.
    - b. Fittings: Copper press fittings with EPDM seal, 0 to 250°F, maximum 200 psi.
    - c. Joints: Press joints by fitting manufacturer approved tool.
- B. 2-1/2" and Larger:
1. Pipe: ASTM A53, Grade B, Type E or S, standard weight, carbon steel
  2. Fittings: ASTM A234 Grade WPB/ASME B16.9, standard weight, seamless, carbon steel weld
  3. Flanges: Class 300. Refer to Unions and Flanges in this Section
- C. Type F pipe may be used for 2-1/2" through 4" size.
- D. Contractor may use carbon steel as specified below in lieu of copper tube for 2" and smaller.
1. Pipe: ASTM A53, Type F, standard weight, carbon steel
  2. Fittings: ASME B16.4, Class 125, cast iron, threaded or ASME B16.3, Class 150, malleable iron, threaded
  3. Unions: ASME B16.39, malleable iron, Class 300. Refer to Unions and Flanges in this Section

## 2.5 CHILLED WATER

- A. 2" and Smaller:
1. Pipe: ASTM B88 seamless, Type L, hard temper copper tube
  2. Fittings: ASME B16.22, wrought copper solder joint
  3. Joint: ASTM B32, lead free solder, Bridgit, Silvabrite, Silverflow or Canfield
  4. Unions: ASME B16.18 cast copper alloy or ASME B16.22 wrought copper solder joint, Class 125. No unions to be used for lines sizes 3/4" and smaller. Unions shall be used for line sizes over 1".
  5. Flanges: ASME B16.24, Class 150, cast copper alloy
  6. Use solder joints for valves and piping specialties in copper piping.
  7. Press Joint Option:
    - a. Contractor may use press copper fittings as manufactured by Viega. Other acceptable manufacturers are Nibco and Elkhart.
    - b. Fittings: Copper press fittings with EPDM seal, 0 to 250°F, maximum 200 psi.
    - c. Joints: Press joints by fitting manufacturer approved tool.
- B. Contractor may use carbon steel as specified below in lieu of copper pipe for 2" and smaller.
1. Pipe: ASTM A53, Grade B, Type E or S, standard weight, carbon steel
  2. Fittings: ASME B16.4, Class 125, cast iron, threaded or ASME B16.3, Class 150, malleable iron, threaded.

3. Unions: ASME B16.39, malleable iron, Class 300. Refer to Unions and Flanges in this Section
- C. 2-1/2" through 24":
1. Pipe: ASTM A53, Grade B, Type E or S, standard weight, carbon steel
  2. Fittings: ASTM A234 Grade WPB/ASME B16.9, standard weight, seamless, carbon steel weld
  3. Flanges: Class 150. Refer to Unions and Flanges in this Section
- D. ASTM A53, Type F, standard weight, carbon steel pipe may be used through 24" size.

## 2.6 LOW TEMPERATURE CHILLED WATER

- A. 6" and Smaller:
1. Pipe: ASTM B88 seamless, Type L, hard temper copper tube
  2. Fittings: ASME B16.22, wrought copper solder joint
  3. Joint: ASTM B32, lead free solder, Bridgit, Silvabrite, Silverflow or Canfield
  4. Unions: ASME B16.18 cast copper alloy or ASME B16.22 wrought copper solder joint, Class 125
  5. Flanges: ASME B16.24, Class 150, cast copper alloy
  6. Use solder joints for valves and piping specialties in copper piping.
  7. Press Joint Option (2" and smaller):
    - a. Contractor may use press copper fittings as manufactured by Viega. Other acceptable manufacturers are Nibco and Elkhart.
    - b. Fittings: Copper press fittings with EPDM seal, 0 to 250°F, maximum 200 psi.
    - c. Joints: Press joints by fitting manufacturer approved tool.

## 2.7 CLEANROOM PROCESS CHILLED WATER AND CLEANROOM AIR HANDLING UNIT CHILLED WATER

- A. 6" and Smaller:
1. General
    - a. Piping, fittings, and valves that are to be heat fused shall be products of same manufacturer.
    - b. Dimensions of end connections for valves shall be compatible with pipe and fittings.
  2. Pipe, fittings, & joints
    - a. Pipe: CPVC, Schedule 80, meeting requirements of ASTM F-441 and F-439 and manufactured from CPVC that meets requirements of D-1784 for Type IV, Grade 1, Class 23447-B
    - b. Fittings: CPVC, Schedule 80, meeting requirements of ASTM F-441 and F-439 and manufactured from CPVC that meets requirements of D-1784 for Type IV, Grade 1, Class 23447-B, female socket ends
    - c. Flanges: PVC flanges conforming to ANSI B1 6.5, Class 150
    - d. Solvent Cement: solvent cement shall conform to ASTM F-493 and to NSF International for use on potable water systems. (Threaded fittings are to be used only where required to connect to equipment.)

## 2.8 RECLAIM WATER

- A. 2" and Smaller:
  - 1. Pipe: ASTM B88 seamless, Type L, hard temper copper tube
  - 2. Fittings: ASME B16.22, wrought copper solder joint
  - 3. Joint: ASTM B32, lead free solder, Bridgit, Silvabrite, Silverflow or Canfield
  - 4. Unions: ASME B16.18 cast copper alloy or ASME B16.22 wrought copper solder joint, Class 125. No unions to be used for lines sizes 3/4" and smaller. Unions shall be used for line sizes over 1".
  - 5. Flanges: ASME B16.24, Class 150, cast copper alloy
  - 6. Use solder joints for valves and piping specialties in copper piping
- B. Contractor may use carbon steel as specified below in lieu of copper pipe for 2" and smaller:
  - 1. Pipe: ASTM A53, Grade B, Type E or S, standard weight, carbon steel.
  - 2. Fittings: ASTM A126/ASME B16.4, Class 125, cast iron, threaded or ASTM A197/ASME B16.3, Class 150, malleable iron, threaded
  - 3. Unions: Malleable iron, Class 300. Refer to Unions and Flanges in this Section
- C. 2-1/2" and Larger:
  - 1. Pipe: ASTM A53, Grade B, Type E or S, standard weight, carbon steel
  - 2. Fittings: ASTM A234 Grade WPB/ASME B16.9, standard weight, seamless, carbon steel weld
  - 3. Flanges: Class 300. Refer to Unions and Flanges in this Section
- D. ASTM A53, Type F, standard weight, carbon steel pipe may be used through 4" size.

## 2.9 RAW WATER MAKE-UP

- A. Refer to Section 21 1118 - Water Distribution System

## 2.10 CHEMICAL TREATMENT

- A. Closed Water System (Hot Water, Chilled Water, Glycol, etc.):
  - 1. Use pipe and fittings as indicated for the system to which chemical treatment piping is connected.

## 2.11 VENTS AND RELIEF VALVES

- A. Use pipe and pipe fittings as indicated for the system to which relief valve or vent is connected.
- B. Use ASTM A53, Type F, carbon steel pipe with standard weight, carbon steel fittings for steam vents.
- C. Use ASTM A53, Type F, carbon steel pipe with ASTM A234 Grade WPB/ASME B16.9, standard weight, seamless carbon steel weld fittings for refrigerant vent piping.

## 2.12 PRESSURE GAUGES AND TAPPINGS

- A. Use pipe and pipe fittings as indicated for the system to which pressure gauge or tapping is connected. Use "Threadolets", "Sockolets" or tee fittings for tappings. Refer to Part 3 under General for use of "Threadolets" and "Sockolets".
- B. Gauge pipe shall be 1/4" unless otherwise indicated.

## 2.13 COOLING COIL CONDENSATE DRAIN

- A. Piping shall be as follows:
  - 1. Pipe: ASTM B88, Type M, hard temper copper tubing
  - 2. Fittings: ASTM B16.22 wrought copper fittings
  - 3. Joint: ASTM B32, 95-5 tin-antimony solder, Bridgit or Silvbrite

## 2.14 DIELECTRIC UNIONS, FLANGES AND FITTINGS

- A. Copper to Steel Pipe:
  - 1. 2" and Smaller: Use ball valves specified in Section 232118 for dielectric purpose.
  - 2. 2-1/2" and Larger: EpcO Model GWX or Watts dielectric flange fittings Series 3100/3110 with dielectric gasket, 175 psi at 210°F.

## 2.15 UNIONS AND FLANGES

- A. Unions:
  - 1. 2" and Smaller: Malleable iron, ASME B16.39 with ground joint, bronze or brass to iron. Provide black malleable iron for carbon steel piping and galvanized malleable iron for galvanized steel piping. Unless otherwise specified, pressure class and joint type of union shall be equal to that specified for fittings of respective piping service. Minimum pressure class of unions shall be Class 300.
  - 2. 2" and Smaller: Forged steel, ASTM A105 Grade 2, ASME B16.11, 3000 lb. WOG with steel to steel seats. Joint type shall match that specified for fittings of respective piping service.
- B. Flanges:
  - 1. 2-1/2" and Larger: ASTM A105, ASME B16.5, hot forged steel, welding neck pattern. Slip-on pattern are not allowed. Bore dimension of welding neck flange shall match inside diameter of connected pipe.
  - 2. Use raised face flanges for mating with other raised face flanges with self-centering flat ring gaskets. Use flat face flanges for mating with other flat face flanges with full face gaskets.
  - 3. Flange pressure class indicated in respective piping service is minimum required. Mating flange pressure class shall match pressure class of connected device, such as valves and piping specialties.

- C. Flange Gaskets:
1. Gasket material shall be asbestos free and suitable for pressures, temperatures and fluid of respective piping system. Non-metallic gaskets shall be in accordance with ASME B16.21 and ASTM F104. Unless otherwise indicated or recommended by manufacturer, gaskets shall be similar to Garlock IFG 5500 with 1/16" thick gasket.
  2. Service Temperature (250°F thru 800°F) - Flexitallic, Garlock, Lamos equal to Flexitallic Style CG, flexible graphite filler, 304 SS winding, carbon steel centering ring, 0.175" thickness.
- D. Bolting:
1. Bolts, bolt studs, nuts and washers shall have zinc plated finish.
  2. Thread shall be in accordance with ASME B1.1, Class 2A tolerance for external threads and Class 2B tolerance for internal threads. Threads shall be coarse-thread series except that alloy steel bolting 1-1/8" and larger in diameter shall be 8 pitch thread series.
  3. Threaded rods are not allowed as fastening elements.
  4. For Class 150 and Class 300 flanges not exceeding 400°F temperature, use carbon steel bolts or stud bolts conforming to ASTM A307, Grade B with nuts conforming to ASTM A194.
    - a. Bolts conforming to ASTM A307, Grade A may be used for piping governed by ASME B31.9.

## 2.16 THREADED JOINT SEALANTS

- A. Paste type for brush application or cord type. Products shall be non-toxic, chemically inert, non-hardening, rated for -50°F to 400°F and up to 10000 psi (liquids) and 2600 psi (gases), certified by UL, CSA, and NSF.
- B. Use sealant similar to Loctite Model 54531 for piping handling oil or petroleum products.

## PART 3 EXECUTION

### 3.1 GENERAL

- A. Remove foreign materials before erection. Ream ends of piping to remove burrs.
- B. Install piping parallel to building walls and ceilings and at such heights so as not to obstruct any portion of window, doorway, stairway, or passageway. Install piping to allow adequate service space for equipment. Refer to drawings and/or manufacturer's recommendations. Install vertical piping plumb. Where interferences develop in field, offset or reroute piping as required to clear such interferences. In all cases, consult drawings for exact location of pipe spaces, ceiling heights, door and window openings or other Architectural details before installing piping.
- C. Provide anchors, expansion joints, swing joints and expansion loops so that piping may expand and contract without damage to itself, equipment or building.



- D. Mitered elbows, welded branch connections, notched tees and "orange peel" reducers are not allowed. Unless specifically indicated, reducing flanges and reducing bushings are not allowed. Reducing bushings may be used for air vents and instrumentation connections.
- E. Unless otherwise indicated, use fittings as specified in Part 2 of this Section for elbows, tees, reducers, etc.
- F. "Weldolets" with outlet size 2-1/2" and larger and "Threadolets" or "Sockolets" with outlet size 2" and smaller may be used for branch takeoff up to one half (1/2) diameter of main. Use "Threadolets" where threaded fittings are specified and use "Sockolets" where socket weld fittings are specified. Materials of "Weldolets", "Threadolets" and "Sockolets" shall match material of piping.
- G. Install drains throughout systems to permit complete drainage of entire system.
- H. Do not install piping over electrical panelboards, switchgear, switchboards or motor control centers.
- I. Install valves, control valves and piping specialties, including items furnished by others, as specified and/or detailed. Provide reducing fittings for valves smaller than pipe size.
- J. Make connections to all equipment installed by others where that equipment requires piping services indicated in this Section.
- K. For piping within the scope of ASME B31.1 Power Piping, transfer piping material specification and "Heat Number" to each segment of pipe prior to cutting.

### **3.2 THREADED PIPE JOINTS**

- A. Threads of pipe and fittings shall conform to ASME B1.20.1.
- B. Ream pipe ends after cutting and clean before erection. Apply thread sealants to cleaned male threads. Assemble joint to appropriate depth and remove any excess pipe joint compound from tightened joint.

### **3.3 FLANGED JOINTS**

- A. Clean flange surfaces and align them parallel. Bolt holes of gaskets shall be cut slightly larger than bolt diameter. Gasket ID shall be slightly larger than flange ID.
- B. Position gasket concentrically so compression is equally distributed over entire gasket surface.
- C. Lubricate bolts and run nuts down by hand.
- D. By using torque wrench, tighten nuts in the proper sequence so gasket is compressed evenly, and to the appropriate torque specified by bolt manufacturer.
- E. Re-torque bolts 12 to 24 hrs after start up.

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### 3.4 WELDED PIPE JOINTS

- A. Inspect pipe and pipe fittings for roundness before they are fit-up or set in place.
- B. Properly clean and prepare pipe base material before fit-up. Verify joint land and bevel.
- C. Preheat pipe base material as required by welding procedure specification. Temperature of pipe material must be minimum of 32°F before welding.
- D. Properly align and adjust joint as required by welding procedure and thickness of material. Verify tolerances after tacking sequence.
- E. Use weld material diameter as procedurally required for type and thickness of work being done.
- F. Use sufficient argon pre-purge and argon post-purge for GTAW processes. Post purge should be until weld is no longer glowing plus 5 seconds. Maintain purge for at least 2 layers of weld material.
- G. Properly store welding materials.
- H. Clean tacks before welding out. Remove slag after each pass by grinding to avoid slag inclusion.
- I. Weld reinforcement shall not exceed limits established in Chapter V of ASME B31.1.
- J. Brush each weld free of rust and paint with rust resistant product that matches piping surface color.
- K. For piping within scope of ASME B31.1, each weld shall be permanently marked by welder performing weld. Each welder shall sign and date field welding log record for all welds performed by welder as indicated in Part 1.
- L. Conduct radiographic test for sections or joints that cannot be tested by hydrostatic test methods (such as joints cut into existing piping systems) by qualified radiographic testing firm.

### 3.5 COPPER PIPE JOINTS

- A. Cutting of tubing shall not make tubing out of round. Ream cut tube ends to full inside diameter.
- B. Remove slivers and burrs remaining from tube cut by reaming and filing both pipe surfaces. Clean fitting and tube with emery or sand cloth. Remove residue from cleaning operation, apply flux and assemble joint. Use solder or brazing to secure joint as specified for specific piping service.
- C. Press Joint Option:
  - 1. Cut pipe square and ream before assembly
  - 2. Insert pipe fully into fitting and mark on pipe at shoulder of fitting

3. Check fitting alignment against mark on pipe to ensure pipe is fully engaged
4. Press joint with press tool approved by fitting manufacturer

### **3.6 PLASTIC PIPE JOINTS**

- A. Use cleaning procedure and solvent cement as recommended by pipe and fitting manufacturers for particular material being used.

### **3.7 CPVC JOINT FABRICATION**

- A. Perform joining in strict accordance with manufacturer's recommended procedures. Cut piping in strict accordance with manufacturer's recommended procedures.
- B. Clean components prior to fusion conscientiously and in strict compliance with Manufacturer's recommendations for high purity services.
- C. Form joints by solvent welding in accordance with appropriate parts of ASTM D-2855, using solvent cement conforming to ASTM F-493 and to NSF International for use on potable water systems.
- D. Use union joints only where indicated on drawings or where necessary to connect to accessories and equipment. Verify that o-ring is correctly indexed prior to tightening. Tighten hand tight only; do not use tools. Tighten flanged connections in strict accordance with manufacturer's recommendations.
- E. Use threaded connections only if only option for connecting to equipment.

### **3.8 ULTRA LOW PRESSURE STEAM (STEAM-TO-STEAM HUMIDIFIER)**

- A. Use ultra low pressure steam from steam to humidifier to distribution manifold.
- B. Pitch steam mains down at 1" per 40 ft in direction of flow. Pitch runouts to terminal equipment and control valves at 1/2" per 1 ft for proper condensate drainage. Install drip traps at each rise and at horizontal termination of each steam main.
- C. Pitch steam condensate lines down at 1" per 20 ft in direction of flow.
- D. Install minimum of 3 elbows in each pipe runout to terminal equipment to provide flexibility for expansion and contraction of piping system.

### **3.9 STEAM AND STEAM CONDENSATE**

- A. Pitch steam mains down at 1" per 40 ft in direction of flow. Pitch runouts to terminal equipment and control valves at 1/2" per 1 ft for proper condensate drainage. Install drip traps at each rise and at horizontal termination of each steam main.
- B. Pitch steam condensate lines down at 1" per 20 ft in direction of flow.
- C. Unless otherwise indicated, use eccentric fittings for changes in horizontal pipe sizes with fittings installed for proper condensate drainage (bottom of pipe straight). Concentric fittings may be used for changes in vertical pipe sizes.

- D. For steam branch connections and runouts, use top or top 45° connection to main.
- E. For condensate branch connections to condensate mains, use top or top 45° connection to main.
- F. For condensate connections from steam mains, use bottom connection to main.
- G. Install minimum of 3 elbows in each pipe runout to terminal equipment to provide flexibility for expansion and contraction of piping system.

### **3.10 STEAM CONDENSATE PUMP DISCHARGE**

- A. Pitch mains down at 1" per 40 ft in direction of flow. In limited space situations and where specifically indicated on drawings, horizontal lines may be run dead level. Where 2 separate pump discharge mains join together, provide check valve in each line before tee. Provide gate valve between check valve and tee for line isolation.

### **3.11 WATER SYSTEMS**

- A. Pitch horizontal mains up at 1" per 40 ft in direction of flow. Install manual air vents at all high points where air may collect. If vent is not in accessible location, extend air vent piping to nearest code acceptable drain location with vent valve located at nearest accessible location to pipe.
- B. Main branches and runouts to terminal equipment may be made at top, side or bottom of main provided that there are drain valves suitably located for complete system drainage and manual air vents are located as described above.
- C. Unless otherwise indicated, for upfeed risers, use top or top 45° connection to main and for downfeed risers use side or bottom 45° connection to main. If side or bottom 45° connection is not practical and bottom connection to main must be used, provide line size Y strainer with shut-off valve at each side at branch connection.
- D. Use minimum of 3 elbows in each pipeline to terminal equipment to provide flexibility for expansion and contraction of piping systems.
- E. Use eccentric fittings for changes in pipe sizes and for valves smaller than pipe sizes, in horizontal lines, with fittings installed for proper air venting (top of pipe straight). Concentric fittings may be used for changes in pipe sizes and for valves smaller than pipe sizes in vertical lines.

### **3.12 RAW WATER MAKE-UP**

- A. Refer to Section 22 1118 - Water Distribution System
- B. Install piping where indicated, including valves, piping specialties and dielectric unions required for functional system.
- C. Raw water make-up piping for this Section is defined as fill line containing pressure reducing valve for water systems.

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### **3.13 CHEMICAL TREATMENT**

- A. Install piping as indicated on drawings, as detailed, and as recommended by supplier of chemical treatment equipment.

### **3.14 VENTS AND RELIEF VALVES**

- A. Install vent and relief valve discharge lines as indicated on drawings, as detailed, and as specified for each specific valve or piping specialty item.

### **3.15 COOLING COIL CONDENSATE DRAIN**

- A. Trap each cooling coil drain pan connection with trap seal of sufficient depth to prevent conditioned air from moving through piping. Extend drain piping to nearest code approved drain location. Construct trap with plugged tee for cleanout purposes.
- B. Pitch pipe down at 1/4" per one foot for proper drainage.
- C. Where copper piping is allowed, joints and fittings may be secured with 95-5 tin-antimony solder or brazing alloys.

### **3.16 DIELECTRIC UNIONS AND FITTINGS**

- A. Install dielectric unions, flanges or fittings in main and branch piping of water systems at each point where copper to steel pipe connection occurs. Dielectric unions or fittings shall not be used at terminal device connections.
- B. Concealed dielectric unions and fittings are not allowed.

### **3.17 UNIONS AND FLANGES**

- A. Install union or flange at each automatic control valve and at each piping specialty or piece of equipment that requires tube pull or removal for maintenance, repair or replacement. If required, provide additional unions or flanges in order to facilitate removal of piping sections that interfere with tube pulls or equipment removal. Where valve is located at piece of equipment, provide flange or union connection on equipment side of valve.
- B. Concealed unions or flanges are not allowed.

### **3.18 PIPING SYSTEM PRESSURE TESTS**

- A. Owner and/or Owner's representative may elect to witness pressure test. Notify Owner and/or Owner's representative at least 3 days in advance.
- B. Conduct pressure test prior to flushing and cleaning of piping systems.
- C. Conduct hydrostatic (HYDRO) test in accordance with ASME B31.1 137.4. Test pressure shall be in accordance with ASME B31.1, but shall not be lower than the minimum test pressure listed below.

- D. If leaks are found, repair with new materials and repeat test until leaks are eliminated. Caulking will not be acceptable.
- E. Pressure tests may be made of isolated portions of piping systems to facilitate general progress of installation. Any revisions made in piping systems require retesting of affected portions of piping systems.
- F. No systems shall be insulated until it has been successfully tested. If required for additional pressure load under test, provide temporary restraints at expansion joints or isolate them during test. Unless otherwise noted, minimum test time shall be 4 hrs plus such additional time as may be necessary to conduct examination for leakage.
- G. No pressure drop shall occur during test period. Any pressure drop during test period indicates leakage.
- H. Provide pumps, gauges, instruments, test equipment, temporary piping and personnel required for tests and provide removal of test equipment and draining of pipes after tests have been made.
- I. For hydrostatic tests, remove air from piping being tested by means of air vents. Measure and record test pressure at high point in system. Where test pressure at high point in system causes excessive pressure at low point in system due to static head, portions of piping system may be isolated and tested separately to avoid undue pressure. However, every portion of piping system must be tested at the specified minimum test pressure.
- J. Conduct pressure tests with parameters indicated below:

<u>System</u>	<u>Minimum Test Pressure</u>	<u>Remarks</u>
Low pressure steam and condensate	75 psig	HYDRO
Steam condensate pump discharge	150 psig	HYDRO
Heating hot water	100 psig	HYDRO
Chilled water	100 psig	HYDRO
Cleanroom process chilled water	100 psig	HYDRO
Low temperature chilled water	100 psig	HYDRO
Cleanroom air handling unit chilled water	100 psig	HYDRO
Reclaim water	100 psig	HYDRO

- K. Contractor shall provide all pumps, gauges, instruments; test equipment, flow meters, temporary piping and personnel required for tests and provide removal of test equipment and draining of pipes after tests have been made.
- L. If piping system is drained after testing and left empty or untreated for more than 3 days, add Nalco 2572 at recommended dosages for dry system lay-up.

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### **3.19 FLUSHING AND CLEANING PIPING SYSTEMS**

- A. All open and closed piping systems are to be flushed, cleaned, and disinfected prior to placing them in operation. Cleaning and disinfecting shall be done by the University water treatment supplier and included in the Contractor's bid. Disinfection shall meet the requirements of University of Minnesota Department of Environmental Health and Safety.
- B. Flush new water, steam and condensate systems thoroughly for 15 minutes or longer, as required to ensure removal of dirt and foreign matter from piping system. Bypass pumps and equipment and remove strainers from strainer bodies. Provide circulation by Contractor-supplied portable pumping apparatus.
- C. Provide temporary piping or hose to bypass coils, control valves, heat exchangers, other factory-cleaned equipment, and any component that may be damaged, unless acceptable means of protection are provided and subsequent inspection of hide-out areas takes place.
- D. Sectionalize system to obtain minimum velocity of 6 fps. Provide temporary piping to connect dead-end supply and return headers as necessary. Flush bottoms of risers.
- E. For pipes 18" and larger, maintain velocity as close as 6 fps possible, but not below 5 fps.
- F. After initial flushing of system, use portable pumping apparatus to circulate cold water detergent for water systems. Refer to Section 232514CR - Chemical Treatment Systems for pipe cleaning.
- G. After initial flushing of system, use portable pumping apparatus for continuous 24 hr minimum circulation of cold water detergent similar to Nalco 2567 cleaner. Flush detergent clear with continuous draining and raw water fill for additional 12 hrs or until all cleaner is removed from system. Replace strainers and reconnect permanent pumping apparatus and all apparatus bypassed.
- H. Refer to Section 232514CR - Chemical Treatment Systems for water analysis.

### **3.20 INITIAL SYSTEM FILL AND VENT**

- A. Fill and vent systems with proper working fluids.
- B. Use fluids chemically treated as specified in Section 23 2514 - Chemical Treatment Systems.
- C. Glycol system shall be filled with treated glycol as specified in Section 23 2514 - Chemical Treatment Systems.

### **3.21 PIPE PAINTING**

- A. Exposed exterior carbon steel, black iron or other ferrous pipe and fittings shall be prepared and painted by qualified painters using corrosion inhibitive paints. Pipe shall be prepared in accordance with paint manufacturer's instructions and primed (2

coats) and finish painted (2 coats). Paint type shall be approved by Architect/Engineer.

- B. Protect piping from weather and paint promptly to prevent corrosion.
- C. Include painting of exposed piping (UMFM Standards 15010.10)

**END OF SECTION**



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## SECTION 23 2118CR

### VALVES

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 20 0700 - Mechanical Systems Insulation
- B. Section 25 3002CR - Process Control Valves and Dampers
- C. Section 23 2120CR - Piping Specialties (Flow Sensors and Meters)

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 SUBMITTALS

- A. Shop Drawings for each system for all sizes including, but not limited to, the following:
  - 1. Name of System
  - 2. Manufacturer's name
  - 3. Type
  - 4. Model number
  - 5. Materials of construction
  - 6. Temperature/pressure ratings
  - 7. Manufacturer's data sheets clearly cross-referenced
  - 8. All other appropriate data

#### PART 2 PRODUCTS

##### 2.1 MANUFACTURERS

- A. Gate valves, globe valves, check valves, and drain valves: Crane, Nibco, Stockham, Powell, Milwaukee, Hammond, Kitz or Grinnell equal to manufacturer's Figure number listed. Provide valves of same make for these services.
- B. Other valves: acceptable manufacturers and Figure Number listed under each item.

## 2.2 CHILLED WATER, LOW TEMPERATURE CHILLED WATER AND HOT WATER SYSTEM VALVES

- A. General:
1. Valves 2" and smaller, in steel piping shall have threaded ends.
  2. Valves 2" and smaller, in copper piping shall have solder ends.
  3. Provide valve neck extensions with sufficient length to allow for insulation where insulation is specified.
- B. Ball Valves:
1. 2" and Smaller: ASTM B584 bronze body, stainless steel ball, full port for 3/4" and smaller and conventional port for 1"25mm and larger, Teflon seat rings, blowout-proof stem, 2-piece construction, 600 psi4130 kPa WOG, 150 psi1030 kPa SWP, Nibco Fig. T(S)-580-70, Apollo No. 70, Watts, Milwaukee BA-150, Hammond, Kitz or Anvil.
- C. Globe Valves:
1. 2" and Smaller: ASTM B62 bronze body, renewable TFE disc, union or screw-over bonnet, malleable iron hand wheel, Class 150 (300 psi WOG), conforming to MSS SP-80, Nibco Figure T-235Y.
  2. 2-1/2" and Larger: iron body, bronze mounted OS&Y, flanged, renewable bronze seat and disc, Class 125 (200 psi WOG), Nibco Figure F-718.
- D. Spring Loaded Check Valves:
1. 2" and Smaller: bronze or iron body, Class 125 (200 psi WOG), Nibco Figure T(S)-480, Mueller Figure 303-AP or Metraflex No. 700.
  2. 2 1/2" and Larger: cast iron body, wafer type, 316 stainless steel spring, aluminum bronze or carbon steel disc, Buna-N seat, Class 125 (200 psi WOG), Nibco Figure W-910, Milwaukee 1400, Metraflex No. 700, Stockham Figure WG-970, Mueller Sure Check Model No. 71, or Crane Duo-check II.
  3. For valves 8" and larger, provide lifting lugs or threaded holes for lifting eye bolts.
- E. Spring Loaded Check Valves:
1. 2" and Smaller: bronze, Mueller Steam Figure 303-BP, 400 psi WOG, ANSI 250 pound class.
  2. 2-1/2" and Larger: carbon steel body, wafer type, 316 stainless steel spring, carbon steel disc, Buna N seat, Class 150 (285 psiWOG), Mueller Sure Check No. 72, or Crane Duo-Check II.
  3. For valves 8" and larger, provide lifting lugs or threaded holes for lifting eye bolts.
- F. Swing Check Valves:
1. 2" and Smaller: ASTM B62, bronze body, threaded, regrinding, Y-pattern swing type, renewable TFE seat disc, Class 150 (300 psi WOG), conforming to MSS SP-80, Nibco Fig. T-433.
  2. 2-1/2" and Larger: Iron body, bronze or brass trim, or bronze mounted, renewable seat and disc, Class 125 (200 psi WOG), conforming to MSS SP-71, Nibco Fig. F-918.

- G. Shut-Off Valves:
1. 2" and Smaller: ball valves as specified in this Section.
  2. 2-1/2" and Larger: butterfly valves as specified in this Section.
- H. Balancing Valves:
1. 2" and Smaller: calibrated balancing valves:
    - a. Variable orifice with multiple turn valve type as manufactured by Armstrong Series CBV or ABV, Victaulic 786 or 787, NIBCO 1709 or 1710, or fixed orifice with ball valve type as manufactured by Flow Design Inc., Preso, Gerand, Nexus, HCi or Taco. Bronze or brass body, 250 psi maximum working pressure, 250°F maximum operating temperature. Furnish valve with adjustable memory stop and quick disconnect taps with built-in check valve for pressure differential measurement, integral valve setting index and memory locking device.
    - b. Valves shall measure down to 0.3 gpm with accuracy of  $\pm 3\%$ .
    - c. Valves shall be leak-tight at full rated working pressure.
    - d. Unless otherwise indicated, size balancing valves so that at design flow rate, pressure drop across balancing valve with valve approximately 50% open will be at minimum 25% of reading range of meter used for balancing.
  2. 2-1/2" and Larger: Armstrong Series CBV or Tour and Anderson STAF-SG/STAG, ductile iron body, ASME/ANSI B16.42 Class 150 flange, 250 psi maximum working pressure, 250°F maximum operating temperature. Fixed orifice with ball valve type as manufactured by FDI, Presco or Gerand, Class 150 flange, 250 psi maximum working pressure, 250°F maximum operating temperature will be acceptable up to 4" size. Butterfly valves, as specified in this Section, together with averaging Pitot tube flow sensors, as specified in Section 232120 - Piping Specialties, under Flow Sensors and Meters between check valve and butterfly valve may be used when sizes for Armstrong or T/A valves are not available. Furnish butterfly valves with adjustable memory stops to limit return of valves to preset open position after shut-off.
  3. Furnish portable meter kit within durable case similar to Gerand Model "R". Furnish meter with minimum 4-1/2" 115mm diameter aluminum or brass body/brass internals with reading range of either 0" to 50" or 0" to 100" 0 water column differential as appropriate, 200°F maximum temperature, 300 psi working pressure. Meter accuracy shall be  $\pm 2\%$  full scale. Provide in kit: equalizing valves, 10 ft purge hose and size devices specified. Meter shall become property of Owner.
  4. Contractor shall furnish meter for calibration and shall retain meter after final calibration.
- I. Terminal Unit Valve Assembly
1. Terminal unit valve assembly may be used instead of individual valve and other components, provided each valve and component meets specified requirements.
  2. HCi, Nexus or FDI are acceptable.
  3. Inlet assembly shall be combination of isolation ball valve, strainer, union, and PT readout port similar to HCi Terminator Y, and outlet assembly shall be combination of isolation ball valve, union, PT readout ports and venturi flow meter similar to HCi Terminator B.

- J. Butterfly Valves (High Performance):
1. Manufacturers: DeZurik Type BHP, Xomox, Jamesbury, Bray Series 40, or Posi-Seal
  2. Carbon steel or stainless steel body, ANSI Class 150 design rated for 275 psi at 100°F, bubble-tight shut off with pressures in either direction to 275 psi, threaded lug type, upper and lower body bearings with thrust bearings, one piece single or double offset shaft of 316 stainless steel and centerless ground and polished to minimize bearing and packing wear, PTFE seats, PTFE adjustable V-ring packing, capable of service in temperature ranges of -100 to 300°F, 316 stainless steel discs and totally enclosed, factory lubed, handwheel rotary actuator with external disc position indication.
  3. Dead end pressure rating shall be 275 psi without downstream flanging.
- K. Water Pressure Regulating Valves:
1. Manufacturers: Thrush, Watts, Cash-Acme, Taco, or B & G
  2. Spring and diaphragm operated, pressure adjustable with check valve and inlet strainer and designed for maximum working pressure of 125 psig/860 kPa and maximum operating temperature of 160°F/71°C.
- L. Lockshield Valves:
1. Ball valves as specified above with locking handles for padlocking in open or closed position.
- M. Drain Valves:
1. Ball valve as specified above with hose thread adapter and cap. Provide 3/4" minimum drain valve for piping larger than 1/2", except strainer blowdown valves shall be blowdown connection size. Provide 1/2" drain valve for 1/2" piping. If 3-piece ball valves are specified, use 2-piece ball valves with same construction.

### **2.3 CLEANROOM PROCESS CHILLED WATER AND AIR HANDLING UNIT CHILLED WATER (CPVC VALVES)**

- A. Diaphragm Valves
1. Weir type, self-draining, PTFE diaphragm backed by EPDM, non-rising stem, position indicator, stroke limit stops.
  2. Size 2" and smaller: Georg Fischer type 315
  3. Size 2-1/2" and larger: Georg Fischer type 317
- B. Ball Valves
1. True union type, full port, Viton seals, Teflon seats
  2. Georg Fisher type 346
- C. Sampling valves
1. Needle valve for sampling, Teflon seals
- D. Check Valves
1. Ball check valves, Viton seals, CPVC ball

## 2.4 LOW PRESSURE STEAM AND CONDENSATE SYSTEM VALVES (15 PSIG AND LOWER)

- A. Gate Valves:
1. 2" and Smaller: Steel body, weld end or threaded, solid wedge, rising stem, welded bonnet, stainless steel seat rings, malleable iron hand wheel, Class 800 (800 psi WP steam), conforming to MSS SP-80, Bonney Forge W-11-T.
  2. 2-1/2" and Larger: Steel body, OS&Y, bolted bonnet, renewable seat, solid wedge, flanged, Class 125 (125 psi WP steam), conforming to MSS SP-70, Milwaukee 1550.
- B. Globe Valves:
1. 2" and Smaller: Cast steel body, threaded, renewable TFE seat disc, union or screw-over bonnet, malleable iron handwheel, Class 800 (800 psi WP steam), conforming to MSS SP-80, Bonney Forge W-31-T.
  2. 2-1/2" and Larger: forged steel body, flanged or weld ends, bolted bonnet, renewable stainless steel seat and disc, Class 300 (300 psi 860 kPa WP steam), conforming to MSS SP-85, Milwaukee 3065.
- C. Swing Check Valves:
1. 2" and Smaller: ASTM B62, bronze body, threaded, regrinding, Y-pattern swing type, renewable TFE seat disc, Class 300 (300 kPa WP steam), conforming to MSS SP-80, Milwaukee 510.
  2. 2-1/2" and Larger: cast steel body, bronze or brass trim, or bronze mounted, renewable seat and disc, Class 150 (150 psi WP steam), conforming to MSS SP-71, Milwaukee 1570..
- D. Spring Loaded Check Valves (Condensate Pump Discharge):
1. 2" and Smaller: stainless steel body, threaded, stainless steel trim, 600 psi WOG, similar to Mueller Fig. 303-HT.
  2. 2-1/2" and Larger: iron body, wafer type, stainless steel trim, 200 psi WOG, Mueller Sure Check No. 71, or Duo-Check II.
- E. Shut-Off Valves:
1. Use gate valves as specified above.
- F. Drain Valves:
1. Gate valve as specified above with hose thread adapter and cap. Provide 3/4" minimum drain valve size except strainer blowdown valves to be blowdown connection size.

## 2.5 WATER RELIEF VALVES

- A. Manufacturers: Kunkle, Consolidated, Thrush, Watts, Cash-Acme, Lonergan, Keckley, or B & G. Iron or bronze body, with non-ferrous seat and designed for maximum working pressure of 150psig.
- B. Valves to conform to State Requirements and have ASME Stamps.

## **2.6 GAUGE VALVES**

- A. Unless otherwise indicated, gauge valves for steam, steam condensate and feedwater services shall be gate valves. Gauge valves for all other services shall be needle valves, brass body, 2000 psig, 300°F similar to Trerice Model 735. Gauge valve size shall match gauge pipe size as specified in Section 23 2116 - Pipe and Pipe Fittings.

## **2.7 CHAIN WHEEL OPERATORS**

- A. Similar to Babbitt cast iron or ductile iron adjustable sprocket rims and chain guides. Use galvanized or brass chain and chain closure links to form continuous loop of chain at each operator.

## **PART 3 EXECUTION**

### **3.1 GENERAL**

- A. Install valves as shown on plans, details and according to manufacturer's installation recommendations.
- B. After piping systems have been pressure tested and put into service, but before final adjusting and balancing, inspect valves for leaks. Adjust, replace packing or replace valves to stop leaks.
- C. Install control valves furnished under Control Systems. Provide increaser and decreaser fittings as required.
- D. Refer to Section 23 2116, Part 3 for reducing fittings requirement for valves smaller than pipe size.
- E. Provide chain operators for manually operated valves 4" and larger, located more than 8 ft above equipment room floor.

### **3.2 SHUT-OFF VALVES**

- A. Provide shut-off valves at all equipment, at riser take-offs at each floor, and at each automatic valve for servicing.
- B. Install steam system shut-off valves in horizontal piping. Shut-off valves are not allowed in vertical piping.

### **3.3 BALANCING VALVES**

- A. Provide balancing valves where indicated on drawings and as required for complete balancing of water systems.
- B. Provide straight inlet and outlet pipe length in accordance with manufacturer's recommendation.

- C. For buildings with multiple stories, provide balancing valve in return line at riser take-offs at each floor. Provide shut off valve in supply line at each riser take-off.

### **3.4 GAUGE VALVES**

- A. Provide gauge valves at each pressure gauge as shown and at each pressure tapping where pressure sensing tubing is connected.

### **3.5 DRAIN VALVES**

- A. Provide drain valves at all low points of piping systems for complete drainage of systems.

### **3.6 WATER PRESSURE REGULATING VALVES**

- A. Set valves for pressure required or as scheduled.

### **3.7 WATER RELIEF VALVES**

- A. Unless otherwise indicated, provide one relief valve in each closed water system in the pump inlet piping.

### **3.8 SPRING LOADED CHECK VALVES**

- A. Provide spring loaded check valve in each pump discharge line.

### **3.9 SWING CHECK VALVES**

- A. Provide swing check valves at steam condensate lines if lifted at outlet of traps. Install check valve between trap and gate valve.

**END OF SECTION**





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## **SECTION 23 2120CR**

### **PIPING SPECIALTIES**

#### **PART 1 GENERAL**

##### **1.1 RELATED WORK**

- A. Section 23 0594CR – Water Systems Test Adjust Balance
- B. Section 25 3003CR – Process Control Instrumentation (Temperature and Pressure Sensing Requirements)
- C. Section 23 2118CR - Valves

##### **1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### **1.3 REFERENCE STANDARDS**

- A. Metal bellows expansion joints shall be constructed and applied in accordance with "Standards of the Expansion Joint Manufacturer's Association", 8th Edition, 2003.

##### **1.4 SUBMITTALS**

- A. Shop Drawings for all items in this Section including, but not limited to, the following:
  - 1. Manufacturer's name and model number
  - 2. Identification as referenced in the Documents
  - 3. Materials of construction
  - 4. Dimensional data
  - 5. Capacities/ranges
  - 6. Temperature/pressure ratings
  - 7. Pressure drop
  - 8. Expansion joint schedule indicating joint tag no., system, proximity to rotating or reciprocating equipment, required movement in all planes, service pressure, test pressure, service temperature, fluid velocity and cycles to failure (both thermally and seismically, if applicable).
  - 9. All other appropriate data.

#### **PART 2 PRODUCTS**

##### **2.1 MATERIALS**

- A. Unless otherwise specified, select devices for highest pressures and temperatures existing in respective systems in accordance with ANSI Specifications.

- B. Piping specialties in copper piping shall have bronze or brass body with solder ends.

**2.2 THERMOMETERS**

- A. Manufacturers: Taylor, Trerice, Weksler, Miljoco, Winters, or Weiss
- B. Pipeline mounted thermometers: 9" scale cast aluminum case and frame, clear acrylic plastic window front, permanently stabilized glass tube with mercury free indicating fluid, adjustable angle stem, extended neck suitable for insulated piping as required, and compatible with sockets as specified herein.
- C. Panel or remote mounted thermometers: vapor actuated dial type with remote bulb, 4-1/2" minimum diameter cast metal casing with double front. Sensing bulbs shall be of length to suit pipe diameter with extended necks as required for insulated piping, suitable for insertion in separable brass sockets as specified herein.
- D. Duct type thermometers: dial type with minimum dial size of 4-1/2" and maximum graduations of 2°F, complete with swivel mounting arrangement to permit up to 45° rotation for easy reading.
- E. Range of thermometer for particular installation shall extend from point at least 40°F below lowest point of equipment's or system's operating range to point at least 40°F above highest point of that range.

F. Range of thermometers shall be:

<u>Service</u>	<u>Scale Range</u>	<u>Increment</u>
Chilled Water	0°F to 100°F	1°F
Cleanroom Process Chilled Water	0°F to 100°F	1°F
Low Temperature Chilled Water	0°F to 100°F	1°F
Cleanroom Air Handling Unit Chilled Water	0°F to 100°F	1°F
Reclaim Water	0°F to 100°F	1°F
Steam Condensate	30°F to 300°F	2°F
Air (indoor)	0°F to 160°F	2°F
Air (outdoor)	-40°F to 100°F	2°F

- G. Thermometers by temperature control manufacturer meeting above Specification will be acceptable.

**2.3 THERMOMETER SOCKETS AND TEST WELLS**

- A. Brass construction for carbon steel piping with threaded connections suitable for thermometer bulbs and control sensing devices, well length suitable for pipe diameter with extended neck as required to suit pipe insulation. Trerice 5550 Series or approved equal.
- B. For test wells for stainless steel piping, use same material as piping.

## 2.4 PRESSURE GAUGES

- A. Manufacturers: Ashcroft, U.S. Gauge, Marsh, Trerice, Miljoco, Marshalltown, Winters or Weiss equal to Trerice 600 Series
- B. Minimum 4-1/2" diameter die cast aluminum case, glass or acrylic plastic window, phosphor bronze bourdon tube with bronze bushed movement, recalibration from front of gauge dial and 1/4" NPT forged brass socket.
- C. Gauge accuracy shall meet ANSI B40.1 Grade 1A (1% full scale).
- D. Reading range of gauges shall be:
- | <u>Service</u>                            | <u>Scale Range</u>            |
|---|-------------------------------|
| Chilled Water                             | 0 to 100 psig                 |
| Cleanroom Process Chilled Water           | 0 to 100 psig                 |
| Low Temperature Chilled Water             | 0 to 100 psig                 |
| Cleanroom air Handling unit Chilled Water | 0 to 100 psig                 |
| Reclaim Water                             | 0 to 100 psig                 |
| Low Pressure Steam                        | 30" mercury vacuum to 30 psig |
- E. Pressure Snubbers:
- 1/4" or 1/2" size, matching gauge pipe size as specified in Section 23 2116 - Pipe and Pipe Fittings, 1000 psig WP. Brass for carbon steel pipe or copper pipe. Stainless steel for stainless steel pipe.
- F. Coil Syphons:
- 1/4" or 1/2" size, matching gauge pipe size as specified in Section 23 2116, 500 psig WP. Material shall match gauge pipe material.

## 2.5 PRESSURE/TEMPERATURE TEST STATIONS

- A. Pete's plugs made by Peterson Equipment Company, Sisco, Super Seal by Flow Design Inc. (FDI), or approved equal.
- B. Test plugs shall be 1/4" or 1/2" NPT, brass body and cap, 1-1/2" length for non-insulated pipe and 3" length for insulated pipe, with Nordel self-closing valve cores, rated at 500 psig at 275°F, and shall receive either temperature or pressure probe with 1/8" OD.

## 2.6 PIPELINE STRAINERS

- A. Manufacturers: Metraflex, Mueller Steam Specialty, Hoffman, Hayward, Sarco, Keckley, Armstrong, Wheatley, Conbraco or Streamflo

**B. Liquid System:**

1. 2" and Smaller: full pipeline size, Y-type, with removable screen caps, cast iron, Class 250 (400 psi/150°F WOG), threaded ends for carbon steel piping and bronze, Class 150 (200 psi/150°F WOG), solder ends for copper piping. Screen caps shall have threaded blowdown connection.
2. 2-1/2" and Larger: full pipeline size, Y-type, Class 125 (200 psi/150°F WOG), cast iron, flanged ends. Furnish strainer with bolted screen retainer and off-center blowdown connection.
3. Liquid Service Screens: stainless steel with screen perforation as indicated below. For strainers serving equipment where manufacturer requires specific screen perforation, provide per manufacturer requirements. Maximum pressure drop shall be 4 ft WG through clean strainer.

<u>Pipe Size</u>	<u>Closed System</u>	<u>Open System</u>
2" and smaller	1/32" (20 mesh)	1/8"
2 1/2" to 4"	1/16"	1/8"
5" and over	1/8"	1/8"

**C. Steam and Condensate System (through 15 psig):**

1. 2" and Smaller: full pipeline size, Y-type, Class 250, cast iron, threaded ends with removable screen caps. Screen caps shall have threaded blowdown connection.
2. 2-1/2" and Larger: full pipeline size, Y-type, Class 125, cast iron, flanged ends. Furnish strainer with bolted screen retainer and off-center blowdown connection.

**D. Steam Service Screens:** stainless steel for low pressure and monel for high pressure with screen perforation size as indicated below. For strainers serving equipment where manufacturer requires specific screen perforation, provide per manufacturer requirements. Net area of screen shall be at least 4 times that of connected pipe.

<u>Pipe Size</u>	<u>Perforation Size</u>
2" and smaller	1/50" (30 mesh)
2 -1/2" to 10"	3/64" (.045")
12" and over	1/16" (.062")

**2.7 STEAM TRAPS**

- A. Manufacturers: Armstrong, Sarco, Hoffman, or Watts
- B. Trap bodies shall be suitable for minimum 1.5 times system pressure, but not less than 125 psig.
- C. Traps shall have threaded end connections.
- D. Unless otherwise indicated, determine trap capacity with the following safety factor, differential pressure and steam pressure at apparatus inlet. Minimum trap size (pipe connection size) shall be 3/4" for all types.
  1. Apply safety factor to maximum steam rate of apparatus served and at saturated steam temperature.

2. 0-15 psig steam:
  - a. Safety factor of 2:1 at 1/2-psi pressure differential
- E. Size main drip, end-of-main or drip-and-rise traps with 2:1 safety factor at full differential pressure for supervised warm-up load, but not less than 250 lb per hour and not smaller than 3/4" size.
- F. Where 2 traps are shown in parallel, each trap shall have full design capacity of equipment without safety factor.
- G. Thermostatic Traps:
  1. Cast brass body with removable cover, renewable stainless steel seats, plungers and diaphragm or bellows.
- H. Float and Thermostatic Traps:
  1. Cast iron or semi-steel body for steam pressures below 15 psig and cast steel body for steam pressures above 16 psig with removable cover, stainless steel float, diaphragm or bellows thermostatic operator, integral strainer and stainless steel valve mechanism.
- I. Inverted Bucket Traps for steam pressures below 15 PSI:
  1. Cast iron with removable cover, stainless steel bucket, and stainless steel valve mechanism assembly. Armstrong Series 880.

## 2.8 EXPANSION TANKS

- A. Manufacturers: Amtrol, Taco, Bell and Gossett, Armstrong, Wheatley, or Wessels
- B. Tanks shall be replaceable bladder type air pre-charged to initial fill pressure as scheduled. Furnish tank suitable for 125 psig WP, constructed, tested and stamped in accordance with ASME Code, and sealed-in elastomer bladder suitable for operating temperature of 240°F. Bladder shall be compatible with water and with ethylene and propylene glycol. Furnish mounting saddles for horizontal tanks and mounting base for vertical tanks. Furnish tanks with system connections; drain connections for floor-mounted tanks, and air charging valves.

## 2.9 AIR SEPARATORS

- A. Manufacturers: Bell and Gossett, Amtrol, Armstrong or Taco
- B. 1-1/2" and Smaller: Cast iron construction with steel diffuser tube, bottom and side threaded inlet connections, bottom and top threaded outlet connections, threaded top connection for air elimination, designed for maximum 125 psig WP.
- C. 2" and Larger: Cast iron or welded steel construction, flanged and/or threaded connections, perforated stainless steel air collector tube to direct air toward air elimination connection at top of unit, tangential water inlet and outlet connections, bottom blow down connections, constructed in accordance with ASME Boiler and Pressure Vessel Code and stamped for 125 psig design pressure.

## 2.10 PUMP SUCTION DIFFUSERS

- A. Manufacturers: Bell & Gossett, Armstrong, Mueller Steam Specialty, Wheatley or Taco
- B. Angle type body with inlet vanes and combination diffuser-strainer-orifice cylinder with 3/16" diameter openings, 175 psi WP, at 250°F. Orifice cylinder shall have free area of at least 5 times cross section area of pump suction opening. Furnish each unit with disposable fine mesh start-up strainers, gauge tapings and adjustable support foot to carry weight of suction piping.

## 2.11 AIR VENTS

- A. Manual Air Vents:
  - 1. Manufacturers: Bell & Gossett Model 4V, 125 psig at 210°F or approved equal. Use 1/2" ball valve for main pipes.
- B. Automatic Air Vents:
  - 1. Manufacturers: Amtrol, Watson McDaniel, B&G, or Hoffman
  - 2. Metal construction, non-corrosive working parts, 150 psig WP at 240°F
  - 3. Normal capacity vent shall be similar to B&G Model 87
  - 4. High capacity vent shall be float actuated and shall have minimum air elimination rate of 10 cfm at 100 psig, similar to B&G Model 107A.
- C. Thermostatic Air Vents:
  - 1. Balanced pressure type, cast bronze body, bronze bellows caged in stainless steel, stainless steel valve and seat, 1/2" threaded connection, 125 psig WSP, equal to Armstrong Model TV-2.

## 2.12 VACUUM RELIEF/BREAKERS

- A. Kadant Johnson Series VB-8 with brass body, stainless steel ball, EPR seat, stainless steel spring, suitable for pressures to 300 psig at 365°F, or Sarco Model VB-14.

## 2.13 FLOW ELEMENTS (MEASURING STATIONS) AND METERS

- A. Averaging Pitot Tube Flow Elements (2-1/2" and Larger):
  - 1. Manufacturers: Dieterich Standard, or Preso
  - 2. Elements shall be averaging differential pressure type consisting of sensing tube with 2 internal chambers; one for sensing upstream pressure and one for sensing downstream pressure.
  - 3. Furnish each flow measuring station complete with safety shut-off valves, quick coupling connections and permanent metal tag showing designed flow rates, meter readings for designed flow rates, metered fluid, line size and tag, station or location number. Annular measuring element shall be constructed of stainless steel. Stations shall be nipple section or weld insert type and be rated to 250 psi at 250°F.
  - 4. Hot tap type flow stations shall include isolation valve and packing gland retraction assembly. Connection shall be flange type. Station shall be rated to 250 psi at 250°F.

5. Portable differential pressure meter set shall be of totally dry single diaphragm type with min. 4-1/2" dial pointer indicator, 0" to 50" reading range, accuracy of  $\pm 3.0\%$  full scale, and wetted metal parts of brass or stainless steel. Meter shall include variable pulsation dampening control, integral equalizing valve, and 2 bleed valves.
6. Furnish meter set complete with master chart for direct conversion of meter readings to gpm rust proof carrying case, two minimum 10 ft rubber test hoses, with brass valves for quick connections to flow sensor. Meter shall become property of Owner.
7. Furnish elbow mounted Pitot tube measuring stations at locations where manufacturer's recommended straight pipe lengths are not available for straight pipe mounted measuring stations.

#### **2.14 STRAIGHTENING VANES**

- A. Manufacturers: Daniel Industries, Inc., Houston, Texas or approved equal
- B. Straightening vane assembly shall consist of series of carbon steel pipes firmly welded together and to line size pipe. Furnish vanes with class 150 psi flanges for insertion into piping system.

#### **2.15 WATER FILTERS**

- A. Manufacturers: Pall Corporation, Ronningen-Petter, Graver Technologies (Consler), FSI, Filterite or Parker Hannifin
- B. Housing shall be constructed of carbon steel for 150 psig WP, constructed in accordance with ASME Code, painted with manufacturer's standard paint.
- C. Filter access shall be with bolted and gasketed steel or cast iron head, threaded for 2" and smaller, flanged for 2-1/2" and larger.
- D. Cartridge Filter Media:
  1. Construct filter cartridges of disposable media with minimum media area of 4.5 square feet per cell.
  2. Cartridges to be capable of proper operation at pressure differentials up to 75 psig and temperature to 250°F.
  3. Furnish 3 sets of filter cartridges, 2 sets capable of removing 98% of solid particles 5 microns or larger and one set capable of removing 98% of solid particles 75 microns or larger. Use 75 micron filters at initial start-up. When loaded up, replace with 5 micron filters.
  4. To insure against by passing, provide positive seal on each cartridge stack consisting of internal tie rod and seal nut arrangement, or equivalent. Single continuous cartridge per stack to be used.

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## **PART 3 EXECUTION**

### **3.1 GENERAL**

- A. Install piping specialties as indicated on plans, details and according to manufacturer's recommendations.

### **3.2 THERMOMETERS**

- A. Install thermometers in thermowells sockets in locations indicated.

### **3.3 THERMOMETER TEST WELLS**

- A. Install test wells in locations as shown and at each point where temperature-sensing device is required under Control Systems.

### **3.4 PRESSURE GAUGES**

- A. Install gauges for services other than steam with pressure snubbers and gauge valves.
- B. Install gauges for steam service with coil syphons and gauge valves.

### **3.5 PRESSURE GAUGE TAPPING**

- A. Install tappings with gauge valves at each point where sensing device is required under Control Systems and at gauge locations as shown.
- B. Use threadolets or tee fittings to mount gauge tappings or test stations. Install fittings for side mounting to avoid collection of air or dirt.

### **3.6 PRESSURE/TEMPERATURE TEST STATIONS**

- A. Pete's plug may be used in lieu of thermometer test well and pressure gauge tappings.
- B. Use threadolets or tee fittings to mount gauge tappings or test stations. Install fittings for side mounting to avoid collection of air or dirt.

### **3.7 PIPELINE STRAINERS**

- A. Provide drain valve at each strainer blowdown connection with hose threaded adapter and cap. Valve size shall be same as blowdown connection size.
- B. Install strainers in steam system on entering side of all automatic control valves and as indicated elsewhere.
- C. Install strainers in water systems on suction side of all pumps, entering side of automatic control valves of heating and cooling coils of air handling units, and as indicated elsewhere.
- D. Install clamped cover basket strainers in condenser water system as indicated.



### **3.8 STEAM TRAPS**

- A. Install steam traps on discharge side of all steam using terminal apparatus, at steam headers, at steam mains, at end of steam mains, at end of branch piping exceeding 10 ft, at points where steam piping must rise, and elsewhere as indicated on drawings. Individually trap each coil of steam coil bank. Unless otherwise indicated, provide steam main drip/traps at intervals not exceeding 300 ft.
- B. Install to permit gravity flow of condensate to trap.
- C. Install valved test tee on discharge of each trap.
- D. Unless otherwise shown, do not lift condensate from discharge of any trap without written permission of Engineer.
- E. Support traps weighing over 25 lbs independently of connecting piping.

### **3.9 AIR SEPARATORS**

- A. Provide valved blow down connections and extend drain piping to nearest floor drain.

### **3.10 PUMP SUCTION DIFFUSERS**

- A. Pipe blow down to the nearest floor drain with drain valve at unit.
- B. Remove disposable fine mesh start-up strainers after start-up. Clean permanent strainer and replace after pipe cleaning process.

### **3.11 AIR VENTS**

- A. Install manual air vents at all high points in water systems where air may collect and where shown on drawings.
- B. Install automatic air vent at top of air separator and where shown on drawings. Provide shut-off valve to isolate air vent from system. Pipe automatic air vent to the nearest floor drain.
- C. Install high capacity automatic air vent at air separator.

### **3.12 THERMOSTATIC AIR VENTS**

- A. Install thermostatic air vents where shown. Install vents at the highest points of steam chambers. Locate vents higher than outlet connections to chambers.

### **3.13 VACUUM BREAKERS**

- A. Install vacuum breakers at steam condensate outlet from steam heating coils, at steam-to-water heat exchangers, and as required for proper condensate drainage at any other steam using apparatus.

### **3.14 FLOW ELEMENTS/FLOWMETERS**

- A. Flow elements/flowmeters located in common piping after multiple pump discharge lines shall be furnished with hot tap feature.
- B. If flow elements/flowmeters are furnished by Control Contractor, this Contractor shall install them in accordance with manufacturer's installation instructions. Wiring of flowmeters will be provided by, Control Contractor.

### **3.15 WATER FILTERS**

- A. Install water filter in by-pass arrangement across system pumps. Allow clearance at top of filter for removal of cover and filter changes.
- B. Install shut-off valves at filters and pressure gauges for measuring pressure drop across filters.

**END OF SECTION**

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## SECTION 23 2123CR

### PUMPS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 20 0513 - Motors
- B. Section 20 0514 - Variable Frequency Drive (VFD) System
- C. Section 23 0550CR - Vibration Isolation
- D. Section 23 2120CR - Piping Specialties

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 SUBMITTALS

- A. Shop Drawings including, but not limited to, the following:
  - 1. Specification Compliance Review: This specification shall be marked up line-by-line with "C" indicating the product Complies with the Specification, or "D" indicating the product Does Not Comply or Deviates from the Specification section. For any line marked "D" or does not comply, a written explanation shall accompany why this product meets the intent of the specification or cannot comply with the specification.
  - 2. Manufacturer's name and model number
  - 3. Identification as referenced in the documents
  - 4. Capacities/ratings
  - 5. Pump curves with operating point clearly indicated. For parallel pump applications, indicate operating point of combined case as well as operating point of only one pump.
  - 6. Motor data (refer to Section 20 0513 - Motors)
  - 7. Seals
  - 8. Materials of construction
  - 9. Dimensions and weights
  - 10. Manufacturer's installation instructions
  - 11. All other appropriate data
- B. Complete equipment data sheet attached at end of this Section for each piece of equipment and submit with Shop Drawings. Shop Drawings will be returned without review if data sheets are not provided for each piece of equipment and if data sheet is not filled out completely.

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#### 1.4 DESIGN CRITERIA

- A. Pump sizes, capacities, pressures and operating characteristics shall be as scheduled.
- B. Pumps shall meet or exceed operating efficiencies scheduled.
- C. Furnish pumps complete with motors, impellers, drive assemblies, bearings and accessories as hereinafter specified. Furnish pump couplings with OSHA compliant coupling guards.
- D. Where pump is indicated for parallel operation, scheduled conditions are for that pump with two pumps operating; i.e., total system flow rate is twice that scheduled for single pump. When only one of two pumps is operating, operating point of that pump must fall within manufacturer's recommended operating range.
- E. Select motor with sufficient hp rating for non-overloading operation over entire pump curve.
- F. When fan is scheduled to be served by a VFD the motor shall be inverter duty and have shaft grounding kits installed. Refer to section 20 0513 Motors.
- G. Furnish each pump and motor with nameplate giving manufacturer's name, serial number of pump, capacity in GPM and head in feet at design condition, hp, voltage, frequency, speed and full load current.
- H. Test pumps hydraulically at 150% of rated pressure per Hydraulic Institute Standards, clean and paint before shipment. Manufacturer shall certify all pump ratings.
- I. Pumps shall operate without objectionable noise or vibration.
- J. After completion of balancing, if water balancing results in pump discharge balancing valve being closed 50% or more, replace or trim impeller so that balancing valve is opened at least 75% to maintain design flow rate. Where pumps are driven by VFDs, balancing should be performed with pumps at design speed.
- K. Furnish one spare seal for each pump to Owner.
- L. Head for pumps submitted for pumping through evaporators and condensers of chillers and water coils shall be increased, if necessary, to match the equipment approved for project.

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## **PART 2 PRODUCTS**

### **2.1 END SUCTION CENTRIFUGAL PUMPS (FLEXIBLE COUPLED)**

- A. Manufacturers: Bell and Gossett, Taco, Armstrong, Peerless, Aurora, PACO or Goulds
- B. Pumps shall be base mounted, end suction, flexible coupled, cast iron casing, bronze fitted with working pressure of 175 psi and continuous operating temperature of 225°F. Pump design shall allow for servicing of impeller and bearing assembly without disturbing piping, motor or requiring shaft realignment.
- C. Casings shall have tapped and plugged openings for vent, drain, and suction and discharge gauge connections.
- D. Impellers shall be single suction enclosed type made of bronze, hydraulically and dynamically balanced to ANSI/HI 1.1-1.5-1994, Section 1.4.6.1.3.1, Figure 1.106 Balance Grade G6.3, keyed and locked to pump shafts and protected by replaceable bronze shaft sleeves.
- E. Pump shafts shall be high strength carbon steel, sealed and gasketed from pumped fluid.
- F. Chilled water and hot water pumps shall be furnished with mechanical seals with carbon rotating faces, ceramic stationary seats, Buna-N elastomer and 316 SS spring, rated up to 225°F continuous operation.
- G. Bearing assemblies shall be cast iron with regreasable ball bearings
- H. Spacer type couplings or couplings with extended hubs shall be used to allow for pump servicing.
- I. Pumps shall be furnished with groutable steel base plates
- J. Pump bases shall be furnished with drip pans and drain connections for pumps with packed stuffing box shaft seals.

### **2.2 IN-LINE CENTRIFUGAL PUMPS**

- A. Manufacturers: Bell and Gossett, Taco, Armstrong or Aurora
- B. Pumps shall be pipeline mounted, single suction type with cast iron casing, bronze fitted with working pressure of 175 psi and continuous operating temperature of 225°F.
- C. Casings shall have tapped and plugged openings for vent, drain, and suction and discharge gauge connections.
- D. Impellers to be single suction enclosed type made of bronze, hydraulically and dynamically balanced, keyed and locked to pump shafts and protected by replaceable bronze shaft sleeves.

- E. Impellers shall be directly hung from motor shafts without using flexible couplings.
- F. Pump shafts shall be high strength carbon steel or alloy steel, sealed and gasketed from pumped fluid.
- G. Pumps shall be furnished with mechanical seals of single unbalanced type with carbon rotating faces, ceramic stationary seats and Buna-N elastomer.
- H. Bearing assemblies and motors shall have oil lubricated sleeve bearings or regreasable ball bearings.

### **PART 3 EXECUTION**

#### **3.1 INSTALLATION**

- A. Install pumps in strict accordance with manufacturer's instructions to avoid any stress and misalignment.
- B. Set base mounted pumps on concrete bases, or concrete inertia base, level and bolt down prior to grouting. Fill entire base with non-shrinking grout. Use end caps during grouting to prevent overflow when end caps are not integral with base plates.
- C. Align flexible coupled pumps after base grouting is complete. Align pump and motor in all four planes: vertical angular, horizontal angular, vertical parallel and horizontal parallel. Alignment shall be within the recommended value by manufacturer, but not over 1/64" for parallel alignment and 1/64" per inch of coupler radius for angular alignment. Record and submit all results of alignment procedure to Engineer. After alignment is complete, pin pump and motor to base.
- D. Install full line size spring loaded check valve in pump discharge piping. Balancing valves shall be used only on constant speed pumps.
- E. Where pump connection size and indicated line sizes are not identical, provide necessary concentric reducers/increasers for vertical piping at pump connection and eccentric reducers/increasers for horizontal piping at pump connection. Install eccentric reducers/increasers with top of pipe level. Valves and piping specialties shall be full line size as indicated on drawings.

#### **3.2 STARTUP**

- A. Verify that piping system has been flushed, cleaned and filled.
- B. Prime pump, vent air from casing and verify that rotation is correct. To avoid damage to mechanical seals, never start or run pump in dry condition.
- C. Verify lubrication of motor and pump bearings and lubricate properly in accordance with manufacturer's recommendation and Section 20 0000, Part 3, under LUBRICATION.

- D. After several days' operation, verify removal of disposable startup strainer in suction diffuser and turn them over to Owner.
- E. Perform field mechanical balancing, if necessary, to meet vibration tolerance specified in Section 23 0550 - Vibration Isolation.

**END OF SECTION**





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## SECTION 23 2514CR

### CHEMICAL TREATMENT SYSTEMS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 23 2116CR - Pipe and Pipe Fittings

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 SUBMITTALS

- A. Shop Drawings for each system including, but not limited to, the following:
  - 1. Manufacturer's name and model number
  - 2. Capacities/ratings
  - 3. Chemicals; description of chemicals, its composition and function
  - 4. Operating sequence
  - 5. Composite wiring diagrams
  - 6. Materials of construction
  - 7. Dimensions and weights
  - 8. Manufacturer's installation instructions
  - 9. All other appropriate data
- B. Submit overall installation diagram for each system locating chemical injecting points, bleed-off assemblies, water meters, number of tanks and pumps, and field piping.
- C. Submit complete make-up water analysis.
- D. Submit directly to Owner, Material Safety Data Sheets (MSDS) for all chemicals used in chemical treatment systems. Include with MSDS written notice of Owner's responsibility to notify its employees of the use of those chemicals.

##### 1.4 OPERATION AND MAINTENANCE DATA

- A. Provide for services of manufacturer's trained, representative to approve installation, and instruct Owner's representative in operation, testing and maintenance of each system.
- B. Include data on chemical feed pumps, meters, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test and adjust procedures including target concentrations.

## 1.5 MAINTENANCE SERVICE

- A. Provide initial supply of chemicals, University of Minnesota shall take over chemical treatment systems at date of substantial completion.

## 1.6 WATER ANALYSIS

- A. Submit complete water analysis and results of performance test of each system signed by manufacturer's service representative.
- B. Water analysis shall include the following:
  - 1. Hot, Air Handling Unit Chilled, Cleanroom Process Chilled and Chilled Water:
    - a. Hardness
    - b. pH
    - c. M" alkalinity
    - d. Inhibitor level
    - e. Total dissolved solids
    - f. Temperature
  - 2. Glycol Water:
    - a. Corrosion inhibitor level
    - b. Percentage of glycol by volume
    - c. Freeze point
    - d. "M" alkalinity
    - e. Conductivity
    - f. Test data for dilution water including total dissolved hardness and conductivity. (If on-site deionizer is used for dilution water, provide test of initial and final water coming from deionizer.)

## 1.7 DESIGN CRITERIA

- A. Periodic test procedure and chemical shall be recommended for each system.
- B. Chemicals shall be suitable for pipe material, fluid medium and intended treatment.
- C. Materials of construction for equipment used shall be compatible with water treatment chemicals provided.
- D. Treat the following systems:
  - 1. Air handling unit chilled water
  - 2. Cleanroom process chilled water
  - 3. Glycol-water (Low temperature chilled and reclaim water)
- E. Provide initial chemical treatment and equipment for all systems based on complete system fluid analysis, including make-up water, prior to equipment installation.
- F. Initial supply of chemicals for chemical treatment of each system shall be adequate for start up and testing period, for the time systems are being operated by Contractor for temporary heating and cooling, and for 1 yr after start-up of system.
- G. Inhibitor for closed water systems shall use nitrites or phosphonate as primary inhibitor.

## **1.8 WATER QUALITY REQUIREMENTS**

- A. Minimum water quality requirements for closed hot and/or chilled water systems shall be as follows:
1. pH 9.0 - 10.5
  2. TDS
  3. Conductivity
  4. Iron
  5. Dissolved Oxygen <0.04 ppm
  6. Ryznar Index >6.0
  7. Suspended Solids ≤10 micron
  8. Bacteria Counts (Chilled Water System) ≤100 cfu per mL

## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Manufacturers: Betz-Dearborn, Diversey Water Technologies, Nalco, HOH Chemical, or Ecolab

### **2.2 PIPING SYSTEM CLEANER**

- A. Use cleaning compound similar to Nalco 2567 to remove organic soil, hydrocarbons, flux, pipe mill varnish, pipe compounds, iron oxide, and like deleterious substances, with or without inhibitor, suitable for system metals without deleterious effects. Cleaner shall not contain phosphate.

### **2.3 CLEANROOM PROCESS CHILLED WATER, HEAT RECOVERY WATER, LOW TEMPERATURE CHILLED WATER AND AIR HANDLING UNIT CHILLED WATER CHEMICAL TREATMENT**

- A. Provide by-pass type batch feeder to receive chemicals in liquid or pellet form. Chemical treatment shall control corrosion, scale, and biological growths.
- B. Feeder shall have minimum capacity of 5 gal and shall be constructed of steel with minimum working pressure of 150 psig. Feeder shall be complete with air vent, drain valve, inlet ball valve, and outlet balancing valve, and unions.
- C. Furnish feeders with screw type cover with replacement gaskets, or valved funnel opening and with exterior prime coat finish.

### **2.4 GLYCOL WATER TREATMENT (RECLAIM AND LOW TEMPERATURE CHILLED WATER)**

- A. Provide glycol fill pump and tank assembly as shown.
- B. Assembly shall be completely packaged, fully automatic, factory piped, wired and have the following:
1. 50 gal polyethylene tank
  2. Bronze rotary gear pump, 1/3HP hp, single-phase, 115 V, 1725 rpm motor
  3. Steel frame for mounting tank and pump
  4. NEMA 1 control panel including:

- a. Hand-off-auto selector switch for pump
  - b. Pump "on" indicator light
  - c. "low" tank level indicator light and alarm
  - d. Motor Starter with overload protection
  - e. Terminal strip for connection to 115 V/60 Hz power source
5. Pressure switch for controlling glycol addition
  6. Liquid level switch for low level pump shut off and alarm
  7. Suction PVC tubing and fittings with ball valve and strainer
  8. Discharge Schedule 80 PVC pipe and fittings with ball valve, check valve, pressure ga, pressure relief valve with return to tank.
  9. Dry contact for remote alarm
- C. Assembly shall be similar to HOH Model GLC-10 or Neptune Glycol Feed Systems.
- D. Fill pump shall be capable of 1.5 gpm at 50 psi.
- E. Mix treated glycol with water in ratio of 30% glycol by volume.
- F. Glycol shall be pre-treated ethylene glycol Dow Therm SR-1, Nalco 2812, HOH ETH KOOL 39 or Intercool NFE, with corrosion inhibitors and stability compounds.
- G. Use pre-diluted solution produced by glycol manufacturer. Dilution water shall be distilled water, deionized water or water having chloride and sulfate levels less than 25 ppm each, total hardness less than 60 ppm and iron less than 0.5 ppm. If glycol needs to be diluted at site, submit test results of water for approval prior to mixing. .

### **PART 3 EXECUTION**

#### **3.1 ELECTRICAL WIRING**

- A. Provide all field electrical wiring for system, in metal conduit and in accordance with Division 26 and all applicable Electric Codes.

#### **3.2 APPLICATION OF CHEMICALS**

- A. Apply initial chemical treatment for each system after systems have been cleaned and flushed.
- B. Add, adjust or modify treatment based on results of period tests until turned over to Owner.

#### **3.3 PERFORMANCE TEST**

- A. Conduct performance test for each system to determine required capacity and performance of chemical treatment system. Refer to Part 1 for water analysis and water quality requirements.
- B. Conduct water quality test in all systems weekly and submit test result reports to Mechanical Contractor and Owner until project is turned over to Owner.

- C. Conduct water quality tests before and after new work tie-in to existing systems.

### **3.4 BATCH FEEDERS**

- A. Install in bypass arrangement at pump discharge as indicated.

### **3.5 PIPE CLEANING**

- A. General:
  1. Piping systems shall be cleaned before they are used for any purpose except pressure tests, which shall be conducted before cleaning. Add cleaner to closed systems at concentrations as recommended by cleaner manufacturer. Remove water filter elements from system before starting circulation.
  2. Use neutralizer agents on recommendation of system cleaner supplier and approval of Architect/Engineer.
  3. Remove, clean, and replace strainer screens or filters.
  4. Inspect, remove sludge, and flush low points with clean water after cleaning process is completed.
  5. New piping system shall not be connected to existing system for operation until flushing and cleaning have been completed. Obtain permission from Owner prior to opening up new work to existing system.
- B. Water Systems:
  1. Piping systems shall be filled, vented and circulated employing chemical cleaner solution for period of at least 24 hrs or more in accordance with manufacturer's recommendations and job site chemical tests. Bring concentration to level, which raises M Alkalinity to manufacturer's recommended value above that for existing water used for fill. Conduct chemical tests to verify levels and submit results to Architect/Engineer. Flush detergent clear with continuous draining and make-up water fill for period of at least 12 hrs or more until original M Alkalinity level is achieved (or until pH of system water is within 0.5 pH of make-up water). Conduct chemical tests to verify levels and submit results to Architect/Engineer. When cleaning process is complete, replace strainers or filters and reconnect permanent pumping apparatus.
- C. Steam Systems:
  1. Apply heat to produce steam for piping system and maintain for 8 hrs minimum. Bypass traps and waste condensate. When cleaning process is complete, replace strainers and connect traps for service.

### **3.6 GLYCOL WATER TREATMENT**

- A. Provide glycol water treatment for Heat Recovery System and Low Temperature Chilled Water System.
- B. Follow glycol manufacturer's recommendation for pipe cleaning, flushing and fill preparation and procedure.

- C. City water is not allowed for diluting glycol. Use dilution water specified in Part 2.

**END OF SECTION**

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## SECTION 23 3114CR

### DUCTWORK

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 20 0529 - Mechanical Supporting Devices
- B. Section 20 0700 - Mechanical Systems Insulation
- C. Section 23 0550CR - Vibration Isolation
- D. Section 23 0595CR - Air Systems Test Adjust Balance
- E. Section 25 3002CR - Process Control Valves and Dampers
- F. Section 23 3314CR - Ductwork Specialties

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 SUBMITTALS

- A. For each duct system, submit schedule utilizing reinforcement tables from SMACNA HVAC Duct Construction Standards where applicable. Each duct system schedule shall include, but not be limited to, the following:
  - 1. Name of Contractor/manufacturer fabricating each duct system
  - 2. Material and gauge
  - 3. Pressure class
  - 4. Transverse joint type and length and reinforcement rigidity class with designated joint T number or proprietary duct connection if utilized for each system
  - 5. Certified test results of proprietary joint products, if used, tested in accordance with SMACNA procedures
  - 6. Intermediate reinforcement spacing and rigidity class with metal angle dimensions and gauge
  - 7. Type of longitudinal seam
  - 8. Fitting construction details
  - 9. Support methods including spacing, upper attachments, and lower attachments
  - 10. Sealant and gasket
  - 11. Sealing class
- B. Duct leakage testing methods, apparatus and apparatus certification signifying meter is in conformance with ASME Requirements for testing meters.

- C. Duct liner including data on thermal conductivity, air friction correction factor, and temperature and velocity limitation.
- D. Submit the following information for welded sheet metal ductwork:
  - 1. Welding Procedure Specification (WPS) for welded joints. Form to be similar to ANSI/AWS D9.1-90 Code, Appendix "D".
  - 2. Procedure Qualification Record (PQR) for each WPS. Form to be similar to ANSI/AWS D9.1-90 Code, Appendix "E".
  - 3. Welder Qualification Test Record (satisfactory performance) for each field or shop welder. Form similar to ANSI/AWS D9.1-90 Code, Appendix "F".

#### 1.4 DESCRIPTION

- A. Furnish and erect ductwork free of objectionable vibration, chatter, and pulsations. Verify dimensions at site, making field measurements and drawings necessary for fabrication and erection.
- B. Duct sizes indicated are net inside dimensions.
- C. Where size for a duct segment is not indicated, the duct segment size shall be equal to the largest duct segment to which it is connected. Transition to smaller size shall occur on side of fitting where smaller size is indicated.

#### 1.5 DESIGN CRITERIA

- A. All products shall conform to NFPA 90A, and shall possess flame spread rating of not over 25 and smoke developed rating no higher than 50.
- B. Unless otherwise indicated, construct all ductwork of galvanized sheet metal for pressure class not less than +2" WG for positive pressure ductwork and not less than -2" WG for negative pressure ductwork.
- C. Ductwork shall comply with Local, State and Federal requirements.
- D. Unless otherwise indicated, pressure class for fume hood exhaust ductwork between exhaust fan inlet and exhaust valve outlet shall be equal to static pressure at exhaust fan inlet but not less than -4" WG.
- E. Unless otherwise indicated, pressure class for constant air volume system ductwork shall be equal to external static pressure (fan entrance or discharge pressure minus associated unit internal component pressure drop), but not less than + or - 2" WG.
- F. Duct transverse joints and reinforcement material, including angle ring flanges and stiffeners, shall be of same material as duct.
- G. Except as modified in this Section of specifications, use material, weight, thickness, gauge, construction and installation methods as outlined in the following SMACNA publications:
  - 1. HVAC Duct Construction Standards, Metal and Flexible, 3<sup>rd</sup> Edition, 2005, for rectangular and round ductwork up to positive 10" WG and negative 10" WG and flat oval ductwork up to positive 10" WG.



- a. Internal tie rods or bracing are not allowed for ductwork 36" and smaller. Tie rods shall be 1/2", 3/4", 1", or 1-1/4" galvanized steel EMT/conduits with bolt assembly consisting of rubber washer and friction anchored threaded insert similar to Ductmate Easyrod or PPI Condu-Lock.
  - b. Internal tie rods are not allowed for welded ductwork and special exhaust systems, such as fume hood exhaust, BSC exhaust, animal room exhaust, BSL-3 exhaust, cagewash exhaust, shower room exhaust, kitchen hood exhaust, dishwasher exhaust, etc.
  - c. Midpanel tie rods described in SMACNA Addendum No. 1, November 1997, are not allowed.
2. Round Industrial Duct Construction Standards, 2nd Printing 1999.
  3. Round Industrial Duct Construction Standards, 2nd Edition, September, 1999.
  4. Rectangular Industrial Duct Construction Standards, 8th Printing, 1997.
  5. Accepted Industry Practice for Industrial Duct Construction, 1st Edition, 4th Printing, 1988, for round ductwork -4" to -20" WG (Table 1-A) and for rectangular ductwork -4" to -20" WG (Table 2-A).

## 1.6 WELDING REQUIREMENTS

- A. The following requirements cover arc and braze welding of nonstructural sheet metal ductwork for HVAC, architectural metal and other FDA process applications where pressures do not exceed 120" WG (positive or negative). These requirements also apply to welding of structural members whose sole purpose is stiffening, supporting, or reinforcing of sheet metal material, as well as attachment of brackets or other accessories/components required to provide complete systems.
- B. Procedure and Qualification:
  1. Welding Procedure Specification (WPS) and Procedure Qualification Record (PQR) shall be prepared by installing contractor and/or fabricator prior to execution of related work. Qualification of welding procedure shall meet or exceed requirements of the latest revision of American Welding Society, Sheet Metal Welding Code ANSI/AWS D9.1.
  2. Provide certification of satisfactory performance testing for all welders and welding operators, which provide welding services on Project.
  3. Establish and provide written quality assurance/quality control (QA/QC) procedures to ensure compliance with specification requirements. Clearly identify appropriate steps for safe welding procedures (review Appendix J of D9.1) including additional safety material, screens, eye, personnel and clothing protection, fire suppression equipment, and fume extraction equipment needed adjacent to welding work area.

## PART 2 PRODUCTS

### 2.1 GALVANIZED STEEL SHEET

- A. First quality, Lock Former Quality (LFQ), cold rolled, open hearth soft steel sheet capable of double seaming without fracture, ASTM A924 or ASTM A653. Galvanized coating shall be G90.

- B. Use G90 Galvaneal or Zincgrip where painting is specified.

## 2.2 STAINLESS STEEL SHEET

- A. First quality, cold rolled annealed, pickled, ASTM A240 and A480, Finish No. 2B for concealed work and Finish No. 4 for exposed work. Unless otherwise indicated, use Type 316L.

## 2.3 TEFLON COATED STAINLESS STEEL DUCTS

- A. Manufacturers: Fab-Tech Inc., Viron International Co., or approved equal. Pure Guard SS (ECTEF fluoropolymer) as manufactured by Composites USA is an approved equal.
1. Fab-Tech Incorporated (PSP PermaShield Pipe)
    - a. 480 Hercules Drive, Colchester VT 05446-6800
    - b. (802) 655-8800
  2. Viron International Co.
    - a. 505 Hintz, Owosso MI 48867-9603
    - b. (989) 723-8255
  3. Composites USA
    - a. One Peninsula Drive North East, MD 21901
    - b. (410) 287-2700
- B. Qualifications
1. Manufacturer connections shall be made in accordance with procedures established by the as described in the product literature and in the "Installation and Assembly Techniques" video.
  2. Use 304 stainless steel.
  3. Teflon® ETFE as manufactured by E.I. Du Pont de Nemours and Company or ECTEF fluoropolymer
    - a. 532-6005 Primer
    - b. 532-6012 Top Coat
  4. ECTEF fluoropolymer
  5. Wall thickness per SMACNA.
- C. Fabrication, Erection, Testing and Examination
1. Fabrication, erection, testing, and examination of installation shall be done in accordance with the latest edition of SMACNA Industrial Duct Construction Standard.
  2. On site spark testing of coating, if needed, shall be performed at 2500 volts DC.
- D. Cleaning
1. When stored inside protect from dirt and debris. When stored outside, store above ground and enclose with waterproof wrapping to protect from dirt and debris.
- E. Ductwork – Teflon Coated
1. Low carbon 300 series stainless steel duct per SMACNA, longitudinal seams shall be fusion welded with no weld seam filler. All ducts shall be interiorly finished with Teflon® ETFE\* thermoplastic resin coating consisting of a prime coat 2 to 3 mil thick and a top coat 7 to 8 mils thick. All coated surfaces shall pass spark test at the factory using a DC spark tester set at 480 volts per mil.

See Factory Mutual research Standard 4922. Duct manufacturer shall have FM 4922 approval prior to quotation and at least 5 years experience coating FM approved duct products.

F. Fittings – Teflon Coated

1. VS flange - Low carbon 300 series stainless steel. PSP-EZ Van Stone angle ring fittings, dampers, blast gates, etc. Fabricated and coated as specified under duct. Gasket and hardware same as specified under joints, supplied by manufacturer.

G. Joints – Teflon Coated

1. Stainless steel Van Stone 300 series stainless steel rolled angle flange with 100% expanded PTFE joint sealant gasket. SAE grade 5 plated high strength fasteners. Torque values and hole patterns from manufacturer product literature. Gasket and all hardware to complete joints to be supplied by manufacturer.

**2.4 FLEXIBLE DUCT**

- A. Flexible duct is not allowed.

**2.5 GLASS FIBER DUCT LINING**

- A. Glass fiber duct lining is not allowed.

**2.6 MANUFACTURED ROUND DUCTWORK (POSITIVE PRESSURE)**

A. Single Wall:

1. Manufacturers: Ajax, Lindab, Semco or United McGill, equal to United McGill Uni-Seal duct and fittings suitable to positive 10" WG.
2. Ducts shall be machine formed round and/or flat oval as shown on drawings, constructed of G90 galvanized steel. Use spiral lockseam construction. Longitudinal seam construction may be used for ductwork over 80" diameter with minimum 16 ga. Use fittings as indicated on drawings, as specified, and as required in accordance with manufacturer's published data.
3. Unless otherwise indicated, connection shall be slip type with minimum 2" insertion length or flanged joint in accordance with manufacturer's recommendations. When flange joints are required, use Van Stone angle rings welded to duct.
4. Internal bracing is not allowed.

**2.7 MANUFACTURED ROUND DUCTWORK (NEGATIVE PRESSURE)**

- A. Manufacturers: United McGill Industrial duct and fittings. Semco and Lindab are acceptable manufacturers, provided meeting requirements in this Section.
- B. Ducts shall be machine formed round duct constructed of G90 galvanized steel. Use spiral lockseam construction unless otherwise indicated. Use fittings as indicated on drawings, as specified, and as required in accordance with manufacturer's published data.

- C. Connection shall use slip coupling, angle ring or Van Stone connectors in accordance with manufacturer's recommendations.
- D. Round spiral duct gauge/reinforcement shall be as follows:

<u>Duct Diameter</u> <u>(Inches)</u>	<u>-10" to -20" WG</u> <u>Gauge/Reinforcement</u>
3 - 7	26 ga
7-1/2 - 8	26 ga
8-1/2 - 12	24 ga
12-1/2 - 15	22 ga
16 - 18	20 ga
19 - 22	18 ga
23 - 26	18 ga
27 - 34	18 ga w/AR 12 ft c/c or 16 ga
35 - 42	18 ga w/FL + AR 6 ft c/c or 16 ga w/FL
44 - 50	18 ga w/FL + AR 4 ft c/c or 16 ga w/FL
52 - 60	18 ga w/FL + AR 4 ft c/c or 16 ga w/FL
62 - 72	16 ga w/FL + AR 6 ft c/c or 14 ga w/FL

AR = single angle ring reinforcement at maximum indicated ft on center spacing.

FL = fully welded flange angle rings as joint connections at maximum 12 ft spacing.

- E. Fitting gauge shall be one even gauge heavier than the lightest allowable gauge of connecting downstream section of duct.

## 2.8 DUCT SEALANT AND GASKET

- A. Sealant:
1. UL Classified sealant as compounded specifically for sealing joints and seams in ductwork. Hardcast, United McGill, Ductmate, Mon-Eco Industries or H.B. Fuller/Foster. Duct tapes are not allowed.
  2. Select sealants as recommended by manufacturer for specific application.
  3. Submit sealant manufacturer's data sheets including performance data, pressure ratings, surface burning characteristics data, detailed installation instructions.

- B. Gaskets:
  - 1. Butyl, copolymer or neoprene based tape similar to Ductmate 440 Gasket Tape or Neoprene Gasket Tape for flanged joints.
- C. Duct Sealant and Gaskets for Fume Hood Exhaust Ductwork:
  - 1. Sealant shall be similar to Hardcast Sure-Grip 404 Ductmate Proseal.
  - 2. Gasket material shall be Teflon based similar to Gore-Tex Series 300.
  - 3. Gasket thickness and width shall be as required for flange and surface irregularities to seal joint air tight.
- D. Provide filter system on duct inlet to test blower. Filter system to be equal to final filtering efficiency of the AHU supply air duct system. Not required for negative pressure testing.

### **PART 3 EXECUTION**

#### **3.1 GENERAL**

- A. Install ductwork parallel to building walls and ceilings and at such heights not to obstruct any portion of ceiling, window, doorway, stairway, or passageway. Install ductwork to allow adequate access and service space for equipment. Refer to drawings and/or manufacturer's recommendations. Install vertical ductwork plumb. Where interferences develop in field, offset or reroute ductwork as required to clear such interferences. In all cases, consult drawings for exact location of duct spaces, ceiling heights, door and window openings or other architectural details before installing ductwork.
- B. Make allowances for beams, pipes or other obstructions in building construction and for work of other contractors. Check plans showing work of other trades and consult with Engineer in event of interference. Transform, divide, or offset ducts as required, in such a manner as to maintain same cross sectional area of duct as indicated on drawings. Where it is necessary to install pipes or similar obstructions through ducts, consult with Engineer and obtain written approval from Engineer and Owner. If approved, provide streamlined encasement or collar designed in accordance with SMACNA Standards and seal to prevent air leakage.
- C. Ductwork shall be free of kinks and dents.
- D. Fabricate and install duct, fittings, joints, seams, reinforcement, supports, sealing, liner, etc., in sizes indicated on drawings and in accordance with manufacturer's published data and SMACNA Standards except as modified in this Section of Specifications.
- E. Provide transitions where different size or different shape ductwork segments are connected. Use concentric transitions unless otherwise shown. Unless otherwise indicated, make diverging transitions with maximum angle of 15 ° per side (30 ° total diverging) and converging transitions with maximum angle of 25 ° per side (50 ° total converging).

- F. Provide transitions at ductwork system components and connections to equipment. Refer to Specification Section 23 3713 – Diffusers, Registers, and Grilles, for additional information regarding diffuser/register/grille connections.
- G. Refer to ductwork symbols list on drawings for additional and dimensional requirements for fittings.
- H. Seal duct seams and joints to meet SMACNA Class A as minimum for all ductwork including low-pressure ductwork.
- I. Construct ductwork so that interior surfaces are smooth. Internal duct hangers and internal bracing are not allowed. Refer to Part 1, Design Criteria for internal tie rods.
- J. Support coils, filters, air terminals, dampers or other devices installed in duct systems with angles or channels, and make all connections to such equipment including equipment furnished by others. Secure frames with gaskets, nuts, bolts and washers.
- K. Air terminal devices may be supported by strap hangers if air terminal manufacturer approves. Strap hangers are not allowed for fan powered devices, double wall type and Titus Steri-Loc type devices.
- L. Install outside air intake duct to pitch down at minimum 1" per 20 ft toward intake louver or plenum and to drain to outside of building. Solder or seal seams to form watertight joints.
- M. Install exhaust air duct to pitch down at minimum 1" per 20 ft toward exhaust louver.
- N. Blank off unused portion of outside air intake or exhaust louvers.
- O. Where 2 different metal ducts meet, install joint in such a manner that metal ducts do not contact each other by using proper gasket seal or compound.
- P. Install motor operated dampers and connect to or install equipment furnished by others. Provide necessary blank-off plates or transitions to mount control dampers as specified in Section 23 0901 - Control Systems Integration.
- Q. Do not install ductwork over electrical panelboards, switchgear, switchboards or motor control centers.
- R. When original galvanized finish is altered or damaged, apply field galvanizing paint as follows:
  - 1. Prepare surface with use of power sanders or wire brushes to remove rust, paint, etc.
  - 2. Apply cold galvanizing material equal to ZRC Products, Inc.

### **3.2 ELBOWS**

- A. Rectangular Duct:
  - 1. Unless specific type is indicated, use radius elbows with minimum centerline radius to width or diameter ratio of 1.5. Where 1.5 radius elbows do not fit, use the following elbows.

- a. Supply Air Ductwork:
    - 1) 1.0 radius elbows
    - 2) Square throat elbows with turning vanes where 1.0 radius elbows do not fit
  - b. Return or Exhaust Air Ductwork:
    - 1) 1.0 radius elbows with full splitter vanes (SMACNA Type RE3) as follows:
      - a) One vane for duct width 24" to 48"
      - b) Two vanes for duct width 49" to 72"
      - c) Three vanes for duct width 73" and larger
      - d) Fabricate vanes in accordance with SMACNA HVAC Duct Construction Standard, chart 4-1(p 4.11) and Figure 4-9 (p 4.13).
    - 2) 45° throat with radius heel elbows with full splitter vanes as follows where 1.0 radius elbows do not fit:
      - a) One vane for duct width 12" to 24"
      - b) Two vanes for duct width 25" to 36"
      - c) Three vanes for duct width 36" and larger
      - d) Fabricate vanes in accordance with SMACNA HVAC Duct Construction Standards, Chart 4-1 and Figure 4-9.
    - 3) Square throat - radius heel elbows or square throat elbows with turning vanes are not allowed unless specifically indicated.
- B. Round Duct:
1. Unless specific type is indicated, use radius elbows with centerline radius to diameter ratio of 1.5. Where 1.5 radius elbows do not fit, use 1.0 radius elbows.

### 3.3 LONGITUDINAL SEAM

- A. Rectangular Duct:
1. Unless otherwise indicated, use Pittsburgh lock seam for rectangular ductwork.
  2. Button punch snap lock construction (SMACNA L-2) may be used for ductwork for 2" WG (+/-) and lower, and sizes 48" and smaller in width.
  3. Button punch snap lock construction is not allowed for ductwork in chases and areas above inaccessible ceiling.
  4. Button punch snap lock construction is not allowed on aluminum ductwork.
- B. Round Duct:
1. Unless otherwise indicated, longitudinal seams shall be in accordance with SMACNA HVAC Duct Construction Standards. Snaplock seams are not allowed.

### 3.4 TRANSVERSE JOINT

- A. Rectangular Duct:
1. Transverse joints shall be in accordance with SMACNA HVAC Duct Construction Standards.

2. Ductmate 25/35 connection systems with corner clips or optional nuts and bolts may be used. Incorporate use of all Ductmate accessories to ensure integrity of transverse connection. Install joints in strict accordance with the latest edition of Ductmate 25/35 Assembly and Installation Instruction Manual and Duct Construction Standards. Nexus or WDCI will be acceptable.
  3. Lockformers TDC or Engles TDF may be used in accordance with T-25 flanges of SMACNA HVAC Duct Construction Standards, Metal and Flexible, Second Edition, 1995, provided that corner pieces with bolts are used. If TDF/TDC flanges are damaged, replace the damaged joint(s) by straightening and reinforcing with minimum 1-1/2" x 1-1/2" x 1/4" angle at each side of transverse joint.
  4. Refer to Detail for non-externally insulated outdoor ductwork.
- B. Round Duct:
1. Unless otherwise indicated, use beaded sleeve joints (SMACNA RT-1) with minimum 2" insertion length or flange joints (SMACNA RT-2 or RT-2A).
  2. Connection systems manufactured by Ductmate Industries (Spiralmate and Ovalmate) may be used for supply air ductwork.
  3. AccuFlange connected systems may be used with gaskets specified in Part 2 of this Section.

### 3.5 DUCT SUPPORTS

- A. Unless otherwise indicated, use straps or Z bar hangers with 3/8" rods to support rectangular ducts 60" wide and smaller and trapeze hangers with rods or angles to support rectangular ducts over 60" wide.
1. Use trapeze hangers to support externally insulated ductwork with weight bearing inserts. Refer to Section 20 0700 – Mechanical Systems Insulation and details.
- B. For round ducts 24" diameter or smaller, use single hanger.
1. Cable Suspension System may be used up to 16" diameter at spaces higher than 8 ft above floor or platform.
  2. Round Duct Strap Bracket by Ductmate Industries may be used up to 24" diameter.
- C. For round ducts 25" diameter or larger, use 2 minimum 3/8" rods, with trapeze in accordance with the following schedule:
- | <u>Duct Size</u> | <u>Trapeze (Half Round)</u>                 |
|------------------|---|
| 25" through 36"  | 1-1/2" x 1-1/2" x 1/8"                      |
| 37" through 48"  | 1-1/2" x 1-1/2" x 1/4"<br>or 2" x 2" x 1/8" |
| 49" through 60"  | 2" x 2" x 1/4"                              |
| 61" through 84"  | 2-1/2" x 2-1/2" x 1/4"                      |
- D. Refer to Section 20 0700 - Mechanical Systems Insulation for ductwork insulation, weight bearing inserts and insulation protection shield requirements.
- E. Support ducts located on roof as detailed.
- F. Support vertical ducts at every floor, but not exceeding 12 ft.



- G. The following upper attachments, upper attachment devices, lower hanger attachments, hanger devices, and/or hanger attachments are not allowed except where specifically indicated:
1. Hook or loop
  2. Nailed pin fasteners
  3. Expansion nails without washers
  4. Powder charged or mechanically driven fasteners (forced entry anchors)
  5. Beam or "C" clamps without retaining clips or friction clamps (provide retaining clips for "C" clamps)
  6. Friction clamps for ductwork over 12"
  7. Non-factory manufactured upper attachments for metal pan deck including wire coil and double circle (Items 16 and 17 of Fig 4-3 of SMACNA HVAC Duct Construction Standards 95)
  8. Wire hanger
  9. Trapeze hangers supported by wires or straps
  10. Rods, straps or welded studs directly attached to metal deck
  11. Drilled hole with attachment to structural steel
  12. Lag screw expansion anchor
  13. Rivets
- H. Supporting devices shall be standard products of manufacturers having published load ratings.
- I. Refer to Section 20 0529 - Mechanical Supporting Devices for additional support requirements including attachments to structures.
- J. For welded ducts, soldered ducts or ducts with water tight joints, do not use supports utilizing screws or other penetrations into ductwork.
- K. Unless Architectural Documents indicate the required framing, provide angle iron framing around roof opening where duct penetrates through roof decking, to maintain roof decking structural integrity in accordance with roof decking manufacturer's recommendations. This is not required for concrete decking. For concrete decking, consult with the project structural engineer for location and size of opening prior to execution of Work.

### **3.6 SHEET METAL WELDING**

- A. Welded ductwork shall be butt-welded unless otherwise indicated. Backing material and slip joints are not allowed.
1. SMACNA T-21 or T-21a welded flange joints are acceptable with continuous welding including at each corner for rectangular ducts.
- B. Attach welding cable leads directly to base metal to be welded. Do not jumper welding cable leads through building structure, to avoid emission of stray voltage/current through building structure.
- C. Welds on exposed ductwork in occupied spaces shall be brush polished with stainless steel brush.

- D. Welds at exterior of building shall be ground smooth and brush polished with stainless steel brush to prevent atmospheric contamination and rust formation.

### **3.7 PROTECTION OF DUCTWORK**

- A. Protect ductwork during construction against entry of foreign matter and construction dirt.
- B. Keep ductwork capped when work is complete for the day or when duct is not being worked on or added to. Use of polyvinyl (VISQUEEN) with duct tape wrap is an adequate measure as long as it is secure with no openings or tears in product.
- C. If ductwork is not protected, remove dirt and foreign matter from the duct system and obtain inspection and approval from Engineer upon completion of cleaning before operating fans.
- D. Return fans are not allowed to operate during construction to avoid intake of construction dirt/dust into return air ductwork.

### **3.8 DUCT LEAKAGE TEST**

- A. Refer to Test and Balancing portion of Section 20 0000 - General Mechanical Requirements.
- B. Owner and/or Owner's representative may elect to witness leakage tests. Notify Owner and/or Owner's representative at least 3 days in advance.
- C. Test 25% of total duct area of each supply, return, and exhaust ductwork from fan to air terminal devices where air terminal devices are used, unless otherwise indicated in this section.
- D. Leakage test procedures shall be in accordance with test method described in Section 3 of SMACNA HVAC Air Duct Leakage Test Manual, except as modified in this Section. Test apparatus shall be in accordance with Section 5 of SMACNA HVAC Air Duct Leakage Test Manual.
- E. Test pressure shall be equal to duct pressure class. Negative pressure ductwork shall be tested with negative test pressure.
- F. Air leakage shall not exceed limits specified. If leakage exceeds allowable limits, identify leaked areas, repair, seal and retest.
- G. Provide filter system on duct inlet to test blower. Filter system shall be equal to final filtering efficiency of AHU supply air duct system. Filters are not required for negative pressure testing.
- H. Do not insulate ductwork until it has been successfully tested.
- I. Allowable leakage rates of ductwork systems are indicated on schedules on drawings.

- J. Allowable leakage rates of each ductwork (L in cfm/100 sf duct surface area) shall be calculated by:
- K.  $L = C_L \times P^{0.65}$
1. P = test pressure (duct pressure class).
  2.  $C_L$  = duct leakage class, 3 for round/oval ducts and 6 for rectangular ducts and flexible ducts.
  3. Total allowable leakage in a duct section:  
= L x (total duct surface area of the section)
- L. Welded ductwork shall be air and watertight and shall have no air leakage with allowance stated below.
1. When using test apparatus and procedure described in SMACNA HVAC Air Duct Leakage Test Manual, 1<sup>st</sup> Edition, Chapter 5 (modified for negative pressure), the following losses can be expected during testing and are acceptable:
    - a. 1 cfm per 1" WG of static pressure is allowed for the test equipment and test connections (e.g. 3 CFM when testing at 3" WG).
    - b. 0.10 cfm per inch of diameter of temporary caps, regardless of pressure (e.g. 1 cfm for a cap on 10" diameter duct).
  2. To the extent possible, walk and observe welded ductwork under test to check for cracked or hissing welds. All leaks in welded sections of ductwork shall be reported to the Client's Representative and repaired by welding. No caulking or sealing is allowed.
- M. Leakage Test for Ductwork Downstream of Air Terminal Devices:
1. Representative samples of ductwork (approximately 10% of total linear feet of ductwork) shall require leakage test.
  2. Engineer will decide samples of ductwork to be tested and date of leakage test to be conducted.
  3. If test results are acceptable to Engineer, remainder of ductwork is permitted to proceed without further testing. If ductwork fails test, repair all ductwork including ductwork not tested. Then repeat leakage tests for new samples of ductwork as described above.

### **3.9 LOW PRESSURE DUCT CONSTRUCTION (PRESSURE CLASS 2" WG AND UNDER)**

- A. Use welds, rivets or nuts, and bolts for fabricating ductwork. Fully threaded sheet metal screws may be used on duct hangers, transverse joints and other SMACNA approved locations if screw does not extend more than 1/2" into duct. Sheet metal "TEK" screws 3/4" in length may be used as fasteners in conjunction with factory made transverse joints.
- B. Unless otherwise indicated, construct branch take-off fittings as follows:
1. For branch take-offs including branch ducts serving more than one diffuser or grille, use 45 ° entry fittings. For supply air ducts, expanded or conical taps may be used.
  2. For take-offs serving single diffuser, register or grille, use straight spin-in collars with manual balancing dampers.

- C. Do not use splitter dampers and/or extractors unless manual volume dampers alone do not accomplish the intended balancing. Obtain Engineer's written approval before installing them. Use of splitter dampers and/or extractors will not eliminate need for specified or indicated manual volume dampers.

### **3.10 LOW PRESSURE DUCT LININGS**

- A. Low pressure duct linings are not allowed.

### **3.11 HIGH PRESSURE DUCT CONSTRUCTION (PRESSURE CLASS 3" WG AND OVER)**

- A. Use manufactured ductwork or Contractor fabricated ductwork meeting specified Construction Standards.
- B. Submit construction details including materials, type of service, reinforcing methods, and sealing procedures.
- C. Use elbows, tees, laterals, crosses and accessory fittings as shown on drawings and as required to fabricate duct system.
- D. Use expanded or conical tees for branch take-offs from mains.
- E. Provide manufactured bellmouth fittings at each fan supply air plenum to provide smooth entrance of air into duct system.
- F. Provide positive pressure relief doors as indicated on drawings.
- G. Provide negative pressure relief doors as indicated on drawings.
- H. Ductwork pressure class is to be as indicated in 3.12.

### **3.12 AIR HANDLING UNIT SYSTEM DUCTWORK PRESSURE CLASS**

- A. Cleanroom Supply Air System:
  - 1. System consists of all ductwork served by air handling units AHU-C1.
  - 2. Construct ductwork of galvanized steel sheet with mechanical seams and mechanical transverse joints.
  - 3. Duct pressure class to be as follows:
    - a. Outside air intake plenum -2" WG
    - b. From AHU discharge to shaft +4" WG
    - c. Ductwork located in shafts +4" WG
    - d. From shaft to diffuser +3" WG
- B. Cleanroom Supply Air System:
  - 1. System consists of all ductwork served by air handling units AHU-C18 and AHU-C19.
  - 2. Construct ductwork of galvanized steel sheet with mechanical seams and mechanical transverse joints.
  - 3. Duct pressure class to be as follows:
    - a. From AHU discharge to diffuser +2" WG
    - b. From return grille to AHU inlet -2" WG

- C. Solvent Exhaust System
1. System consists of all ductwork served by exhaust fans EF-SE-1 and EF-SE-2.
  2. Construct ductwork of Type 316L stainless steel sheet with welded seams and butt welded transverse joints.
  3. Use longitudinal seam construction with seam at top on horizontal runs. Spiral seams are not allowed on round duct.
  4. Construct elbows with centerline radius to width or diameter ratio of at least 1.5 and 45° lateral branch take-offs from mains.
  5. Use 18 ga or heavier stainless steel sheet with all joints and seams butt-welded airtight.
  6. Grind and polish smooth all interior joints.
  7. Duct pressure class to be as follows:
    - a. From fume hood, grille or exhaust capture device to exhaust air terminal device -2" WG
    - b. From air terminal device to branch main -4" WG
    - c. From branch main to shaft -4" WG
    - d. Ductwork in shaft -6" WG
    - e. From shaft to heat recovery unit -6" WG
    - f. From heat recovery unit to automatic shutoff damper -6" WG
    - g. Automatic shutoff damper to fan inlet -10" WG
    - h. Exhaust stack +2" WG
    - i. Refer to Fan Exhaust Stacks in this Section
- D. Corrosive Exhaust System
1. System consists of all ductwork served by exhaust fans EF-CE-1 and EF-CE-2.
  2. Construct ductwork of Teflon Coated Type 316 stainless steel sheet with flanged joints.
  3. Use longitudinal seam construction with seam at top on horizontal runs. Spiral seams are not allowed on round duct.
  4. Construct elbows with centerline radius to width or diameter ratio of at least 1.5 and 45° lateral branch take-offs from mains.
  5. Duct pressure class to be as follows:
    - a. From fume hood, grille or exhaust capture device to exhaust air terminal device -2" WG
    - b. From air terminal device to branch main -4" WG
    - c. From branch main to shaft -4" WG
    - d. Ductwork in shaft -6" WG
    - e. From shaft to automatic shutoff damper -6" WG
    - f. Automatic shutoff damper to fan inlet -10" WG
    - g. Exhaust stack +2" WG
    - h. Refer to Fan Exhaust Stacks in this Section

**END OF SECTION**



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**SECTION 23 3314CR**  
**DUCTWORK SPECIALTIES**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 23 0595CR - Air Systems Test Adjust Balance
- B. Section 25 3002CR – Process Control Valves and Dampers (Control and Smoke Dampers)

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 SUBMITTALS**

- A. Shop Drawings including, but not limited to, the following:
  - 1. Manufacturer's name and model number
  - 2. Capacities
  - 3. Temperature/pressure ratings
  - 4. Materials of construction
  - 5. Dimensions
  - 6. Manufacturer's installation instructions and/or detailed drawings
  - 7. All other appropriate data

**1.4 DESIGN CRITERIA**

- A. Products and materials shall conform to NFPA Section 90A, possessing flame spread rating of not over 25 and smoke developed rating no higher than 50.
- B. Ductwork specialties exposed to air stream, such as dampers, turning vanes and access doors, shall be of same material as duct at where the specialties are mounted, unless otherwise noted.
- C. Unless otherwise noted, ductwork specialties shall be designed and manufactured to conform to same pressure class as ductwork in which they are installed.

**PART 2 PRODUCTS**

**2.1 MANUAL BALANCING DAMPERS**

- A. Manufacturers: Ruskin, Vent Products or Air Balance, constructed in accordance with SMACNA HVAC Duct Construction Standards, except as modified below.

- B. Rectangular Dampers:
1. For low pressure ductwork, for damper blade height up to 12", use single blade type with minimum 22 ga galvanized steel blade with minimum 3/8" rod for blade width up to 18", and with minimum 18 ga galvanized steel blade with minimum 1/2" continuous rod for blade width from 19" to 48". For damper blade height more than 12", use multiple blade type with minimum 16 ga galvanized steel channel frames, opposed blade linkage operation, with blades minimum 16 ga and 6" to 8" maximum blade width, minimum 1/2" continuous rod and 1/2" x 1/2" galvanized steel angle blade stops. Bearings shall be nylon or molded synthetic. Construct dampers over 48" in width or height in multiple sections with mullions.
  2. For high pressure ductwork, dampers shall be constructed to withstand maximum pressure of 5 inches WG at closed position and maximum velocity of 3000 fpm at open position. Frame and blades shall be constructed of minimum 16 ga with minimum 1/2" diameter or square rod.
- C. Single Blade Round Damper
1. For low pressure ductwork, damper shall have blade 24 ga, but no less than two gauges more than duct gauge. Rod shall be minimum 3/8" diameter or square continuous. Bearings shall be nylon or molded synthetic.
  2. For high pressure ductwork, damper blade shall be minimum 16 ga. Rod shall be minimum 1/2" square continuous and tack welded to blade. Provide sealed end bearing similar to Ventlok #609 and acorn nut type dial regulator similar to Ventlok #635 or 641.
- D. Provide damper operators with locking devices and damper position indicators. Sheet metal screws are not allowed in construction or installation of dampers. Use rivets or tack welds.
- E. Dampers shall be properly stiffened and fabricated to prevent vibration, flutter or other noise.
- F. Extend damper shafts through duct insulation or use elevated regulators for externally insulated ducts to accommodate specified insulation thickness.

## 2.2 TURNING VANES

- A. Construct turning vanes in accordance with SMACNA HVAC Duct Construction Standards.
- B. Square Throat Elbow Turning Vanes (Vane Runner Length up to 18" and Vane Length up to 36"):
1. Use single thickness vanes having 2" radius and 1-1/2" spacing, 24 ga minimum. Construct vanes in accordance with SMACNA HVAC Duct Construction Standards.
- C. Square Throat Elbow Turning Vanes (Vane Runner Length over 18" or Vane Length over 36"):
1. Use double thickness vanes having 4.5" radius and 3.25" spacing, 22 ga minimum.



- D. Radius Elbow Splitter Vanes:
  - 1. Splitter vanes for radius elbows shall be extended entire length of fitting and constructed in accordance with SMACNA HVAC Duct Construction Standards.

### **2.3 BACKDRAFT DAMPERS**

- A. Manufacturers: Ruskin, Air Balance, Prefco, Greenheck, Nailor, or Louvers and Dampers,
- B. Dampers shall be multi-blade, weighted type with counter-balanced blades and with 12 ga galvanized steel frame and extruded aluminum airfoil-shaped blades equal to Ruskin Type CBS 92. Blade edges shall have silicon rubber seals with ball bearings. Dampers shall be suitable for flange and gasket connection to ductwork or fan outlet.
- C. Dampers shall be rated to maximum velocity of 4000 fpm, maximum temperature of 250°F and maximum system pressure of 5" WG for damper width of 60" and 14" WG for damper width of 12".
- D. Maximum damper leakage shall be 13.5 cfm/sf based on pressure differential of 1" WG.

### **2.4 FIRE DAMPERS**

- A. Manufacturers: Air Balance, Prefco, Greenheck, Nailor, Cesco, Pottorff Louvers and Dampers, or Ruskin
- B. Fire damper assemblies shall be listed by UL with 165°F fusible link and shall meet construction standards as set forth in NFPA 90A.
- C. Fire resistance rating of fire dampers shall be as shown on drawings.
- D. Minimum damper size is to be 12" x 8" or 10" round.
- E. Dampers shall be dynamic type dampers rated to minimum 2000 fpm and 4" WG.
- F. Dampers shall be curtain type with blades out of air stream when in open position. Where curtain type dampers are not available because of size, use multiple blade type dampers.
- G. For round ducts, dampers equal to Ruskin Model FDR25 may be used.
- H. Damper fire rating shall be compatible with rating of building surface in which damper is used.
- I. Submit UL installation details to showing mounting method and duct connection method.
- J. Where ceiling fire dampers are used, they are to be equal to Ruskin CFD(R) 2 or 3, UL Classified for installation in fire rated floor or roof/ceiling assemblies.

## 2.5 COMBINATION FIRE AND SMOKE DAMPERS

- A. Manufacturers: Ruskin, Air Balance, Prefco, Greenheck, Nailor, Cesco, Pottorff, Louvers and Dampers similar to Ruskin FSD-60
- B. Dampers shall meet requirements of NFPA 90A. Dampers shall be 1-1/2 or 3 hr rated as shown on drawings, leakage rated at no higher than leakage Class I (4 cfm/ft<sup>2</sup> at 1" WG and 8 cfm/ft<sup>2</sup> at 4" WG ) under UL 555/555S at temperature category 350°F, and compatible with system static pressures. Furnish dampers with factory-mounted, caulked sleeves and damper operators.
- C. Dampers shall use airfoil shaped damper blades. Dampers shall be rated pressures to 4" WG and velocities to 2000 fpm.
- D. For round ducts, dampers equal to Ruskin Model FSDR 25 may be used.
- E. Minimum damper size is to be 12" x 8" or 10" round.
- F. Operators shall be 120 V electric powered with auxiliary switch built in for position indication, similar to Ruskin Model MS 4120S, factory installed outside airstream, linked to dampers for fail closed operation, and be UL Listed and labeled for the application. Operators to be capable of closing damper at pressures encountered in system. Electric operators shall be rated for energized hold open position period of 6 months or more.
- G. Dampers shall be furnished with heat sensor set at 165°F.
- H. Smoke detector required at each damper will be provided by Electrical Contractor.
- I. Submit UL installation details showing mounting method and duct connection method.

## 2.6 ACCESS DOORS

- A. Access doors shall be rectangular, minimum 22 ga frame and minimum 24 ga door, fit air tight with gasket and shall be suitable for duct pressure class. Doors shall be double-wall, insulated when installed in insulated ductwork or unit casing and located for greatest ease of access. Access doors constructed with sheet metal screw fasteners are not acceptable.
- B. Access doors for fire and combination fire smoke dampers to have ¼" wire glass panels.
- C. Low Pressure Ducts (Pressure Class 2" and Under):
  - 1. Doors shall be hinged type with sash lock for exposed application and non-hinged type with cam latches for concealed application.
  - 2. Access doors constructed in accordance with SMACNA HVAC Duct Construction Standard (Figure 7-2) or similar to Ruskin Model ADC or ADH will be acceptable.
  - 3. Sandwich style access doors made by Ductmate, Ward Industries, or Flexmaster are acceptable, provided that they meet insulation requirements and include edge protection.

- D. High Pressure Ducts (Pressure Class 3" and Over):
  - 1. Use access doors factory fabricated and rated by manufacturer's published literature for installation in systems with pressures to positive or negative 10" WG.
  - 2. Sandwich access doors made by Ductmate, Ward Industries, or Flexmaster are acceptable, provided that they meet insulation requirements and include edge protection.

## 2.7 FLASHINGS

- A. Construct counterflashings of 16 ga galvanized Armco Zinc-Grip. Flashings are by General Contractor unless otherwise indicated.

## 2.8 DUCT FLEXIBLE CONNECTIONS

- A. Manufacturers: Unless specifically indicated, Ventfabrics, Inc. or Duro Dyne, equal to Duro Dyne model indicated. Material shall be glass fabric, fire retardant, waterproof, air tight and comply with UL Standard 214 and NFPA 90A.
- B. General Supply, Return and Exhaust Ductwork:
  - 1. Material for indoor use to be 30 oz per square yard, double coated with neoprene, suitable for -40 to 200°F continuous operation similar to Duro Dyne Neoprene.
  - 2. Material for outdoor use shall be combination of inner layer of Duro Dyne Neoprene and outer layer of 24 oz per yard, coated with Hypalon, UV resistant, suitable for -40°F up to 250°F, similar to Duro Dyne Durolon.
- C. Special Exhaust Ductwork:
  - 1. Material for indoor use shall be 17 oz per yard, teflon or silicon coated, suitable for -65 to 500°F, similar to Duro Dyne Thermafab.
  - 2. Material for outdoor use shall be combination of inner layer of Thermafab and outer layer of Durolon.

## 2.9 SOUND ATTENUATING DEVICES

- A. Manufacturers: Industrial Acoustics Company, Semco, Aerosonics, United McGill, Aeroacoustic, Commercial Acoustics, Vibro-Acoustics, VAW Systems, Ruskin Sound, or Dynasonics
- B. Units shall be tested in accordance with ASTM E-477-99 silencer test standard in aero-acoustic test facility which is NVLAP accredited for ASTM E-477-99 Standard. Each test shall have been conducted within last 12 month period. Submit copy of laboratory's NVLAP accreditation certificate on dynamic insertion loss, self-noise power levels, and aerodynamic performance.
- C. Outer casing of units shall be not less than 22 ga G90 galvanized steel in accordance with recommendations in the latest edition of ASHRAE Guide and Data Book for high pressure rectangular ductwork for 8" WG or pressure class indicated for duct system, if it is higher than 8" WG. Seams shall be lock formed or continuously welded and mastic filled.

- D. Ends of attenuators shall be covered at factory with plastic, heavy-duty paper, cardboard, or other appropriate material to prevent entrance of dirt, water, or any other foreign matter to inside of attenuators. Caps shall not be removed until attenuator is installed in duct system.
- E. Unless otherwise indicated, sound attenuating devices shall meet acoustical performance requirements as scheduled in each octave band frequency under the flow conditions.
- F. Sound Attenuating Devices for Air Handling Unit AHU-C1:
  - 1. Provide units at supply air discharges as scheduled. Unit length shall be as scheduled.
  - 2. Rectangular type constructed entirely of galvanized steel, in accordance with recommendations in the latest edition of ASHRAE Guide and Data Book for high pressure rectangular ductwork. Seams shall be lock formed. Units shall contain no sound absorptive material. Attenuation shall be accomplished by, controlled impedance membranes and broadly tuned resonators. Units shall not fail structurally when subjected to differential air pressure of 8" WG inside to outside of casing.
- G. Sound Attenuating Devices for Solvent Exhaust Fans EF-SE1 and EF-SE2:
  - 1. Provide units at exhaust fan outside air bypass as scheduled. Unit length shall be as scheduled.
  - 2. Rectangular type constructed entirely of Type 316L stainless steel, in accordance with recommendations in the latest edition of ASHRAE Guide and Data Book for high pressure rectangular ductwork. Seams shall be lock formed. Units shall contain no sound absorptive material. Attenuation shall be accomplished by, controlled impedance membranes and broadly tuned resonators. Units shall not fail structurally when subjected to differential air pressure of 8" WG inside to outside of casing.
- H. Sound Attenuator Devices for Exhaust Fans EF-C1 and EF-C2- Teflon Coated
  - 1. Provide units at exhaust fan outside air bypass as scheduled. Unit length shall be as scheduled.
  - 2. Sound attenuator manufacturer shall furnish all welded 316L stainless steel packless sound attenuators to be coated by Teflon coating manufacturer, in accordance with recommendations in the latest edition of ASHRAE Guide and Data Book for high pressure rectangular ductwork. Seams shall be lock formed. Units shall contain no sound absorptive material. Attenuation shall be accomplished by, controlled impedance membranes and broadly tuned resonators. Units shall not fail structurally when subjected to differential air pressure of 8" WG inside to outside of casing.
  - 3. Coordinate construction of silencer with sound attenuator manufacturer.

## **2.10 LOUVERS**

- A. Louvers will be provided by General Contractor.
- B. Blank-off panels on unused portion of louver shall be 2" thick insulated panels fabricated of minimum 22 ga galvanized steel on both surfaces. Insulation to be rigid

type with minimum R value of 10. Panels shall be reinforced with minimum 20 ga steel stiffeners.

### **2.11 BIRD AND INSECT SCREENS**

- A. Bird screens shall be 1/2" square mesh formed with 0.063" diameter aluminum wire. Insect screen to be 18 x 16 with 0.017" diameter aluminum mesh.
- B. Frame shall be removable type of minimum 12 ga, extruded aluminum.

### **2.12 AIR FLOW MEASURING UNITS**

- A. Furnished by Control Contractor.

### **2.13 INSTRUMENT TEST HOLES**

- A. Manufacturers: Ventlok 699 (up to 1" insulation thickness) or Ventlok 699-2 (over 1" insulation thickness).
- B. Use concave gaskets for round ductwork.

### **2.14 CONTROL DAMPERS**

- A. Furnished by Control Contractor.

### **2.15 SMOKE DAMPERS**

- A. Furnished by Control Contractor.

## **PART 3 EXECUTION**

### **3.1 MANUAL BALANCING DAMPERS**

- A. Install manual balancing dampers in all branch ducts of supply, return and exhaust ductwork, as indicated on drawings and as required to regulate airflow to meet air balance requirements.
- B. Install manual balancing damper in branch duct to each diffuser and grille. Install dampers as close as possible to take-offs.
- C. Install balancing dampers so as not to flutter or vibrate and as far as possible upstream from the air outlet.
- D. Balancing dampers are not required for supply ductwork upstream of air terminal devices.
- E. Balancing damper is not required where terminal air device serves a single diffuser or grille.

- F. Do not install manual balancing dampers in the following exhaust ductwork:
  - 1. Corrosive exhaust ductwork.
  - 2. Solvent exhaust ductwork.

### **3.2 TURNING VANES**

- A. Install turning vanes as shown on drawings and for rectangular square throat elbows unless otherwise indicated. Install turning vanes in accordance with SMACNA Standards and/or manufacturer's recommendations.
- B. Turning vanes are not required in transfer air ducts.
- C. Install turning vanes so that they are tangent to airflow direction.
- D. Do not install manual turning vanes in the following exhaust ductwork:
  - 1. Corrosive exhaust ductwork.
  - 2. Solvent exhaust ductwork.

### **3.3 BACKDRAFT DAMPERS**

- A. Install backdraft dampers where indicated on drawings.
- B. Where motorized dampers are shown in exhaust fan discharge duct, or in duct connecting to relief or exhaust louver, backdraft dampers are not required unless specifically indicated. Where motorized dampers are not shown, provide backdraft dampers in these locations.

### **3.4 FIRE DAMPERS AND COMBINATION FIRE/SMOKE DAMPERS**

- A. Install dampers where shown on drawings in accordance with manufacturer's installation instructions and requirements of NFPA 90A. Install dampers complete with mounting collars, retaining angles, connections to adjoining ductwork and duct access doors. Install duct access door at each damper with door size large enough to permit replacement of fusible links and resetting of dampers.
- B. Test and demonstrate proper operation of each damper after system is installed and ready for operation.
  - 1. Manually test each damper for proper operation by removing fusible link or actuating EFL or PFL. Repair or replace any damper that does not close completely. Replace fusible link and certify in writing that each damper was installed according to manufacturer's installation instructions and that each damper can be expected to close completely when fusible link melts.
  - 2. Notify Owner and/or Owner's representative at least 48 hrs prior to testing to allow for witnessing.
- C. Contractor shall provide letter from manufacturer's representative indicating that dampers are installed per manufacturer's installation instructions.

### 3.5 ACCESS DOORS

- A. Install access doors as specified, as indicated on drawings, and anywhere that provision for maintenance, service, cleaning or examination is required, including each automatic damper, fire damper, smoke damper, smoke detector, fan bearing, heating and cooling coil, reheat coils, humidifier, filter, bird/insect screen, valve and control device within duct or casing, at outside air intake duct and at inlet side of turning vanes in return ductwork.
- B. Size and quantity of duct access doors shall be sufficient to perform intended service, but not less than the following:

<u>Rectangular Duct Size</u>	<u>Minimum Access Door Quantity and Size</u>
15" and smaller	(1) 16" x 12"
16" - 21"	(1) 18" x 14"
22" - 27"	(1) 18" x 18"
28" - 47"	(1) 24" x 24"
48" - 96"	(2) 24" x 24"

<u>Round Duct Size</u>	<u>Minimum Access Door Size</u>
10" and smaller	8" x 4"
15" and smaller	12" x 8"
29" and smaller	16" x 12"
30" and over	24" x 18"

- C. Increase duct size to accommodate access door size indicated above where required.

### 3.6 FLASHINGS

- A. Install counterflashings where shown on drawings. Install in accordance with SMACNA recommendations.

### 3.7 DUCT FLEXIBLE CONNECTIONS

- A. Install duct flexible connections between ductwork and fans or equipment casing containing fans not internally isolated. Installed width shall be suitable for specific application but shall not be less than 4". Install flexible connections in accordance with SMACNA Standards with double lock or "Grip Loc" connection.
- B. Duct flexible connections are not allowed for fan connection serving kitchen hood, dishwasher, or perchloric acid hood.

### 3.8 SOUND ATTENUATING DEVICES

- A. Install sound attenuating devices as indicated on drawings and/or as scheduled.
- B. For modular installation of sound attenuators, install galvanized steel holding frame, gaskets, seals, supports and fasteners in accordance with manufacturer's recommendations for multiple unit installation.

### **3.9 LOUVERS**

- A. Provide insulated metal panel on unused portion of louver.
- B. Louvers will be provided by General Contractor.

### **3.10 AIR FLOW MEASURING UNITS**

- A. Install where indicated on the drawings and/or as scheduled and in accordance with manufacturer's recommendations.

### **3.11 CONTROL DAMPERS**

- A. Install dampers in locations indicated on drawings, as detailed and according to manufacturer's instructions.
- B. Install blank-off plates or transitions as specified in Control Sections.
- C. Provide adequate operating clearance and access to operators.

### **3.12 SMOKE DETECTORS**

- A. Smoke detectors will be provided by Electrical Contractor in locations indicated on drawings. Install access door in ductwork for access to detector sampling device.

### **3.13 INSTRUMENT TEST HOLES**

- A. Provide instrument test holes at air entering and air leaving side of all internal air handling system components for static pressure differential ( $\Delta P$ ) or temperature differential ( $\Delta T$ ) measurements.
- B. Provide ductwork instrument test holes as shown on drawings, or as directed by TAB personnel, or Engineer.

**END OF SECTION**



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## SECTION 23 3400CR

### FANS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 20 0513 - Motors
- B. Section 20 0514 - Variable Frequency Drive (VFD) System
- C. Section 23 0550CR - Vibration Isolation
- D. Section 26 2816CR - Enclosed Switches and Circuit Breakers

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 SUBMITTALS

- A. Shop Drawings including, but not limited to, the following:
  - 1. Manufacturer's name and model number
  - 2. Identification as referenced in the documents
  - 3. Capacities/ratings
  - 4. Fan curves
  - 5. Materials of construction
  - 6. Sound power levels
  - 7. Fan type, size, class, drive arrangement, discharge/rotation, bearings, drives
  - 8. Wheel type, diameter, rpm, tip speed
  - 9. Required fan horsepower including drive losses
  - 10. Motor data (refer to Section 20 0513 - Motors)
  - 11. Vibration isolators furnished with fans
  - 12. Dimensions and weights
  - 13. Special coatings where applicable
  - 14. Color selection charts where applicable
  - 15. Manufacturer's installation instructions
  - 16. All other appropriate data
- B. Fan curves shall include series of curves indicating relationship of flow rate (cfm) to static or total pressure for various fan speeds, brake horsepower curves, and selection range (surge curves, maximum rpm, etc).
- C. Indicate performance data, based on both design air quantity and 110% of design air quantity.

- D. For variable air volume application, indicate operating points at 100, 80, 60 and 40% of design capacity on fan curves including data to indicate effect of variable frequency drives on flow, pressure and horsepower.
- E. Complete equipment data sheet attached at end of this Section for each piece of equipment and submit with shop drawings. Shop Drawings will be returned without review if data sheets are not provided for each piece of equipment and if data sheet is not filled out completely.

#### 1.4 DESIGN CRITERIA

- A. Fan ratings shall be tested and certified in accordance with AMCA Standards 211 and 311 and fans shall bear AMCA Seal.
- B. Fans shall be furnished complete with motors, wheels, drive assemblies, bearings and accessories as hereinafter specified. Motors for V-belt drives shall be furnished with adjustable rails or bases.
- C. Each fan wheel shall be statically and dynamically balanced to grade G6.3 per ANSI S2.19. Complete fan assembly shall be factory balanced statically and dynamically in accordance with Standard AMCA 204-96 for Balance Quality and Vibration Levels for Fans and meet or exceed guidelines in Application Category BV-3.
- D. For fans furnished with 5 hp or larger hp motors, each fan assembly shall have factory run test including vibration signatures taken on each bearing in horizontal, vertical and axial direction. Filter-in reading as measured at fan, scheduled rpm shall not exceed the following values when fan is rigidly mounted.
  - 1. Direct Drive 0.08 in/sec peak velocity
  - 2. Written records of run test and vibration test shall be available upon request.
- E. Select each fan to operate at single stable operating point as predicted by fan curve. Fans having 2 potential operating points on fan curves are not acceptable.
- F. Provide OSHA Compliant belt and shaft guards for belt driven fans. Provide speed test openings at shaft locations. Paint guards bright yellow.
- G. Sound power levels shall be based on tests performed in accordance with AMCA Standards 300 and 301.
- H. Each fan and motor combination shall be capable of delivering 110% of air quantity scheduled at scheduled static pressure. Motor furnished with fan shall not operate into motor service factor in any of these cases.
- I. Consider drive efficiency in motor selection according to manufacturer's published recommendation, or according to AMCA Publication 203, Appendix L.
- J. Where inlet and outlet ductwork at any fan is changed from that shown on drawings, submit scaled layout of change and system effect factor calculations indicating increased static pressure requirements as described in AMCA Publication 201. This Contractor shall be responsible for costs associated with any motor, drive, and/or wiring changes required as a result of duct configuration changes at fan.

- K. Exhaust fans EF-CE-1, EF-CE-2, EF-SE-1 and EF-SE-2 shall be marked with arrows to indicate proper direction of rotation.
- L. Unless otherwise scheduled, AMCA Type C spark resistant construction shall be used for fans handling flammable vapors. Fans having spark resistant construction shall be electrically grounded so as to prevent static electricity from building up.
- M. Fans scheduled with baked phenolic coating shall have internal parts in contact with air stream sand blasted to white metal finish and coated within 24 hrs. Coating thickness shall be 5 mils minimum, equal to Heresite P-403 (first 3 coats) and L-66L (final 2 coats) with each coat baked separately. Dry film thickness must be verified before final baking. Paint all exterior metal parts with prime coat after metal cleaning and surface preparation. In addition, apply second coat of paint to all exterior surfaces.

## **PART 2 PRODUCTS**

### **2.1 SOLVENT EXHAUST CENTRIFUGAL FANS (SE-1 AND SE-2)**

- A. Manufacturers: Twin City, Greenheck, Chicago Blower, PennBarry or Cook
- B. General: Unless otherwise indicated, furnish fans with baked phenolic coating, drive arrangement 4 direct drive, AMCA Class C spark resistant construction and TEFC Motors.
- C. Housings: Heavy gauge steel, continuously welded throughout, braced and supported by structural channels or angle irons to prevent vibration or pulsation, flanged outlet, fully streamlined inlet.
- D. Wheels: Backwardly Inclined (BI) blades welded to spun wheel cones.
- E. Bearings: Air handling quality, heavy duty, grease lubricated, ball or roller, self-aligning, pillow block type. Bearings shall be selected for minimum life of 80,000 hrs (ABMA L-10) at maximum cataloged operating speed. Furnish bearings with pressure relief type external grease fittings.
- F. Air flow meter: Each fan assembly shall be supplied with a complete flow measuring system, similar to Greenheck Sure-Aire, which indicates airflow in Cubic Feet per Minute. The flow measuring system shall consist of a flow measuring station with one static pressure taps and one total pressure tubes located at the throat of the fan inlet cone. The flow measuring station shall not obstruct the inlet of the fan and shall have no effect on fan performance (flow or static) or sound power levels. Accuracy to be  $\pm$  3%. Provide a 4-20 ma output control signal for use in the BAS.
- G. Mounting Rails: Furnish common mounting rails for fan and motor as appropriate for fan arrangement indicated.
- H. Access Doors: Bolted and gasketed type in fan housing for inspection of interiors and wheel.

- I. Drain Connection: 3/4" NPT external threads located at the lowest point of fan housing.
- J. Coating: Provide baked phenolic coating as specified in paragraph 1.4.M.
- K. Weather Covers: Provide weather covers suitable for outdoor installation.

## **2.2 CORROSIVE EXHAUST CENTRIFUGAL FANS (CE-1 AND CE-2)**

- A. Manufacturers: Twin City, Greenheck, Chicago Blower, PennBarry or Cook
- B. General: All components in contact with airstream shall be Teflon coated 316L stainless steel. Unless otherwise indicated, furnish fans with Teflon coated 316L stainless steel, drive arrangement 4 direct drive, AMCA Class C spark resistant construction and TEFC Motors.
- C. Housings: Heavy gauge Teflon coated 316L stainless steel, continuously welded throughout, braced and supported by structural channels or angle irons to prevent vibration or pulsation, flanged outlet, fully streamlined inlet.
- D. Wheels: Backwardly Inclined (BI) blades welded Teflon coated 316L stainless steel to spun wheel cones.
- E. Bearings: Air handling quality, heavy duty, grease lubricated, ball or roller, self-aligning, pillow block type. Bearings shall be selected for minimum life of 80,000 hrs (ABMA L-10) at maximum cataloged operating speed. Furnish bearings with pressure relief type external grease fittings.
- F. Air flow meter: Each fan assembly shall be supplied with a complete flow measuring system, similar to Greenheck Sure-Aire, which indicates airflow in Cubic Feet per Minute. The flow measuring system shall consist of a flow measuring station with one static pressure taps and one total pressure tubes located at the throat of the fan inlet cone. The flow measuring station shall not obstruct the inlet of the fan and shall have no effect on fan performance (flow or static) or sound power levels. Accuracy to be  $\pm 3\%$ . Provide a 4-20 ma output control signal for use in the BAS.
- G. Mounting Rails: Furnish common mounting rails for fan and motor as appropriate for fan arrangement indicated.
- H. Access Doors: Bolted and Gasketed type in fan housing for inspection of interiors and wheel.
- I. Drain Connection: 3/4" NPT external threads located at the lowest point of fan housing.
- J. Weather Covers: Provide weather covers suitable for outdoor installation.

## **2.3 PLENUM FANS**

- A. Manufacturers: Twin City, Huntair, Greenheck, Chicago Blower, PennBarry or Cook

- B. General: Fans shall be airfoil centrifugal type designed for industrial duty and suitable for continuous operation. Fans shall be single width, single inlet, arrangement 4, plenum fans with capacities and operating characteristics as indicated on schedules.
- C. Hubs: Hubs shall be cast or welded fabricated hubs with straight bores and keyways. Hubs shall be screwed to the shaft with a minimum of 2 set screws for positive attachment. Hubs using taper lock bushings are not acceptable.
- D. Wheels: Airfoil type, double skinned and welded to center and wheel sideplates. Fan impeller diameters shall conform to AMCA Standard 99-2401-82. Fan blades shall be designed to provide smooth airflow over all surfaces of blade. Fan shafts shall be solid AISI 1040 or 1045 steel. Straight shafts shall be turned, ground and polished to a minimum 16 micro-inch finish. Shaft shall be sized to run at a minimum of 20% greater than the maximum AMCA class speed.
- E. Bearings: Air handling quality, heavy-duty, grease lubricated, pillow block, self-aligning ball or roller type. Bearings shall be selected for minimum life (ABMA L10) of not less than 80,000 hr operation at maximum cataloged operating speed.
- F. Screen Enclosure: Entire plug fan and drive assembly shall be encased with protective screen enclosure. Enclosure shall be constructed of aluminum or galvanized steel mesh or expanded metal and sized to have no measurable system effect on fan performance. Screen shall be reinforced as required to maintain stable structure during fan operation. Access shall be provided for periodic service. Door shall be of suitable size to allow service personnel into enclosure. Enclosure shall be designed and constructed to allow for complete disassembly.
- G. Backdraft dampers: Backdraft dampers shall have aluminum blades, ball bearings and be rated to 4000 fpm. Dampers shall have blade and jamb seals with leakage rating no higher than 13.5 cfm/ft<sup>2</sup> for damper width 36" and larger based on pressure differential of 1" WG. Pressure drop not exceed .05" WC at 2000 fpm.
- H. Air flow meter: Each fan assembly shall be supplied with a complete flow measuring system, similar to Huntair Flow-Cone, which indicates airflow in Cubic Feet per Minute. The flow measuring system shall consist of a flow measuring station with one to four static pressure taps and one to four total pressure tubes located at the throat of the fan inlet cone. The flow measuring station shall not obstruct the inlet of the fan and shall have no effect on fan performance (flow or static) or sound power levels. Provide a 4-20 ma output control signal for use in the BAS.
- I. Inlet Screens: Heavy gauge, corrosion resistant, zinc plated steel wire for fans without inlet ductwork.
- J. Inlet Cones: Inlet cones shall be precision spun. Inlet cones shall be aerodynamically matched to wheel side plate to insure full loading of blades. Inlet cones shall be heavy gauge steel.
- K. Painting: All metal parts to be painted with prime coat after metal cleaning and surface preparation. In addition, apply second coat of paint to all exterior surfaces.

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Install units as shown on drawings, and according to manufacturer's installation instructions. On units provided with drain connection, install drain valve and cap discharge of drain.
- B. Verify lubrication of motor and fan bearings and lubricate properly in accordance with manufacturer's recommendation and Section 20 0000, Part 3 under LUBRICATION.
- C. General Contractor will install curbs furnished with fans unless otherwise indicated.
- D. Perform field mechanical balancing, if necessary, to meet vibration tolerance specified in Section 23 0550CR - Vibration Isolation.

**END OF SECTION**

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## **SECTION 23 3600CR**

### **AIR TERMINAL DEVICES**

#### **PART 1 GENERAL**

##### **1.1 RELATED WORK**

- A. Section 25 0901CR – Process Control Systems Integration
- B. Section 25 0993CR – Process Control Sequences
- C. Section 23 3114CR – Ductwork (Support)

##### **1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### **1.3 SUBMITTALS**

- A. Shop Drawings including, but not limited to, the following:
  - 1. Manufacturer's name and model number
  - 2. Identification as referenced in the documents
  - 3. Capacities/ratings
  - 4. Materials of construction
  - 5. Sound rating data
  - 6. Dimensions
  - 7. All other appropriate data

##### **1.4 QUALITY ASSURANCE**

- A. Electrical Components, Devices and Accessories: Listed and labeled as defined in NFPA 70 by qualified testing agency and marked for intended location and application.
- B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1 – 2007, Section 5 – “Systems and Equipment” and Section 7 – “Construction and System Start-Up.”

##### **1.5 DESIGN CRITERIA**

- A. Unless otherwise stated, units shall be system pressure independent and maintain air volume within  $\pm 5\%$  of required airflow regardless of system air pressure. Inlet velocity pressure sensor shall be multi-point center averaging type and be capable of amplifying pressure signals.
- B. Unless otherwise stated, unit casings shall be constructed of aluminum meeting SMACNA or ASHRAE Standards, but not lighter than 22 ga.

- C. Joints and seams of air terminal devices shall be sealed with appropriate sealant to minimize casing air leakage. Seal joints and seams not factory sealed in field as specified in Part 3.
- D. Unit performance shall be certified in accordance with AHRI Standard 880 including sound rating data certified for both casing discharge and radiated sound levels from 125 through 4000 Hz.
- E. Supply air units shall be capable of operating from minimum inlet static pressure scheduled to 3" WG.
- F. Unit manufacturer or manufacturer's designated representative will be required to verify air terminal device performance and adjust or replace device within warranty period when it is determined that problem exists in area served by device.

## **PART 2 PRODUCTS**

### **2.1 EXHAUST AIR TERMINAL DEVICES (VALVES)**

- A. General:
  - 1. The following requirements apply to cleanroom airflow control system manufactured by Phoenix Controls Corporation.
- B. Air Terminal Devices - General:
  - 1. Air terminals shall be pressure independent over a 0.6 to 3.0" WG drop across the air terminal. An integral pressure independent assembly shall respond and maintain specific airflow within one second of a change in duct static pressure irrespective of the magnitude of pressure and/or flow change or quantity of airflow controllers on a manifold system.
  - 2. Airflow accuracy shall be +/- 5% of airflow (not velocity pressure) over an airflow turndown range of no less than 10 to 1.
  - 3. Provide differential pressure switch mounted across each air terminal or other means to signal alarm under low flow condition at each fume hood.
- C. Solvent Exhaust System Air Terminals:
  - 1. All air terminals for solvent exhaust airstreams, such as fume hood, snorkel, gas cabinet and equipment exhaust shall have minimum 16 ga aluminum with 2 baked-on coats of Heresite P-403, 5 mils minimum thickness. Air terminal's shaft and shaft support brackets shall be made of 316 stainless steel. Pivot arm and internal mounting brackets shall be made of a combination of aluminum and 316L stainless steel. Pressure independent springs shall be of combination 302 and 316 stainless steel. All shaft bearing surfaces shall be made of Teflon or Celenex composite.
  - 2. Refer to Air Terminal Devices schedules for definition of materials of construction for each air terminal.



- D. Corrosive Exhaust System Air Terminals:
1. All air terminals for corrosive exhaust airstreams (All air terminal associated with EF-CE-1 and EF-CE-2), such as fume hood, snorkel, gas cabinet and equipment exhaust shall have minimum 16 ga aluminum with PVDF (polyvinylidene fluoride fluoropolymer) coating. The device's shaft shall be made of 316 stainless steel with a Teflon coating. The shaft support brackets shall be made of 316 stainless steel with PVDF coating. The pivot arm and internal mounting link shall be made of 316 or 303 stainless steel with PVDF coating. The pressure independent springs shall be a spring-grade stainless steel with PVDF coating. The internal nuts, bolts and rivets shall be stainless steel with PVDF coating. All shaft bearing surfaces shall be made of Teflon composite.
  2. Refer to Air Terminal Devices schedules for definition of materials of construction for each air terminal.
- E. Air Terminal Actuators
1. For CAV operation, actuators are not required.
- F. Certification
1. Air terminals shall be individually marked with air terminal specific model number, and quality control inspection numbers. Information shall be stored on computer CD diskette in ASCII Format by manufacturer for future retrieval or for hard copy printout to be included with as-built documentation.

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Install units as shown on drawings and according to manufacturer's installation instructions.
- B. Install units with sufficient service space to unit control, actuators and access panels.
- C. Seal joints and seams of units not factory sealed to meet allowable leakage rate specified for low pressure ductwork.
- D. Provide access panels compatible with ceiling for all units located above non-accessible ceilings.
- E. If venturi type air terminal devices are used for supply air application, provide external insulation in accordance with Section 20 0700 - Mechanical System Insulation.

**END OF SECTION**



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## SECTION 23 3713CR

### DIFFUSERS, REGISTERS AND GRILLES

#### PART 1 GENERAL

##### 1.1 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.2 SUBMITTALS

- A. Shop Drawings including, but not limited to, the following:
  1. Manufacturer's name and model number
  2. Identification as referenced in the Documents
  3. Capacities/ratings
  4. Materials of construction
  5. Sound ratings
  6. Dimensions
  7. Finish
  8. Color selection charts where applicable
  9. Manufacturer's installation instructions
  10. All other appropriate data

##### 1.3 DESIGN CRITERIA

- A. Performance data shall be based on tests conducted in accordance with ASHRAE Standard 70.
- B. Screw holes on surface shall be counter sunk to accept recessed type screws.

#### PART 2 PRODUCTS

##### 2.1 MANUFACTURERS

- A. Titus, Price, Carnes, Nailor, Anemostat, or Krueger
- B. Acceptable manufacturers for specialty products are listed under each item.

##### 2.2 REGISTERS AND GRILLES

- A. Registers and grilles shall be aluminum or steel as scheduled unless otherwise indicated, and furnished with frame type appropriate to installation.
- B. Supply registers and grilles shall be double deflection type blades to provide for air deflection adjustment in all directions.

- C. Return and exhaust registers and grilles shall have fixed blade core.
- D. Registers shall be furnished complete with opposed blade volume control dampers, operable from face.
- E. Register and grille models, sizes and finishes shall be as shown on drawings and/or as scheduled. Unless noted otherwise, registers and grilles shall have baked enamel finish with color selected by Architect.
- F. Interior of perforated face grilles shall be finished in flat black.

### **2.3 WIRE MESH GRILLES**

- A. Grilles shall be 2 X 2 mesh (1/2") galvanized steel or aluminum hardware cloth in spot welded galvanized steel frame with 1-1/2" width.

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Install grilles, registers and diffusers as shown on drawings and according to manufacturer's instructions.
- B. Unless otherwise indicated, size ductwork drops to diffusers or grilles to match unit collar sizes.
- C. Seal connections between ductwork drops and diffusers/registers/grilles air tight.
- D. Blank off unused portion of linear diffusers and grilles.
- E. Where diffusers, registers and grilles cannot be installed to avoid seeing inside duct, paint inside of duct with flat black paint to reduce visibility.
- F. Protect diffusers, registers and grilles from construction dirt. Clean or replace those soiled or stained prior to turnover to Client.
- G. In clean rooms, caulk space between diffuser or grille and ceiling or wall to be air and water tight. Use clear, non-hardening silicone sealant compatible with ceiling or wall surface. Sealant shall be resistant to microbiological growth and shall meet CGMP requirements. Refer to Section 20 0000 – General Mechanical Requirements for sealant.

**END OF SECTION**

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## SECTION 23 4114CR

### FILTERS

#### PART 1 GENERAL

##### 1.1 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.2 SUBMITTALS

- A. Shop Drawings including, but not limited to, the following:
  1. Manufacturer's name and model number
  2. Identification as referenced in the Documents
  3. Capacities/ratings; cfm, area, face velocity
  4. Efficiencies and initial/final pressure drop
  5. Materials of construction
  6. Dimensions
  7. Filter gauges data
  8. Manufacturer's installation instructions
  9. All other appropriate data

##### 1.3 DESIGN CRITERIA

- A. Filters shall have UL, Class I or Class II Listing.
- B. Holding frames or housings specified in this Section may be furnished by filter manufacturers listed below, or where applicable, as part of factory packaged air handling units.

#### PART 2 PRODUCTS

##### 2.1 MANUFACTURERS

- A. American Air Filter, Camfil/Farr, Flanders Precisionaire, Glasfloss, Airguard or Filtration Group unless otherwise noted under individual filter.

##### 2.2 DISPOSABLE PANEL FILTERS

- A. Media shall be non-woven, fine fibered material laminated to rigid backing to hold pleat formation, having minimum efficiency MERV 8 based on ASHRAE Test Standard 52.2.
- B. Filter housing shall consist of air handling or cabinet fan unit manufacturer's low velocity filter section, or holding frame, as scheduled. When holding frame is indicated, it may be furnished by, filter manufacturer or it may be contractor fabricated.

- C. Filters shall be 2" thick of size and capacity as scheduled. Clean filter pressure drop shall not exceed 0.28" WG based on 500 fpm face velocity.

### **2.3 DISPOSABLE PANEL FILTERS**

- A. Similar to Farr 40/40 or Flanders Precisionaire PrePleat 40.
- B. Media shall be non-woven, fine fibered material laminated to rigid backing to hold pleat formation, having minimum efficiency MERV 8 based on ASHRAE Test Standard 52.2 (average efficiency of 35 to 40% based on ASHRAE Test Standard 52.1).
- C. Filter housing shall consist of air handling or cabinet fan unit manufacturer's low velocity filter section, or holding frame, as scheduled. When holding frame is indicated, it may be furnished by, filter manufacturer or it may be contractor fabricated.
- D. Filters shall be 4" thick of size and capacity as scheduled. Clean filter pressure drop shall not exceed 0.5 " WG based on 500 fpm face velocity.

### **2.4 DISPOSABLE RIGID CARTRIDGE TYPE AIR FILTERS**

- A. Similar to Farr E-Series RIGA-FLO or Flanders Precisionaire
- B. High performance deep pleated, rigid, disposable type filters. Each filter shall consist of high efficiency media, enclosing frame, contour stabilizers on both air entering and exiting sides and support grilles. Filters shall be designed to withstand minimum differential pressure of 6" WG without structural damage to filter frame, seals or media.
- C. Filter thickness, size and capacity shall be as scheduled.
- D. Filters shall have minimum efficiency MERV 14 based on ASHRAE Test Standard 52.2 (average efficiency of 90-95% based on ASHRAE Test Standard 52.1). Initial resistance at 500 fpm face velocity shall not exceed 0.57" WG.

### **2.5 HIGH EFFICIENCY PARTICULATE AIR (HEPA) FILTERS**

- A. Filters shall be high capacity type. Clean filter pressure drop shall not exceed 1.35" WG based on 500 fpm face velocity.
- B. Filter size, capacity, and static pressure drop shall be as scheduled.
- C. Filters shall be individually tested and certified shall be 99.97% minimum efficient with handling 0.3 micron particles in accordance with DOP test method. DOP efficiency along with filter serial number and name of manufacturer shall be marked on filter.

- D. Each filter element shall consist of glass fiber media, fire retardant epoxy or self-extinguishing neoprene rubber sealer and neoprene gasket all contained in suitable protected steel frame. Each filter element shall be constructed without use of spacers of any kind, including separators, tape, string or strips of medium by self-supporting pleating continuous sheet of formed, corrugated medium. Mount filters in side access housing or holding frames specified elsewhere in this section.
- E. Filters shall be listed or classified under UL 586 test standard.

## **2.6 SIDE ACCESS FILTER HOUSINGS**

- A. Provide for all prefilter and afterfilter banks as scheduled.
- B. Construct housings with galvanized steel with aluminum or galvanized steel filter mounting tracks. Mounting tracks shall have gaskets to minimize air bypass around filters.
- C. Each housing shall have door on both sides to facilitate changing filters. Doors shall have perimeter gaskets to minimize air leakage, shall be hinged, and shall have cam-lock or lever handle latches to secure the door. Doors shall not be secured with nuts and bolts or sheet metal screws.
- D. Each prefilter housing in 2 filter bank air handling unit or each filter housing in single filter bank air handling unit shall include integral prefilter track for 2" prefilters.
- E. Each prefilter housing in 2 filter bank air handling unit shall be internally insulated by manufacturer or externally insulated in the field. Factory applied internal insulation shall have thermal resistance equivalent to that specified for duct in which housing is located, shall have internal vapor barrier, and shall have flame spread and smoke developed ratings as specified in Section 20 0700 - Mechanical Systems Insulation. Afterfilter housings in air handling units shall be externally insulated in the field.

## **2.7 FILTER HOLDING FRAMES**

- A. Frames shall be minimum 16 ga galvanized steel construction with provisions for assembly in a bank. Frames shall be suitable for filters scheduled and incorporate gaskets and spring clips to prevent air bypass.

## **2.8 LOW VELOCITY FILTER SECTIONS**

- A. Provide for factory packaged, air handling units and cabinet fans as indicated.
- B. Housing shall consist of modular steel section with hinged access doors for filter replacement. Each housing shall be internally insulated by manufacturer or externally insulated in the field. Factory applied internal insulation shall have thermal resistance equivalent to that specified for duct in which housing is located, shall have internal vapor barrier, and shall have flame spread and smoke developed ratings as specified in Section 20 0700 - Mechanical Systems Insulation.

## 2.9 FILTER PRESSURE DROP GAUGES

- A. Dwyer Series 2000 Magnehelic pressure gauge.
- B. Unless otherwise indicated below, select scale range to be most appropriate to clean and dirty filter pressure drops.

<u>Filter Type</u>	<u>Scale Range (inch WG)</u>
Throwaway filters	0 - 0.5
Filters with 25 to 30% efficiency based on atmospheric dust spot test	0 - 1.0
Filters with 31 to 99% efficiency based on atmospheric dust spot test	0 - 2.0
HEPA filters	0 - 4.0

- C. Provide gauges for each filter bank, including gauges across each individual filter bank in built-up rack assemblies, suitable for flush mounting in a panel, including air filter gauge accessory package for use with 1/4" OD copper tubing.
- D. Provide 3/4" spacer at one 2' x 2' filter section between filter elements in built-up rack, adjacent to unit wall for placement of intermediate pressure probe.

## 2.10 ADDITIONAL FILTER MEDIA

- A. For disposable panel filters, enough media for 3 filter changes, shall be provided for each air handler. Media used during construction shall be replaced when system is air balanced. Third set of media not used shall be turned over to Owner as spare.

## PART 3 EXECUTION

### 3.1 INSTALLATION

- A. Install filters as shown on drawings and according to manufacturer's instructions.
- B. Provide supports as required and necessary clearance for changing filters.
- C. Provide structural supports, outside casing and blank-off materials for all field assembled filter banks, and filter banks where housings are not furnished by filter manufacturer.

### 3.2 FILTER PRESSURE DROP GAUGES

- A. Mount gauge near each filter bank and install static pressure sensors according to manufacturer's instructions.
- B. Mount gauge on control panel.



### **3.3 FILTER HOLDING FRAMES**

- A. Provide frames for all filter banks as required. Install built-up filter banks in accordance with manufacturer's installation instructions.

**END OF SECTION**



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## SECTION 23 5214CR

### PRIMARY HEATING EQUIPMENT

#### PART 1 GENERAL

##### 1.1 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.2 SUBMITTALS

- A. Shop Drawings for all items in this Section including, but not limited to, the following:
  - 1. Manufacturer's name and model number
  - 2. Identification as referenced in the documents
  - 3. Capacities/ratings
  - 4. Materials of construction
  - 5. Dimensions and weights
  - 6. Temperature/pressure ratings
  - 7. ASME Construction and Stamp
  - 8. Wiring diagrams
  - 9. Manufacturer's installation instructions
  - 10. All other appropriate data
  - 11. Boiler boil-out procedures
- B. Complete equipment data sheet attached at end of this Section for each piece of equipment and submit with Shop Drawings. Shop Drawings will be returned without review if data sheets are not provided for each piece of equipment and if data sheet is not filled out completely.

##### 1.3 CERTIFICATES

- A. Secure all registration and installation permits required by the State and Local Authorities and complete these requirements before system is placed in operation.

##### 1.4 REFERENCE STANDARDS

- A. Boilers shall be constructed, tested and stamped in accordance with the latest ASME Boiler and Pressure Vessel Code and must receive authorized boiler inspection in factory.

#### PART 2 PRODUCTS

##### 2.1 HEAT EXCHANGERS (PLATE AND FRAME TYPE)

- A. Manufacturers: Bell and Gossett, Mueller, APV, Graham or Alfa-Laval with size, capacity, and operating characteristics as scheduled.

- B. Plate and frame type with removable gasketed plates constructed and stamped in accordance with the latest ASME Code. Each unit shall be registered with National Board of Boiler and Pressure Vessel Inspectors.
- C. Heat exchangers shall be suitable for working pressure of 125 psi and test pressure of 250 psi.
- D. Heat exchange plates shall be 304 stainless steel with gasketing material suitable for potable water systems and compatible with hot water heating system chemical treatment.
- E. Furnish units with epoxy coated structural steel framework as required to adequately support assembled plates, stainless steel guide bars, galvanized bolts and nuts
- F. Furnish Units with steel flanges.
- G. Construct nozzles of 304L stainless steel.
- H. Unless otherwise indicated, fouling margin (extra heat exchange surfaces) shall be 10% minimum.

### **PART 3 EXECUTION**

#### **3.1 INSTALLATION**

- A. Install units as shown on plans, as detailed, and according to manufacturer's installation instructions.
- B. Install all items shipped loose by equipment manufacturer under supervision of equipment manufacturer's field service personnel.

#### **3.2 HEAT EXCHANGERS**

- A. Provide structural steel framework as indicated and as required to adequately support unit.
- B. Install piping to heat exchangers with flanges or unions as specified to allow for removal of tube bundle.

**END OF SECTION**

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**SECTION 23 6000CR**

**PRIMARY COOLING EQUIPMENT**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 20 0513 - Motors
- B. Section 20 0700 - Mechanical Systems Insulation
- C. Section 23 0550 - Vibration Isolation
- D. Section 25 3002CR – Process Control Valves and Dampers
- E. Section 25 3003CR – Process Control Instrumentation
- F. Section 25 0993CR – Process Control Sequences

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 SUBMITTALS**

- A. Shop Drawings for all items in this Section including, but not limited to, the following:
  - 1. Manufacturer's name and model number
  - 2. Identification as referenced in the documents
  - 3. Performance data
  - 4. Sound ratings
  - 5. Materials of construction
  - 6. Dimensions and weights
  - 7. Wiring and interlocking diagrams
  - 8. Motor data (refer to Section 20 0513)
  - 9. All other appropriate data
- B. Complete equipment data sheet attached at end of this Section for each piece of equipment and submit with Shop Drawings. Shop Drawings will be returned without review if data sheets are not provided for each piece of equipment and if data sheet is not filled out completely.
- C. Submit with unit Shop Drawings, complete interlocking and line diagrams of all electrical wiring required between machine control panel, starter and temperature control devices.
- D. Wiring and interlocking diagram shall include all components of system including, but not limited to chillers, cooling towers, system pumps, automatic valves, flow switches.

- E. Where multiple units are used, diagrams shall incorporate all units.
- F. Prepare diagram specifically for this project. Any incomplete diagrams and shop drawings will be returned without review.

#### **1.4 CERTIFICATES**

- A. Secure registration and installation permits required by the State and local authorities and complete these requirements before system is placed in operation.

#### **1.5 COORDINATION**

- A. Intent of plans and Specifications is to provide for complete installation meeting all functional and applicable Code requirements including ASHRAE 15 Safety Code Requirements. Design and drawings are based on one of acceptable manufacturers listed in this Specification.
- B. Where requirements of equipment provided, differs from equipment on which design is based, this Contractor shall be responsible for coordinating requirements of equipment with other Contractors involved. This Contractor shall be responsible for any additional costs incurred due to such requirements.
- C. Equipment manufacturer shall review control sequences specified in Section 25 0993CR - Control Sequences and provide all necessary hardware and/or software required for proper operation of the equipment.

#### **1.6 OPERATION AND MAINTENANCE DATA**

- A. Manufacturer shall provide for services of factory-trained service engineer to supervise and approve installation; start-up, test and adjust unit for proper operation. Manufacturer shall provide a minimum of 8 hrs of instruction to Owner's representative in operation and maintenance of machine. This shall include furnishing start-up and test log showing all initial settings and readings; signed by manufacturer's service representative. Provide two additional 4 hr training sessions to be scheduled with Owner. Training shall be for up to 8 people.
- B. Before acceptance by Owner, manufacturer shall approve, in writing, complete installation, including piping and wiring connections, and proper functioning of all operational and safety controls.

#### **1.7 EXTENDED WARRANTY**

- A. Refrigeration machine manufacturer shall provide additional 4 year motor/transmission/compressor parts and labor warranty including refrigerant.
- B. Extended warranty shall start from the date when the 1 yr guarantee specified in Part 1 of Section 20 0000 ends.

## 1.8 MAINTENANCE SERVICE

- A. Furnish service and preventative maintenance of refrigeration machines for period of 1 year from Date of Substantial Completion.
  
- B. A minimum of one inspection is required the first year with 2 inspections for each subsequent year. Under "Annual Inspection and Service Program", the minimum items to be performed shall be as follows:
  - 1. Winter Maintenance Inspection:
    - a. Leak check refrigeration side and repair any leaks.
    - b. Take oil sample (while unit is running) for professional lab analysis and changing oil and oil filters if lab oil analysis indicates breakdown or contamination. Drain oil, disposal shall be included.
    - c. Clean purge system, checking and calibrating as necessary.
    - d. Megometer check of compressor and oil pump motors' insulation valves.
    - e. Calibrate safety controls.
    - f. Check and adjust vane operation.
    - g. Lubricate vane control linkage bearings, ball joints, pivot points, and vane operator shaft.
    - h. Check motor starter panel and contactors. Tighten and adjust electrical connections and terminals.
    - i. Check condenser for tube fouling - recommended cleaning as needed.
    - j. Verify calibration of refrigerant monitor following manufacturers recommended procedures.
    - k. Visually inspect unit and control panel for operational abnormalities.
    - l. Review maintenance procedures and past problems with Owners' operator.
  - 2. Spring Inspection:
    - a. Check and log of all operating pressures, temperatures, electrical loads, and refrigerant levels to ensure maximum efficiency level of chiller.
    - b. Take oil sample (while unit is running) for professional lab analysis and changing oil and oil filters if lab oil analysis indicates breakdown or contamination. Drain oil disposal shall be included.
    - c. Check operation of safety controls.
    - d. Visually inspect unit and control panel for operational abnormalities.
    - e. Review operation and maintenance procedures with Owner's operator.
  - 3. Mid-Season Check:
    - a. Log and record all machine functions to ensure chiller is performing up to manufacturer's specifications.
    - b. Re-check operation of all safety controls.
    - c. Visually inspect unit and control panel for operational abnormalities.
    - d. Review overall operation, problems, and pending maintenance schedule with Owners' operator.

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## **PART 2 PRODUCTS**

### **2.1 REFRIGERATION MACHINES (AIR COOLED TYPE)**

- A. General:
1. Provide 1 packaged air-cooled water chillers.
  2. Chillers shall be installed in accordance with this specification and perform at specified conditions as scheduled.
  3. Air cooled chiller to be compatible with variable primary flow with a minimum flow rate of 110 GPM. Chiller shall operate stably with up to a 10% per minute evaporator flow change.
- B. Manufacturers: Trane, York or Carrier, McQuay
- C. Compressors
1. Construct chiller using hermetic, scroll type compressors with a minimum of two independent circuits, with a minimum of two compressors per circuit.
  2. Statically and dynamically balance rotating parts.
  3. Provide oil lubrication system with oil charging valve and oil filter to ensure adequate lubrication during starting, stopping, and normal operation.
  4. Provide vibration isolator mounts for compressors
  5. Provide constant speed compressor motor, suction gas cooled with - compressor motor overloads capable of monitoring compressor motor current. Furnish chiller with starter. Compressor motor power factor shall be .90 or greater. If the compressor motor power factor is less than .90 power factor correction capacitors must be installed.
  6. Provide crankcase heater to evaporate refrigerant returning to crankcase during shut down. Energize heater when compressor is not operating.
- D. Evaporator
1. Provide shell-and-tube type evaporator, seamless or welded steel construction with cast iron or fabricated steel heads, seamless internally finned copper tubes, roller expanded into tube sheets or brazed plate heat exchanger made of stainless steel with copper as brazing material.
  2. Design, test, and stamp refrigerant side and water side for proper working pressure in accordance with ANSI/ASME SEC 8.
  3. Provide water drain connection, vent, and fittings -and thermostatically controlled heaters to protect to -30°F ambient in off cycle.
  4. Water connections shall be grooved pipe. Evaporator shall have only one entering and one leaving connection.
  5. Evaporator shall be covered with ¾" flexible, closed-cell foam insulation.
  6. Evaporator to utilize a 30% ethylene glycol water solution.
  7. Provide electric heating tracing of the evaporator, to maintain the evaporator at 28°F.
- E. Condenser and Fans
1. Low-ambient controls for operation down to 30°F.
  2. High-ambient controls for operation up to 105°F.



3. Construct condenser coils of aluminum fins mechanically bonded to seamless copper tubing or construct condenser coils of a single material (micro-channel aluminum), coils and headers are to be brazed as one piece. Provide sub-cooling circuits. The design working pressure of the coil is to be 650 psig.
  4. Provide factory-mounted, louvered, painted steel panels. Panel louvers shall cover the condenser coils.
  5. Provide vertical discharge direct-driven propeller type condenser fans with fan guard on discharge. Entire fan assembly shall be statically and dynamically balanced, and fan assembly shall be either glass fiber reinforced composite blades, painted or zinc-coated steel. Fan guard shall be either PVC, chrome, or zinc coated.
  6. Fan motors to be high efficiency, direct drive, insulation type F, current protected Totally Enclosed Air-Over (TEAO), rigid mounted, with double sealed, permanently lubricated, ball bearings.
- F. Enclosures
1. External structural members shall be constructed of heavy gauge, galvanized steel coated with baked on powder paint which, when subjected to ASTM B117, 1000 hour 5% salt spray test, yields minimum ASTM 1654 rating of "6"
  2. Unit panels, decorative louvered panels, and control panels shall be finished with baked-on powder paint. Control panel doors shall have door stays. Paint system shall meet the requirements for outdoor equipment of Federal government Agencies.
  3. Mount starters in weatherproof panel provided with full opening access doors.
- G. Refrigerant Circuit
1. All units shall have 2 refrigeration circuits to provide redundancy, each with 2 or more (manifolded) compressors on each circuit. Single refrigerant circuit chillers are not acceptable.
  2. Provide for each refrigerant circuit:
    - a. Liquid line shutoff valve
    - b. Filter dryer (replaceable core type)
    - c. Liquid line sight glass and moisture indicator
    - d. Electronic or thermal expansion valve sized for maximum operating pressure
    - e. Charging valve
    - f. Discharge and oil line check valves
    - g. Compressor suction and discharge service valves
    - h. High-side pressure relief valve
    - i. Full operating charge of R-410A and oil.
  3. Provide compressor suction service valves and discharge service valves in order to have ability to isolate compressor from rest of refrigerant system.
- H. Controls
1. Chilled water temperature control shall be microprocessor based, proportional and integral controller to show water and refrigerant temperature, refrigerant pressure, and diagnostics. This microprocessor-based controller shall be supplied with each chiller by chiller manufacturer. Controls shall include the following readouts and diagnostics:
    - a. Over/under voltage protection
    - b. Low-chilled-water temperature protection

- c. High and low refrigerant pressure protection
  - d. Load-limit thermostat to limit compressor loading on high-return water temperature
  - e. Condenser fan sequencing to automatically cycle fans in response to load, expansion valve pressure, and condenser pressure to optimize unit efficiency
  - f. Display diagnostics
  - g. Oil pressure control
  - h. Compressors: Status (on/off), % RLA, solid-state anti-short cycle timer, and automatic compressor lead-lag
2. On chiller, mount weatherproof control panel, containing starters, power and control wiring, non-fused disconnect switch (UL Listed) or unit mounted circuit breaker with external lockable operator handle. Provide single-point power connection on units with MCA less than 500 amps. Provide primary and secondary fused-control power transformer and a single 115V, single-phase connection for evaporator heat tape.
- a. Unit controller shall utilize the following components to automatically take action to prevent unit shutdown due to abnormal operating conditions which will perform as follows:
    - 1) High-pressure switch that is set 20 PSIG lower than factory-pressure switch that will automatically unload compressor to help prevent high-pressure condenser control trip. One switch is required for each compressor, and indicating light shall also be provided.
    - 2) Motor-surge protector that is set at 95% of compressor RLA that will automatically unload compressor to help prevent over current trip. One protector is required for each compressor, and indicating light shall also be provided.
    - 3) Low-pressure switch that is set at 5 psig above factory low-pressure switch that will automatically unload compressor to help prevent low-evaporator temperature trip. One switch is required for each compressor, and indicating light shall also be provided.
  - b. In above case, chiller will continue to run in unloaded state, and will continue to produce some chilled water in attempt to meet cooling load. However, if chiller reaches trip-out limits, chiller controls will take chiller off line for protection and manual reset will be required. Once "near-trip" condition is corrected, chiller will return to normal operation and can then produce full load cooling.
  - c. For each compressor, provide across-the-line starter on 460 V applications.
- I. Provide the following safety controls with indicating lights or diagnostic readouts.
1. Low chilled water temperature protection
  2. High refrigerant pressure
  3. Low oil flow protection
  4. Loss of chilled water flow
  5. Contact for remote emergency shut-down
  6. Motor current overload
  7. Failure of water-temperature sensor used by controller
  8. Compressor status (on or off)

- J. Provide the following operating controls:
1. Chiller manufacture to guarantee leaving water temperature at  $\pm 1.5^{\circ}\text{F}$ .
  2. Four (4) or more step leaving chilled water temperature controller which cycles compressors. If manufacturer is unable to provide at least 4 steps of unloading or cannot guarantee leaving water temperature at  $\pm 1.5^{\circ}\text{F}$ , providing Hot Gas Bypass shall be required.
  3. Five-minute, solid-state, anti-recycle timer to prevent compressor from short cycling. If a greater than 5-minute, solid-state, anti-recycle timer is provided, Hot Gas Bypass shall be provided to insure accurate temperature control in light-load applications.
  4. Load-limit thermostat to limit compressor loading on high return-water temperature to prevent nuisance trip outs.
  5. Compressor current sensing unloader unit that unloads compressors to help prevent current overload nuisance tripouts.
  6. Auto lead-lag functions that constantly even out run hours and compressor starts automatically. If Contractor cannot provide this function, then cycle counter and hour meter shall be provided for each compressor so Owner can be instructed by the Contractor on how to manually change lead-lag on compressors and even out compressor starts and running hours.
  7. Low-ambient-lockout control with adjustable setpoint.
  8. Condenser fan sequencing which automatically cycles fans in response to ambient, condensing pressure, and expansion valve pressure differential, thereby optimizing unit efficiency.
- K. Provide pre-piped gauge board with pressure gauges for suction and discharge refrigerant pressures or digital display of pressures on microprocessor.
- L. Unit shall be furnished with single electrical connection.
- M. Communication interface:
1. The chiller controller shall communicate all data to the Clean Room PLC via Modbus RTU or Modbus/TCP communication protocols. The data shall include the following as a minimum:
    - a. Operating Hours
    - b. Entering / Leaving Chilled Water Temperature
    - c. Evaporator Refrigerant Temperature & Pressure
    - d. Condenser Refrigerant Temperature & Pressure
    - e. Loss of Cooling Water Flow
    - f. Chiller Temperature Setpoint
    - g. Chiller Current Limit Setpoint
  2. Provide all hardware, controllers, network controllers, network switches, power supplies, software and devices as required for this interface.
  3. Provide listing of all input/output points including, but not limited to, node number, Modbus Address Registers, point descriptions and associated engineering units for each point. Energy Chiller provider shall be responsible for coordination of all communication requirements with Control Contractor, translation of network protocols, testing of communications between systems, and joint commissioning of systems.

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## 2.2 WATER STORAGE TANK (ST-1)

- A. Lannon Corp., A and S Welding Co., Adamson, Niles Steel Tank (NST), Cemline Corporation, Wheeler Tank Mfg., Inc. or Richmond Engineering Co.
- B. Tank shall have nominal capacity of 500 gal with dimensions of 42 in diameter by 8 ft long.
- C. Tank shall be ASME Construction and ASME Stamped for 150 psig working pressure.
- D. Furnish vertical tank with minimum 4 angle legs. Unless otherwise indicated, tank shall have one outlet near top and one outlet near bottom with bottom of tank 12" above floor or concrete pad.
- E. Provide tank with factory applied one coat of rust inhibitive prime paint for external finish and 2 coats of epoxy paint for internal finish. Epoxy coating to be equal to Plasite 7156 with 10 to 12 mil DFT.
- F. Provide tank with the following openings:
  - 1. One 4" chilled water in
  - 2. One 4" chilled water out
  - 3. One 2" drain
  - 4. One 18" diameter or 12" x 16" oval manhole
- G. Provide 150 lb ANSI flanges for openings 2-1/2" and larger.

## PART 3 EXECUTION

### 3.1 INSTALLATION

- A. Install equipment as shown on drawings, and in accordance with manufacturer's installation instructions.
- B. Install all necessary auxiliary water piping, control devices, and drain and vent piping as shown and required by units.
- C. Install necessary piping with insulation for lubricating system cooler if required.

**END OF SECTION**

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**SECTION 23 7313**

**PACKAGED AIR HANDLING UNITS**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 20 0513 - Motors
- B. Section 20 0514 - Variable Frequency Drive (VFD) System
- C. Section 23 0550CR - Vibration Isolation
- D. Section 25 3002CR - Process Control Valves and Dampers
- E. Section 23 3314CR - Ductwork Specialties (Duct Flexible Connection)
- F. Section 23 4114CR - Filters
- G. Section 23 8216CR - Coils

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 SUBMITTALS**

- A. Shop Drawings including, but not limited to, the following:
  - 1. Manufacturer's name and model number
  - 2. Identification as referenced in the documents
  - 3. Capacities/ratings
  - 4. Fan curves
  - 5. Materials of construction
  - 6. Coils with computer calculated performance data
  - 7. Filters; size, efficiency
  - 8. Sound power levels
  - 9. Fans; type, bearings, drives
  - 10. Motor data (refer to Section 20 0513 - Motors)
  - 11. Vibration isolators furnish with units
  - 12. Dimensions and weights
  - 13. Manufacturer's installation instructions
  - 14. All other appropriate data
- B. Fan curves shall include a series of curves indicating relationship of cfm and static pressure for various rpm, brake horsepower curves, and selection range (surge curves, maximum rpm, etc.)

- C. Indicate operating point on fan curves at design air quantity and at 110% of design air quantity.

#### **1.4 DESIGN CRITERIA**

- A. Furnish factory fabricated air handling units complete with fans, motors, coils, drain pans and filter sections, meeting configuration and as shown on drawings and/or as scheduled.
- B. Units shall be tested, rated, and certified in accordance with ARI Standard 430 and UL or ETL listed. All material shall meet NFPA 90A Flame Spread and Smoke Generation requirements.
- C. Each fan and motor combination shall be capable of delivering 110% of air quantity scheduled at the scheduled static pressure.
- D. Select each fan to operate at single stable operating point as predicted by fan curve. Fans having 2 potential operating points on fan curves are not acceptable.
- E. Air handling unit static pressure shall take into consideration actual static pressure loss of components furnished within unit.
- F. Motor furnished with fan shall not operate into motor service factor in any of these cases. Drive efficiency shall be considered in motor selection according to manufacturer's published recommendation, or according to AMCA Publication 203, Appendix L.
- G. When fan is scheduled to be served by a VFD the motor shall be inverter duty and have shaft grounding kits installed. Refer to section 20 0513 Motors.
- H. Where inlet and outlet ductwork at any fan is changed from that shown on drawings, submit scaled layout of the change and system effect factor calculations, indicating increased static pressure requirement as described in AMCA Publication 201. This Contractor shall be responsible for any motor; drive and/or wiring changes required as result of duct configuration changes at fan.

#### **1.5 INSPECTION AND CERTIFICATION**

- A. Unit manufacturer's representative shall inspect and verify that installation is conforming to manufacturer's recommendations.
- B. Submit report to Engineer in writing certifying that installation is in accordance with manufacturer's recommendations.

### **PART 2 PRODUCTS**

#### **2.1 MANUFACTURERS**

- A. Manufacturers: Carrier, Trane, McQuay or York

- B. This section applies to AHU-C18, AHU-C19 and AHU-C-20.
- C. Factory Fabricated Custom Unit Manufactures are acceptable and may provide packaged air handling units.

## 2.2 CASINGS

- A. Double wall construction with minimum 16 ga G90 galvanized steel outside panel, minimum 20 ga G90 galvanized steel inner liner and insulation between panels.
- B. Fabricate casing of channel posts and removable panels assembled with mechanical fasteners. Assemble sections with high compression gasketing between each frame member and unit panel or door to prevent thermal bridging from interior to exterior of unit.
- C. Access doors shall be double wall construction similar to casing, constructed of G90 galvanized steel, flush mounted to cabinetry, and provided with gasketed seal. Furnish doors with metal hinges, door latch and handle assembly.
  - 1. Furnish inspection window in access door at fan section.
- D. Casing leakage rate shall not exceed 1% of design air flow at 6" WG static pressure.
- E. Insulation shall be foam 2 inch thick, 1-1/2 lb per ft<sup>3</sup> density, with a minimum R value of 8.
- F. Drain pans for cooling coils shall be constructed from 304 stainless steel, cross broken and pitched (double sloped) to drain connection. Drain pan shall extend full depth of cooling coil section to completely drain any condensate. Intermediate drain pans shall be provided for cooling coil banks two coils high.
- G. Coils to be individually supported to allow coils to be removed individually.

## 2.3 PLENUM FANS

- A. General: Fans shall be airfoil centrifugal type designed for industrial duty and suitable for continuous operation. Fans shall be single width, single inlet, arrangement 4, plenum fans with capacities and operating characteristics as indicated on schedules.
- B. Hubs: Hubs shall be cast or welded fabricated hubs with straight bores and keyways. Hubs shall be screwed to the shaft with a minimum of 2 set screws for positive attachment. Hubs using taper lock bushings are not acceptable.
- C. Wheels: Airfoil type, double skinned and welded to center and wheel sideplates. Fan impeller diameters shall conform to AMCA Standard 99-2401-82. Fan blades shall be designed to provide smooth airflow over all surfaces of blade. Fan shafts shall be solid AISI 1040 or 1045 steel. Straight shafts shall be turned, ground and polished to a minimum 16 micro-inch finish. Shaft shall be sized to run at a minimum of 20% greater than the maximum AMCA class speed.

- D. Bearings: Air handling quality, heavy-duty, grease lubricated, pillow block, self-aligning ball or roller type. Bearings shall be selected for minimum life (ABMA L10) of not less than 80,000 hr operation at maximum cataloged operating speed.
- E. Screen Enclosure: Entire plug fan and drive assembly shall be encased with protective screen enclosure. Enclosure shall be constructed of aluminum or galvanized steel mesh or expanded metal and sized to have no measurable system effect on fan performance. Screen shall be reinforced as required to maintain stable structure during fan operation. Access shall be provided for periodic service. Door shall be of suitable size to allow service personnel into enclosure. Enclosure shall be designed and constructed to allow for complete disassembly.
- F. Inlet Screens: Heavy gauge, corrosion resistant, zinc plated steel wire for fans without inlet ductwork.
- G. Inlet Cones: Inlet cones shall be precision spun. Inlet cones shall be aerodynamically matched to wheel side plate to insure full loading of blades. Inlet cones shall be heavy gauge steel.
- H. Painting: All metal parts to be painted with prime coat after metal cleaning and surface preparation. In addition, apply second coat of paint to all exterior surfaces.
- I. Fan sections shall have hinged access doors.

## **2.4 COILS**

- A. Unit heating and/or cooling coils shall be equal to sizes and capacities scheduled and in accordance with requirements of Section 23 8216 - Coils.
- B. Coils mounted in casing shall be accessible for service and to be removable from either side of unit without dismantling entire unit. Coil header and U-bends shall be fully enclosed within unit casing, with supply and return connections extending through casing. Support coils along their entire length within the casing and pitch for proper drainage.
- C. Coil connections shall be factory sealed with grommets and sleeves where piping extends through unit casing to prevent air leakage.
- D. Coil vents and drains shall be provided on coil connection outside unit casing; vent connections at highest point to assure proper venting and drain connections at lowest point to insure proper drainage.
- E. Refer to Item 2.2 - CASINGS for drain pans. Where multiple cooling coils are used in single stacked arrangement, intermediate drain pans shall be provided between each coil.

## **2.5 FILTERS**

- A. Filter section shall include filter racks, and hinges and latching access doors on either, or both sides of section for side loading and removal of filters.



- B. Filter section shall be suitable for installation of filters as indicated in Section 23 4114CR - Filters. Filter section to be furnished as part of air handling unit.

### **PART 3 EXECUTION**

#### **3.1 INSTALLATION**

- A. Install air handling units and accessories as indicated on drawings and/or as scheduled and according to manufacturer's installation instructions.

#### **3.2 PROTECTION OF OPENINGS**

- A. Protect openings on unit housings during construction against entry of foreign matter and construction dirt until ductwork is connected.

**END OF SECTION**



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**SECTION 23 7323CR**

**FACTORY FABRICATED RECIRCULATING AIR CUSTOM AIR HANDLING UNITS**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 20 0513 - Motors
- B. Section 20 0514 - Variable Frequency Drive (VFD) System
- C. Section 20 0529 - Mechanical Supporting Devices
- D. Section 20 0700 - Mechanical Systems Insulation
- E. Section 23 0550CR - Vibration Isolation
- F. Section 25 0901CR - Process Control Systems Integration
- G. Section 25 3002CR - Process Control Valves and Dampers
- H. Section 25 0993CR - Process Control Sequences
- I. Section 23 2116CR - Pipe and Pipe Fittings
- J. Section 23 2118 CR - Valves
- K. Section 23 2120CR - Piping Specialties
- L. Section 23 3314CR - Ductwork Specialties
- M. Section 23 3400CR - Fans
- N. Section 23 4114CR - Filters
- O. Section 23 7214 - Heat Recovery equipment
- P. Section 23 8216CR - Coils
- Q. Section 23 8413CR - Humidification Equipment
- R. Section 26 0519 - Low-Voltage Electrical Power Conductors and Cables
- S. Section 26 0533 - Raceway and Boxes for Electrical Systems
- T. Section 26 2726 - Wiring Devices
- U. Section 26 2816 - Enclosed Switches and Circuit Breakers

V. Section 26 2913 - Enclosed Controllers

W. Section 26 5100 - Lighting

## 1.2 REFERENCE

A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplemental Conditions, and sections under Division 01 General Requirements.

## 1.3 Scope

A. This section applies to:  
1. Custom re-circulating air handling units AHU-C2 through AHU-C16 is to be constructed as indoor units.

## 1.4 SUBMITTALS

A. Shop Drawings for all equipment including, but not limited to, the following:  
1. Appropriate identification  
2. Complete drawings showing plans and sections including details of construction  
3. Overall unit dimensions and individual components and sections dimensions  
4. Shipping and operating weight of unit and/or sections  
5. Structural design load  
6. Details of component support  
7. Capacities/ratings  
8. Materials of construction  
9. Thermal and acoustical performance of wall, roof and floor panels  
10. Pressure ratings and leakage ratings  
11. Thermal break construction details and performance calculations or test data  
12. Each component manufacturer's name, model number and data (Refer to each component section for submittal requirements.)  
13. Air leakage rates and test data  
14. Wiring diagrams and terminal points for control panels provided with units  
15. Manufacturer's installation instructions  
16. Air handling unit manufacturer's local representative and phone number

## 1.5 DESIGN CRITERIA

A. For housings and floors operating under positive pressure (fan discharge side), maximum allowable deflection shall not exceed 1/240th of any span in any direction at + 10" WG.

B. For housings and floors operating under negative pressure (fan inlet side), maximum allowable deflections shall not exceed 1/240th of any span in any direction at - 10" WG.

C. Air handling unit manufacturer shall provide equipment as specified and install equipment furnished by others to result in complete and operational unit. Unit manufacturer shall assume single source responsibility for all air handling unit components and accessories.

- D. Furnish units complete with fans, piping, valves, piping specialties, actuators, motors, coils, humidifiers, drain pans, filter sections, damper sections and interior lighting, meeting configuration and as shown on drawings, specified and as scheduled. All unit components shall meet this Section of specification and all requirements specified in each section and division listed under Related Work. Control dampers shall be provided by unit manufacturer. Control dampers actuators will be furnished by Control Contractor for factory mounting by unit manufacturer.
- E. All materials shall meet NFPA 90A Flame and Smoke Generation Requirements.
- F. Unless otherwise indicated, galvanized steel shall be G90 according to ASTM A924 (formerly ASTM A525), A653 and ASTM A-90 and aluminum sheet shall be 3003-H14 alloy, conforming ASTM B209.
- G. Each fan and motor combination shall be capable of delivering 110% of air quantity scheduled at scheduled total static pressure without operating into motor service factor.
- H. Motor furnished with fan shall not operate into motor service factor in any cases.
- I. When fan is scheduled to be served by a VFD the motor shall be inverter duty and have shaft grounding kits installed. Refer to section 20 0513 Motors.
- J. Where inlet and outlet ductwork at any fan is changed from that shown on drawings, submit scaled layout of the change and system effect factor calculations, indicating increased static pressure requirement as described in AMCA Publication 201. This Contractor shall be responsible for any motor drive and/or wiring changes required as result of duct configuration changes at fan.
- K. Air handling unit static pressure to take into consideration actual static pressure loss of components furnished within unit.
- L. Wire brush all welds with solvent and wipe clean all bare metal before painting.

## **1.6 FINAL CLEANING**

- A. Outside and inside of each air handling unit shall be thoroughly cleaned. Use industrial grade cleaners to remove construction dust, sheet metal mill finish or grease. All proposed cleaning materials shall have contents identified and approved prior to use. Cover unit openings with sheet metal or other proper material until ductwork is connected to maintain unit cleanliness.

## **1.7 MANUFACTURER QUALIFICATIONS**

- A. Air handling units shall be manufactured by qualified unit manufacturer that has been making custom units for at least 10 yrs, and shall carry manufacturer's nameplate. Unit manufacturer shall be held responsible for specified performance of units.

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## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Huntair with operating characteristics as scheduled and physical dimensions as shown on drawings and/or detailed.

### **2.2 UNIT BASE**

- A. Unit base shall be fabricated from structural steel.
- B. Base shall be sized to provide sufficient height above floor to accommodate cooling coil drain trap height indicated on details. Additional steel base may be used as sub-base to provide the required trap height. Sub-base may be provided at factory by unit manufacturer or provided at field by Installing Contractor.
- C. Weld steel solid at connection points to assure rigidity. Size perimeter steel to allow for rigging and handling.
- D. Locate and size base cross supports to support internal components.
- E. Provide lifting lugs to perimeter base steel. Incorporate means of attaching cable or chain into each lug.
- F. Base shall be split in maximum size pieces to allow for economical shipment to jobsite and placement within building. Provide bolting structural steel on both sides of split for field joining.
- G. Unit base shall be primed and finished with rust inhibiting epoxy paint.

### **2.3 UNIT FLOOR**

- A. Unit floor shall be constructed to meet the maximum allowable deflection, and constructed of no lighter than:
  - 1. 12 ga plate of galvanized steel, aluminum or black steel with anti-slip epoxy paint, or 304 stainless steel.
- B. Unless otherwise indicated floor joints and seams for air handling units shall be sealed to meet allowable housing leakage rate specified. Use acrylic latex sealant meeting ASTM C834-76 (1981) or polyurethane sealant, ASTM C-920, Type S, Grade NS, Class 25, USDA Approved.
- C. Weld flooring material to structural members below. Drive screw attachment is not acceptable.
- D. Entire floor including base drain pans shall be insulated on underside to have same thermal and acoustical performance specified for unit housing. Insulation shall be supported by minimum 20 ga galvanized steel liner with joints sealed to provide continuous vapor barrier.

- E. Base Drain Pans:
1. Drain pans shall be constructed from minimum 16 ga 304 SS sheet, all seams continuously welded with minimum 2" turned up.
  2. Drain pan shall be double sloped; pitched down in direction of air flow and pitched sideways to drain connection.
  3. Locate drain connections at lowest point of pan, one on either end. Connections shall extend through perimeter base channel and be continuously welded to insure air-tight seal as well as eliminate requirement for backup wrench during field piping. Provide removable cap on each drain connection.
  4. Refer to Cooling Coil Section for cooling coil drain pan requirements.

## 2.4 UNIT HOUSING

- A. Unit housing shall be constructed of 2" thick double wall panels meeting thermal, acoustical and structural requirements specified.
- B. Panels shall utilize modular panel type construction. Panels may be self-supporting with internal support structure or supported by structural frame work.
- C. Panel joints and seams shall be sealed with proper gasket and caulking to meet maximum allowable housing leakage rate specified.
- D. Panel system shall incorporate thermal break design at panel frames, joining mullions, supporting base, or corners.
- E. Unit manufacturer shall submit, as part of Shop Drawings, details of thermal break construction and calculations or test data indicating that thermal break design will prevent condensation on outside surface of unit casing with specified air temperatures at outside of unit and specified air temperature at inside of unit.
- F. Outer face of panels shall be constructed of no lighter than:
1. 16 ga galvanized steel or 18 ga if injected foam panels are used.
- G. Unless otherwise indicated solid inner face of panels shall be constructed of no lighter than:
1. 20 ga galvanized steel
  2. Unit casing shall be insulated with minimum 3 pcf density glass fiber, or 3 pcf density polyurethane foam insulation. Composite panel shall have heat transfer factor not greater than 0.08 Btu/hr·sq ft·°F. All products as applied shall meet NFPA 90A possessing flame spread rating of not over 25 and smoke developed rating of not over 50.
- H. Use solid inner surface for all sections
- I. Provide blank-off panels with proper gaskets and sealants to prevent air bypass around equipment such as filters, coils, humidifiers and sound attenuators. Blank-off panels shall be constructed of galvanized steel no lighter than 16 ga unless otherwise noted. Blank-off panels at cooling coil sections shall be 2" thick double wall construction with same insulation as housing panels. Do not insulate blank-off panels between cooling coils located above drain pans.

- J. Panel manufacturer shall have published literature available stating sound absorption coefficient of panel system obtained using ASTM Method of Test for Sound Absorption of Acoustical Materials in Reverberation Rooms (ASTM Designation C423-66), and sound transmission loss obtained using procedures conforming to ASTM Designation E90-70, E413-70T and other pertinent standards.
1. Sound Transmission Loss in accordance with ASTM E90 shall equal or exceed the following:

	Octave Band Center Frequency (Hz)					
	125	250	500	1000	2000	4000
Transmission Loss (dB) of 2" Panels	19	23	33	43	52	57

2. Sound performance tests must be documented by independent laboratory (ETL, Riverbank Laboratories, Kideras Labs, etc.).
- K. Manufacturer shall also have published literature available describing load-carrying capabilities and thermal characteristics of the panel system.
- L. Entire roof of outdoor plenums shall be constructed with standing seam water-tight joints and sloped 1/4" per foot.

**2.5 ACCESS DOORS**

- A. Each unit section shall have 18" x 72" access door, unless shown differently on drawings.
- B. Fan section access door shall be sized to allow removal of fan wheel and motor through door, but not smaller than 30" x 72". If access door needs to be wider than 36", removable access panel may be provided.
- C. Access doors and door frames shall have similar thermal break construction as specified under Unit Housing.
- D. Access doors shall be same construction as housing panels.
- E. Access doors located downstream of cooling coils shall be true thermal break design with no metal to metal contact.
- F. Access doors shall be guaranteed tight closing through use of seals around entire periphery. Provide neoprene gasket between door frame and housing for air tight seal.
- G. Each access door shall contain 1/4" thick wire glass or double glazed tempered glass window minimum size of 12" x 12" or 12" round. Window shall be double paned with vapor seal construction.
- H. Each access door shall be furnished with corrosion resistant metal hinges or continuous piano hinge and shall have at least 2 stainless steel or aluminum alloy handles operable from both sides.
- I. Doors shall open against higher air pressure to effect seal.



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## 2.6 ACCESS SECTIONS

- A. Access sections shall allow minimum of 24" between adjoining equipment. Provide access doors as indicated on the plans.

## 2.7 FILTER SECTIONS

- A. Filters shall be provided as specified and scheduled. Holding frames shall be installed by unit manufacturer to raise filters off floor and to prevent leakage in accordance with filter manufacturer's installation recommendation by unit manufacturer.

## 2.8 COOLING COIL SECTIONS

- A. Provide cooling coils, piping and piping specialties specified, and indicated on drawings.
- B. Install coils, internal piping, and specialties not to block face area of coils. Terminate piping outside of unit casing for connection by Mechanical Contractor. Provide necessary pipe supports and hangers.
- C. Each coil shall be supported by 304 stainless steel frame which is independent of unit casing. Support frame shall allow individual coil removal. Coils shall be removable through unit access doors or removable access panels. Blank-off panels shall be 304 stainless steel sheet with insulation as specified.
- D. Each coil support shall include minimum 16 ga 304 stainless steel all welded condensate drain pan extending min. 6", but no more than 12" downstream of coil face. Each drain pan shall have sufficient depth to hold condensate water but not less than 2". Drain pan shall be sloped in 2 directions (pitched down in direction of airflow and pitched sideways to drain connection) for self-drainage at minimum 1/4" per foot slope. Drain pan shall be individually piped down to drain pan located below, and bottom drain pan to be piped to hub drain at exterior of unit. Drain connection opening shall be flush with bottom of pan. Side pan connection located at lowest point of pan may be used only where bottom pan connection cannot be used. Drain pipe shall be 304 stainless steel with sufficient size, but not less than 1-1/2".
- E. Instead of drain pan under bottom coil, recessed pan, integral with unit floor may be used. It shall be constructed as specified above including thermal insulation and drain lines, and shall incorporate required drain trap height.

## 2.9 FAN AND FAN SECTION

- A. Fan and motor shall be provided as scheduled and meet requirements of appropriate Specification Sections.
- B. Fans to be Fan Wall Technology, consist of 4 direct drive plenum fans.

## 2.10 DISCHARGE AIR SECTION

- A. Provide with framed discharge opening conforming to size and configuration of the cleanroom supply air plenum.

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## 2.11 FLOOR OPENING PROTECTION

- A. Floor openings shall have safety grates using 1" x 1/8" galvanized steel bar stock on 1-1/4" center spacing. Grates shall have same finish as floor. Provide 1-1/2" lip of galvanized steel at entire perimeter of opening.

## 2.12 CONTROLS

- A. Control devices shall be by same manufacturer providing control devices for the remainder of the building.
- B. Control devices, will be furnished by Control Contractor and shall be factory installed by unit manufacturer as shown on plans and as described in control section of Specifications.

## 2.13 TESTING

- A. Owner and/or Owner's representative may elect to witness tests. Notify Owner and/or Owner's representative of test date at least 2 weeks in advance. Submit certified test data to Engineer for approval.
- B. Unit manufacturer shall provide factory tests to verify casing leakage after units are assembled.
- C. Unit manufacturer and installing contractor shall jointly provide field tests to verify casing leakage after units are installed at jobsite. Coordinate with Electrical Contractor for power to unit test fan.
- D. Casing leakage tests shall verify that unit casing leakage is less than 1% of design air flow at specified static pressure.
  - 1. Seal duct openings in positive pressure section. Connect this section to fan developing 10" WG positive static pressure, and read air flow of this fan using approved air flow measuring device. Fan air flow measurement shall be considered casing leakage of this Section.
  - 2. Seal duct openings in suction side of unit. Connect this section to fan developing 10 in WG negative static pressure, and read fan air flow of this fan using approved air flow measuring device. Fan air flow shall be considered casing leakage of this Section.
  - 3. Conduct casing leakage test individually for each air handling unit. Total casing leakage shall be calculated as sum of positive pressure section leakage and negative pressure sections leakage. Total casing leakage shall not exceed the allowable rate specified above.
- E. Unit manufacturer shall provide factory panel deflection test. Conduct this test in conjunction with casing leakage testing.
  - 1. Panel deflection test for panels under positive pressure shall verify that unit casing deflection is less than 1/200 of the longest plane being measured at 1-1/2 times design static pressure or 10" WG positive, whichever is greater.

2. Panel deflection test for panels under negative pressure shall verify that unit casing deflection is less than 1/200 of the longest plane being measured at 1-1/2 times design static pressure or 10" WG negative, whichever is more negative.
3. Deflection shall be measured at 2 points for positive pressure sections and 2 points for negative pressure sections (total 4 points at panel seams) at mid-point of panel height.

## **2.14 ELECTRICAL SERVICE**

- A. Provide adequate lighting and switching so equipment can be observed and maintained in safe manner. Combination lighting and convenience outlet circuit is required for each section of unit. Each access section shall contain a minimum of one light fixture. Sections wider than 12 ft shall have multiple light fixtures with maximum spacing of 6 ft.
  1. Provide light switch with pilot light for each access section. Locate switch near access door.
  2. Wire all lights to single junction box with single switch with pilot light.
  3. Provide timer for light switch to automatically turn off lights after preset time. Timer shall be similar to Intermatic Model FF2H with 0-2 hour range and hold feature to override automatic shut-off function.
  4. Light fixtures shall be: fluorescent tube type. Provide bulbs for each fixture.
- B. Lights, switches, convenience outlets, wiring and conduit shall meet requirements of appropriate Specification Sections of Division 26.
- C. Wiring and conduit inside of unit shall be provided by unit manufacturer meeting requirements of NEC and appropriate Specification Sections of Division 26.
  1. Provide junction box for each fan motor at outside of unit wall for 3-phase, 480 V power connection and separate junction box for single-phase, 120 V power connection.
  2. Provide two points of power connection, one for 3-phase, 480 V and one for single-phase, 120 V power connection.
- D. Seal electrical penetrations into unit air-tight.

## **2.15 PIPED SERVICE**

- A. Interior piping and equipment installation shall be complete. Piping shall be installed and tested per appropriate specification section. Unit manufacturer shall be responsible for any leaks, which occur in unit during system testing which occurs before system startup.
- B. Extend piping for each coil and humidifier if used through panel casing. Terminate piping with flange for pipe 2-1/2" and larger or threaded connection for pipe 2" and smaller with caps.

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## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Units shall be assembled in unit manufacturer's plant to allow for testing of complete unit.
- B. Unit manufacturer shall supervise and be responsible for all field joining of the modules, including sheet metal, electrical and piping. Local trades may provide labor for unit assembly and installation.
- C. Joints in floor between modules shall be air and water tight.
- D. Unit manufacturer shall provide and install all equipment within unit as specified including fans, motors, coils, humidifiers, dampers, sound attenuating devices, piping, piping specialties, ductwork specialties, lights, switches and all equipment necessary to complete air handling equipment contained within housings. Mechanical and electrical connections (i.e., piping and conduit) shall be stubbed through housing so that appropriate Contractor may provide service to air handling unit. Electrical wiring and control wiring shall terminate in junction boxes on accessible side of unit.
- E. Provide structural steel sub-base as required. Refer to Unit Base in Part 2.
- F. Field mounting of any equipment on housing walls or roof is not allowed without prior approval of Engineer.
- G. Unit manufacturer and installing contractor shall coordinate with other trade Contractors, all necessary requirements to assure proper air handling unit installation.

### **3.2 INSTRUMENT TEST HOLES**

- A. Provide instrument test holes at air entering and air leaving side of all internal air handling unit components for static pressure differential or temperature measurements. Refer to Section 23 3314 - Ductwork Specialties, for instrument test holes.

### **3.3 PROTECTION OF OPENINGS**

- A. Protect openings on housings during construction against entry of foreign matter and construction dirt.

### **3.4 FIELD TESTING**

- A. Unit manufacturer and installing contractor shall jointly perform field casing leakage test on each completed housing assembly as previously specified and shall be responsible for repair of all leaks. Submit certified test data to Engineer for approval.

- B. Temporary sealing of access doors, condensate drains, etc. is not allowed during field testing except to troubleshoot leakage points.

**END OF SECTION**



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**SECTION 23 7328CR**

**FACTORY FABRICATED OUTSIDE AIR CUSTOM AIR HANDLING UNITS AND HEAT RECOVERY UNITS**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 20 0513 - Motors
- B. Section 20 0514 - Variable Frequency Drive (VFD) System
- C. Section 20 0529 - Mechanical Supporting Devices
- D. Section 20 0700 - Mechanical Systems Insulation
- E. Section 23 0550CR - Vibration Isolation
- F. Section 25 0901CR – Process Control Systems Integration
- G. Section 25 3002CR – Process Control Valves and Dampers
- H. Section 25 0993CR – Process Control Sequences
- I. Section 23 2116CR - Pipe and Pipe Fittings
- J. Section 23 2118 CR- Valves
- K. Section 23 2120CR - Piping Specialties
- L. Section 23 3314CR - Ductwork Specialties
- M. Section 23 3400CR - Fans
- N. Section 23 4114CR – Filters
- O. Section 23 7214 – Heat Recovery equipment
- P. Section 23 8216CR - Coils
- Q. Section 23 8413CR - Humidification Equipment
- R. Section 26 0519 - Low-Voltage Electrical Power Conductors and Cables
- S. Section 26 0533 - Raceway and Boxes for Electrical Systems
- T. Section 26 2726 - Wiring Devices
- U. Section 26 2816 - Enclosed Switches and Circuit Breakers

V. Section 26 2913 - Enclosed Controllers

W. Section 26 5100 - Lighting

## 1.2 REFERENCE

A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplemental Conditions, and sections under Division 01 General Requirements.

## 1.3 Scope

A. This section applies to:

1. Custom outside air, air handling unit AHU-C1 is to be constructed as indoor unit.
2. Heat recovery units (HRU) which are to be constructed as outdoor units.

B. Heat recovery unit (HRU-SE-1) is to be constructed with all 316 stainless steel interior with all welded floors similar to wash down unit.

## 1.4 SUBMITTALS

A. Shop Drawings for all equipment including, but not limited to, the following:

1. Appropriate identification
2. Complete drawings showing plans and sections including details of construction
3. Overall unit dimensions and individual components and sections dimensions
4. Shipping and operating weight of unit and/or sections
5. Structural design load
6. Details of component support
7. Capacities/ratings
8. Materials of construction
9. Thermal and acoustical performance of wall, roof and floor panels
10. Pressure ratings and leakage ratings
11. Thermal break construction details and performance calculations or test data
12. Each component manufacturer's name, model number and data (Refer to each component section for submittal requirements.)
13. Air leakage rates and test data
14. Wiring diagrams and terminal points for control panels provided with units
15. Manufacturer's installation instructions
16. Air handling unit manufacturer's local representative and phone number



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## 1.5 DESIGN CRITERIA

- A. For housings and floors operating under positive pressure (fan discharge side), maximum allowable deflection shall not exceed 1/240th of any span in any direction at + 10" WG.
- B. For housings and floors operating under negative pressure (fan inlet side), maximum allowable deflections shall not exceed 1/240th of any span in any direction at - 10" WG.
- C. Air handling unit manufacturer shall provide equipment as specified and install equipment furnished by others to result in complete and operational unit. Unit manufacturer shall assume single source responsibility for all air handling unit components and accessories.
- D. Furnish units complete with fans, piping, valves, piping specialties, actuators, motors, coils, humidifiers, drain pans, filter sections, damper sections and interior lighting, meeting configuration and as shown on drawings, specified and as scheduled. All unit components shall meet this Section of specification and all requirements specified in each section and division listed under Related Work. Control dampers shall be provided by unit manufacturer. Control dampers actuators will be furnished by Control Contractor for factory mounting by unit manufacturer.
- E. All materials shall meet NFPA 90A Flame and Smoke Generation Requirements.
- F. Unless otherwise indicated, galvanized steel shall be G90 according to ASTM A924 (formerly ASTM A525), A653 and ASTM A-90 and aluminum sheet shall be 3003-H14 alloy, conforming ASTM B209.
- G. Each fan and motor combination shall be capable of delivering 110% of air quantity scheduled at scheduled total static pressure without operating into motor service factor.
- H. Motor furnished with fan shall not operate into motor service factor in any cases.
- I. When fan is scheduled to be served by a VFD the motor shall be inverter duty and a shaft grounding kit shall be installed. Refer to section 20 0513.
- J. Where inlet and outlet ductwork at any fan is changed from that shown on drawings, submit scaled layout of the change and system effect factor calculations, indicating increased static pressure requirement as described in AMCA Publication 201. This Contractor shall be responsible for any motor drive and/or wiring changes required as result of duct configuration changes at fan.
- K. Air handling unit static pressure to take into consideration actual static pressure loss of components furnished within unit.
- L. Wire brush all welds with solvent and wipe clean all bare metal before painting.

## **1.6 FINAL CLEANING**

- A. Outside and inside of each air handling unit shall be thoroughly cleaned. Use industrial grade cleaners to remove construction dust, sheet metal mill finish or grease. All proposed cleaning materials shall have contents identified and approved prior to use. Cover unit openings with sheet metal or other proper material until ductwork is connected to maintain unit cleanliness.

## **1.7 MANUFACTURER QUALIFICATIONS**

- A. Air handling units shall be manufactured by qualified unit manufacturer that has been making custom units for at least 10 yrs, and shall carry manufacturer's nameplate. Unit manufacturer shall be held responsible for specified performance of units.

## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Haakon, Buffalo, Huntair, Governair, Racan, Climate Craft, Ventrol, Scott Springfield, Trane Custom, York Custom, MarCraft, or TMI with operating characteristics as scheduled and physical dimensions as shown on drawings and/or detailed.

### **2.2 UNIT BASE**

- A. Unit base shall be fabricated from structural steel.
- B. Base shall be sized to provide sufficient height above floor to accommodate cooling coil drain trap height indicated on details. Additional steel base may be used as sub-base to provide the required trap height. Sub-base may be provided at factory by unit manufacturer or provided at field by Installing Contractor.
- C. Weld steel solid at connection points to assure rigidity. Size perimeter steel to allow for rigging and handling.
- D. Locate and size base cross supports to support internal components.
- E. Provide lifting lugs to perimeter base steel. Incorporate means of attaching cable or chain into each lug.
- F. Base shall be split in maximum size pieces to allow for economical shipment to jobsite and placement within building. Provide bolting structural steel on both sides of split for field joining.
- G. Unit base shall be primed and finished with rust inhibiting epoxy paint.

## 2.3 UNIT FLOOR

- A. Unit floor shall be constructed to meet the maximum allowable deflection, and constructed of no lighter than:
  - 1. Air Handling Units:
    - a. 12 ga plate of galvanized steel, aluminum, black steel with anti-slip epoxy paint, or 304 stainless steel.
  - 2. Heat Recovery Units:
    - a. 12 ga plate 316 stainless steel.
- B. Unless otherwise indicated floor joints and seams for air handling units shall be sealed to meet allowable housing leakage rate specified. Use acrylic latex sealant meeting ASTM C834-76 (1981) or polyurethane sealant, ASTM C-920, Type S, Grade NS, Class 25, USDA Approved.
- C. Floor joints and seams for AHU-C1 and HRU-SE-1 shall be continuously welded water tight. Each section shall have turned up lip around section perimeter with welded corner to form drain pan type floor capable of retaining minimum 1-1/2" of water without leakage. Locate drain connection at lowest point of each pan type floor section. Connections shall extend through perimeter base channel and be welded water tight. Provide removable cap on each drain connection.
- D. Weld flooring material to structural members below. Drive screw attachment is not acceptable.
- E. Entire floor including base drain pans shall be insulated on underside to have same thermal and acoustical performance specified for unit housing. Insulation shall be supported by minimum 20 ga galvanized steel liner with joints sealed to provide continuous vapor barrier.
- F. Base Drain Pans:
  - 1. For HRU-SE-1 and AHU-C1 provide recessed drain pans as integral part of unit floor throughout entire heat recovery exhaust plenum.
  - 2. Drain pans shall be constructed from minimum 16 ga 316 SS sheet, all seams continuously welded with minimum 2" turned up.
  - 3. Drain pan shall be double sloped; pitched down in direction of air flow and pitched sideways to drain connection.
  - 4. Locate drain connections at lowest point of pan, one on either end. Connections shall extend through perimeter base channel and be continuously welded to insure air-tight seal as well as eliminate requirement for backup wrench during field piping. Provide removable cap on each drain connection.
  - 5. Refer to Cooling Coil Section for cooling coil drain pan requirements.

## 2.4 UNIT HOUSING

- A. Unit housing shall be constructed of 3 or 4" thick double wall panels meeting thermal, acoustical and structural requirements specified.
- B. Panels shall utilize modular panel type construction. Panels may be self-supporting with internal support structure or supported by structural frame work.

- C. Panel joints and seams shall be sealed with proper gasket and caulking to meet maximum allowable housing leakage rate specified.
- D. Panel system shall incorporate thermal break design at panel frames, joining mullions, supporting base, or corners. Thermal break is defined as prevention of condensation on outside surface of unit casing with 95°F dry bulb and 75°F wet bulb temperature in adjacent space and 50°F dry bulb temperature inside air handling unit for all air handling unit except AHU-C1. Thermal break for AHU-C-1 to be is defined as prevention of condensation on outside surface of unit casing with 95°F dry bulb and 75°F wet bulb temperature in adjacent space and 43°F dry bulb temperature inside air handling unit.
- E. Unit manufacturer shall submit, as part of Shop Drawings, details of thermal break construction and calculations or test data indicating that thermal break design will prevent condensation on outside surface of unit casing with specified air temperatures at outside of unit and specified air temperature at inside of unit.
- F. Outer face of panels shall be constructed of no lighter than:
  - 1. 16 ga galvanized steel or 18 ga if injected foam panels are used.
- G. Unless otherwise indicated solid inner face of panels shall be constructed of no lighter than:
  - 1. 20 ga galvanized steel
  - 2. HRU-SE-1 shall be 18 ga Type 316 stainless steel. All interior panel joints shall be welded air-tight and suitable for washdown.
  - 3. Unit casing shall be insulated with minimum 3 pcf density glass fiber, or 3 pcf density polyurethane foam insulation. Composite panel shall have heat transfer factor not greater than 0.06 Btu/hr-sq ft-°F. All products as applied shall meet NFPA 90A possessing flame spread rating of not over 25 and smoke developed rating of not over 50.
- H. Use solid inner surface for all sections
- I. Provide blank-off panels with proper gaskets and sealants to prevent air bypass around equipment such as filters, coils, humidifiers and sound attenuators. Blank-off panels shall be constructed of galvanized steel no lighter than 16 ga unless otherwise noted. Blank-off panels at cooling coil sections shall be 2" thick double wall construction with same insulation as housing panels. Do not insulate blank-off panels between cooling coils located above drain pans.
- J. Panel manufacturer shall have published literature available stating sound absorption coefficient of panel system obtained using ASTM Method of Test for Sound Absorption of Acoustical Materials in Reverberation Rooms (ASTM Designation C423-66), and sound transmission loss obtained using procedures conforming to ASTM Designation E90-70, E413-70T and other pertinent standards.
  - 1. Sound Transmission Loss in accordance with ASTM E90 shall equal or exceed the following:

	Octave Band Center Frequency (Hz)					
	125	250	500	1000	2000	4000
Transmission Loss (dB) of 4" Panels	21	24	34	44	51	53
Transmission Loss (dB) of 2" Panels	19	23	33	43	52	57

2. Sound performance tests must be documented by independent laboratory (ETL, Riverbank Laboratories, Kideras Labs, etc.).
- K. Manufacturer shall also have published literature available describing load-carrying capabilities and thermal characteristics of the panel system.
- L. For HRU-SE1; Entire roof of outdoor units shall be constructed with standing seam water-tight joints and sloped 1/4: per foot. Roof to be constructed to support a 250 pound person on the roof.

## 2.5 ACCESS DOORS

- A. Each unit section shall have 24" x 72" access door, unless shown differently on drawings.
- B. Fan section access door shall be sized to allow removal of fan wheel and motor through door, but not smaller than 30" x 72". If access door needs to be wider than 36", removable access panel may be provided.
- C. Access doors and door frames shall have similar thermal break construction as specified under Unit Housing.
- D. Access doors shall be same construction as housing panels.
- E. Access doors located downstream of cooling coils shall be true thermal break design with no metal to metal contact.
- F. Access doors shall be guaranteed tight closing through use of seals around entire periphery. Provide neoprene gasket between door frame and housing for air tight seal.
- G. Each access door shall contain 1/4" thick wire glass or double glazed tempered glass window minimum size of 12" x 12" or 12" round. Window shall be double paned with vapor seal construction.
- H. Each access door shall be furnished with corrosion resistant metal hinges or continuous piano hinge and shall have at least 2 stainless steel or aluminum alloy handles operable from both sides.
- I. Doors shall open against higher air pressure to effect seal.

## 2.6 ACCESS SECTIONS

- A. Access sections shall allow minimum of 30" between adjoining equipment. Provide access doors as indicated on the plans.

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## **2.7 REMOVABLE ACCESS PANELS**

- A. Removable access panels shall be provided as indicated on drawings and where equipment removal is not possible through access door. Removable panels shall be same construction as housing panels.

## **2.8 FILTER SECTIONS**

- A. Filters shall be provided as specified and scheduled. Holding frames shall be installed by unit manufacturer to raise filters off floor and to prevent leakage in accordance with filter manufacturer's installation recommendation by unit manufacturer.

## **2.9 PREHEAT COIL SECTION**

- A. Provide preheat coils, piping and internal piping as specified and indicated on drawings.
- B. Install coils, piping, and specialties not to block face area of coils. Terminate piping outside of unit casing for connection by Mechanical Contractor. Provide necessary pipe supports and hangers.
- C. Each coil shall be supported by galvanized steel frame which is independent of unit casing. Support frame shall allow individual coil removal. Coils shall be removable through unit access doors. Blank-off panels shall be galvanized steel sheets.

## **2.10 HEAT RECOVERY COIL SECTION**

- A. The following air handling units shall be provided with run-around loop heat recovery coils:
  - 1. AHU-C1
- B. The following exhaust air heat recovery units shall be provided with run-around loop heat recovery coils:
  - 1. HRU-SE-1
- C. Heat recovery units shall be provided with face dampers upstream of filter section and downstream of heat recovery coil section and bypass section to isolate filters and heat recovery coil from exhaust air stream to facilitate maintenance operations.
- D. Provide heat reclaim coils, piping and internal piping as specified and indicated on drawings.
- E. Install coils, piping, and specialties not to block face area of coils. Terminate piping outside of unit casing for connection by Mechanical Contractor. Provide necessary pipe supports and hangers.
- F. Each AHU-C1 coil shall be supported by 304 stainless steel frame, which is independent of unit casing. Support frame shall allow individual coil removal. Coils shall be removable through unit access doors. Blank-off panels shall be 304 stainless steel sheets with insulation as specified.

- G. Each exhaust heat reclaim unit (HRU-SE1) coil support shall include minimum 16 ga 316 stainless steel all welded condensate drain pan extending min. 6", but no more than 12" downstream of coil face. Each drain pan shall have sufficient depth to hold condensate water but not less than 2". Drain pan shall be sloped in 2 directions (pitched down in direction of airflow and pitched sideways to drain connection) for self-drainage at minimum 1/4" per foot slope. Drain pan shall be individually piped down to drain pan located below, and bottom drain pan to be piped to hub drain at exterior of unit. Drain connection opening shall be flush with bottom of pan. Side pan connection located at lowest point of pan may be used only where bottom pan connection cannot be used. Drain pipe shall be 316 stainless steel with sufficient size, but not less than 1-1/2".

## 2.11 COOLING COIL SECTIONS

- A. Provide cooling coils, piping and piping specialties specified, and indicated on drawings.
- B. Install coils, internal piping, and specialties not to block face area of coils. Terminate piping outside of unit casing for connection by Mechanical Contractor. Provide necessary pipe supports and hangers.
- C. Each coil shall be supported by 304 stainless steel frame which is independent of unit casing. Support frame shall allow individual coil removal. Coils shall be removable through unit access doors or removable access panels. Blank-off panels shall be 304 stainless steel sheet with insulation as specified.
- D. Each coil support shall include minimum 16 ga 304 stainless steel all welded condensate drain pan extending min. 6", but no more than 12" downstream of coil face. Each drain pan shall have sufficient depth to hold condensate water but not less than 2". Drain pan shall be sloped in 2 directions (pitched down in direction of airflow and pitched sideways to drain connection) for self-drainage at minimum 1/4" per foot slope. Drain pan shall be individually piped down to drain pan located below, and bottom drain pan to be piped to hub drain at exterior of unit. Drain connection opening shall be flush with bottom of pan. Side pan connection located at lowest point of pan may be used only where bottom pan connection cannot be used. Drain pipe shall be 304 stainless steel with sufficient size, but not less than 1-1/2".
- E. Instead of drain pan under bottom coil, recessed pan, integral with unit floor may be used. It shall be constructed as specified above including thermal insulation and drain lines, and shall incorporate required drain trap height.

## 2.12 FAN SECTION

- A. Fan and motor shall be provided as scheduled and meet requirements of appropriate Specification Sections.
- B. Fan and motor shall be factory mounted on vibration isolation equipment meeting requirements of Section 23 0550 - Vibration Isolation. Vibration base shall include integral adjustable motor base. If inertia bases are required, provide required concrete in factory.

- C. Provide track in fan section suitable for use with trolley-type winch, to be used for removing fan motor. Track shall be centered with fan section access door.

### **2.13 HUMIDIFIER SECTION**

- A. Provide humidifiers, piping and supports as specified, and indicated on drawings. Terminate piping outside of unit casing for connection by Mechanical Contractor.
- B. Size and locate humidifier distribution tubes to receive uniform air flow on entire tube.
- C. Provide required absorption distance between humidifier and downstream equipment or housing wall.

### **2.14 DISCHARGE AIR SECTION**

- A. Provide with framed discharge opening or spun bellmouth fitting conforming to size and configuration of the ductwork.

### **2.15 CONTROL DAMPERS**

- A. Refer to Section 23 0902 - Control Valves and Dampers, for control dampers.
- B. Outside air dampers shall be equal to Tamco Series 9000 thermally insulated dampers.
  - 1. Extruded aluminum (6063T5) damper frame shall not be less than .080" in thickness. Damper frame shall be 4" deep. Outside air dampers shall be insulated with polystyrofoam on four sides.
  - 2. Blades shall be extruded aluminum (6063T5) profiles. Dampers shall be internally insulated with expanded polyurethane foam and shall be thermally broken. Complete blade shall have an insulating factor of R-2.29 and temperature index of 55.
  - 3. Blade seals shall be of extruded EPDM. Frame seals shall be of extruded TPE thermoplastic. Seals shall be secured in integral slot within aluminum extrusions.
  - 4. Bearings shall be composed of Celcon inner bearing fixed to 7/16" aluminum hexagon blade pin, rotating within polycarbonate outer bearing inserted in frame, resulting in no metal-to-metal or metal-to-plastic contact.
  - 5. Linkage hardware shall be installed in frame side and constructed of aluminum and corrosion-resistant, zinc-plated steel, complete with cup-point trunnion screws for slip-proof grip.
  - 6. Dampers shall be designed for operation in temperatures ranging between -40°F and 212°F.
  - 7. Air leakage through 48" x 48" damper shall not exceed 4.12 cfm/ft<sup>2</sup> against 4" WG differential static pressure at standard air.
  - 8. Pressure drop of fully open 48" x 48" damper shall not exceed .03" WG at 1000 fpm.

### **2.16 FLOOR OPENING PROTECTION**

- A. Floor openings shall have safety grates using 1" x 1/8" steel bar stock on 1-1/4" center spacing. Grates shall have same finish as floor. Provide 1-1/2" lip of galvanized steel at entire perimeter of opening.



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## 2.17 ROOF CURB

- A. Unit manufacturer shall furnish roof curb for exhaust plenums located on roof. Roof curb shall be 18" high and constructed from minimum 12ga galvanized steel. At each of 4 corners, curb shall be joined together with corner post that is welded to one section of curb and then field bolted to adjacent section. Wood nailer shall be attached to inside flange of curb for field attachment of flashing and roof membranes.

## 2.18 CONTROLS

- A. Control devices shall be by same manufacturer providing control devices for the remainder of the building.
- B. Control devices, will be furnished by Control Contractor and shall be factory installed by unit manufacturer as shown on plans and as described in control section of Specifications.

## 2.19 TESTING

- A. Owner and/or Owner's representative may elect to witness tests. Notify Owner and/or Owner's representative of test date at least 2 weeks in advance. Submit certified test data to Engineer for approval.
- B. Unit manufacturer shall provide factory tests to verify casing leakage after units are assembled.
- C. Unit manufacturer and installing contractor shall jointly provide field tests to verify casing leakage after units are installed at jobsite. Coordinate with Electrical Contractor for power to unit test fan.
- D. Casing leakage tests shall verify that unit casing leakage is less than 1% of design air flow at specified static pressure.
  - 1. Seal duct openings in positive pressure section. Connect this section to fan developing 10" WG positive static pressure, and read air flow of this fan using approved air flow measuring device. Fan air flow measurement shall be considered casing leakage of this Section.
  - 2. Seal duct openings in suction side of unit. Connect this section to fan developing 10 in WG negative static pressure, and read fan air flow of this fan using approved air flow measuring device. Fan air flow shall be considered casing leakage of this Section.
  - 3. Conduct casing leakage test individually for each air handling unit. Total casing leakage shall be calculated as sum of positive pressure section leakage and negative pressure sections leakage. Total casing leakage shall not exceed the allowable rate specified above.

- E. Unit manufacturer shall provide factory panel deflection test. Conduct this test in conjunction with casing leakage testing.
  - 1. Panel deflection test for panels under positive pressure shall verify that unit casing deflection is less than 1/200 of the longest plane being measured at 1-1/2 times design static pressure or 10" WG positive, whichever is greater.
  - 2. Panel deflection test for panels under negative pressure shall verify that unit casing deflection is less than 1/200 of the longest plane being measured at 1-1/2 times design static pressure or 10" WG negative, whichever is more negative.
  - 3. Deflection shall be measured at 2 points for positive pressure sections and 2 points for negative pressure sections (total 4 points at panel seams) at mid-point of panel height.

## 2.20 ELECTRICAL SERVICE

- A. Provide adequate lighting and switching so equipment can be observed and maintained in safe manner. Combination lighting and convenience outlet circuit is required for each section of unit. Each access section shall contain a minimum of one light fixture. Sections wider than 12 ft shall have multiple light fixtures with maximum spacing of 6 ft.
  - 1. Provide light switch with pilot light for each access section. Locate switch near access door.
  - 2. Wire all lights to single junction box with single switch with pilot light.
  - 3. Provide timer for light switch to automatically turn off lights after preset time. Timer shall be similar to Intermatic Model FF2H with 0-2 hour range and hold feature to override automatic shut-off function.
  - 4. Light fixtures shall be: fluorescent tube type. Provide bulbs for each fixture.
- B. Lights, switches, convenience outlets, wiring and conduit shall meet requirements of appropriate Specification Sections of Division 26.
- C. Wiring and conduit inside of unit shall be provided by unit manufacturer meeting requirements of NEC and appropriate Specification Sections of Division 26.
  - 1. Provide junction box for each fan motor at outside of unit wall for 3-phase, 480 V power connection and separate junction box for single-phase, 120 V power connection.
  - 2. Provide two points of power connection, one for 3-phase, 480 V and one for single-phase, 120 V power connection.
- D. Seal electrical penetrations into unit air-tight.

## 2.21 PIPED SERVICE

- A. Interior piping and equipment installation shall be complete. Piping shall be installed and tested per appropriate specification section. Unit manufacturer shall be responsible for any leaks, which occur in unit during system testing which occurs before system startup.
- B. Extend piping for each coil and humidifier if used through panel casing. Terminate piping with flange for pipe 2-1/2" and larger or threaded connection for pipe 2" and smaller with caps.

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## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Units shall be assembled in unit manufacturer's plant to allow for testing of complete unit.
- B. Unit manufacturer shall supervise and be responsible for all field joining of the modules, including sheet metal, electrical and piping. Local trades may provide labor for unit assembly and installation.
- C. Joints in floor between modules shall be air and water tight.
- D. Unit manufacturer shall provide and install all equipment within unit as specified including fans, motors, coils, humidifiers, dampers, sound attenuating devices, piping, piping specialties, ductwork specialties, lights, switches and all equipment necessary to complete air handling equipment contained within housings. Mechanical and electrical connections (i.e., piping and conduit) shall be stubbed through housing so that appropriate Contractor may provide service to air handling unit. Electrical wiring and control wiring shall terminate in junction boxes on accessible side of unit.
- E. Provide structural steel sub-base as required. Refer to Unit Base in Part 2.
- F. Field mounting of any equipment on housing walls or roof is not allowed without prior approval of Engineer.
- G. Unit manufacturer and installing contractor shall coordinate with other trade Contractors, all necessary requirements to assure proper air handling unit installation.

### **3.2 INSTRUMENT TEST HOLES**

- A. Provide instrument test holes at air entering and air leaving side of all internal air handling unit components for static pressure differential or temperature measurements. Refer to Section 23 3314 - Ductwork Specialties, for instrument test holes.

### **3.3 PROTECTION OF OPENINGS**

- A. Protect openings on housings during construction against entry of foreign matter and construction dirt.

### **3.4 FIELD TESTING**

- A. Unit manufacturer and installing contractor shall jointly perform field casing leakage test on each completed housing assembly as previously specified and shall be responsible for repair of all leaks. Submit certified test data to Engineer for approval.

- B. Temporary sealing of access doors, condensate drains, etc. is not allowed during field testing except to troubleshoot leakage points.

**END OF SECTION**

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## SECTION 23 8216CR

### COILS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 23 8214CR - Heating and Cooling Terminal Devices

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 SUBMITTALS

- A. Shop Drawings including, but not limited to, the following:
  1. Manufacturer's name and model number
  2. Identification as referenced in the documents
  3. Capacities/ratings
  4. Flow rate and pressure drop
  5. Materials of construction
  6. Dimensions and weights
  7. Manufacturer's installation instructions
  8. All other appropriate data

##### 1.4 DESIGN CRITERIA

- A. This Section covers coils in factory-packaged air handling unit, custom air handling units and field-erected air handling units.
- B. Coil sizes, capacities, configuration and operating characteristics to be as shown on plans and/or as scheduled. Coil performance data shall be certified in accordance with AHRI Standard 410.
- C. Unless otherwise specified, temperature profile of discharge air from entire coil face shall be uniform within 12" of coil face.

##### 1.5 CORROSION PROTECTION COATING

- A. Where coils are specified to be corrosion protection coated, protect coils with coating similar to Heresite P-413 baking phenolic with plasticizer.
- B. Apply coating by 4 consecutive total immersions. After each of first 3 immersions, coating shall be partially cured in oven. Following fourth immersion and 1 spray coat, coating shall be totally cured in oven.

- C. Total dry film thickness (DFT) of coating shall be approximately 2-3 mils. Coating shall withstand dry heat up to 205°C (400°F), and show no sign of attack after 3000 hrs of salt spray test to ASTM Specification B117.

## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Manufacturers: Buffalo, Carrier, McQuay, Trane, Marlo, Heatcraft, Aerofin, RAE, or Temtrol

### **2.2 HOT WATER COILS**

- A. Coils shall be constructed of 0.024" tube wall, 1/2" or 5/8" OD seamless copper tubes with aluminum fins suitable for working pressures to 200 psig and temperatures to 220°F. Coils shall be tested at 250 psig under water.
- B. Coil fins shall be continuous serpentine or plate fin type.
- C. Coil headers shall be cast iron with tubes expanded into headers, steel pipe with brazed tube connections, or heavy seamless copper with tubes brazed to header.
- D. Casings shall be minimum 16ga galvanized steel having galvanized steel end supports and top and bottom channels of rigid construction with allowance for expansion and contraction of finned tube section.
- E. Coils shall be equipped with bronze spring turbulators where required to provide capacities indicated.

### **2.3 CHILLED WATER COILS**

- A. Coils shall be constructed of 0.035" tube wall, 1/2" or 5/8" OD seamless copper tubes with 0.0095" aluminum fins suitable for working pressures to 200 psig. Coils shall be tested at 250 psig under water.
- B. Coil fins shall be continuous plate fin type.
- C. Coil headers shall be constructed of cast iron with tubes expanded into headers, steel pipe with brazed tube connections, or heavy seamless copper with tubes brazed to header.
- D. Casings shall be minimum 16ga stainless steel having stainless steel end supports and top and bottom channels of rigid construction with allowance for expansion and contraction of finned tube section.
- E. Select coils for tube velocity not less than 3.0 fps.
- F. Maximum allowable fin spacing shall be 10 fins per inch. Coil depth shall not exceed 8 rows.

- G. Coils shall be drainable type having separate header for each tube row and separate drain and vent plugs to assure complete drainage.

## **2.4 EXHAUST AIR HEAT RECOVERY COILS**

- A. Coils shall be constructed of 0.024" tube wall, 5/8" OD seamless copper tubes with aluminum fins suitable for working pressures to 200 psig. Coils shall be tested at 250 psig under water.
- B. Coil fins shall be continuous plate fin type.
- C. Coil headers shall be constructed of cast iron with tubes expanded into headers, steel pipe with brazed tube connections, or heavy seamless copper with tubes brazed to header.
- D. Casings shall be minimum 16ga 304 stainless steel having stainless steel end supports and top and bottom channels of rigid construction with allowance for expansion and contraction of finned tube section.
- E. Maximum allowable fin spacing shall be 10 fins per in. Coil depth shall not exceed 8 rows.
- F. Coils shall be drainable type having separate header for each tube row and separate drain and vent plugs to assure complete drainage.
- G. Provide corrosion protection on coils. Refer to Part 1 of this Section.

## **2.5 OUTSIDE AIR HEAT RECOVERY COILS**

- A. Coils shall comply with all requirements of chilled water coils.

## **PART 3 EXECUTION**

### **3.1 GENERAL**

- A. Install coils as indicated on drawings and/or as detailed. Pitch coils for proper drainage according to manufacturer's installation instructions. Install shims as required.
- B. Clean oil film from coil fins with hot water/detergent as recommended by coil manufacturer.
- C. Comb out fins when bent or crushed before enclosing coils in housing. Clean dust and debris from each coil to ensure its cleanliness.
- D. Provide offsets in piping to facilitate coil removal. Unless otherwise specified, pipe coils for counter flow arrangement.
- E. Install piping flexible connections and/or piping vibration isolation supports as specified in Section 23 0550CR - Vibration Isolation.

- F. Provide piping flexible connections for floor-mounted coils.
- G. Provide air vent and drain valve at each water coil.
- H. Provide supply shut-off valve, return balancing valve, drain valve and air vent for each coil for air handling unit with multiple coils.

**END OF SECTION**



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## SECTION 23 8413CR

### HUMIDIFICATION EQUIPMENT

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 25 0901CR – Process Control Systems Integration
- B. Section 25 0993CR – Process Control Sequences

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 SUBMITTALS

- A. Shop Drawings including, but not limited to, the following:
  - 1. Manufacturer's name and model number
  - 2. Identification as referenced in the Documents
  - 3. Capacities/ratings
  - 4. Materials of construction
  - 5. CV of control valves
  - 6. Absorption distances
  - 7. Dimensions
  - 8. Electrical data and wiring diagrams for humidifiers
  - 9. All other appropriate data

#### PART 2 PRODUCTS

##### 2.1 STEAM-TO-STEAM GENERATOR/HUMIDIFIER ASSEMBLIES

- A. Manufacturers: Units shall be Dri-Steem model STS with capacity and operating characteristics as scheduled. Units shall be complete with stainless steel steam generating vessels with top outlet pipe flanges, removable service covers, steam heating coils, control cabinets, F&T steam traps and Y pattern strainers. Make-up water float valves, overflow/skimmer outlets, after cooler similar to Dri-steem Drain Kooler DK-12, bottom drain outlets and steam distribution devices.
- B. Steam control valve(s) and controls for humidifiers shall be furnished by cleanroom controls contractor.
- C. Make-up water to be RO Water.
  - 1. Inlet strainer shall be stainless steel.
  - 2. All valves shall be stainless steel.

- D. Control cabinets shall be NEMA 1 enclosure. Control devices shall include control circuit transformer, numbered terminal strip, all internal wiring and electrical diagram. Provide adjustable end of season drain down cycle.

## 2.2 HUMIDIFIER STEAM DISPERSION UNITS

- A. Manufacturers: DriSteem Ultra-Sorb
- B. Factory-assembled steam dispersion unit shall include the following components:
1. Steam supply header/separator
  2. Condensate collection header
  3. Steam dispersion tubes spanning distance between 2 headers
- C. Each dispersion tube shall be fitted with steam discharge tubelets inserted into tube wall. Each tubelet shall be made of thermal-resin material designed for high steam temperatures. Two rows of tubelets in each dispersion tube shall discharge steam in diametrically opposite directions, perpendicular to airflow.
- D. Each tubelet shall extend through wall of and into center of dispersion tube and contain steam orifice sized for its required steam capacity.
- E. Each packaged humidifier panel assembly of tubes and headers shall be contained within galvanized metal casing to allow convenient duct mounting, or to facilitate stacking of and/or end-to-end mounting of multiple humidifier panels in ducts or air handling unit casings.
- F. Tubes and headers shall be 304 stainless steel and be Heli-arc welded.
- G. Dispersion tubes are to be insulated.
1. Dispersion tubes shall be insulated with a plenum-approved insulating material for in-duct installation and have an R-value not less than 0.5 at a thickness not more than 0.125" for minimal increase in dispersion tube diameter.
  2. Insulating material shall meet the following criteria at 0.125" thickness:
    - a. Fire/smoke index shall be 0/0 per any of the following test procedures:
      - 1) UL 723 fire/smoke index (Test for Surface Burning Characteristics of Building Materials)
      - 2) NFPA 255 (Standard Method of Test of Surface Burning Characteristics of Building Materials).
      - 3) ASTM E84 (Surface Burning Characteristics for Materials Used in Plenums).
    - b. Stable up to 300°F (148°C) continuous – to prevent material degradation, hardening, or crumbling at high temperatures.
    - c. Closed-cell construction does not absorb water or support microbial growth – to negate the need for vapor barriers and jackets.
    - d. Non-toxic and pure as documented in manufacturer's data – to prevent off-gassing and to facilitate use in clean rooms, pharmaceutical applications, and food industries.
    - e. Will not degrade when exposed to UVC light – to negate the need for UV wraps.

- f. Continuous, seam-welded, and held in place without bands or clamps – to minimize surfaces for the accumulation of particulate matter.

### **2.3 AFTERCOOLERS**

- A. Manufacturers: DriSteem, Penn Separator or approved equal. Units shall be similar to DriSteem Drane Kooler.
- B. After coolers shall be constructed of 304 stainless steel and furnished with inlet, vent and drain connections and stainless steel striking plate.
- C. Furnish unit complete with floor supports, strainer and thermostatically controlled water regulator valve to temper 212°F condensate water with cold water to discharge 140°F water to sanitary drain.

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Install access door at downstream side for each duct mounted humidifier.
- B. Refer to Section 23 3314 - Ductwork Specialties, for access doors.
- C. Install make-up water and drain lines. Coordinate with Plumbing Contractor.

### **3.2 STEAM HUMIDIFIERS**

- A. Mount units in air handling units or ductwork as indicated on drawings. Provide additional support for humidifier body or distribution manifolds as recommended by manufacturer.
- B. Install steam and condensate branch lines with minimum of 3 elbows to allow for expansion and contraction. Use pipe size as indicated on drawings or as recommended by manufacturer, whichever is larger. Ream pipe and blow out at full steam pressure before connection to humidifier.

**END OF SECTION**



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## SECTION 25 0901CR

### PROCESS CONTROL SYSTEM INTEGRATION

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 25 3001CR - General Instrumentation Requirements
- B. Section 25 3003CR - Process Instrumentation Device Specifications
- C. Section 25 1100CR - Programmable Process Controllers
- D. Section 25 1514CR - Process Control Application Software Design
- E. Section 25 1522CR - Graphical User Interface Hardware and System Software
- F. Section 25 1524CR - Graphical User Interface Application Design
- G. Section 25 0993CR - Control Sequences

##### 1.2 REFERENCE

- A. The Work under this Section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 DESCRIPTION

- A. Process Control System for Clean Room Systems.

##### 1.4 ABBREVIATIONS AND DEFINITIONS

- A. The following abbreviations, acronyms, and definitions are used in addition to those details found elsewhere in Contract Documents.
  - 1. Abbreviations:
    - a. AI: Analog Input.
    - b. AO: Analog Output.
    - c. ASCII: American Standard Code for Information Interchange.
    - d. BMS: Building Management System.
    - e. CPU: Central Processing Unit.
    - f. CV: Controlled variable (controller output).
    - g. DI: Discrete Input.
    - h. DCS: Distributed Control System.
    - i. DDC: Direct Digital Control.
    - j. DO: Discrete Output.
    - k. EEPROM: Electrically Erasable Programmable Read Only Memory.

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- l. FC: Fail Closed position of control device or actuator. Device moves to closed position on loss of control signal or energy source.
  - m. FMS: Facility Management System linking two or more BMS.
  - n. FO: Fail Open position of control device or actuator. Device moves to open position on loss of control signal or energy source.
  - o. FSD: Functional Software Description.
  - p. GUI: Graphical User Interface.
  - q. HMI: Human-Machine Interface.
  - r. I/O: Input/Output Controller function module, which converts analog or discrete field signals to digital signals usable by computer based process controller.
  - s. MCR: Main Control Relay.
  - t. MES: Manufacturing Execution System.
  - u. MV: Measured Variable.
  - v. NC: Normally Closed position of switch after control signal is removed or normally closed position of manually operated valves or dampers.
  - w. NO: Normally Open position of switch after control signal is removed or normally open position of manually operated valves or dampers.
  - x. PID: Proportional - Integral - Derivative.
  - y. PLC: Programmable Logic Controller.
  - z. PV: Process variable.
  - aa. RAM: Random Access Memory.
  - bb. ROM: Read Only Memory.
  - cc. RTD: Resistive Temperature Detector.
  - dd. SCADA: Supervisory Control And Data Acquisition.
  - ee. SSLC: Stand-alone Single Loop Controllers.
  - ff. T/C: Thermocouple.
2. Actuator: Control device to provide motion of valve or damper in response to control signal.
  3. Analog: Continuous time domain function/variable state over stated range of values.
  4. Application Software (Program): Unique software written to perform specific tasks using different standard configuration software blocks or instructions; e.g. ladder logic. The application program consists of data into standard blocks or instructions to make blocks function as control operations.
  5. Auto-Tune: Software routine used to adjust tuning parameters based on historical data.
  6. Building Management System: Control system applied to HVAC systems and energy management systems. BMS manages systems not associated with processes or manufacturing.
  7. Configuration Software: Software which is written in sets of different standard software blocks, commands, or instructions, which may be configured/assembled to perform computer tasks by application programmers. Configuration software executes as processor operating system. Blocks or instructions cannot be altered by application programmer.
  8. Data Table: Location in memory where particular data or group of data is located. Data can be constants used for conversion, values from measurements, states of coils or contacts, preset values of counters or timers, etc.

9. Discrete: Binary or digital state.
10. Distributed Control System: Type of process controller capable of multiple I/O, regulatory control, and sequential control.
11. Function module: Group of application software which performs significant control task e.g. forward pump control sequencing including pump start, lead/lag, run-time management, system shut-down, alarm manager, and failure monitoring.
12. Graphical User Interface: Fully configured graphical based display and operator input system. Graphics may be implemented either by pixel or object based programming. Operator input may be implemented with function keys, touch screens, or push buttons.
13. Human-Machine Interface: Computer based device for process display and operator input. HMI includes both workstation platform and system software but not user configured application programming.
14. Instrument: Device used directly or indirectly to measure, monitor, record or control variable. Term includes primary elements, transmitters, analyzers, controllers, recorders, transducers, final control elements, signal converting or conditioning devices, computing devices, and electrical devices such as annunciators, switches, and push-buttons. Term does not apply to parts (e.g.; receiver bellows or resistor) that are internal components of instrument.
15. Instrument Piping/Tubing: Piping, tubing, tubing bundles, tube track and channel, valves, air supply filters and regulators, fittings, supports, hardware, and supplies required for Impulse Lines and Process Connections, for Pneumatic Signals and Interconnections, and for Air Supplies shall constitute instrument piping/tubing system.
16. Ladder logic: Controller executable instructions expressed in relay logic graphical format used to communicate programmer's intention to controller CPU. Ladder logic may include special instructions not traditionally associated with physical electrical relays.
17. Manufacturing Execution System: Group of computer and paper systems, which manage manufacturing processes on production floor.
18. Measured Variable: Same as Process Variable (see below).
19. Modulating: Movement of control device through entire range of values proportional to infinitely variable input value.
20. Node: User workstation, process controller, or other control device connected to communication's network.
21. Peer-to-Peer: Mode of communication between controllers in which each device connected to network has equal status and each shares its database values with other devices connected to network.
22. PID: Proportional - Integral - Derivative control, control mode with continuous correction of final controlled output element versus input signal based on proportional error, its time history (reset/integral), and rate at which its changing (derivative/rate).
23. Program: Complete set of software instructions to perform specific computer task residing in memory.
24. Programmable Logic Controller: Type of process controller capable of multiple I/O, regulatory control and sequential control.
25. Proportional: Control mode with continuous linear relationship between observed input signal and final controlled output element.

26. Proportional - Integral: Control mode with continuous proportional output plus additional change in output based on both amount and duration of change in controlled variable (Reset control).
27. Proportional - Integral - Derivative: Control mode with continuous correction of final controlled output element versus input signal based on proportional error, its time history (reset), and rate at which it is changing (derivative).
28. Process Variable: Control system input from field sensor device.
29. Regulatory Control: Analog control, control based on continuous time varying analog signals as measurement where controller calculates another continuous time varying analog signal for output to final control element whose position may have multiple different positions within same device.
30. Remote Mounted Instruments: Instruments or components of instruments, which are not mounted directly into process or utility piping systems. (e.g., pressure instruments, remote transmitters/totalizers, and analyzers.)
31. Rung: One line of ladder logic code. One rung may have several parallel input and output branches. Each rung is sequentially numbered. Cross-reference uses rung number to locate ladder logic element.
32. Sequential Control: Discrete Control, control based on variable states (either on or off) where controller determines output through a series of physical or virtual switches and output to final control element which can only have two positions (for example: on/off or open/close).
33. Setpoint: Desired process control point.
34. Solenoid: Electric two position actuator.
35. Stand-alone Single Loop Controller: Type of process controller dedicated to single process analog control loop.
36. Supervisory Control and Data Acquisition: System which performs long term process/controlled variable storage, trending, and reporting with the capacity to perform complex control algorithms, production starts/stops, alarm management, equipment assignments, recipe functions, etc.
37. Workstation: CPU, RAM, fixed disk, removable disk, input keyboard type device, pointing device, monitor, communication cards, etc., comprised to make-up hardware platform for HMI based SCADA System.

B. Purpose:

1. This section defines system specifications for Clean Room Air HVAC Systems. It is intended to work in close conjunction with Control Sequences, whether as shown on drawings or in Section 25 0993CR - Control Sequences.
2. Refer to Section 25 1100CR - Programmable Process Controllers for Controller hardware, operating system and packaged software, system performance, testing, start-up, and training requirements. Provide process controllers as required in Section 25 1100CR - Programmable Process Controllers.
3. Refer to Section 25 1514CR - Process Control Application Software Design for application software development, documentation, and performance requirements. Provide process control application programming as required in Section 25 1514CR - Process Control Application Software Design.
4. Refer to Section 25 1522CR - Graphical User Interface Hardware and System Software for graphical user interface (GUI) hardware platform, operating system software, and application development system software requirements. Provide GUI system as required in Section 25 1522CR - Graphical User Interface Hardware and System Software.



5. Refer to Section 25 1524CR - Graphical User Interface Application Design for implementation of hardware and software for GUI devices. Provide programming and software for GUI as required in Section 25 1524CR - Graphical User Interface Application Design.
6. Refer to Division 25 specification sections for instrumentation and control panel requirements. Provide devices as required in these sections or as required to meet intended control functions.

## 1.5 SCOPE OF WORK

- A. Provide labor and materials for complete fully functioning control systems in accordance with Contract Documents.
- B. Engineering services shall be performed by experienced application engineers (two years minimum). System shall be installed by electrical contractor under supervision of Control Contractor's field representative.
- C. Provide instruments and associated devices and systems associated with Clean Room HVAC systems.
- D. Labor shall include, but is not limited to:
  1. Engineering services to produce submittals requested and working construction drawings and record drawings as specified herein.
  2. Engineering services for controller application software programming required.
  3. Engineering services for GUI application programming specified.
  4. Project management services with single point contact to coordinate construction related activities.
  5. Field supervision for field device installation supervision for devices for which Control Contractor designs, specifies, supplies, or develops application software.
  6. Field technicians to start-up, calibrate, adjust, and tune control loops per specifications.
  7. Field technicians to perform system check out, testing, and complete required reports.
  8. Field representatives or classroom instructors to provide Owner training as specified.
- E. Control Contractor shall be responsible for complete installation of control devices (except as noted), wiring, and pneumatic terminations at controller locations to accomplish control sequences specified in project manual or on drawings. Control Contractor is required to provide power to all field mounted. Control Contractor shall also be responsible for additional instrumentation described in point schedules found in Contract Documents, which may not be directly related to specified control sequences.
- F. Mechanical Contractor shall provide wells, taps, and other mechanical interfaces required for control equipment mounting into piping systems. Mechanical Contractor shall install in-line mounted devices, such as valves, dampers, flow meters, static pressure probes, etc., furnished by Control Contractor. Control Contractor shall be responsible for installation of other control devices, such as actuators, linkages, sensors, flow transducers, remote mounted control devices, control panels, control transformers, etc.

- G. Electrical work required as integral part of control work is responsibility of Control Contractor. Control Contractor is responsible for providing final power connections, including conduit, wire, and/or disconnect switches, to control devices from appropriate electrical distribution panels.
  - 1. Electrical Contractor will provide circuit breakers required to provide electrical power to controllers.
  - 2. Should any change in number of controllers or addition of other electrical equipment after Contracts are awarded, Control Contractor shall immediately notify Electrical Contractor of change. Additional costs due to these changes shall be responsibility of Control Contractor.
  - 3. Coordinate with Electrical Contractor for additional power requirements.
- H. Materials shall be as specified unless approved through procedures for product substitution specified in Division 01. Provide components not specifically indicated or specified, but necessary to make system function within the intent of specification.
- I. Drawings shall be produced on Auto Cad per Owner drawing/drafting standards, CADD title block, layer, color, and symbology if available.

## 1.6 SUBMITTALS

- A. Extended Service Agreement:
  - 1. Upon completion of warranty period, make available to Owner annual service agreement covering labor and material required to effectively maintain control system after warranty period. Owner reserves rights to accept or reject any such offers and to cancel on-going agreements with 30 day written notice.
- B. Shop Drawings:
  - 1. Submit manufacturer's printed product data sheets for control devices and materials listed in bill of material in Control Contractor's control drawings. Datasheets shall be submitted electronically in pdf format with bookmarks provided for each individual device and table of contents listing each device manufacturer and full model number. Organize sheets in order of model number, alphabetically, then numerically. If more than 20 product data sheets are submitted, provide front index with links to devices. Data sheets shall include sufficient technical data to describe instrument parameters required as specified in Section 23 0903 - Control Instrumentation.
  - 2. Submit vendor engineering guidelines for wiring and cabling including type of signal wiring and installation methods including raceway types and grounding methods.
  - 3. System Network Architecture Design Diagram:
    - a. This is a riser diagram that shall show the IP layer and all of the field bus layers.
    - b. It shall show each computer, printer, router, repeater, switch, controller, and protocol translator that is connected to either the IP layer or any of the field busses.
    - c. Each component that is shown shall have a name that is representative of how it will be identified in the completed database and the manufacturer's name and model number.

- d. The physical relationship of one component to another component shall reflect the proposed installation.
- e. Provide unique network addresses for all devices.
- f. This diagram shall not include power supplies, sensors or end devices.
4. Layout Design Drawing for each control panel:
  - a. The layout drawing shall be to scale with all devices shown in their proposed positions.
  - b. All control devices shall be identified by name.
  - c. All terminal strips and wire channels shall be shown.
  - d. All control transformers shall be shown.
  - e. All 120 VAC receptacles shall be shown.
  - f. All IP connection points shall be shown.
5. Wiring/Pneumatic Design Diagram for each control panel:
  - a. The control voltage wiring diagram shall clearly designate devices powered by each control transformer. If the control devices use half wave power, the diagram shall clearly show the consistent grounding of the appropriate power connection. All wire identification numbers shall be annotated on the diagram.
  - b. The Field Bus wiring diagram shall clearly show the use of the daisy chain wiring concept, the order in which the devices are connected to the Field Bus, and the location of end of segment termination devices. All wire identification numbers shall be annotated on the diagram.
  - c. If shielded communication wiring is used, the grounding of the shield shall be shown.
  - d. The terminal strip wiring diagram shall identify all connections on both sides of the terminal strip. Wiring label numbers for all wiring leaving the control panel shall be annotated on the diagram.
  - e. Submit ISA Style loop diagrams. Refer to ISA S5.4 for minimum requirements.
6. Installation Design Detail for each I/O device.
  - a. A drawing of the wiring details for each sensor and/or end device.
  - b. For devices with multiple quantities, a standard detail may be submitted.
7. System Flow Design Diagram for each controlled system:
  - a. A two dimensional cross sectional diagram showing key components such as fans, coils, dampers, valves, pump, etc.
  - b. Identify the locations and names of all sensors and end devices that are associated with the control system. Label the panel name and terminal numbers where the connections are landed.
  - c. A legend shall be provided for all symbols used.
8. Control System Hardware Technical Data.
  - a. A complete bill of materials of equipment to be used indicating quantity, manufacturer, and model number.
  - b. Manufacturer's description and technical data for each unique device to include performance curves, product specification sheets, and installation instructions. When a manufacturer's data sheet refers to a series of devices rather than a specific model, the data specifically applicable to the project shall be highlighted or clearly indicated by other means.

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- c. This requirement applies to:
    - 1) Controllers
    - 2) Transducers/Transmitters
    - 3) Sensors
    - 4) Actuators
    - 5) Valves
    - 6) Relays and Switches
    - 7) Control Panels
    - 8) Power Supplies
    - 9) Batteries
    - 10) Operator Interface Equipment
  - 9. Sequence of Control: A sequence of control for each system being controlled. Include the following as a minimum.
    - a. Process control sequence for each end device.
    - b. Supervisory logic sequence of control for each system.
    - c. Within the sequence of control, all application parameters that are to be user adjustable from an Operator Workstation shall be annotated with (FA) after the name of the parameter. This shall include set points, reset schedule parameters, calibration offsets, timer settings, control loop parameters such as gain, integral time constant, sample rates, differentials, etc.
    - d. Within the sequence of control, all calculated values that are to be viewable at the Operator Workstation shall be annotated with (rpt) after the name.
    - e. All points that shall be subject to manual control from an operator workstation.
    - f. A list of all alarm points, a description of the alarm and a description of the alarm criteria.
    - g. A list of all variables for which historical trending will be applied, the sample rates and any criteria used to start and stop the historical trending.
  - 10. Graphic Pages: Submit a sample graphic page for each type of page described in Section 23 0924 - Graphical User Interface Integration.
  - 11. All submittal documents shall be provided electronically in any of the following formats:
    - a. Microsoft Office components
    - b. Adobe Acrobat portable document format
    - c. HTML format
    - d. AutoCAD latest version used by the resource management group
  - 12. Electronic submittal shall be provided with relative hyperlinks to all the documents. One set of all submittals and electronic documents shall be provided in searchable Portable Document Format. This electronic document shall be organized with either bookmarks or hyperlinks to allow navigation from an electronic table of contents directly to individual control drawings, product data, schedules, wiring diagrams, etc.

## 1.7 DOCUMENTATION

- A. Controller functions shall be fully tested and documented in accordance with good engineering practice.

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- B. Operating and Maintenance Manuals:
1. Operating and maintenance manuals shall provide descriptions of maintenance on system components, including sensors and controlled devices. These shall include inspection requirements, periodic preventative maintenance, fault diagnosis, and repair or replacement of defective components, calibration instructions, parts lists, and manufacturer representative's name, address, and phone number.
  2. Provide 1 copy of the programmable controller service and programming manual with each system installation.
  3. O/M manuals shall include:
    - a. Catalog Cut sheets on Control System equipment.
    - b. Spare Parts List.
    - c. Vendor Listing including name, address, and telecommunication numbers.
    - d. Functional Software Description.
    - e. Listing of Controller Software with full documentation and cross references.
    - f. Data Dictionary.
    - g. System Dip Switch Settings.
    - h. Screen Prints of GUI Screens.
    - i. Listing of GUI databases.
      - 1) Alarm Listing.
      - 2) Trend Listing.
    - j. Listing of GUI Documentation.
    - k. Drawings (on Auto Cad):
      - 1) System Architecture
      - 2) P & ID's
      - 3) Control Sequences (if in flow chart format)
      - 4) Controller I/O Schematics (for controller)
      - 5) Power Schematic
      - 6) Loop Diagrams (if applicable)
      - 7) Control Panel fabrication
    - l. Drawings shall be 11" x 17" format fan-folded and as-built.
    - m. Information shall be organized into 3-ring binders with each of above sections separated by tabs. Fill the binders to 75% of listed fill, e.e.; maximum fill for 2" binder shall be 1-1/2".
    - n. Provide 3 bound hard copies and 3 software copies on removable magnetic media of static graphics, run-time databases, on-line documentation, and off-line documentation.
- C. Drawing Production Format:
1. Drawings shall be produced on AutoCAD. Conversion from other CADD package after drawings have been produced is unacceptable.
- D. Record Drawings
1. Refer to Division 01 - General Requirements.
  2. Submit revised shop drawings indicating changes during project. All record drawings shall be submitted on a CD/DVD and include a hard copy.

- E. Warranty:
  - 1. Provide upgrades to system software for 1 year.
  - 2. Provide full system warranty including both software and hardware (controllers, sensors, devices, accessories, etc.) for 18 months. Correct deviations from control sequences during warranty period.

## **PART 2 PRODUCTS**

### **2.1 SYSTEM DESCRIPTION**

- A. Provide control system as shown on P & ID's and described in related specifications.

## **PART 3 EXECUTION**

### **3.1 CHECK-OUT, START-UP, AND COMMISSIONING REQUIREMENTS:**

- A. Check-out
  - 1. Verify valves, actuators, and instruments are calibrated.
  - 2. Check each valve, actuator, and instrument for proper connection to control system by point-to-point wire checks and verifying proper pneumatic connections.
  - 3. Energize controller/GUI hardware.
  - 4. Verify proper valve action and motor rotation.
- B. Start-up
  - 1. Tune control loops to maintain controlled process variable at setpoint as required in Section 25 1514 - Process Control Application Software Design.
  - 2. Regulatory control loop performance shall be documented by 3 - 8 hour printed trend log reports of PV versus setpoint for each analog control loop.
  - 3. Sequential control shall be verified by, adjusting setpoints and verifying proper control sequence operation. Each control sequence function shall be tested, for example low to high temperature excursions.
  - 4. Commissioning shall be as follows:
    - a. "Dry Commissioning" - Equipment shall be stepped through control modules without raw materials or utilities. This test is to verify proper equipment sequencing with focus on abnormal event handling. Equipment that might be damaged without utilities (i.e., water-cooled pump) shall not be sequenced in this step.
    - b. "Wet Commissioning" - Equipment shall be stepped through control modules with water substituted for raw materials to ensure proper sequencing, abnormal operation recovery, and mechanical equipment operation. Support utilities shall be functional. Water or other suitable fluid shall be used in lieu of Raw Materials. Wet Commissioning is complete when salable product can be produced in less than capacity quantities.

5. Alarms shall be tested for each controller and device connected to network, and ensure that alarms are properly acknowledged at operator's workstation. Test verification shall be printed alarm testing. Each alarm shall be initialed and dated to show verification.
6. Owner may witness testing.

### **3.2 TRAINING AND SUPPORT**

- A. Controller/GUI Manufacturer Support
  1. Manufacturer shall provide detailed hardware and software manuals that cover installation, application, and programming.
  2. Manufacturer shall make detailed trouble-shooting guide available. Block diagram format is preferred.
  3. Manufacturer shall provide 24-hour engineering and application support service to assist the user with technical product information and application analysis.
  4. Manufacturer shall make training services and materials available for engineering, maintenance, and operating personnel. Available materials shall include videotapes and self-paced instruction manuals.
  5. Manufacturer shall make available such diagnostics, programming, schematics, and related data to meet FDA requirements.
- B. Support After Start-up and Before Final Acceptance
  1. Provide support engineer to assist running system after systems have been started and are regularly used until Owner has completed on-site training specified. Engineer shall be an on-call basis with 2-hour (maximum) response time during normal business hours.
- C. System Integrator Training
  1. Operators shall have 8 hours of "hands-on" instruction after system has been fully tested and validated (if applicable), using systems designed to assist operators as they perform their functions. 8 hours of technical training shall be provided for plant instrument technicians and Engineers.
  2. Training shall be provided for 2 operators and for 2 instrument staff at Owner's site. Pure water systems manufacturer need not repeat Operator training for Engineers and technicians, however Engineers and technicians may participate in Operator training at Owner's choice.
  3. Conduct training sessions during normal business hours after system is fully operational. Scheduling of training session(s) will be established by Owner. Portions of training may be performed before system is completely operational, but no sooner than one month before system is planned to be fully operational. Final training session shall be held after systems are complete.
  4. Information about system exceptions or anomalies shall be covered in operator training to prevent confusion; i.e., for GUI training, animated pump appears to be running on unit graphic as motor starter is sealed-in, but may not be operating because motor shaft is sheared in system where motor starter auxiliary contacts are used to indicate motor operation in lieu of direct proof-of-flow or current switch measurement.

5. Technical training shall cover each design technique implemented and discuss each controller and GUI task. Special attention shall be paid to custom configurations, which are not direct implementation of controller or GUI standard tasks.
6. Controller course content for operators shall include, but not limited to, the following topics:
  - a. Explain P & ID's and control sequences. Include which sensors are used and how each output device operates.
  - b. Explain control drawings and manuals, including symbols, abbreviations, and overall organization.
  - c. Walk-through project to identify instrumentation, valve/damper, and control panel locations.
  - d. Review operation of operator interface unit including hardware.
7. Controller course content for engineers/technicians shall also include:
  - a. Review engineering drawings.
  - b. Review controller configuration software.
  - c. Review operating and maintenance of hardware devices including controllers, instrumentation, and valves. Include schedule for routine maintenance.
  - d. Review Engineering Drawings including ladder/logic drawings.
8. Scheduling of training session(s) will be established by Owner.
9. GUI system operator training shall cover following areas:
  - a. Access and use of each system graphic.
  - b. Use of each operator input or operator action (equipment start/stop, process-batch system start/stop, password access data entry, function key's or touch-screen keys, trending functions, etc.).
  - c. Procedures for machine failure recovery.
  - d. Procedures for weekly start-ups.
  - e. Procedures for data archive (if applicable).

### **3.3 TESTING AND FINAL OWNER ACCEPTANCE**

- A. Final acceptance shall be after owner training is complete and documentation is collated, submitted, and approved.
- B. For final acceptance, systems manufacturer shall demonstrate to Owner's witness functionality of each control sequence function and system shall function for duration of five working days without software or hardware problem before acceptance.
- C. Prior to final acceptance by Owner, "dead" or non-functional application program software shall be removed from each part of process control system. Contractor shall be responsible for removal of "dead" code, relative to production/facility equipment system at time of final acceptance, whenever discovered after including warranty period.

**END OF SECTION**



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## **SECTION 25 0993CR**

### **CONTROL SEQUENCES**

#### **PART 1 GENERAL**

##### **1.1 REFERENCE**

- A. The Work under this section is subject to requirements of the Contract Documents including the Uniform General Conditions, Supplementary General Conditions, and Division 1 of the specifications.
- B. All work covered by this Section of these Specifications shall be accomplished in accordance with all applicable provisions of the Contract Documents and any addenda or directives which may be issued herewith, or otherwise.

##### **1.2 DEFINITIONS**

- A. Refer to Section 200514CR - Variable Frequency Drive (VFD) System
- B. Refer to Section 230594CR - Water Systems Test, Adjust, and Balance
- C. Refer to Section 230595CR - Air Systems Test Adjust Balance
- D. Refer to Section 250901CR - Process Control System Integration
- E. Refer to Section 251100CR - Programmable Process Controllers
- F. Refer to Section 251316CR - Control Panels
- G. Refer to Section 251514CR - Process Control Application Software Design
- H. Refer to Section 251524CR - Graphical User Interface Application Design
- I. Refer to Section 253001CR - General Instrumentation Requirements
- J. Refer to Section 253002CR - Process Control Valves and Dampers
- K. Refer to Section 253003CR - Process Instrumentation Device Specifications
- L. Refer to Section 23 5214CR - Primary Heating Equipment
- M. Refer to Section 23 6000CR - Primary Cooling Equipment
- N. Refer to Section 23 7313CR - Packaged Air Handling Units
- O. Refer to Section 23 7328CR - Factory Fabricated Custom Air Handling Units

### **1.3 INPUT AND OUTPUT POINTS**

- A. It is the intent of the drawings and the control sequences to provide for complete fully functioning systems. The following sequences list many, but not all control points required. Contractor shall review and utilize P&ID Flow/Control Diagrams to supplement the information provided in these sequences.
- B. Definition of Point Type
  - 1. AI Analog Input (4-20 mA, 0-5 volt DC, 0-10 volt DC, RTD, etc.)
  - 2. DI Digital (Binary) input
  - 3. AO Analog Output (4-20 mA, 0-5 volt DC, 0-10 volt DC, etc.)
  - 4. DO Digital (Binary) output

### **1.4 ALARMS**

- A. Program alarm levels as indicated in sequences, based on the following levels.
  - 1. Level 1 Critical
  - 2. Level 2 Non Critical
- B. All points of cleanroom control system shall be fully accessible for monitoring, programming, and control override at each operator workstation location and at Clean Room Managers Office. Operator workstations are to be located as indicated in this specification section.
- C. All Input/Output points and Programmable Logic Controller (PLC) data objects shall have alarm parameters available for defining alarms.
- D. Alarm monitoring and programming functions will be restricted by password protection.
- E. Coordinate alarm action requirements (printing, automatic dialing, etc.) with Owner.
- F. Alarms shall remain active until alarm condition has cleared and alarm is reset manually.

### **1.5 SETPOINTS**

- A. All controlling setpoints shall be field adjustable.

### **1.6 PRESSURE TRANSMITTER/SENSORS**

- A. Pressure transmitter/sensors shall be hardwired directly back to the PLC that provides control signal to the VFD(s). Sharing the static pressure signal via the network shall not be allowed for control.

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## **PART 2 PRODUCTS**

### **2.1 NOT APPLICABLE TO THIS SECTION.**

## **PART 3 EXECUTION**

### **3.1 CONTROL SEQUENCE - GENERAL**

- A. Systems shall perform in accordance with the control sequences specified here in.
- B. Refer to Control Diagrams for additional information.
- C. Unless indicated otherwise, all specified setpoints, time intervals, and limits shall be field adjustable. Controls Contractor shall verify setpoints, time intervals, and limits based on actual field conditions. All setpoints, time intervals, and limits shall be optimized to achieve stable system operation, prevent damage to equipment, minimize maintenance requirements, and eliminate nuisance alarms (such as premature filter loading, false tripping of freezestats and other similar conditions).
- D. Provide control points for all interface points provided with all package equipment.
- E. Valve and Damper Operation Feedback:
  - 1. Actuators for all valves and dampers shall fail as indicated on the drawings.
  - 2. When a damper or valve is required to open, the PLC shall command the device to open by energizing the discrete output (or modulating open) to the damper actuator. The damper or valve shall remain open until the PLC commands the device to close by de-energizing the discrete output (or modulating closed) to the actuator or equipment failure occurs.
  - 3. For all two position actuators and for all outside air damper modulating actuators
    - a. Open failure is detected by loss of discrete input open status when the device is commanded open, or is open, or anytime open status does not equal commanded state within 60 seconds (FA) of command change of state. Upon a open failure, the damper/valve command shall be removed and status shall be reported to PLC. Actuator failure must be manually reset at the PLC before valve/damper close command can be restarted.
    - b. Close failure is detected by loss of discrete input close status when the device is commanded close, or is close, or anytime close status does not equal commanded state within 60 seconds (FA) of command change of state. Upon a close failure, the damper/valve command shall be removed and status shall be reported to PLC. Actuator failure must be manually reset at the PLC before valve/damper close command can be restarted.
  - 4. Damper actuator positions shall be monitored by position end switches installed on damper shaft.
  - 5. Two position valve actuator positions shall be monitored by position end switches integral to actuator.

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- F. Pump or Fan Operation Feedback
1. When a device is required to run, the control system shall command the device to start by energizing the discrete output to the motor starter/VFD. The device shall run until the control system commands the device to stop by de-energizing the discrete output to the motor starter/VFD or an equipment failure occurs.
  2. Equipment failure is detected by opening of a current switch or VFD Fault input when the device is commanded on or is operating, or anytime equipment status does not equal commanded state within 60 seconds (FA) of command changed of state. If a failure occurs, the device shall be stopped and an alarm shall be annunciated at the PLC designating that device has failed (see each sequence for alarm type details). Pump or fan shall be locked out after failure until manually reset through the PLC.
- G. Primary/stand-by device operation
1. The primary device shall be defined as the active device.
  2. Designation of primary and standby devices shall be manually definable through PLC operator interface.
  3. Equalize run time on devices based on accumulated run time (FA). When primary device total operating hours exceeds total operating hours of standby device by 720 hours (FA), the stand-by device shall be started and the primary device shall stop. The stand-by device shall become the primary. This run time based switchover shall be initiated automatically by the PLC during the first occurrence of the time of day and day of week (e.g. 8:00 am Monday, operator adjustable), established by the operator through PLC operator interface, after exceeding the run time hours indicated above.
  4. For VFD driven devices, primary/standby initiate switchover by starting standby device and allow device to ramp up while lead device ramps down to maintain system pressure. When standby device is proven operational by device status switch and primary and standby devices are operating in parallel, original primary device shall ramp down while standby device ramps up to maintain system pressure. When original primary device reaches programmed minimum speed, original primary device shall stop and primary/standby device designations shall be switched.
  5. On a failure of the primary device as sensed by feedback instrumentation (e.g., current switch), the stand-by device shall become the primary and started. The original primary device shall be disabled and an alarm generated at the PLC.
  6. When disabled device is released from lockout by a software command from the PLC, the device shall become the standby device.
  7. Provide manual reset switches at the device control panel to reset locked out devices locally as well as through the PLC.
- H. Parallel equipment powered by VFDs
1. The devices shall operate as primary/standby devices as defined above.
  2. On failure of process transmitter, as, indicated by loss of control signal, pumps/fans shall be controlled at the last known speed and PLC shall annunciate alarm.
  3. Upon signal loss to the VFD, or when signaled to stop, the VFD shall ramp down to the minimum pre-programmed speed at the programmed ramp rate.

4. On a failure of the VFD as defined by an output from the VFD, an alarm shall be generated at the PLC.
  5. When any device is commanded to start locally via VFD Hand switch, the following sequence shall occur:
    - a. Device shall start and operate at speed selected on VFD, standby device shall be locked out in PLC program, and an alarm shall be annunciated at the PLC.
    - b. When an H-O-A switch is in any position other than Auto an alarm shall be annunciated at the PLC.
    - c. Any time an operator manually operates any devices via H-O-A, the operator takes full responsibility to manually operate all devices as required to maintain system pressure at setpoint.
  6. When any device is commanded to stop via local VFD H-O-A switch, device shall stop and standby device shall be commanded to start and operate to maintain system pressure and an alarm shall be annunciated at the PLC.
  7. When device with VFD H-O-A switch in OFF mode is placed back in Auto mode, the devices shall resume normal device control operation as indicated previously in this section.
- I. Alarm Trip Points
1. Provide each alarm trip point with adjustable time delay to prevent nuisance tripping or short cycling. These time delays apply to all switchable hardware or software points and are for normal operation. Additional or longer delays may be necessary during start up as noted.
- J. Variable Frequency (speed) Drives:
1. VFD shall start at minimum speed setting and shall ramp to control point. Unless otherwise noted, VFD shall ramp up and down full scale over 15 seconds. VFD shall not be allowed to operate at less than 15 Hz.
  2. If electrical disconnect is connected between VFD and driven equipment, auxiliary contacts provided by the Division 26 contractor shall be terminated to VFD safety circuit by the Division 26 contractor. The auxiliary switch contacts shall open the VFD safety circuit and shall stop the VFD prior to disconnecting the electrical feed to the motor to prevent power surges in the VFD if the disconnect is pulled while the motor is operating.
  3. All safety devices such as, freezestats, high static pressure safety switches, low static suction safety switches, smoke detectors, etc. shall be hardwired in series with safety circuits on VFD's and shall stop when safety device is tripped. Safety circuit shall be functional on drives without bypass contactors and shall be functional in both VFD modes.

### **3.2 POWER FAILURE MODE**

- A. General:
1. Electrical service entrance system consists of two electrical services, each service is connect to service electrical entrance switchgear. Both service electrical entrance switchgears are cross connected.
  2. There is no emergency generator.

3. Life safety automatic transfer switch LSATS, located in penthouse, serves exhaust fans CE-1, CE-2, SE-1 and SE-2. Control Contractor is responsible for obtaining status signal and all necessary wiring for status signal from automatic transfer switches to PLC.
  4. Power failure of one of entrance services shall be determined by position of service entrance breakers and tie breaker, located in basement. Control Contractor is responsible for obtaining status signal and all necessary wiring for status signal from each breaker to PLC.
  5. Pump and fan VFDs shall be programmed for automatic restart after a complete stop, when normal power is lost.
  6. All control valves serving reheat coils (labs, offices, classrooms, building support) shall maintain their last control position upon loss of power or loss of control signal.
- B. Managed Restart:
1. PLC shall monitor normal power indication via incoming switchgear breakers. On loss of normal power for duration of 2 seconds (FA) or longer, all equipment shall be commanded to be stopped by the PLC. When normal power is established, as indicated by service electrical entrance switchgear tie breaker, PLC shall restart system components.
  2. Start sequence under automatic transfer switch LSATS shall not begin until power is established has been proven. Start-up of subsequent equipment shall not be delayed for proof of actual operation of equipment. Once all equipment has been commanded to start, proceed immediately to start-up of subsequent equipment. When power is re-established as indicated by service electrical entrance switchgear power indication for 60 consecutive seconds (FA), CE-1 or CE-2 and SE-1 or SE-2 shall begin restarting and operate as indicated in each systems control sequence. Provide software adjustable time delay between starting of components serving a common system (set initial delay at 5 seconds (FA)).
- C. Monitor and Alarm:
1. Monitor, through PLC, the following points associated with standby power system and generate the alarms indicated:
    - a. Service entrance electrical entrance switchgear breakers (DI - typ of 3).
    - b. Generate Level 1 alarm on loss of normal power and stop all HVAC equipment.
  2. Life safety automatic transfer switch LSATS – Power (DI).
    - a. Generate Level 1 alarm on loss of normal power and stop all HVAC equipment.

### **3.3 CLEANROOM PROCESS CHILLED WATER SYSTEM - CONTROL SEQUENCE**

- A. General:
1. Refer to drawing crm7.08
  2. System consists of two pumps sized at 100% of the respective cleanroom process chilled water flow.
  3. System consists of two heat exchangers, sized at 100% of the cleanroom process chilled water system requirements.

- 
- B. Pump Control:
1. Primary pump shall operate continuously when system is enabled.
  2. Pumps shall operate as described under "Primary/Standby Device Operation" under general control sequences. Provide primary -standby software switch to select primary pump.
- C. System Operation:
1. System shall operate continuously in one mode of operation.
  2. System shall be manually enabled/disabled by a single command from operator workstation.
  3. When the system is commanded to start via normal change of PLC data point, the following sequence shall occur:
    - a. Primary heat exchanger shall be enabled and its associated 2-position isolation valve shall open. Valve position shall be proven via position switch.
    - b. After primary heat exchanger inlet Isolation valve is proven open, primary pump shall start ramp, up to minimum speed and hold. After 30 seconds (FA) system pressure control shall be enabled.
    - c. During the initial start up while pump is held at minimum speed, system pressure shall be monitored. If system pressure during the initial start up is less than system setpoint, pump speed shall be released to control and bypass valve shall remain closed. If system pressure differential during the initial start up is greater than system setpoint, bypass valve shall be released to control while pump speed is held at minimum speed.
    - d. After pump operation and valve position are proven, modulating chilled water control valve serving primary heat exchanger shall be allowed to modulate for water temperature control.
- D. System Pressure Control:
1. PLC shall modulate Pump VFD to maintain process chilled water supply pressure setpoint of 60 psig (FA).
  2. Control Contractor shall work in association with Test and Balance Contractor to determine actual required pressure setpoint. Actual supply pressure setpoint shall be the minimum pressure required to achieve system design flow through system.
  3. Provide one process chilled water supply pressure transmitter as indicated on mechanical plans.
  4. Upon signal loss to VFD, VFD shall ramp down at programmed ramp rate to pre-programmed minimum speed and held.
- E. System minimum Flow Control:
1. PLC shall modulate bypass valve to maintain minimum system flow of 32.5 gpm (FA) as indicated by system flow meter WFM-C1.
- F. Temperature Control:
1. PLC shall modulate chilled water control valve serving primary heat exchanger to maintain cleanroom process chilled water supply temperature setpoint of 60°F (FA).

2. Whenever the primary operating heat exchanger fails as proven by respective valve position switch not indicating open within 60 second (FA) of primary pump run status indication or heat exchanger discharge temperature 5°F (FA) greater than setpoint for 10 consecutive minutes (FA), the standby heat exchanger shall be enabled, failed heat exchanger shall be disabled and an alarm generated at the PLC.
  3. A manual command shall be available from PLC to lock out a heat exchanger for maintenance. Whenever a heat exchanger is locked out, the next heat exchanger in rotation shall automatically index to the available position. Anytime a heat exchanger is locked out of operation, an alarm shall be annunciated at the PLC.
    - a. When a manually locked out heat exchanger is released from lockout, the heat exchanger shall resume its normal position in the primary/standby rotation.
- G. Safeties:
1. Pumps shall not be allowed to operate, in either Hand or Auto (PLC control), unless at least one heat exchanger isolation valve is proven open.
- H. Power Failure Mode:
1. Cleanroom process chilled water pumps are not served by standby power.
  2. When normal power fails, all operating chilled water pumps shall be commanded stopped.
  3. Upon resumption of normal power, normal pump control sequence shall resume. Refer to POWER FAILURE MODE, previously documented in this specification section for restart sequence of stopped pumps.
- I. Monitor and Alarm:
1. Monitor, through PLC, the following points associated with process chilled water and generate the alarms indicated:
    - a. Cleanroom process chilled water supply pressure – (AI)
    - b. Cleanroom process chilled water supply temperature – (AI)
      - 1) Generate Level 2 alarm if temperature rises 5°F (FA) above setpoint.
    - c. Cleanroom process chilled water pump status – each pump (DI)
      - 1) Generate Level 2 alarm if pump status does not match commanded state within 60 seconds (FA) of command change of state.
    - d. Cleanroom process chilled water distribution return temperature – (AI)
    - e. Cleanroom process chilled water return temperature after bypass – (AI)
    - f. Cleanroom process chilled water system pressure – (AI)
      - 1) Generate Level 2 alarm if pressure falls below 35 psig (FA).
    - g. Heat exchanger chilled water return temperature – (AI)
    - h. Cleanroom process chilled water pressure differential – (AI)
      - 1) Generate Level 1 alarm if pressure differential exceeds setpoint by ±5 psi (FA) for 5 consecutive minutes (FA).
    - i. Cleanroom process chilled water pump VFD fault - each pump (DI)
      - 1) Generate Level 1 alarm.
    - j. VFD H-O-A (Hand-Off-Auto) switch – all VFDs (DI)



- 1) Generate Level 1 alarm anytime H-O-A switch is in any position other than Automatic.
- k. Heat exchanger chilled water inlet isolation valve position – open and closed – each heat exchanger valve (DI).
  - 1) Generate Level 2 alarm if valve is not proven open within 60 seconds of valve open command and index the next heat exchanger in rotation to start.
  - 2) Generate Level 2 alarm if valve is not proven closed within 60 seconds of valve closed command.
- l. Cleanroom process chilled water flow meter WFM-C1- (AI)

### 3.4 CLEANROOM AIR HANDLING UNIT CHILLED WATER SYSTEM - CONTROL SEQUENCE

- A. General:
  1. Refer to drawing crm7.06
  2. System consists of two pumps sized at 100% of the respective cleanroom air handling unit chilled water flow.
  3. System consists of two heat exchangers, sized at 100% of the cleanroom air handling unit chilled water system requirements.
- B. Pump Control:
  1. Primary pump shall operate continuously when system is enabled.
  2. Pumps shall operate as described under “Primary/Standby Device Operation” under general control sequences. Provide primary -standby software switch to select primary pump.
- C. System Operation:
  1. System shall operate continuously in one mode of operation.
  2. System shall be manually enabled/disabled by a single command from operator workstation.
  3. When the system is commanded to start via normal change of PLC data point, the following sequence shall occur:
    - a. Primary heat exchanger shall be enabled and its associated 2-position isolation valve shall open. Valve position shall be proven via position switch.
    - b. After primary heat exchanger inlet Isolation valve is proven open , primary pump shall start, ramp up to minimum speed and hold. After 30 seconds (FA) system pressure control shall be enabled.
    - c. During the initial start up while pump is held at minimum speed, system pressure shall be monitored. If system pressure during the initial start up is less than system setpoint, pump speed shall be released to control and bypass valve shall remain closed. If system pressure differential during the initial start up is greater than system setpoint, bypass valve shall be released to control while pump speed is held at minimum speed.
    - d. After pump operation and valve position are proven, modulating chilled water control valve serving primary heat exchanger shall be allowed to modulate for water temperature control.

- D. System Pressure Control:
1. PLC shall modulate Pump VFD to maintain cleanroom air handling unit chilled water differential pressure setpoint of 15 psig (FA).
  2. Control Contractor shall work in association with Test and Balance Contractor to determine actual required pressure setpoint. Actual supply pressure setpoint shall be the minimum pressure required to achieve system design flow through system.
  3. Provide one cleanroom air handling unit chilled water differential pressure transmitter as indicated on mechanical plans.
  4. Upon signal loss to VFD, VFD shall ramp down at programmed ramp rate to pre-programmed minimum speed and held.
- E. System minimum Flow Control:
1. PLC shall modulate bypass valve to maintain minimum system flow of 57.5 gpm (FA) as indicated by system flow meter WFM-C2.
- F. Temperature Control:
1. PLC shall modulate chilled water control valve serving primary heat exchanger to maintain cleanroom air handling unit chilled water supply temperature setpoint of 58°F (FA).
  2. Whenever the primary operating heat exchanger fails as proven by respective valve position switch not indicating open within 60 second (FA) of primary pump run status indication or heat exchanger discharge temperature 5°F (FA) greater than setpoint for 10 consecutive minutes (FA), the standby heat exchanger shall be enabled, failed heat exchanger shall be disabled and an alarm generated at the PLC.
  3. A manual command shall be available from PLC to lock out a heat exchanger for maintenance. Whenever a heat exchanger is locked out, the next heat exchanger in rotation shall automatically index to the available position. Anytime a heat exchanger is locked out of operation, an alarm shall be annunciated at the PLC.
    - a. When a manually locked out heat exchanger is released from lockout, the heat exchanger shall resume its normal position in the primary/standby rotation.
- G. Safeties:
1. Pumps shall not be allowed to operate, in either Hand or Auto (PLC control), unless at least one heat exchanger isolation valve is proven open.
- H. Power Failure Mode:
1. Cleanroom air handling unit chilled water pumps are not served by standby power.
  2. When normal power fails, all operating chilled water pumps shall be commanded stopped.
  3. Upon resumption of normal power, normal pump control sequence shall resume. Refer to POWER FAILURE MODE, previously documented in this specification section for restart sequence of stopped pumps.

- I. Monitor and Alarm:
1. Monitor, through PLC, the following points associated with cleanroom air handling unit chilled water and generate the alarms indicated:
    - a. Cleanroom air handling unit chilled water supply pressure – (AI)
    - b. Cleanroom air handling unit chilled water supply temperature – (AI)
      - 1) Generate Level 2 alarm if temperature rises 5°F (FA) above setpoint.
    - c. Cleanroom air handling unit chilled water pump status – (DI)
      - 1) Generate Level 2 alarm if pump status does not match commanded state within 60 seconds (FA) of command change of state.
    - d. Cleanroom air handling unit chilled water return temperature – (AI)
    - e. Cleanroom air handling unit chilled water return temperature after bypass – (AI)
    - f. Cleanroom air handling unit chilled water system pressure – (AI)
      - 1) Generate Level 2 alarm if pressure falls below 25 psig (FA).
    - g. Heat exchanger chilled water return temperature – (AI)
    - h. Cleanroom air handling unit chilled water pressure differential – (AI)
      - 1) Generate Level 1 alarm if pressure differential exceeds setpoint by  $\pm 2$  psi (FA) for 5 consecutive minutes (FA).
    - i. Cleanroom air handling unit chilled water pump VFD fault - each pump (DI)
      - 1) Generate Level 1 alarm.
    - j. VFD H-O-A (Hand-Off-Auto) switch – all VFDs (DI)
      - 1) Generate Level 1 alarm anytime H-O-A switch is in any position other than Automatic.
    - k. Heat exchanger cleanroom air handling unit chilled water inlet isolation valve position – open and closed – each heat exchanger valve (DI).
      - 1) Generate Level 2 alarm if valve is not proven open within 60 seconds of valve open command and index the next heat exchanger in rotation to start.
      - 2) Generate Level 2 alarm if valve is not proven closed within 60 seconds of valve closed command.
    - l. Cleanroom air handling unit chilled water flow meter WFM-C1- (AI)

### 3.5 LOW TEMPERATURE CHILLED WATER SYSTEM - CONTROL SEQUENCE

- A. General:
1. Refer to drawing crm7.07
  2. System has one air cooled chiller.
  3. Variable primary pump arrangement is used for chilled water pumping system.
  4. Two primary low temperature chilled water pumps are sized for 100% capacity and are piped in parallel.
  5. Chiller has packaged safety and capacity control system furnished by chiller manufacturer as specified in Section 236000CR - Primary Cooling Equipment.
  6. Control Contractor shall be responsible for all chiller control devices and work that is not factory installed and wired by chiller manufacturer and is required for proper system operation as herein specified.

7. Chiller manufacturer/mechanical contractor shall provide pressure differential switch to prove flow through chiller.
  8. Chiller control panels shall be provided with single point data connection for integrating each chiller with PLC. Control contractor shall be responsible for providing interface cabling, communication software and hardware, and programming for monitoring chiller control and alarm points via the PLC.
- B. Pump Control:
1. Primary pump shall operate continuously when system is enabled.
  2. Pumps shall operate as described under “Primary/Standby Device Operation” under general control sequences. Provide primary-standby software switch to select primary pump.
- C. System Operation:
1. System shall operate continuously in one mode of operation.
  2. System shall be manually enabled/disabled by a single command from operator workstation.
  3. When the system is commanded to start via normal change of PLC data point, the following sequence shall occur:
    - a. Primary pump shall start, ramp up to minimum speed. After 30 seconds (FA) system pressure control shall be enabled.
    - b. After pump has proven operation via current switch and flow has been proven via flow meter, start chiller. Once chiller is energized and flow has been proven through evaporator, chiller shall be automatically cycled by packaged chiller controller furnished by chiller manufacturer to maintain chilled water supply temperature of 34°F (FA).
    - c. During the initial start up while pump is held at minimum speed, system pressure shall be monitored. If system pressure during the initial start up is less than system setpoint, pump speed shall be released to control and bypass valve shall remain closed. If system pressure differential during the initial start up is greater than system setpoint, bypass valve shall be released to control while pump speed is held at minimum speed.
  4. When system is commanded to stop the following shall occur:
    - a. PLC shall send “stop” signal to packaged chiller controller. Chiller shall be disabled and stopped by automatic chiller control panel.
    - b. Primary chilled water pump for chilled water loop shall be stopped 5 minutes (FA) after chiller is proven not running.
- D. System Pressure Control:
1. Pump VFD shall be controlled in sequence through PLC to maintain chilled water differential pressure setpoint of 15 psi (FA).
  2. Control Contractor shall work in association with Test and Balance Contractor to determine actual required pressure setpoint. Actual differential pressure setpoint shall be the minimum pressure required to achieve system design flow through system.
  3. Provide one process chilled water differential pressure transmitter as indicated on mechanical plans.
  4. Upon signal loss to VFD, VFD shall ramp down at programmed ramp rate to pre-programmed minimum speed and held.

- E. Minimum Flow Sequence:
1. PLC shall modulate bypass chilled water control valve to maintain minimum total system flow rate of 100 gpm (FA) as indicated by chilled water flow meter.
  2. On an decrease in chilled water flow through the chiller, bypass chilled water control valve shall be modulated open to bypass building chilled water loop and provide the required amount of flow through the chiller. The reverse shall occur as chilled water flow through chillers increases.
  3. Bypass valve shall fail last position (FLP).
- F. Glycol Fill Tank:
1. Glycol fill tank shall have pump operating status and tank low level alarm monitored by PLC for alarm annunciation. Glycol fill tank control panel shall be provided with dry contacts for use by PLC.
  2. Control Contractor shall be responsible for wiring contacts provided for general alarm to PLC.
- G. Power Failure Mode:
1. Low temperature chilled water system is not served by standby power.
  2. When normal power fails as indicated by power system monitor, low temperature chillers and pumps shall be commanded to stop.
  3. Upon resumption of normal power as indicated by power system monitor, low temperature chiller and pumps shall be restarted as described in normal operation above and in restart order with delay as indicated in POWER FAILURE MODE as explained previously in this section.
- H. Monitor and Alarm:
1. Monitor, through PLC, the following points associated with low temperature chilled water system and generate the alarms indicated:
    - a. Low temperature chilled water pump status – each pump (DI)
      - 1) Generate Level 2 alarm if pump status does not match commanded state within 60 seconds (FA) of command change of state.
    - b. Low temperature chilled water system chilled water return temperature – (AI)
    - c. Low temperature chilled water pressure differential –(AI)
      - 1) Generate Level 1 alarm if pressure differential exceeds setpoint by  $\pm 2$  psi (FA) for 5 consecutive minutes (FA).
    - d. VFD fault - all VFDs (DI)
      - 1) Generate Level 1 alarm.
    - e. VFD H-O-A (Hand-Off-Auto) switch – all VFDs (DI)
      - 1) Generate Level 1 alarm anytime H-O-A switch is in any position other than Automatic.
    - f. Low temperature chilled water system chilled water system pressure – (AI)
    - g. Generate Level 2 alarm if pressure falls below 25 psig (FA).
    - h. Glycol fill station pump status – each pump (DI)
    - i. Glycol fill station tank low level switch – (DI)
      - 1) Generate Level 1 alarm if level is below setpoint.
    - j. Low temperature chilled water flow meter WFM-LC1- (AI)

2. Monitor, through PLC via Modbus communication interface, the following points associated with low temperature chilled water chiller and generate the alarms indicated:
  - a. Entering chilled water temperature – (AI)
  - b. Leaving chilled water temperature – (AI)
    - 1) Generate Level 2 alarm if temperature is 2°F (FA) above setpoint.
  - c. Condenser refrigerant temperature – (AI)
  - d. Condenser refrigerant pressure – (AI)
  - e. Operating Hours – (AI)
  - f. Loss of cooling water flow – (DI)
    - 1) Generate Level 1 alarm.
  - g. Chiller temperature setpoint – (AO)
  - h. Chiller current limit setpoint – (AO)

### 3.6 HEAT RECOVERY SYSTEM - CONTROL SEQUENCE

- A. General:
  1. Refer to drawings crm7.02, crm7.03, crm7.05 and m7.16
  2. System consists of two pumps. Each pump is designed for 100% of the total design heat recovery flow.
  3. System shall be controlled through PLC.
- B. Glycol Pump Start/Stop:
  1. Primary glycol heat recovery pump shall start when air handling unit supply fan AHU-C1 and any heat recovery unit exhaust fan is operating and outside air temperature is below 50°F (FA) or above 80°F (FA). Primary Glycol pump shall stop when outside air temperature rises above 52°F (FA) or drops below 78°F (FA) for 10 consecutive minutes (FA) or when all AHU-C1 supply fans are off, and all HRU associated exhaust fans are off.
  2. Pump failure shall be defined as, anytime a pumps status does not match the pumps' commanded state within 30 seconds (FA) after the pumps commanded state changes. If a pump failure occurs, as detected by a current switch, the pump shall be commanded to stop and an alarm shall be generated at the PLC. This pump alarm shall be disabled for first 30 seconds (FA) after the pump is initially commanded to start or stop. On pump failure, pump shall be locked out until manually reset through the PLC.
  3. When either pump is commanded to start via H-O-A switch, the following sequence shall occur:
    - a. In hand mode, pump shall start.
      - 1) When an H-O-A switch is in any position other than Auto, an alarm shall be annunciated at the PLC.
- A. Glycol Fill:
  1. Glycol fill shall be from low temperature chilled water glycol fill system.
- C. Power Failure Mode:
  1. Pumps are not served by standby power.
  2. When normal power fails, all operating pumps shall be commanded stopped.
  3. Upon resumption of normal power, normal pump control sequence shall resume with no interruption of power to operating pumps. Refer to POWER

FAILURE MODE, previously documented in this specification section for restart sequence of stopped pumps

- D. Monitor and Alarm:
1. Monitor, through BAS, the following points and generate the alarms indicated:
    - a. Pump current switch – each pump (DI)
      - 1) Generate Level 1 alarm if pump status does not match command state within 60 seconds (FA) change of command state.
    - b. H-O-A (Hand-Off-Auto) switch – each pump (DI)
      - 1) Generate Level 1 alarm anytime H-O-A switch is in any position other than Automatic.
    - c. Glycol system pressure – (AI)
      - 1) Generate Level 2 alarm if pressure falls below 25 psig (FA).
    - d. Glycol supply temperature from AHU-C1 (AI)
    - e. Glycol return temperature from exhaust (AI)

### 3.7 CLEAN ROOM AIR HANDLING UNIT AHU-C1 - CONTROL SEQUENCE

- A. General:
1. Refer to drawing crm7.02
  2. AHU-C1 is located in the penthouse.
  3. System is designed as heating-cooling-humidification, single duct, constant volume reheat system.
- B. Operating Modes:
1. System shall operate continuously with single operating mode.
  2. In addition to the normal operating modes, system shall be provided with an emergency smoke control operating mode.
- C. System and Fan Operation:
1. Unit operation shall be automatic and activated through PLC.
  2. PLC shall start/stop and run all AHUs continuously by a single command from operator via PLC discrete output point.
  3. When system is commanded to start via command of PLC output point, the following sequence shall occur:
    - a. AHU supply fans shall start and hold at minimum speed while outside air damper open. When outside air damper are proven open via open position end switches, AHU supply shall be released to control and allowed to ramp up.
    - b. Whenever the outside air damper (FC) does not prove open via open position end switches within 60 seconds (FA) of open command, the damper shall close, the AHU shall fail, and an alarm shall be annunciated at the PLC. The failed AHU shall be locked out and remain locked out until manually reset through the PLC.
    - c. AHU supply fans shall start by slowly ramping up to minimum speed.
  4. When system is commanded to stop, supply and interlocked exhausts fan shall stop and the outside air dampers shall close.
  5. When any supply fan is commanded to start via H-O-A switch on VFD, the following sequence shall occur:

- a. In hand mode, supply fan shall start and operate at speed selected on VFD, and an alarm shall be annunciated at the PLC.
  - b. On indication of H-O-A switch in Hand Mode, outside air damper shall open.
  - c. When a VFD H-O-A switch is in any position other than Auto, an alarm shall be annunciated at the PLC.
- D. Fan Failure Detection:
1. If an AHU supply fan failure occurs, as detected by loss of flow, or VFD fault indication from VFD output, fan shall be stopped and an alarm shall be annunciated at the PLC. This alarm interlock shall be disabled for 60 seconds (FA) after the fan is initially commanded to start. Upon failure, effected supply fan shall shut down while remaining supply fans continues to operate. Failed supply fan shall be locked out and remain locked out until manually reset through PLC.
  2. When failed AHU is reset through PLC, outside air damper shall be commanded open and, failed AHU shall restart on minimum speed. When outside air damper is proven open with end switch and failed AHU is proven operational by current switch.
  3. Provide a manual reset switch at the AHU temperature control panel to reset all locked out fans locally as well as through the PLC.
- E. Interlocking:
1. Whenever supply fan stops, AHU outside air damper shall close and be proven closed by end switches.
  2. Refer to “Solvent and Corrosive Exhaust System – Control Sequences”.
  3. Interlock associated humidifiers so that humidifiers will be inoperative when the respective air handling unit supply fan is not operating.
  4. When air handling unit is commanded on, heat recovery system shall start. When air handling unit is commanded off, heat recovery system shall stop. Refer to “Heat Recovery Units Control:” section that follows.
  5. When an air handling unit is not operating except during low temperature switch shutdown, control devices shall be in the following positions:
    - a. Outside air damper Closed
    - b. AHU-C1 by-pass damper (D-C1-1B) Closed
    - c. Heat recovery units Off
    - d. Pre-heat coil control valve Under Control
    - e. Preheat coil pump Under Control
    - f. Cooling coil control valve Closed
    - g. Low temperature cooling coil control valve Closed
    - h. Reheat coil control valve Closed
    - i. Cooling coil freeze protection pump Refer to “Cooling Coil Freeze Protection Pumps – Control Sequence”
    - j. Supply fans Off
- F. Occupied and Unoccupied Operation:
1. Unit shall operate continuously.
- G. Supply System Air Volume Control:
1. System static pressure control shall be accomplished by variable frequency drive(s).



2. Refer to section 3.1, G – Variable Frequency Drives
  3. Whenever a fan is signaled to stop, on failure of the respective fan speed control signal, on failure of the respective VFD, or on failure of a fan as indicated by differential pressure switch, program controls so that the VFD ramps down to the minimum preprogrammed speed at the programmed ramp rate and stops.
  4. Control Contractor shall work in association with Test and Balance Contractor to determine actual required static pressure setpoints. Actual static pressure setpoints shall be the minimum static pressure required to achieve system design flow.
  5. PLC shall modulate VFD to maintain gowning to corridor differential pressure setpoint of  $+0.05$ " WC (FA) relative to adjacent corridor. Provide space differential pressure sensors and transmitters as shown on drawings. Refer to section 1.6 – Pressure Transmitter/Sensors
  6. All space differential pressure sensors and transmitters shall be installed shall meet sensor manufacturer's recommendations for locating devices of this type. Controls Contractor shall verify location of fire/smoke dampers in the supply duct. All fire/smoke dampers located in supply air duct shall have damper position monitored with end switches by the PLC. When fire/smoke dampers are proven closed by end switches, all supply and interlocked exhaust fans shall stop.
  7. On drop in space differential pressure below setpoint, speed of supply fan shall increase until space differential pressure has been satisfied. On rise in space differential pressure above setpoint, speed of supply fan shall decrease until space differential pressure is satisfied.
- H. AHU-C1 Make-up Air Damper (D-C1B) Control:
1. AHU-C1 make-up air damper shall be closed whenever AHU-C1 or AHU-O1 supply fan(s) are not operating.
  2. Outside air temperature below  $51^{\circ}\text{F}$  (FA), AHU-C1 make-up air damper (FC) shall modulate to maintain a mixed air temperature setpoint of  $51^{\circ}\text{F}$  (FA). Mixed air temperature sensor shall be located on the inlet side of the pre-heating coil.
  3. Outside air temperature between  $52^{\circ}\text{F}$  (FA) and  $70^{\circ}\text{F}$  (FA), AHU-C1 make-up air damper (FC) shall be closed.
  4. Outside air temperature above  $70^{\circ}\text{F}$  (FA), AHU-C1 make-up air damper (FC) shall be fully open.
- I. Heat Recovery Coil Control :
1. When glycol heat recovery pumps are operating and outside air temperature is below  $50^{\circ}\text{F}$  (FA), three-way heat recovery coil control valve (fail to bypass coil) shall modulate to maintain a heat recovery coil discharge air temperature of  $52^{\circ}\text{F}$  (FA) as sensed by temperature sensor downstream of heat recovery coil.
  2. As heat recovery coil discharge air temperature increases above setpoint, three-way control valve shall modulate to bypass heat recovery coil to decrease heat recovery coil discharge air temperature. The reverse shall occur as heat recovery coil discharge air temperature decreases.
  3. When outside air temperature rises above "pre-cool" set point of  $80^{\circ}\text{F}$  (FA), three-way control valve shall open to provide full flow to coil for cooling mode of heat recovery system.

4. When the unit is off or when the outside air temperature is between pre-cool and preheat set points for a minimum of 10 minutes (FA), heat recovery coil control valve shall be closed to heat recovery coil.
  5. PLC shall provide low heat recovery return water temperature override heat recovery coil discharge air temperature control loop to maintain minimum system return fluid temperature of 35°F (FA) to prevent freezing of exhaust HRU coil condensation.
  6. As heat recovery coil leaving water temperature decreases below setpoint, three-way heat recovery coil control valve shall modulate to bypass heat recovery coil to increase glycol return temperature. As the glycol return temperature rises above the glycol return temperature setpoint, the heat recovery coil discharge air temperature control shall be allowed to control the three-way heat recovery coil control valve.
  7. When heat recovery pumps are off, three-way control valve shall fail to bypass coil position.
- J. Pre-Heat Coil Control:
1. PLC shall modulate pre-heat coil control valves (FLP) to maintain 52°F (FA) pre-heat coil leaving air temperature.
  2. Pre-heat Coil Discharge Air Temperature Control – Normal Operation:
    - a. Control valve V-C-1C (1/3 valve) shall modulate to maintain pre-heat coil leaving air temperature setpoint. When control valve V-C-1C is greater than 90% (FA) open for more than 10 seconds (FA), slowly increment control valve V-C-1B (full valve) an additional 10% (FA) open and modulate control valve V-C-1C to maintain setpoint. Control valve V-C-1B shall gradually modulate over 15 second (FA). When control valve V-C-1C is less than 15% (FA) open for more than 10 seconds (FA), slowly decrement control valve V-C-1B an additional 10% (FA) closed and modulate control valve V-C-1C to maintain setpoint.
  3. Pre-heat Coil Discharge Air Temperature Control – AHU Not Running Operation:
    - a. PLC shall modulate pre-heat coil control valve V-C-1C to maintain 52°F (FA) pre-heat coil leaving air temperature anytime AHU is not running, outside air temperature is less than 52°F (FA), and safety low temperature limit control (freeze-stat) is not in alarm.
    - b. Control valve V-C-1B shall remain fully closed.
  4. Pre-heat coil control valves shall be locked in closed position whenever outside air temperature is above 52°F (FA) for 10 consecutive minutes (FA).
  5. Preheat coil control valves are to be sized as follows:
    - a. Control valve V-C-1B shall be sized for 75 GPM.
    - b. Control valve V-C-1C shall be sized for 35 GPM.
- K. Pre-Heat Coil Circulating Pumps
1. Pre-heat coil circulating pumps shall be energized automatically through PLC.
  2. Pre-heat coil circulating pump shall start whenever the outside air temperature is less than 50°F (FA) without regard to the AHU operating status, and shall operate continuously below this temperature. Pump shall stop whenever the outside air temperature is greater than 51°F (FA) for 10 consecutive minutes (FA).
  3. Pre-heat coil circulating pump shall start if respective air handling unit freezestat is activated.

4. On failure of pre-heat coil circulating pump, as determined by comparing commanded state of pump to current switch pump status indication, an alarm shall be annunciated at the PLC.
  5. Minimum pump run time shall be 5 minutes (FA). Minimum pump off time shall be 5 minutes (FA).
- L. Cooling Coil Discharge Air Temperature Control:
1. PLC shall modulate cooling coil control valve (FLP) to maintain cooling coil discharge air temperature of 54°F (FA)  $\pm$  1°F as indicated by averaging type sensor located in the air handling unit at leaving side cooling coil.
  2. In cooling mode when outside air temperature is above 50°F (FA) as discharge air temperature increases, cooling coil control valve shall modulate open to maintain cooling coil discharge air temperature setpoint. The reverse shall occur as discharge air temperature decreases.
  3. Cooling coil control valve shall be locked in closed position whenever outside air temperature is below 50°F (FA) for 10 consecutive minutes (FA) or whenever associated supply fan is not operating.
- M. Low Temperature Cooling Coil Control:
1. PLC shall modulate low temperature cooling coil control valve (FLP) to maintain low temperature cooling coil discharge air temperature of 43°F (FA)  $\pm$  0.5°F as indicated by averaging type sensor located in the air handling unit at leaving side cooling coil.
  2. In cooling mode when outside air temperature is above 40°F (FA) and cleanroom relative humidity is above 40% RH (FA) as measured by humidity sensor located in cleanroom, as discharge air temperature increases, low temperature cooling coil discharge air controller shall be overridden and cooling coil control valve shall modulate open to maintain relative humidity setpoint. The reverse shall occur as discharge air temperature decreases.
  3. Cooling coil control valve shall be locked in closed position whenever outside air temperature is below 40°F (FA) for 10 consecutive minutes (FA) or whenever all associated supply fans are not operating.
- N. Low Temperature Cooling Coil Dehumidification Control:
1. When outside air temperature is above 40°F (FA), primary and booster humidifiers and at 0% output and cleanroom relative humidity is above 40% RH (FA), as measured by dewpoint sensor located in cleanroom, low temperature cooling coil discharge air temperature control shall be overridden and low temperature cooling coil control valve shall modulate to maintain supply air relative humidity setpoint.
- O. Cooling Coil Freeze Protection Pump
1. Cooling coil freeze protection pumps shall be energized automatically through PLC.
  2. Cooling coil freeze protection pumps shall start whenever the outside air temperature is less than 40°F (FA) without regard to the AHU operating status, and shall operate continuously below this temperature. Pump shall stop whenever the outside air temperature is greater than 41°F (FA) for 10 consecutive minutes (FA).
  3. Cooling coil freeze protection pump shall start if respective air handling unit freezestat is activated.

4. On failure of cooling coil freeze pump, as determined by comparing commanded state of pump to current switch pump status indication, an alarm shall be annunciated at the PLC.
  5. Minimum pump run time shall be 5 minutes (FA). Minimum pump off time shall be 5 minutes (FA).
- P. Reheat Coil Temperature control;
1. PLC shall modulate reheat coil control valve (FLP) to maintain supply air temperature of 68°F (FA)  $\pm$  0.5°F via averaging type sensor located in the supply duct as shown on the drawings.
- Q. Primary Humidifier Control (H-C1):
1. Humidifier is steam to steam type.
  2. Control humidifier steam valves to maintain unit discharge air humidity as indicated by sensor located in supply ductwork as shown on crm7.02. Supply duct humidity sensor shall be located a minimum of 10'-0" downstream of H-C2 in supply air ductwork
  3. PLC shall modulate humidifier steam control valves in sequence through PID control loop to maintain supply air humidity setpoint.
    - a. Humidity setpoint shall be 30% RH at 68°F
    - b. Supply air humidity sensor shall be located in supply air duct upstream of HEPA filter. Refer to drawings for locations.
  4. PLC shall provide interlock signal to humidifier controller to shut-down humidifier if air flow is below 8750 cfm (FA). Control Contractor shall be responsible for wiring interlock signal to humidifier control panel.
- R. Space Humidity Control:
1. Booster Humidifier, H-C2, is steam to steam type.
  2. Supply air humidity setpoint shall be reset based on cleanroom space humidity as indicated by sensor located in the cleanroom, refer to drawings for location. Supply duct humidity sensor shall be located a minimum of 10'-0" downstream of H-C2 in supply air ductwork. Space humidity setpoint shall be 40% RH (FA)  $\pm$  2% RH at 68°F
  3. Modulate humidifier steam control valve to maintain supply duct humidity as indicated by sensor located in supply ductwork as shown on crm7.02.
  4. With outside air temperature above 40°F (FA) and both primary and booster humidifiers at 0% output and cleanroom relative humidity above 40% RH (FA), low temperature cooling coil discharge air temperature control shall be overridden and low temperature cooling coil control valve shall modulate to maintain supply air relative humidity setpoint.
  5. PLC shall provide interlock signal to humidifier controller to shut-down humidifier if air flow is below 8750 cfm (FA). Control Contractor shall be responsible for wiring interlock signal to humidifier control panel.
- S. Smoke Control:
1. Refer to Smoke/Fire Alarm Mode.
- T. Safeties:
1. Provide safety low temperature limit control (freeze-stat), with 3 minute (FA) time delay from fan start signal at entering side of cooling coil. Low limit shall de-energize unit supply fan, close outside air damper, open cooling coil control

- valve and modulate preheat coil control valve to maintain preheat coil discharge air temperature (measured downstream of preheat coil) at 60°F (FA) when air temperature falls below 38°F (FA). Low limit shall be functional in VFD and H-O-A modes of operation.
2. Provide high static pressure safety switch located in the supply duct before the first fire/smoke damper stop to associated supply fans and interlocked exhaust fans when pressure reaches 4" WC (FA). High pressure safety switch shall have local manual reset for restarting AHU.
- U. Power Failure Mode:
1. Air handling unit supply fans, pre-heat coil and cooling coil circulating pumps are not connected to standby power.
  2. When normal power fails, all operating fans and pumps shall be commanded stopped.
  3. Upon resumption of normal power, normal air handling unit and pump control sequence shall resume. Refer to POWER FAILURE MODE, previously documented in this specification section for restart sequence of stopped pumps
- V. Monitor and Alarm:
1. Monitor, through BAS, the following points associated with each air handling unit and generate the alarms indicated:
    - a. Discharge air temperature (AI)
      - 1) Generate Level 2 Alarm if temperature exceeds setpoint by  $\pm 3^{\circ}\text{F}$  (FA).
    - b. Heat Recovery Coil discharge air temperature – (AI)
    - c. Preheat coil discharge air temperature (AI)
      - 1) Generate Level 2 alarm if outside air temperature is less than preheat coil discharge air temperature setpoint and temperature exceeds setpoint by  $\pm 5^{\circ}\text{F}$  (FA).
    - d. Coiling coil discharge air temperature (AI)
      - 1) Generate Level 2 alarm if temperature exceeds setpoint by  $\pm 3^{\circ}\text{F}$  (FA).
    - e. Low temperature coiling coil discharge air temperature (AI)
      - 1) Generate Level 2 alarm if temperature exceeds setpoint by  $\pm 2^{\circ}\text{F}$  (FA).
    - f. Supply fan current switch (DI)
      - 1) Generate Level 1 alarm if fan status does not match fan command state within 60 seconds (FA) change of command state.
    - g. Supply fan speed VFD feedback signal (AI)
    - h. Supply fan VFD Fault (DI)
      - 1) Generate Level 1 alarm.
    - i. VFD H-O-A switch – each VFD (DI)
      - 1) Generate Level 1 alarm if switch is in any position other than auto.
    - j. Outside air damper position – open and closed (DI)
      - 1) Generate Level 1 alarm if damper is not proven open within 60 seconds (FA) of AHU start signal or closed within 60 seconds (FA) of AHU stop signal.
    - k. Prefilter pressure drop – summer position (AI)

- 1) Generate Level 1 alarm when filter pressure drop exceeds setpoint of 0.8" WC (FA).
  - l. Prefilter pressure drop – winter position (AI)
- 1) Generate Level 3 alarm when filter pressure drop exceeds setpoint of 0.8" WC (FA).
  - m. Final filter pressure drop (AI)
- 1) Generate Level 3 alarm when filter pressure drop exceeds setpoint of 1.5" WC (FA).
  - n. HEPA filter pressure drop (AI)
- 1) Generate Level 3 alarm when filter pressure drop exceeds setpoint of 2.0" WC (FA).
  - o. AHU fire/smoke damper position – open and closed (DI)
- 1) Generate Level 1 alarm if damper is not proven open within 60 seconds (FA) of fan start signal or proven closed within 60 seconds (FA) of fan stop signal.
  - p. Fan discharge high static pressure safety switch (DI)
- 1) Stop fan and generate Level 1 alarm if pressure exceeds 4.5" WC (FA).
  - q. Duct static pressure transmitter – (AI)
- 1) Generate Level 3 alarm if pressure exceeds setpoint by  $\pm 1.0$ " WC (FA).
  - r. Low limit thermostat (freezestat) (DI)
- 1) Generate Level 1 alarm if low limit trips.
  - s. Chilled water coil return temperature (AI)
  - t. Chilled water coil supply temperature (AI)
  - u. Low temperature chilled water coil return temperature (AI)
  - v. Low temperature chilled water coil supply temperature (AI)
  - w. Reheat coil supply temperature (AI)
  - x. Reheat return from coil temperature (AI)
  - y. Discharge air temperature (AI)
  - z. Duct discharge air temperature (AI)
- 1) Generate Level 2 alarm if temperature exceeds setpoint by  $\pm 2^{\circ}\text{F}$  (FA)
  - aa. Pre-heat coil supply temperature (AI)
  - bb. Pre-heat return from coil temperature (AI)
  - cc. Supply fan discharge smoke detector (DI)
  - dd. Pre-heat coil circulating pump current switch (DI)
    - 1) Generate Level 2 alarm anytime pump status does not match commanded state within 60 seconds (FA) of command change of state.
  - ee. Pre-heat coil circulating pump H-O-A (Hand-Off-Auto) switch (DI)
    - 1) Generate Level 1 alarm anytime H-O-A switch is in any position other than Automatic.
  - ff. Cooling coil circulating pump current switch (DI)
    - 1) Generate Level 2 alarm anytime pump status does not match commanded state within 60 seconds (FA) of command change of state.
  - gg. Cooling coil circulating pump H-O-A (Hand-Off-Auto) switch (DI)

- 1) Generate Level 1 alarm anytime H-O-A switch is in any position other than Automatic.
2. Refer to flow diagram for additional monitoring requirements.

### **3.8 CLEANROOM AIR HANDLING UNITS (AHU-C5, AHU-C7, AHU-C8, AHU-C10, AHU-C11 THROUGH AHU-C17) – CONTROL SEQUENCE**

- A. General:
1. Refer to drawing crm7.04.
  2. There are 11 cleanroom re-circulating air handling units and 5 future cleanroom recirculating air handling units:
    - a. AHU-C5, AHU-C7, AHU-C8, AHU-C10, AHU-C11 through AHU-C17.
    - b. AHU-C3, AHU-C-6 and AHU-C9 are future.
    - c. AHU-C-2 and AHU-C4 are cleanroom alternate bid.
  3. Air handling unit AHU-C1 provides conditioned outside air for use as make air for exhaust and cleanroom pressurization.
  4. Cleanroom re-circulating air handlings units are factory custom units with an opening for supply air.
- B. Operating Modes:
1. System shall operate continuously with single operating mode.
  2. In addition to the normal operating modes, system shall be provided with an emergency smoke control operating mode.
- C. System and Fan Operation:
1. Unit operation shall be automatic and activated through PLC.
  2. PLC shall start/stop and run all selected AHUs continuously by a single command from operator via PLC discrete output point.
  3. When system is commanded to start via command of PLC output point, the following sequence shall occur:
    - a. AHU supply fans shall start and hold at minimum speed. After 60 seconds AHU supply fans shall be released to control and allowed to ramp up to CFM setpoint.
  4. When system is commanded to stop, supply fans shall stop and cooling coil valve shall close.
  5. When supply fans are commanded to start via H-O-A switch on VFD, the supply fans shall start and operate at speed selected on VFD, and an alarm shall be annunciated at the PLC.
  6. When a VFD H-O-A switch is in any position other than Auto an alarm shall be annunciated at the PLC.
- D. Fan Failure Detection:
1. If AHU supply fan failure occurs, as detected by pressure differential switch, or VFD fault indication from VFD output, the fan(s) shall be stopped and an alarm shall be annunciated at the PLC. This alarm interlock shall be disabled for 60 seconds (FA) after the fan is initially commanded to start. Upon failure, effected AHU shall shut down. Failed AHU shall be locked out and remain locked out until manually reset through PLC.
  2. When failed AHU is reset through PLC, AHU shall restart on minimum speed. Speed of reset failed AHU supply fans shall ramp up while speed to maintain discharge static pressure setpoint.

3. Provide a manual reset switch at the AHU temperature control panel to reset locked out fan locally as well as through the PLC.
- E. Interlocking:
1. When an air handling unit is not operating, supply fans shall be off and cooling coil control valve shall be closed.
- F. Occupied and Unoccupied Operation:
1. Unit shall operate continuously.
  2. In addition to the normal operating modes, system shall be provided with an emergency smoke control operating mode.
- G. Supply System Air Volume Control:
1. System air volume control shall be accomplished by variable frequency drive(s).
  2. See 3.1.G – Variable Frequency Drives
  3. Whenever a fan is signaled to stop, on failure of the respective fan speed control signal, on failure of the respective VFD, or on failure of a fan as indicated by pressure differential switch, program controls so that the VFD ramps down to the minimum preprogrammed speed at the programmed ramp rate and stops.
  4. Control Contractor shall work in association with Test and Balance Contractor to determine actual system air flow setpoints.
  5. PLC shall modulate VFD's to maintain CFM  $\pm 3\%$  supply airflow as measured by air flow meter located at fan inlet (FA). Refer to fan schedule for CFM.
- H. Unit Discharge Air Temperature Control:
1. Discharge air temperature shall be controlled through the PLC with temperature sensors located as specified herein and indicated in drawings.
  2. PLC shall modulate cooling coil control valve (FLP) to maintain unit discharge air temperature of 68°F (FA)  $\pm 1.8^\circ\text{F}$  via sensor located in the discharge air plenum of each unit.
  3. Cooling coil control valve shall be locked in closed position whenever associated supply fan is not operating.
- I. Smoke Control:
1. Refer to Smoke/Fire Alarm Mode.
- J. Power Failure Mode:
1. Air handling units are not served by standby power.
  2. When normal power fails, all operating fans shall be commanded stopped.
  3. Upon resumption of normal power, normal air handling unit control sequence shall. Refer to POWER FAILURE MODE, previously documented in this specification section for restart sequence of stopped pumps
- K. Monitor and Alarm:
1. Monitor, through PLC, the following points associated with each air handling unit and generate the alarms indicated:
    - a. Discharge air temperature (AI)
      - 1) Generate Level 2 Alarm if temperature exceeds setpoint by  $\pm 5^\circ\text{F}$  (FA).



- b. Supply fan pressure differential switch – each fan (DI)
  - 1) Generate Level 2 alarm if fan status does not match fan command state within 60 seconds (FA) change of command state.
- c. Supply fan speed VFD feedback signal – each VFD (AI)
- d. Supply fan VFD Fault – each VFD (DI)
  - 1) Generate Level 2 alarm.
- e. VFD H-O-A switch – each VFD (DI)
  - 1) Generate Level 1 alarm if switch is in any position other than auto..
- f. Filter pressure drop – (DI)
  - 1) Generate Level 2 alarm when filter pressure drop exceeds setpoint of 0.7" WC (FA).
- g. Unit air flow – CFM (AI)
  - 1) Generate Level 1 alarm if air flow exceeds setpoint by  $\pm 5\%$ .
- h. Air handling unit chilled water supply temperature (AI)

### 3.9 AIR HANDLING UNIT AHU-C-19 – CONTROL SEQUENCE

- A. General
  - 1. Refer to drawing crm7.09.
  - 2. Air handling unit is packaged air handling unit serving Gowning.
  - 3. Unit consists of:
    - a. Supply Fan
    - b. Prefilter
    - c. Chilled water cooling coil
    - d. Hot water heating coil
- B. Operating Modes:
  - 1. System shall operate continuously with single operating mode.
- C. System and Fan Operation:
  - 1. Unit operation shall be automatic and activated through PLC.
  - 2. PLC shall start/stop and run all selected AHUs continuously by a single command from operator via PLC discrete output point.
  - 3. When system is commanded to start via command of PLC output point, AHU supply fan shall start.
  - 4. When system is commanded to stop, supply fan shall stop.
  - 5. When supply fan is commanded to start via H-O-A, the supply fan shall start, and an alarm shall be annunciated at the PLC.
  - 6. When H-O-A switch is in any position other than Auto an alarm shall be annunciated at the PLC.
- D. Fan Failure Detection:
  - 1. If AHU supply fan failure occurs, as detected by current status switch, the fan shall be stopped and an alarm shall be annunciated at the PLC. This alarm interlock shall be disabled for 60 seconds (FA) after the fan is initially commanded to start. Failed AHU shall be locked out and remain locked out until manually reset through PLC.
  - 2. Provide a manual reset switch at the AHU temperature control panel to reset locked out fan locally as well as through the PLC.

- E. Discharge Air Temperature Control
  - 1. PLC shall modulate cooling coil control valve (FLP) and heating coil control valve (FC) to maintain space temperature of 68°F (FA) as indicated by sensor located in space.
  - 2. Control valves shall be locked in closed position whenever associated supply fan is not operating.
- F. Smoke Control:
  - 1. Refer to Smoke/Fire Alarm Mode.
- G. Power Failure Mode:
  - 1. Air handling units are not served by standby power.
  - 2. When normal power fails, all operating fans shall be commanded stopped.
  - 3. Upon resumption of normal power, normal air handling unit control sequence shall resume. Refer to POWER FAILURE MODE, previously documented in this specification section for restart sequence of stopped pumps
- H. Monitoring Points
  - 1. Provide the following non-control BAS monitoring points:
    - a. Supply fan current switch (DI)
    - b. Discharge air temperature (AI)
      - 1) Generate Level 2 Alarm if temperature exceeds setpoint by  $\pm 3^{\circ}\text{F}$  (FA).
    - c. Prefilter pressure drop – (AI)
      - 1) Generate Level 1 alarm when filter pressure drop exceeds setpoint of 0.8" WC (FA).

### 3.10 AIR HANDLING UNIT AHU-C-18 – CONTROL SEQUENCE

- A. General
  - 1. Refer to drawing crm7.09.
  - 2. Air handling unit is packaged air handling unit serving Cleanroom Server.
  - 3. Unit consists of:
    - a. Supply Fan
    - b. Prefilter
    - c. Chilled water cooling coil
    - d. Hot water heating coil
- B. Operating Modes:
  - 1. System shall operate continuously with single operating mode.
- C. System and Fan Operation:
  - 1. Unit operation shall be automatic and activated through PLC.
  - 2. PLC shall start/stop and run all selected AHUs continuously by a single command from operator via PLC discrete output point.
  - 3. When system is commanded to start via command of PLC output point, AHU supply fan shall start.
  - 4. When system is commanded to stop, supply fan shall stop.
  - 5. When supply fan is commanded to start via H-O-A, the supply fan shall start, and an alarm shall be annunciated at the PLC.

6. When H-O-A switch is in any position other than Auto an alarm shall be annunciated at the PLC.
- D. Fan Failure Detection:
1. If AHU supply fan failure occurs, as detected by current status switch, the fan shall be stopped and an alarm shall be annunciated at the PLC. This alarm interlock shall be disabled for 60 seconds (FA) after the fan is initially commanded to start. Failed AHU shall be locked out and remain locked out until manually reset through PLC.
  2. Provide a manual reset switch at the AHU temperature control panel to reset locked out fan locally as well as through the PLC.
- E. Discharge Air Temperature Control
1. PLC shall modulate cooling coil control valve (FLP) and heating coil control valve (FC) to maintain space temperature of 68°F (FA) as indicated by sensor located in space.
  2. Chilled water valve shall close when unit is off.
- F. Smoke Control:
1. Refer to Smoke/Fire Alarm Mode.
- G. Power Failure Mode:
1. Air handling units are not served by standby power.
  2. When normal power fails, all operating fans and pumps shall be commanded stopped.
  3. Upon resumption of normal power, normal air handling unit control sequence shall resume. Refer to POWER FAILURE MODE, previously documented in this specification section for restart sequence of stopped pumps
- H. Monitoring Points
1. Provide the following non-control BAS monitoring points:
    - a. Supply fan current switch (DI)
    - b. Room air temperature (AI)
      - 1) Generate Level 2 Alarm if temperature exceeds setpoint by  $\pm 3^{\circ}\text{F}$  (FA).
    - c. Prefilter pressure drop – (AI)
      - 1) Generate Level 1 alarm when filter pressure drop exceeds setpoint of 0.8" WC (FA).

### 3.11 CLEAN ROOM CORROSIVE EXHAUST SYSTEM - CONTROL SEQUENCE

- A. General:
1. Refer to drawing crm7.03.
  2. System consists of the following exhaust fans:
    - a. EF-CE-1
    - b. EF-CE-2
  3. There is one Cleanroom Corrosive Exhaust System. System consists of 2 exhaust fans connected to a common plenum. Exhaust distribution ductwork is interconnected by a plenum located on the roof.
  4. One exhaust fan will operate with second fan being a redundant unit.
  5. Each fan is designed for 100% of the system exhaust air flow.

6. System shall be controlled through PLC.
- B. System and Fan Operation:
1. Unit operation shall be automatic and activated through PLC.
  2. System shall operate continuously in one mode of operation.
  3. System shall manually start/stop and run all EFs continuously by a single command from operator via PLC discrete output point.
  4. When system is commanded to start via command of PLC output point, the following sequence shall occur:
    - a. Lead cleanroom corrosive exhaust fan shall start and hold at minimum speed while outlet air damper opens. When outlet air damper are proven open via open position end switches, cleanroom corrosive exhaust fan shall be released to control and allowed to ramp up.
  - 1) Whenever the outlet air damper (FC) does not prove open via open position end switches within 60 seconds (FA) of open command, the damper shall close, the cleanroom corrosive exhaust fan shall fail, and an alarm shall be annunciated at the PLC. The failed cleanroom corrosive exhaust fan shall be locked out and remain locked out until manually reset through the PLC.
    - b. Cleanroom corrosive exhaust fan shall start by slowly ramping up to minimum speed.
  5. When system is commanded to stop, supply and interlocked exhausts fan shall stop and the outside air and outlet isolation dampers shall close.
  6. When cleanroom corrosive exhaust fan is commanded to start via H-O-A switch on VFD, the following sequence shall occur:
    - a. In hand mode, supply fan shall start and operate at speed selected on VFD, and an alarm shall be annunciated at the PLC.
    - b. On indication of H-O-A switch in Hand Mode, outside air damper shall open.
  - 1) When a VFD H-O-A switch is in any position other than Auto, an alarm shall be annunciated at the PLC.
- C. Fan Failure Detection:
1. If any cleanroom corrosive exhaust fan failure occurs, as detected by current switch, or VFD fault indication from VFD output, fan shall be stopped and an alarm shall be annunciated at the PLC. This alarm interlock shall be disabled for 60 seconds (FA) after the fan is initially commanded to start. Upon failure, effected supply fan shall shut down while remaining supply fans continues to operate. Failed exhaust fan shall be locked out and remain locked out until manually reset through PLC.
    - a. When failed is cleanroom corrosive exhaust fan reset through PLC, outlet air damper shall be commanded open and, failed cleanroom corrosive exhaust fan shall restart on minimum speed. When outlet air damper is proven open with end switch and failed cleanroom corrosive exhaust fan is proven operational by current switch.
  2. Provide a manual reset switch at the control panel to reset all locked out fans locally as well as through the PLC.
  3. System shall manually start/stop and run continuously by interlocked command with cleanroom corrosive exhaust fan control from operator via PLC discrete output point.
    - 1) One exhaust fans will operate with second fan being a redundant unit.

- b. System shall be programmed to allow end user to select operable EFs.
        4. When the cleanroom corrosive exhaust system is commanded to start via command of PLC output point, the following sequence shall occur:
          - a. Lead exhaust fans shall start.
          - b. 10 seconds (FA) after exhaust fan is commanded to start, exhaust fan respective outlet isolation damper shall be commanded open.
            - 1) Whenever an exhaust fan outlet isolation damper (FO) does not prove open via open position end switch within 60 seconds (FA) of open command, the damper shall close, the respective exhaust fan shall fail, and an alarm shall be annunciated at the PLC. The failed exhaust fan shall be locked out and remain locked out until manually reset through the PLC.
        5. When any exhaust fan is commanded to start via H-O-A switch, the following sequence shall occur:
          - a. On indication of H-O-A switch in hand mode, respective exhaust fan outlet isolation damper shall open.
            - 1) When an H-O-A switch is in any position other than Auto, an alarm shall be annunciated at the PLC.
- D. Interlocking:
  1. Interlock exhaust fans with Cleanroom Air Handling Unit AHU-C1 through PLC.
  2. When an EF is not operating, control devices shall be in the following positions:

a. Exhaust fan outlet isolation damper	Closed
b. Outside air bleed damper	Closed
c. Exhaust fan	Off
- E. Lead-Standby Control:
  1. Equalize run time on EF system based on accumulated run time (FA) by manual command from operator. When lead EF total operating hours exceeds total operating hours of standby EF by 720 hours, an alarm shall be annunciated at operator workstation indicating runtime and recommending operators manually reselect lead and standby EF.
  2. If any EF fails as indicated by pressure differential status switch or current switch on exhaust fans, or closed EF outlet isolation damper, EF shall be locked out, the standby EF shall be indexed to start, and an alarm shall be annunciated at the PLC. Once the alarm indicated at the PLC has been cleared, the solvent exhaust system shall automatically resume its scheduled position in the lead-lag-standby rotation.
- F. Exhaust Volume Control:
  1. Exhaust fans operate at constant speed, constant volume and system operates as constant volume.
  2. Exhaust system shall be controlled to maintain exhaust duct system suction pressure as sensed by suction pressure transmitter located in the exhaust plenum.
  3. Static suction pressure control shall maintain exhaust static suction pressure setpoint of -4.0" WC (FA).
    - a. See 1.06 – Pressure Transmitter/Sensors
  4. On drop in exhaust static suction pressure below setpoint (less negative), modulate outside air bleed damper closed until exhaust static suction

pressure transmitter has been satisfied. On rise in exhaust static suction pressure above setpoint (more negative), modulate outside air bleed damper open until setpoint of exhaust static suction pressure transmitter is satisfied.

- G. Miscellaneous:
  - 1. Provide low static suction pressure switch located in unit exhaust duct plenum to stop associated exhaust fans when pressure reaches -6.0" WC (FA).
  
- H. Power Failure Mode:
  - 1. Exhaust fans are not served by standby power.

2. When normal power fails, all operating fans and pumps shall be commanded stopped.
3. Upon resumption of normal power, normal exhaust fan control sequence shall resume. Refer to POWER FAILURE MODE, previously documented in this specification section for restart sequence of stopped pumps

I. Monitor and Alarm:

1. Monitor, through BAS, the following points associated with exhaust air system and generate the alarms indicated:
  - a. Exhaust fan pressure differential switch – each fan (DI)
    - 1) Generate Level 2 alarm if fan status does not match fan command state within 60 seconds (FA) of change of command state.
  - b. Exhaust fan speed VFD feedback signal – each VFD (AI)
  - c. Exhaust fan VFD Fault – each VFD (DI)
    - 1) Generate Level 2 alarm.
  - d. VFD H-O-A switch – each VFD (DI)
    - 1) Generate Level 1 alarm if switch is in any position other than auto.
  - e. Exhaust plenum suction pressure – (AI)
    - 1) Generate Level 2 alarm suction pressure rises above setpoint (becomes less negative) by 0.5” WC (FA).
  - f. Exhaust plenum suction pressure low limit – (DI)
    - 1) Generate Level 1 alarm and shut down EF.
  - g. Exhaust fan outlet isolation damper position – open and closed – each fan (DI)
    - 1) Generate Level 1 alarm if damper is not proven open with open position end switch within 60 seconds (FA) of open signal or closed with closed position end switch within 60 seconds (FA) of closed signal.
  - h. Outside air bleed fan damper position – open and closed – each fan (DI)
    - 1) Generate Level 1 alarm if damper is not proven open with open position end switch within 60 seconds (FA) of open signal or closed with closed position end switch within 60 seconds (FA) of closed signal.
  - i. Exhaust air temperature– (AI)
  - j. EF runtime hours – each EF (AI)
    - 1) Generate Level 2 alarm when lead EF runtime hours exceeds all other EF runtime hours by 720 hours (FA).

### 3.12 CLEANROOM SOLVENT EXHAUST SYSTEM – CONTROL SEQUENCE

- A. General:
  1. Refer to drawing crm7.03
  2. System consists of the following exhaust fans and HRU:
    - a. EF-SE-1
    - b. EF-SE-2
    - c. HRU-SE1

3. There is one Cleanroom Solvent Exhaust System. System consists of 2 exhaust fans connected to a common plenum and one heat recovery unit. Exhaust distribution ductwork is interconnected by a plenum located on the roof.
  4. One exhaust fan will operate with second fan being a redundant unit.
  5. Each fan is designed for 100% of the system exhaust air flow.
  6. System shall be controlled through PLC.
- B. System and Fan Operation:
1. Unit operation shall be automatic and activated through PLC.
  2. System shall operate continuously in one mode of operation.
  3. System shall manually start/stop and run all EFs continuously by a single command from operator via PLC discrete output point.
  4. When system is commanded to start via command of PLC output point, the following sequence shall occur:
    - a. Lead cleanroom corrosive exhaust fan shall start and hold at minimum speed while outlet air damper opens. When outlet air damper are proven open via open position end switches, cleanroom corrosive exhaust fan shall be released to control and allowed to ramp up.
  - 1) Whenever the outlet air damper (FC) does not prove open via open position end switches within 60 seconds (FA) of open command, the damper shall close, the cleanroom corrosive exhaust fan shall fail, and an alarm shall be annunciated at the PLC. The failed cleanroom corrosive exhaust fan shall be locked out and remain locked out until manually reset through the PLC.
    - b. Cleanroom corrosive exhaust fan shall start by slowly ramping up to minimum speed.
  5. When the cleanroom corrosive exhaust system is commanded to start via command of PLC output point, the following sequence shall occur:
    - a. 10 seconds (FA) after exhaust fan is commanded to start, exhaust fans' respective outlet isolation damper shall be commanded open.
  - 1) Whenever an exhaust fan outlet isolation damper (FO) does not prove open via open position end switch within 60 seconds (FA) of open command, the damper shall close, the respective exhaust fan shall fail, and an alarm shall be annunciated at the BAS. The failed exhaust fan shall be locked out and remain locked out until manually reset through the BAS.
    - b. When any exhaust fan is proven operational as detected by pressure differential switch, HRU inlet and outlet isolation dampers shall be commanded open while bypass damper is commanded closed.
    - c. Whenever HRU inlet and outlet isolation dampers (FC) do not prove open via open position end switch and bypass damper does not prove closed via closed position end switch within 60 seconds (FA) of open command, the dampers shall close and an alarm shall be annunciated at the PLC.
  6. When EF is commanded to stop, exhaust fans shall stop and the HRU inlet and outlet isolation dampers, and exhaust outlet isolation dampers shall close, and bypass damper shall open.
  7. When any HRU exhaust fan is commanded to start via H-O-A switch, the following sequence shall occur:
    - a. On indication of H-O-A switch in hand mode, respective exhaust fan outlet isolation damper and HRU inlet and outlet isolation dampers shall open and bypass damper shall close.



- b. When exhaust fan is proven operational as detected by pressure differential status switch or current switch, HRU inlet and outlet isolation dampers shall be commanded open and bypass damper shall be commanded closed.
  - 1) When an H-O-A switch is in any position other than Auto, an alarm shall be annunciated at the PLC.
- C. Fan Failure Detection:
- 1. If any exhaust fan failure occurs, as detected by pressure differential status switch or current switch, the fan shall be stopped and an alarm shall be annunciated at the PLC. This alarm interlock shall be disabled for 60 seconds (FA) after the fan is initially commanded to start. Upon failure, effected exhaust fan shall shut down and close respective inlet isolation damper while exhaust fan continues to operate. Failed HRU exhaust fan shall be locked out and remain locked out until manually reset through PLC.
    - a. When failed exhaust fan is reset through PLC, exhaust fan shall start and 10 seconds later (FA), respective inlet isolation damper shall be commanded open.
  - 2. Provide a manual reset switch at the HRU temperature control panel(s) to reset all locked out fans locally as well as through the PLC.
- D. Interlocking:
- 1. Interlock exhaust fans with Cleanroom Air Handling Units AHU-C1 through PLC.
  - 2. When an EF is not operating, control devices shall be in the following positions:
    - a. Exhaust fan outlet isolation damper                      Closed
    - b. Exhaust fan    Off
  - 3. When both EFs are not operating, control devices shall be in the following positions:
    - a. Exhaust fan outlet isolation damper                      Closed
    - b. Exhaust fan    Off
    - c. HRU outlet isolation air damper                              Open
    - d. HRU inlet isolation air damper                              Open
    - e. HRU bypass damper    Closed
    - f. Outside air bleed damper                                      Closed
- E. Lead-Standby Control:
- 1. Equalize run time on EF system based on accumulated run time (FA) by manual command from operator. When lead EF total operating hours exceeds total operating hours of standby EF by 720 hours, an alarm shall be annunciated at operator workstation indicating runtime and recommending operators manually reselect lead, lag, and standby EF.
  - 2. If any EF fails as indicated by pressure differential status switch or current switch on exhaust fans, or closed EF inlet isolation damper, EF shall be locked out, the standby EF shall be indexed to start, and an alarm shall be annunciated at the PLC. Once the alarm indicated at the PLC has been cleared, the cleanroom solvent exhaust system shall automatically resume its scheduled position in the lead-standby rotation.
- F. Exhaust Volume Control:

1. Exhaust fans operate at constant speed, constant volume and system operates as constant volume.
  2. Exhaust system shall be controlled to maintain exhaust duct system suction pressure as sensed by suction pressure transmitter located in the exhaust plenum upstream of the filters and heat recovery coil (typical). Exhaust volume shall be maintained operating primary exhaust fan at 100% speed and by modulating outside air bleed damper.
  3. Static suction pressure control shall maintain exhaust static suction pressure setpoint of -4.0" WC (FA).
    - a. See 1.6 – Pressure Transmitter/Sensors
  4. On drop in exhaust static suction pressure below setpoint (less negative), modulate outside air bleed damper closed until exhaust static suction pressure transmitter has been satisfied. On rise in exhaust static suction pressure above setpoint (more negative), modulate outside air bleed damper open until setpoint of exhaust static suction pressure transmitter is satisfied.
- G. Miscellaneous:
1. Provide low static suction pressure switch located in unit exhaust duct upstream of heat recovery coil and filters to stop associated HRU exhaust fans when pressure reaches -6.0" WC (FA).
- H. Power Failure Mode:
1. Exhaust fans are served by standby power.
  2. When normal power fails, all operating fans and pumps shall be commanded stopped.
  3. Upon resumption of normal power, normal exhaust control sequence shall resume. Refer to POWER FAILURE MODE, previously documented in this specification section for restart sequence of stopped pumps
- I. Monitor and Alarm:
1. Monitor, through BAS, the following points associated with exhaust air system and generate the alarms indicated:
    - a. Exhaust fan pressure differential switch – each fan (DI)
      - 1) Generate Level 2 alarm if fan status does not match fan command state within 60 seconds (FA) of change of command state.
    - b. Exhaust fan speed VFD feedback signal – each VFD (AI)
    - c. Exhaust fan VFD Fault – each VFD (DI)
      - 1) Generate Level 2 alarm.
    - d. VFD H-O-A switch – each VFD (DI)
      - 1) Generate Level 1 alarm if switch is in any position other than auto.
    - e. Exhaust plenum suction pressure – (AI)
      - 1) Generate Level 2 alarm suction pressure rises above setpoint (becomes less negative) by 0.5" WC (FA).
    - f. Exhaust plenum suction pressure low limit – (DI)
      - 1) Generate Level 1 alarm and shut down EF.
    - g. Exhaust fan outlet isolation damper position – open and closed – each fan (DI)
      - 1) Generate Level 1 alarm if damper is not proven open with open position end switch within 60 seconds (FA) of open signal or

- closed with closed position end switch within 60 seconds (FA) of closed signal.
- h. Outside air bleed fan damper position – open and closed – each fan (DI)
    - 1) Generate Level 1 alarm if damper is not proven open with open position end switch within 60 seconds (FA) of open signal or closed with closed position end switch within 60 seconds (FA) of closed signal.
  - i. Exhaust air temperature (downstream of heat recovery unit) – each HRU (AI)
    - 1) Generate Level 2 alarm if exhaust air temperature falls below 39°F (FA).
  - j. HRU face dampers position – open and closed (DI)
    - 1) Generate Level 1 alarm if damper is not proven open with open position end switch within 60 seconds (FA) of open signal or closed with closed position end switch within 60 seconds (FA) of closed signal.
  - k. HRU bypass damper position – open and closed (DI)
    - 1) Generate Level 1 alarm if damper is not proven open with open position end switch within 60 seconds (FA) of open signal or closed with closed position end switch within 60 seconds (FA) of closed signal.
  - l. Exhaust air temperature (upstream of heat recovery unit) – each HRU (AI)
  - m. Exhaust air temperature (downstream of heat recovery unit) – each HRU (AI)
    - 1) Generate Level 2 alarm if exhaust air temperature falls below 39°F (FA).
  - n. EF runtime hours – each EF (AI)
    - 1) Generate Level 2 alarm when lead EF runtime hours exceeds all other EF runtime hours by 720 hours (FA).
  - o. Filter pressure differential transmitter (AI)
    - 1) Generate Level 2 alarm when filter pressure drop exceeds setpoint of 0.8" WC (FA)

### 3.13 SMOKE/FIRE ALARM MODE - CONTROL SEQUENCE

- A. General:
  - 1. All fire-smoke dampers shall be controlled through fire alarm system.
    - a. PLC shall monitor all fire-smoke damper open and closed position switches.
- B. Smoke Detectors in Ductwork:
  - 1. Smoke detectors will be furnished, installed, and wired to Fire Alarm Control Panel (FACP) by Electrical Contractor.
  - 2. FACP shall provide fire alarm module for AHU-C1. Module shall be hardwired to AHU VFD safety circuit for AHU-C1 shut down upon activation of smoke detector.

- C. Monitor and Alarm:
  - 1. Monitor, through PLC, the following points and generate the alarms indicated:
    - a. Fire-smoke damper limit switch – open and closed (DI)
      - 1) Generate Level 1 alarm upon closed indication of any damper.

### **3.14 AIR TERMINAL DEVICE – CONTROL SEQUENCE**

- A. General:
  - 1. Air terminal devices are constant volume and do not require any controls.

### **3.15 ULTRA PURE WATER SYSTEM MONITORING AND ALARM**

- A. Ultra Pure water system is provided with packaged monitoring and alarm system (PLC). Cleanroom PLC shall communicate with Ultra Pure water system PLC via Ethernet interface for monitoring. Refer to Section 22 6720.15CR and P-series (piping) flow diagrams for additional system information and layout.
- B. Monitoring and Alarming:
  - 1. Monitor, through PLC, the following points via Ethernet communication interface and generate the alarms indicated:
    - a. Hardness and chlorine concentration of water prior to the RO.
    - b. Resistivity of water to RO, from RO, and from EDI.
    - c. Tank level
    - d. Faults from distribution pump VFDs.
    - e. Status of each distribution pump.
    - f. Discrete alarm signals from RO, EDI, UV lights, degass and other equipment to ensure safe and proper operation of those units.
    - g. Sanitization cycle parameters
    - h. Supply to Cleanroom distribution loop: Resistivity, TOC, dissolved oxygen, and pressure.
    - i. Return from Cleanroom distribution loop: Resistivity, TOC, flow, and pressure.
    - j. Ozonation levels in water
    - k. Detection of ozone in air around generator.
    - l. Refer to section 22 6720.15 for alarm parameters. Coordinate final alarm setpoints with installed system.
    - m. Communication Status (handshaking)
  - 2. Monitor, through PLC, the following hardwired points and generate the alarms indicated:
    - a. Ultra Pure water system general alarm (DI)
      - 1) Generate Level 2 alarm if general alarm is indicated.

### **3.16 CLEANROOM HUMIDIFICATION WATER SYSTEM MONITORING AND ALARM**

- A. Cleanroom humidification water system shall be controlled by the UPW PLC. Cleanroom PLC shall communicate with Ultra Pure water system PLC via Ethernet interface for monitoring. Refer to Section 22 6720.13CR and P-series (piping) flow diagrams for additional system information and layout.

- B. Monitoring and Alarming:
  - 1. Monitor, through PLC, the following points via Ethernet communication interface and generate the alarms indicated:
    - a. Tank level
    - b. Distribution loop:
      - 1) Resistivity, on supply line.
    - c. Status of distribution pump.
    - d. Refer to section 22 6720.13 for alarm parameters. Coordinate final alarm setpoints with installed system.
  - 2. Monitor, through PLC, the following hardwired points and generate the alarms indicated:
    - a. Cleanroom humidification system general alarm (DI)
      - 1) Generate Level 2 alarm if general alarm is indicated.

### 3.17 COMPRESSED DRY AIR MONITORING AND ALARM

- A. System consist of the following equipment:
  - 1. Air drier package
- B. Air drier package has its own packaged operating and safety controls. Air drier package is equipped with dry contact for alarm/trouble interface to PLC.
- C. System dew point temperature shall be monitored by PLC. Controls contractor shall provide dew point sensor.
- D. Monitoring and Alarm:
  - 1. Monitor, through BAS, the following points and generate the alarms indicated:
    - a. System dew point temperature (AI)
      - 1) Generate Level 2 alarm if dew point temperature rises above - 35°F (FA) for 10 consecutive minutes (FA).
    - b. Air Drier general alarm dry contact (DI)
      - 1) Generate Level 1 alarm if general alarm is indicated.

### 3.18 NITROGEN SYSTEM

- A. The clean room nitrogen supply system shall be monitored by the PLC for usage data gathering and trend logging. System shall be comprised of 1 main nitrogen flow meter (provided by plumbing contractor).
- B. Provide usage totalization (mass flow) as follows:
  - 1. Daily
  - 2. Monthly
  - 3. Yearly
- C. Provide totalization reset software switch on user graphic display which shall reset running total to zero. Switch shall require appropriate user authorization.
- D. Controls Contractor shall coordinate with plumbing contractor for number and locations of nitrogen meters. Controls Contractor shall be responsible for wiring all integration points from nitrogen meters to BAS.

- E. Monitoring:
  - 1. Monitor, through PLC, the following points:
    - a. Nitrogen Mass Flow – (AI)
    - b. Nitrogen Volumetric Flow – (AI)
    - c. Nitrogen Pressure – (AI)
    - d. Nitrogen Totalized Usage – (Calculated)

### **3.19 TREND LOGGING**

- A. Long term historical trending for all analog points on all systems shall be configured for commissioning efforts, installation and testing performance evaluations, and for the University's long term use.

**END OF SECTION**

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## SECTION 25 1100CR

### PROGRAMMABLE PROCESS CONTROLLERS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Refer to Section 25 0901 - Process Control System Integration.
- B. Refer to Section 25 1514 - Process Control Application Software Design.

##### 1.2 REFERENCE

- A. The Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 SUBMITTALS

- A. Provide operating instruction manuals with adequate information pertaining to following:
  - 1. System specifications.
  - 2. Electrical power requirements.
  - 3. Application considerations.
  - 4. Assembly and installation procedures.
  - 5. Power up procedures.
  - 6. Troubleshooting procedures.
  - 7. Programming procedures.
  - 8. Explanation of internal fault diagnostics.
  - 9. Shut down procedures.
  - 10. Recommended spare parts list.

#### PART 2 PRODUCTS

##### 2.1 PROCESS CONTROLLERS

- A. Controller system shall operate without fault errors due to power supply fluctuations or supply voltage range of 85% to 110% of 120 VAC nominal supply at 60 Hz  $\pm$  5%.
- B. Current or voltage transients or electromagnetic effects shall not cause spurious operation or affect normal operation of Controller. Controller shall meet or exceed requirements of ANSI/IEEE C37.90.1 surge withstand capability and NEMA ICS 1-109.6 showering arc tests. Protection circuitry shall fail to safe condition.
- C. Controller shall operate properly in temperature range of 0 to 60°C (32 to 140°F) measured inside NEMA 12 enclosure in which Controller system will be mounted. It shall be capable of operating continuously at 60°C without additional ventilation or active cooling systems.

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- D. Controller shall operate properly in humidity range of 5% to 95% (non-condensing) per NEMA/ICS 3-304.06.01(b).
- E. Controller and associated devices shall support mechanically secured plug-in modules. Assembled system shall withstand vibration testing of 5-10Hz at 0.2 inch displacement (peak to peak) and 10-200Hz at 1 g and endurance testing (sweep test) of 10-200Hz for 90 minutes per axis and dwell at resonance frequencies (10 minutes per resonance) per MIL Standard 810C and IEC 68-2-6.
- F. Where Controller uses similar modules with unlike functions, modules shall be mechanically keyed to prohibit insertion in incorrect positions or electrically interlocked to prevent operation in incorrect position.
- G. Processors:  
1. Manufacturer: Honeywell HC900.
- H. Application Program Structure:  
1. Static RAM shall store application program(s).  
2. Controller system support addressing up to 48K words, where each word is comprised of 16 data bits.  
3. Memory shall be available in 16K or 48K word segments of RAM memory. Memory capacity shall be configurable to allow for most economical match to intended application.  
4. Controller system shall support upgrading to new processor with larger memory by saving application program, replacing processor, and downloading application program to new processor without making program changes.  
5. System shall support battery backed-up memory capable of retaining stored application program and physical system data through continuous power outage for 1 month with processor powered off (processor not in operating state).  
6. Controller shall support replacing system memory back-up batteries while system is under power.  
7. System shall detect low battery condition through internal diagnostic but shall not automatically generate major fault.  
8. Controller shall support using EEPROM module(s) as backup for volatile memory up to full controller capacity.  
9. Owner shall be able to backup volatile memory, including data and program logic onto either 3 1/2 inch floppy diskettes, CD's or external hard disk.  
10. User memory in processor not used for program storage shall be allocatable from main memory for purpose of data storage. Controller system shall be capable of storing following data types:  
a. External Output Status  
b. External Input Status  
c. Timer Values  
d. Counter Values  
e. Signed Integer Numbers (16 bit)  
f. Floating Point Numbers  
g. Decimal Numbers  
h. Binary Numbers  
i. BCD Numbers  
j. Direct and Indexed addressing



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- k. Internal Processor Status Information
  - l. ASCII Character Data
  - m. ASCII String Data
  - n. Block Transfer Control Structures
  - o. Floating Point PID Control Structures
  - p. File Instruction Control Structures
  - q. Message Control Structures
11. Above listed data types shall be distinguishable to CPU by addressing format. Management of data types into memory subsections shall be automatic function of CPU operating system.
  12. Controller shall support displaying data in following formats:
    - a. Binary
    - b. Octal
    - c. Hexadecimal
    - d. Decimal
    - e. ASCII radices
  13. Function-specific data types such as PID, Message, or Processor Status shall have dedicated displays available annotating meaning of specific control bits and words within them and allowing for selective control where appropriate.
  14. Controller shall support entering select control logic more than once into application program.
  15. Number of times normally open (N.O.) or normally closed (N.C.) contact of internal output can be programmed shall be limited only by memory capacity to store these instructions.
  16. Controller application programs shall support immediate access to control function subroutine structures by address and subroutine mnemonic, such as timer accumulator value, analog value, or PID Process Variable value.
  17. Controller Software Functions:
    - a. Controller shall support minimum function menu consisting of ladder programming including:
      - 1) Basic Relay
      - 2) "Latching" or "Retentive" Relay
      - 3) Retentive Timing
      - 4) Non-retentive Timing
      - 5) Incremental Counting
    - b. Instruction set shall include number comparisons, 4 digit (integer) arithmetic operations, incremental/decremental counting, shift registers, block operations, intelligent inputs and outputs (I/O) such as thermocouple, RTD and ASCII, immediate I/O, PID, subroutine, skip and real time clock.
    - c. Manufacturer's smallest controller application programming instructions shall be subset of largest for full upward compatibility.
    - d. Controller ladder logic line shall accept 7 elements in series minimum and 4 elements in parallel minimum.
    - e. Controller shall support changing contact from normally open to normally closed, add instructions, change addresses, etc. without having to delete and reprogram entire rung, network, or software statement line.
    - f. If contacts, rungs, networks, or software statement lines are deleted from existing application program, remaining program shall be automatically repositioned to fill void.

- g. If contacts, rungs, networks, or software statement lines are inserted into existing program, original program shall be repositioned to accommodate enlarged program without user intervention.
- h. Controller shall support inserting contacts, rungs, networks, or software statement lines anywhere in program, even between existing rungs, insofar as there is sufficient memory to accommodate additions.
- i. Single program command or function shall delete individual rung, network, or software statement line from memory. It shall not be necessary to delete rung, network, or software statement line element by element.
- j. Controller shall support moving entire rung, network, or software statement line into edit buffer where individual parameters may be easily altered.
- k. Controller shall include internal clock/calendar feature. Access to time and date shall be from programming terminal, user program, or message generation.
- l. Controller shall include internal clock/calendar feature. Access to time and date shall be from programming terminal, user program, or message generation.
- m. Latch functions shall be internal and programmable.
- n. Controller shall support addressing software timers and software counters in combination and quantity up to limit of available memory. System shall permit programming timers in "ON" or "OFF" delay modes. Timer programming shall also support interrupting timing without resetting timers. Counters shall be programmable using up-increment and down-increment.
- o. Timer instructions have included selectable time bases in increments of 1.0 second and 10 milliseconds. Timing range of each timer shall be from 0 to > 32,000 increments. Controller shall to programming each timer's preset value and accumulation word/register separately.
- p. Controller shall support data storage in following formats:
  - 1) Signed Integer Numbers ranging from -32,768 to +32,767.
  - 2) Floating Point Numbers consisting of 8 significant digits. For numbers larger than 8 digits, CPU shall convert number into exponential form with range of plus/minus 1.175494 E-38 to plus/minus 3.402824 E +38.
  - 3) Decimal Numbers ranging from 0 to 9,999.
- q. Controller shall support integer and floating point signed math functions consisting of addition, subtraction, multiplication, division, and square root.
- r. When using modules where multiple channels are terminated on 1 module such as analog, it shall be possible to transfer current status of each channel to CPU upon execution of 1 program instruction. This instruction shall be bidirectional to include data transfer from CPU to module or from module to CPU.

- s. Controller shall support instructions which group contiguous 16 bit data words into file. System shall address up to 1000 files/data arrays with up to 1000 words/registers per file. File manipulation instructions such as high-speed "file copy" and "file fill", "file to file" move, "element to file" move, "file to element" move, and "first in-first out" shall be supported by system.
- t. Controller shall support mathematical, logical, and comparison operations:
  - 1) Addition
  - 2) Subtraction
  - 3) Multiplication
  - 4) Division
  - 5) Logical OR
  - 6) Logical AND
  - 7) Logical Exclusive Or (XOR)
  - 8) Less Than/Less Than or Equal
  - 9) Greater Than/Greater Than or Equal
  - 10) Equal
- u. Instructions shall execute on either single word/register or files / data arrays.
- v. Controller shall support instructions, which construct asynchronous and synchronous 16 bit word/register shift functions.
- w. Controller shall support automatic management of data types. For example, if word/register value stored in Integer format is transferred into Floating Point format, controller shall convert integer value into floating point prior to executing transfer.
- x. In applications requiring repeatable logic rungs, controller shall support placing those rungs in subroutine section. Controller shall include instructions, which call subroutine and return to main program. Controller shall support programming several subroutines and define each subroutine by unique program file designator (rung/network number or label).
- y. Controller shall support jump (jump to subroutine) instruction which allows program to "skip" over portions of application program to portion marked by matching label instruction or marked by rung/network number.
- z. Controller shall support nesting of subroutines up to 5 levels deep.
- aa. Controller shall support passing selected values (parameters) to subroutine before executing subroutine, allowing subroutine to perform mathematical or logical operations on data and return results to main program upon completion.
- bb. Controller shall support programming fault recovery routines. If major fault occurs, fault recovery routine shall execute. After fault recovery routine, controller shall determine if fault has been eliminated. Application program execution resumes if fault is eliminated. If fault still exists, system shall either shut down or enter "Hold" state waiting for operator reset.
- cc. Controller shall support programmable interrupt routine, which may be executed regularly. Interrupt routine execution interval shall be user-specified in range of 1 millisecond to 30 seconds.

- dd. Controller shall support programming control logic using symbols from global database.
- ee. Controller shall support indexed and indirect addressing of inputs and outputs, along with data table words/registers.
- ff. System shall support both bit and word/register level diagnostic instructions.
- gg. Controller shall support "always false" instruction to temporarily inhibit execution of application program section to facilitate debugging.
- hh. Controller shall support Master Control Reset (Relay) type functionality to selectively disable sections of application program.
- ii. Processor instruction set shall support variety of ASCII string manipulation instructions such as search, concatenation, extraction, compare, and to/from integer conversion.
- jj. Controller shall support programmable interrupt routine(s), which shall be executed based upon input condition of 1 of 16 discrete hardware inputs in controller chassis. Routine shall be executed within two milliseconds of detection of input signal.
- kk. Controller shall support configuration of up to 16 main application programs, which consist of custom control applications constructed of relay ladder logic, sequential function chart, or structured text operations. These application programs shall share common data table. Each application program may be individually inhibited.
- ll. Controller shall support configurable execution order of main application programs.
- mm. Controller shall support PID Instruction to incorporate closed loop non-linear feedback control systems. "Proportional", "integral", and "derivative" elements shall be accessible to user in order to tune closed loop system. This instruction shall be implemented using floating-point math.
- nn. Controller shall support "one shot" output instructions which may be triggered on either low-to-high (rising) or high-to-low (falling) signal programming.
- oo. Controller shall support trigonometric instructions including Sine, Cosine, Tangent, Inverse Sine, Inverse Cosine, and Inverse Tangent. These instructions shall be implemented using floating-point math.
- pp. Controller shall support following floating-point instructions:
  - 1) Log 10
  - 2) Natural Log
  - 3) Exponential
- qq. Controller shall support complete complex, combined calculations in single instruction, such as flow totalizing or equations of format  $((A+(B-C)*D))|E$ .
- rr. Controller shall support following file function instructions:
  - 1) Sort
  - 2) Average
  - 3) Square Root
  - 4) Standard Deviation
- ss. Controller shall support FOR...NEXT loop constructions.

- tt. Controller shall support application program functions providing ASCII port control such as read, write, handshake line control, buffer examination, etc.
- 18. Controller Programming Languages:
  - a. Controller shall support following application configuration language listed under programming software herein.
- 19. Sequential Function Charts:
  - a. Programming system shall support editing, building, and executing logically-constructed function blocks (steps). These function blocks shall be executed either selectively, based upon application logic (transitions), or simultaneously. System shall support "zooming" in on given step file to allow user to quickly diagnose application program.
  - b. Overall effect of function chart programming shall be to provide more efficient flow of user's application program.
- 20. Controller Scan Performance:
  - a. Controller shall support multiple independent, asynchronous concurrent scans designated for following:
    - 1) Processing of input and output information,
    - 2) Application program execution,
    - 3) Background processing of other processor tasks.
  - b. Input and output devices located in same backplane (local I/O) as CPU shall be scanned synchronously in less than 2 milliseconds. Processing of typical application program shall not exceed 10 milliseconds for 1024 instructions with maximum overhead of 10 milliseconds concurrent with I/O update time.
  - c. Controller Power Supply Requirements:
    - 1) Controller power supply shall include diagnostic indicators easily viewed by user. Indicators shall provide users with controller's DC bus power status.
    - 2) Controller shall support disabling power to CPU via power disconnect switch easily accessible by user.
  - d. System shall support interruption or operation of CPU and I/O cards/modules until controller system voltages are within specifications at time of controller power-up.
  - e. Power supply shall be fuse protected.
- 21. Controller Communications:
  - a. Controller shall support communication with peer level controller's, master controllers, or computers via RS-485 interface or Ethernet. These data ports shall be separate from any required by local hand-held or built-in data access panel or programming devices.
  - b. Application program saving/downloading to remote device shall default to include entire application program memory.
  - c. Selector switch shall be furnished to allow application programming or editing only in program or program/run position. Selector switch shall be of key lock type with key removable in any position. Two keys shall be furnished.

22. Processor Diagnostics:
- a. Controller manufacturer shall provide self-diagnostic routines to ensure proper operation of entire system (Controller and I/O). Upon fault detection, output devices capable of being selected to be de-energized or held in last state (necessary in analog control).
  - b. Status indicating lights on controller face shall verify normal operation. Typical Indications include: AC and DC power, processor cycling, parity error, memory fault, memory support battery low, processor fault, power supply fault, transient suppressor circuitry fault and I/O fault.
  - c. Error Detection and Fault Isolation (EDFI) shall be integral and shall localize faults to lowest modular (plug-in) level.
  - d. Controller shall include local fault annunciation via lights, and program accessible status bits.
  - e. Removal of any I/O module shall not shut down entire Controller system.
  - f. Controller shall support executing multiple diagnostic levels as standard instruction: Level 1, Level 2, or Level 3 diagnostics.
  - g. Level 1 diagnostics use control logic for control with control logic fault detection logic setting fault bits that are monitored by instruction for diagnostic message generation only.
  - h. Level 2 diagnostics use control logic to control outputs, but instruction monitors inputs and conditions to detect faults and generate diagnostic message.
  - i. Level 3 diagnostics instruction controls outputs, monitors inputs for state control, performs diagnostic detection, and generates diagnostic message.
  - j. Diagnostic logic shall always be current and shall be automatically updated whenever user's control program is changed.
  - k. Diagnostic messages shall be assembled without operator intervention using text from controller documentation such as: address comments, symbols, step names, instruction comments, processor name, etc. These fragments will be user configurable in terms of size and usage. These automatic messages shall not require pre-storage by user as they are dynamically assembled and generated.
  - l. Extended editing features shall provide:
    - 1) I/O monitor - dynamic view of configured I/O
    - 2) I/O histogram - histogram of I/O
    - 3) Step histogram - histogram of step
    - 4) Extended status - status of diagnostic instruction
    - 5) Configuration library function - save configuration to file
  - m. Controller operator interface shall provide:
    - 1) Fault log for stations on network
    - 2) Operator guidance facilities
    - 3) Maintenance diary
    - 4) Message queue
    - 5) System menu
    - 6) Machine/process-specific graphics (mouse graphics)
    - 7) Production information such as cycle times
    - 8) Ability to "zoom" in on specific station

23. Quality Requirements:
  - a. Controller shall withstand conducted susceptibility tests as outlined in NEMA ICS 2-230, NEMA ICS 3-304-42, section 2 of IEEE 4721974 and ANSI C37.90A-1974.
  - b. Completed controller units shall be subjected to a burn-in test of 60°C for 96 hours minimum.

## 2.2 PROGRAMMING PORTS/FUNCTIONS

- A. Programming device interface shall be provided with each controller, if not integral to CPU.
- B. Controller shall allow programs to be entered through optional devices such as programming computer over Ethernet
- C. Controller system support programming and testing with power disabled to output loads.

## 2.3 EXPANDABILITY

- A. Complete Controller system shall be capable of minimum of 100% expansion of processors and I/O in future by adding incremental hardware and application software to existing system architecture.
- B. Power Failure Requirements:
  1. Controller shall include non-volatile memory to prevent loss of application programming upon normal or abnormal power loss. Controller shall automatically resume control algorithms/sequencing upon restoration of power.
  2. Hardware, network, and operating system software shall perform orderly recovery upon system re-start. Operations required to provide fully linked and communicating system shall be done with minimal operator intervention.
  3. Controller shall support retaining status or accumulated values in its memory associated with arithmetic operations, data files, latching states and timing functions in event of power failure.
  4. Controller shall not increment/decrement counters nor otherwise cause false movement or change in retained data when power is turned on or off.
- C. Batteries:
  1. Where battery is required to retain Controller memory, internal contact or output, operating as part of CPU and indicating light, shall be available to indicate that memory support battery is low.
  2. Battery shall be replaceable without loss of memory (with power on) when battery is required to retain controller memory. Battery shall be readily available, long life (90 day minimum) type.
  3. Low battery indicator should function minimum of 7 days prior to final battery failure.

## 2.4 CONTROLLER NETWORKS

- A. I/O Hardware
1. I/O modules shall be same manufacturer as processor.
  2. I/O modules shall include permanent nameplate listing manufacturer's name, module model number, serial number and voltage and current ratings.
  3. I/O modules shall include status indicating light for each I/O point. Input indicating light shall be connected on field side, prior to conversion to Controller level voltage. Output indicating light shall be connected across output terminals (field side) and shall function normally without load external to Controller.
  4. I/O modules shall support quick disconnect means for fast and easy card removal without disconnecting field wiring.
  5. Inputs and outputs shall be optically isolated from controller logic circuitry and from other inputs and outputs.
  6. I/O's shall be rated either 120 VAC, 50/60 Hz or 24 VDC required on drawings or as listed. Sink Inputs and Source Outputs shall be used for 24 VDC; other types are not acceptable. Analog to digital (A to D) inputs and outputs (D to A) shall be rated to comply with system requirements.
  7. I/O's should be provided with integral power supply to provide I/O logic and special function reference voltages.
  8. 120 VAC 50/60 Hz inputs shall not turn on and shall turn off with 2.2 mA rms or less of current and shall conduct at least 6 mA rms in on state.
  9. Each AC output shall be rated not less than 2 A continuous and shall be protected by individual overload device.
  10. 24 VDC I/O Modules:
    - a. Only SINK Inputs and SOURCE Outputs shall be used. (This requirement is to prevent energization of outputs or inputs resulting from accidental grounds on system powered from negative-grounded 24 VDC supply, as can occur with Source Inputs and Sink Outputs).
    - b. Visual fault indication shall be provided. Fuses shall be replaceable without soldering and should be accessible without need to remove covers attached with threaded fasteners.
    - c. I/O modules shall not be damaged by removal from, or insertion into, Controller when system power is on and field power is off.
    - d. Sufficient space adjacent to each I/O terminal shall be provided to list at least six alphanumeric characters. This space shall not be on I/O module.
    - e. Following I/O types shall be available:
      - 1) AC/DC (120V)
      - 2) DC (12-24V)
      - 3) AC/DC (240V)
      - 4) DC (24-48V)
      - 5) Contact (reed relay) Output
      - 6) Isolated Input
      - 7) Analog (0-5V, 0-10V, -10V to +10V)
      - 8) Analog (4-20ma)
      - 9) BCD
      - 10) High Speed Counter/Accumulator
      - 11) Thermocouple
      - 12) RTD



- 13) Configurable Flow Meter (Pulse Input)
  - 14) Gray Code Encoder
  - 15) ASCII Module
  - 16) Basic Programming Language
  - 17) Real Time Clock
- f. Analog I/O cards/modules shall have 12 bit resolution as minimum.

## 2.5 REMOTE I/O REQUIREMENTS

- A. Controller shall have ability to communicate with remote I/O rack configured with multiple I/O chassis.
- B. Each logical rack of remote I/O can be configured with one or more chassis containing 2, 4, 6, or 8 I/O groups. I/O status and control information indicates rack faults, reset commands, and inhibit commands at chassis level. Both rack status and control information allowing for indications of rack faults and control including I/O rack reset and inhibit control bits shall be available to quarter rack level.
- C. Controller shall support multiple remote I/O links without requiring additional hardware.
- D. Spare I/O:
1. Not less than 20 percent spare inputs and 20 percent spare outputs of each type and voltage used, totaling not less than ten of each type, shall be furnished and wired to terminal strips for future in-plant use.
  2. Not less than 20 percent spare inputs and 20 percent spare outputs of each type and voltage used, totaling not less than ten of each type, shall be furnished and wired to terminal strips for future in-plant use. Points on spare I/O modules shall be wired to terminal strips, even if they are not directly part of 20 percent spares requirement. Wired spare modules shall have field power wiring connected. Additionally, enclosure at each I/O location shall be sized to allow expansion of I/O point capacity and power supplies to minimum of 20 percent above system's initial requirements.
- E. Controller Chassis:
1. Controller Chassis shall be designed to match with either I/O or controller card/module.
  2. Controller - I/O chassis shall accept all types of I/O and CPU processors required. Chassis shall provide communication between CPU or I/O processor and I/O. Rack shall provide processor and I/O card/module power.
  3. Chassis shall support keyable chassis slots for processor, I/O, and controller accessory modules.
  4. Chassis design shall prohibit upside down insertion of modules as well as safeguard against insertion of module into wrong slot.
  5. Controller shall provide means for mounting chassis in standard cabinet or 19 inch rack.
- F. Cable, Connectors, and Interconnect Devices:
1. Cable, connectors, and interconnect devices shall be same manufacturer as controller processor unless otherwise noted.

2. Cables (with associated plugs, connectors and receptacles) requiring user field installation, shall be designed for commercial use to withstand industrial environment.

## 2.6 PROGRAMMING AND DATA ACCESS

- A. Programming devices shall provide indication of logic state of each element comprising rung or network of logic.
- B. Interlocking within programming device shall not allow more than 1 programming device to communicate with specific controller at 1 time for program changes.
- C. Programming device interface shall be provided with each controller, if not integral to processor.
- D. Compatible computer interface or PCIMIA interface shall be provided for each controller system, if programming software does not use COM1 as communication port.
- E. Controller systems, using remote I/O, shall permit monitoring and programming from I/O locations with main programming device.
- F. Controller manufacturer shall have available documentation system that will print application program with alphanumeric descriptions for inputs, outputs, data, counters, and timers. It shall also display I/O utilization, and cross reference information of utilized I/O and data to their corresponding logic rung number. System shall also have capability to merge detailed user generated text documentation where required by user in hard copy listing. Modifications to user's data base shall be made through line editor as minimum.
- G. Main Programming Device:
  1. Main programming device shall display elements, including pre-set and accumulated values, comprising rung or network of logic simultaneously and should provide capability of displaying system graphics. Main programming device shall lend itself to be utilized as universal programmer. It should be directly compatible with standard off shelf PC.
  2. Main programming device shall provide means of program entry, editing, searching by function and address, timer and counter presetting, and monitoring, and should support password codes and "histogramming".
  3. Main programming device shall incorporate magnetic disc recorder for loading, recording, programming and verifying PC programs both on and off line.
  4. Main programming device shall indicate during programming when output or register address has been previously used.
  5. Main programming device shall be capable of connecting to programmable controller in any mode.
  6. Controller shall permit loading, recording, and verifying Controller programs with main programming device specified above.

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7. Computer interface and data handling capability shall be available and programmable with main programming device. Following features shall be included:
    - a. Computer Interface:
      - 1) Monitor and control of words or bits in I/O data and data table of Controller memory.
      - 2) Load program into Controller memory.
      - 3) Produce list of total content in Controller memory.
      - 4) Conform to Manufacturing Automation Protocol (M.A.P.).
    - b. Data Handling:
      - 1) Provide file manipulation.
      - 2) Provide report generation.
    - c. Controller systems, using remote I/O, shall permit monitoring and programming from I/O locations with main programming device. Interlocking shall not allow more than one programming device to communicate with Controller CPU at one time for program changes.
    - d. Controller system shall be capable of programming and testing with power disabled to output loads.
  8. State Control:
    - a. Control system shall support system of standard hardware and software, which integrates both control and diagnostic program by utilizing a user-friendly, fill-in-the-blank template format. System shall be comprised of integrated architecture that applies various products such as Controllers, computers, motion control, vision, and fastening equipment.
  9. Machine, Process and Program Diagnostic and Communications Capabilities:
    - a. Controllers should be capable of supporting machine/equipment diagnostic systems. Diagnostic system shall:
      - 1) Be self-teaching via menu driven programming (guide or refresher style).
      - 2) Not increase processor scan time more than 20%.
      - 3) Be adaptable to synchronous, semi-synchronous, and non-synchronous processes.
      - 4) Identify faults to level of individual inputs and outputs.
    - b. Acceptability of diagnostic capabilities will be judged on adherence to above diagnostic system features and following Controller diagnostic program criteria:
      - 1) Minimal programming effort.
      - 2) Provision for selecting timing deviation allowances.
      - 3) Remote I/O structure.
      - 4) Distributed system architectures.
      - 5) Provision of semi-automatic updating of diagnostic program to account for changes in machine/equipment sequencing and timing.
    - c. Fault definition shall be available to system loader/terminal, laterally via peer-to-peer communications, and vertically within hierarchical communications network.
    - d. Data comparison for diagnostics shall be capable at bit, word and block/rung level.

10. Programming Software:
- a. Programming software shall display elements, including pre-set and accumulated values, comprising rung or network of logic simultaneously, shall provide capability of displaying system graphics and shall indicate contact or output status by intensification of contact or output on screen. Each element's status shall be shown independently, regardless of circuit configuration.
  - b. Programming software shall lend itself to be utilized as universal programmer and shall be directly compatible with standard off shelf IBM compatible personal computer.
  - c. Programming software shall provide means of program entry, editing, searching by function and address, timer and counter presetting, and monitoring.
  - d. Programming software shall support password codes and "histogramming".
  - e. Programming software shall incorporate magnetic diskette recorder for loading, recording, programming, and verifying controller programs both on and off line.
  - f. Programming software shall indicate during programming when output or register address has been previously used.
  - g. Programming software shall support following languages:
    - 1) Ladder Logic
    - 2) Structured Text
    - 3) Boolean
    - 4) Sequential Function Chart
  - h. Programming Software shall fully support each function/module of IEC-1131 (latest version).
  - i. Programming Software Vendor shall fully support each function/module of IEC-1131 (latest version) or demonstrate plan to become fully IEC-1131 Compliant. Application programs written with current software shall be fully upward compatible with IEC-1131 version or vendor shall provide automatic mechanism to convert application programs written with current programming software version to IEC-1131 Compliant version.
  - j. Deleting all controller software (rungs, networks, or software statement lines) shall require issuing 2 part or 2 step command in order to delete all application software from memory.
  - k. Software shall support adding, removing, or modifying ladder logic rungs during program execution. When changes to ladder logic are made or new logic rungs are added, system shall support testing edits of such rungs before removing prior logic rung/network.
  - l. Software shall support manually setting (force) either on or off hardwired input or output points from programming system or controller chassis front panel. Removal of these forced I/O points shall be by individual point or complete removal of each force in effect by selected keystrokes. Programming system shall display forced I/O points.
  - m. Programming system shall display instructions in program format with appropriate mnemonics to define data entered by user. System shall support "HELP" instruction, which will display list of instructions and data and keystrokes required to enter instruction into system memory when called by user.

- n. Programming system shall support displaying data contained in system memory. This monitoring feature shall be provided for input/output status, timer/counter data, files, and system status. Ladder logic rungs shall be displayed on CRT with rung numbers in sequential order. However, user shall have option of selecting and displaying logic rungs non-contiguously.
- o. Programming System shall support displaying Sequential Function Charts.
- p. Programming System shall support displaying Structured Text.
- q. Programming system shall support entering rung comments above controller ladder logic rungs. These comments may be entered at same time ladder logic is entered.
- r. Programming system shall support entering address comments and symbols. These entities may be entered at same time ladder logic is entered.
- s. Programming software shall support printing application program(s) with alphanumeric descriptions for inputs, outputs, data, counters, and timers. System shall also compile and print I/O utilization, utilized I/O cross reference information, and data cross reference information to corresponding logic rung number.
- t. System shall also merge detailed user generated text documentation in hard copy listing. Modifications to this user's text documentation shall be made through line editor such as DOS Edit or word processor saved in ASCII format.
- u. Systems using remote I/O shall permit monitoring and programming from each I/O location with programming device. Interlocking shall not allow more than 1 programming device to communicate with Controller programmer at 1 time.
- v. Programming software shall support displaying subroutine and main program structures clearly defining each.
- w. Programming software shall have configuration screen with which main application program orders are configured.

## **PART 3 EXECUTION**

### **3.1 PROCESS CONTROLLERS**

- A. Spare Memory Requirement:
  - 1. Provide controller excess memory to support spare I/O capacity plus 40 percent above system's initial requirements. Excess memory requirements shall be based on logic complexity equal to that already programmed into Controller; multiply ladder logic file size (in kilobytes) by 1.4 and provide excess memory accordingly.
- B. Mounting Requirements:
  - 1. Provide control panel enclosure mounted controller chassis.
- C. Controller Chassis:
  - 1. Provide keyable controller chassis and key to accept module as required to prevent incorrect module insertion.

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- D. I/O Hardware:
1. Provide I/O hardware as required to meet requirements of system as defined on P&IDs and control sequences. I/O shall be of same manufacturer as processor. Select appropriate hardware to meet field device requirement with non-thermocouple/RTD analog inputs and analog outputs being 4-20 mA, 24 VDC.
  2. Provide 3-wire RTD input card(s) for field RTD's.
  3. Provide separate thermocouple input card(s)/modules(s) for each thermocouple type (e.g. E, J, K, T, etc.).
  4. Provide relay contact outputs to field systems, which have internal power supplies.
  5. Coordinate with control panel fabricator to ensure proper power supplies and terminal strips are provided for selected I/O.
  6. Controller I/O shall not be located in slot 0 (first slot) of chassis.
  7. Contractor is responsible for cost impacts resulting in changes from listed hardware.
- E. Remote I/O Connection:
1. Controller - I/O Chassis
  2. Provide controller I/O chassis for controller and I/O as shown on System Architecture.
  3. Provide remote I/O interface module for each rack without controller processor.
  4. Provide Remote I/O interface module in local rack where field devices are to directly communicate with controller via remote I/O.
- F. Field Devices Communicating Via Remote I/O:
1. Provide data communication between VFD's and controller via remote I/O.
- G. Remote I/O Installation:
1. Locate remote I/O drops where shown on drawings.
  2. Distribute remote I/O drops to minimize field I/O to controller distances. Locate remote I/O on columns, walls, or equipment so that they are well protected from normal plant/area activity. Do not locate remote I/O where it extends into traffic flows (human or otherwise).
  3. Provide control panel(s) with NEMA rating as required by area for remote I/O chassis or "Flex -I/O". Refer to Section 25 1316 - Control Panels for Control Panel Specifications.
- H. Connectors, Interface Devices and other Miscellaneous Components:
1. Provide connectors, interfaces devices, and other miscellaneous components to interconnect controller components and provide full functionality of each device and integrated control system.
- I. Controller Installation:
1. Insert controller processor, remote I/O, or power supply into first logical rack slot (0 or 1 as applicable).
- J. Power Supply:
1. Size power supply for 100% spare capacity with 0 diversity from initial installation.

- K. Programming Software:
  - 1. Provide 1 programming software license(s) to communicate with each type of controller or controller network.
  
- L. Application Software Design:
  - 1. Provide application programming in accordance with control sequences as shown on drawings and in accordance with Section 25 1514 - Process Control Application Software Design.
  - 2. Provide application programming in accordance with control sequences as detailed in Section 25 0993 - Control Sequences and in accordance with Section 25 1514 - Process Controller Application Software Design.

**END OF SECTION**





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## SECTION 25 1316CR

### CONTROL PANELS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Refer to Section 25 0553CR - Instrumentation Tagging
- B. Refer to Section 25 3001CR - General Instrumentation Requirements
- C. Refer to Section 25 3526CR - Pneumatic Piping Tubing

##### 1.2 REFERENCE

- A. The Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 DESCRIPTION

- A. This Section, in conjunction with above, mentioned Sections, defines requirements for instrument control panels in this Contract.

##### 1.4 DEFINITIONS

- A. Enclosure types shall be:
  - 1. NEMA 1 General Purpose - for use in dry indoor locations.
  - 2. NEMA 3R Weatherproof - for use in wet indoor locations and outdoor installations without controllers.
  - 3. NEMA 4 Watertight - for use in locations where subjected to direct water spray and outdoors.
  - 4. NEMA 4X Watertight Corrosion Resistant - for use in corrosive atmospheres and NEMA 4 applications.
  - 5. NEMA 7/9 Hazardous or Explosive Atmospheres - for use in explosive rated areas.
  - 6. NEMA 12 Industrial use - dust-tight and drip-tight for use indoors where subjected to fibers, flying lint, dust and dirt, light splashing, seepage, dripping and external condensation of non-corrosive liquids.

##### 1.5 SUBMITTALS

- A. Refer to Section 25 0901CR – Process Control System Integration.

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## **PART 2 PRODUCTS**

### **2.1 ENCLOSURES**

- A. Manufacturer: Hoffman, Hammond Manufacturing or approved equal.
- B. Enclosure(s) shall be fabricated of 12 gauge minimum thickness rolled steel for floor mounted panels and minimum 14 gauge minimum thickness rolled steel for wall mounted panels unless otherwise noted and shall be constructed to NEMA 4 Standards.
- C. Sub-panel(s) shall be 12-gauge minimum thickness rolled steel unless otherwise noted.
- D. Framing and Bracing:
  - 1. Enclosure framing shall be of 14 gauge minimum thickness rolled steel.
  - 2. Enclosure face bracing and straightening shall be 1-1/4" x 1/4" rolled steel bar or 1" x 1" x 1/8" rolled steel bar.
  - 3. No framing or bracing shall extend more than 1 inch into top surface area.
  - 4. If enclosures are custom fabricated, side panels, top panels, and doors shall not deflect more than 1/32".
- E. Doors:
  - 1. Enclosures shall have pan type doors with full gaskets. Doors shall have flanges.
  - 2. Each door shall be attached to enclosure with continuous piano-type hinge and shall have three-point latch with lock.
  - 3. To prevent dirt and water from falling into enclosure when doors or access panels are opened, there shall be rolled lip around each door or access panel and around sides of enclosure openings.
  - 4. Print pockets shall be provided on enclosure doors.
  - 5. Two identical master keys shall be provided which will operate locks of all enclosures in this Contract.
  - 6. Each access panel shall be pan type with full gaskets.
- F. PC Folding Shelf:
  - 1. Manufacturer: Hoffman A-CSHELF18 or approved alternate.
  - 2. Folding shelf shall be included on at least one door per enclosure bay on floor mounted panel bays, which contain controllers (Programmable Logic Controllers or Loop controllers).
- G. Miscellaneous Steel Components:
  - 1. Miscellaneous steel components, e.g. standoffs, shall be 12 gauge minimum thickness rolled steel.

### **2.2 NETWORK CABINETS, RACKS, FRAMES AND ENCLOSURES**

- A. Manufacturers: Rittal, CPI, Ortronics, Wrightline, Panduit, Damac or Simon.
- B. Equipment racks shall be:
  - 1. Constructed of painted aluminum
  - 2. Supplied with ground bar (19" wide by 1" high) and #6 AWG ground lugs
  - 3. Supplied with minimum of 12 releasable cable support ties (e.g. "hook and loop")

4. Supplied with spare screws (minimum of 50)
  5. Configured with Channel uprights spaced to accommodate industry standard 19" mounting
- C. Free Standing Equipment Rack shall comply with general requirements above and shall:
1. Be 84" in height
    - a. Have minimum of 45 usable rack mounting units (RU)
    - b. Be self-supporting
  2. Have Minimum base footprint of 15" x 20".
  3. Be double-sided drilled and tapped to accept 12-24 screws
    - a. Uprights shall be drilled on back to accept cable brackets, clamps, power strip(s).
    - b. Hole pattern on rack front and back shall be per EIA/TIA specifications (5/8" - 5/8" - 1/2").

### 2.3 EQUIPMENT

- A. Power Supplies:
1. Manufacturer: Acopian, Sola, Lambda (Invensys) or approved alternate.
  2. Regulated type Power Supplies shall be used for analog control loop power.
    - a. Input Power: 120 VAC 60 Hz
    - b. Output Power: 24 VDC error < ±1.5%
    - c. Regulation:
      - 1) Line: ± 0.07%
      - 2) Load: ± 0.15%
    - d. Operating Temperature: 0 - 50°C
- B. Signal Conditioners:
1. Manufacturer and type: Siemens, Action Instruments or approved alternate.
  2. Signal isolators shall be DC input field configurable type and shall be surface or DIN rail mounted and use 120 VAC 60 Hz input power.
- C. Current/Power Conditioners:
1. Manufacturer: Sola.
  2. Current conditioners shall produce regulated true sine waveform.
    - a. Input Voltage: 120 VAC 60 Hz nominal ± 3% input variation
    - b. Output Voltage: 120 VAC 60 Hz error < ± 1%
    - c. Noise Rejection:
      - 1) > 30dB common mode
      - 2) > 30dB transverse mode
    - d. Efficiency: > 85% at full load
    - e. Operating temperature: 32 to 120°F
  3. Current conditioners shall produce 120 VAC 60 Hz true sine waveform with 120 VAC 60 Hz input.
- D. Wireway:
1. Manufacturers: Panduit, Tyton, or approved alternate.
  2. Wireway shall be grey slotted plastic trough with snap-on covers.

- E. Modular Patch Panels:
1. Manufacturers: Simon, Ortronics, Panduit
  2. Panels shall:
    - a. Consist of Modular-to-IDC connector system
    - b. Be rack-mountable in standard EIA 19" equipment racks
    - c. Be 2 RUs high
    - d. Accommodate 48-port modular jacks in two rows of 24-ports
    - e. Be designed to terminate 4-pair, 100-Ohm [UTP] [F/UTP] cables
    - f. Have ability to terminate 22-26 AWG plastic insulated, solid and stranded copper conductors.
    - g. Be designed to maintain cable's pair twists as closely as possible to point of mechanical termination.
    - h. Have cable support and strain relief devices to secure cables at IDC connector.
    - i. Panel and cable support hardware shall ensure that cabling minimum bend radius requirements are satisfied.
    - j. Have port identification numbers on both front and rear of panel.
    - k. Have color-coded pair designations on rear of panel.
  3. Modular Jacks in Panel shall:
    - a. Be non-keyed, 8 position, 8-conductor (8P8C)
  4. Panels shall meet or exceed TIA Category 6 performance criteria.
- F. POWER STRIP/SURGE SUPPRESSOR
1. Manufacturers: CPI, Hubbell, Ortronics, Wiremold, Pulizzi Engineering
  2. Power Strip/Surge Suppressor shall:
    - a. Be rack mountable in 19" equipment racks
    - b. Provide Transient suppression to 13,000 A
      - 1) Protection shall be in 3 modes (hot-neutral, hot-ground and neutral-ground)
    - c. Provide High Frequency Noise Suppression:
      - 1) >20-dB @ 50-kHz
      - 2) >40-dB @ 150-kHz
      - 3) >80-dB @ 1-MHZ
      - 4) >30-dB @ 6 to 1000 MHZ
    - d. Provide minimum of 320 Joules of AC energy absorption
    - e. Be equipped with minimum 12 ft power cord
    - f. Be rated for 20A load at 120V

## PART 3 EXECUTION

### 3.1 PANEL LAYOUT

- A. Exterior Operator Interface Layout:
1. Unless otherwise shown, arrange pilot lights, switches, and push buttons 3" on center horizontally and vertically. Locate pilot lights between 4'-0" and 6'-6" above finished floor maximum. Locate switches and push buttons between 4'-0" and 5'-6" above finished floor.

2. Space panel indicators, controller face plates, recorders, and Graphical User Interface (GUI)/Man-Machine Interface (MMI) displays with 3" between devices, pilot lights, switches, and push buttons.
- B. Back Panel Layout:
1. Locate controllers without face plates in lower half of back-panel first and upper half second.
  2. Locate terminal strips either horizontally in upper half of back panel or vertically. Do not locate terminal strips below 2'-0" or above 6'-6" above finished floor.
  3. Separate 24 VDC and 120 VAC terminal strips, wire, cable, and devices by 6" minimum space.
  4. Run wiring from terminal strips to panel mounted devices and field wiring in separate wireways. Run 24 VDC in separate wireway from 120 VAC wireway.
  5. Provide terminal strips for total controller I/O count plus 20% spare capacity with analog and discrete spare capacity calculated separately.
  6. Enclose wire and cable in wireways. This does not apply to wire exiting wireways to terminal strips or panel mounted devices.
  7. Space wireways and terminal strips 3" apart.
  8. Size raceway to maximum fill of 40% per NEC.
  9. Space controllers according to manufacturer's requirements with 3" minimum between controllers and other devices on back panel and 6" between controller front and door mounted devices. Ensure adequate space is allowed for device heat dissipation.
  10. Control enclosure interior temperature to 80°F maximum. Provide fan systems or air conditioning systems as required to meet requirement. Size cooling devices including heat gain of internal controllers and devices as well as external environmental heat loads.
  11. Mount cooling devices, receptacles and incandescent lights (if applicable) on enclosure sides.
  12. Do not place controller or control devices on enclosure sides.

### 3.2 SPARE CAPACITY

- A. Provide 20% minimum spare capacity of panel space, PLC chassis space, wireway space, and terminal blocks to allow for future expansion by adding I/O cards and associated cabling.

### 3.3 PANEL CONSTRUCTION

- A. Continuously weld enclosure seams so that there are no leaks. Grind welds smooth and clean. Remove slag, scale, and spatter.
- B. Control Panels shall have square corners. Round exterior corners and grind smooth to nominal 1/16" radius to provide neat appearance. Grind interior edges smooth to prevent damage to wiring, cables, and tubing.

- C. Provide panel and door stiffeners, as well as internal bracing, to ensure adequate rigidity and support for door mounted equipment so that door does not deflect 1/32" when closed and latched and 1" while open. Bracing shall be on panel's interior. Continuously weld bracing, where accessible, on both sides and at joints with other bracing members. No evidence of fastening shall appear on panel exterior.
- D. Provide internal bracing for lifting lugs around bolt holes suitable for supporting panels.
- E. Lifting Lugs:
  - 1. Provide one 3/4" shank removable lifting lug for floor mounted panels at each enclosure end unless otherwise noted for panels < 18" deep and provide one 3/4" shank removable lifting lug at each corner for total of 2 at each end for floor mounted panels > 18" deep. Lifting lug quantities shall be increased if panel weight so requires.
  - 2. Provide two 3/4" shank removable lifting lugs for wall mounted control panels unless otherwise noted.

### 3.4 SURFACE FINISHING

- A. Surface Preparation:
  - 1. Scuff Sand surfaces to be painted using, 250-300 grit sandpaper.
  - 2. On surfaces to be painted, remove grease, oil or other solvent soluble contaminants from panel by solvent cleaning.
- B. Paint:
  - 1. Finish carbon steel control panel exterior and devices with manufacturer's standard premium semi-gloss epoxy paint type.
  - 2. Finish sub-panels with Manufacturer's premium high gloss white epoxy paint.

### 3.5 DEVICE MOUNTING

- A. Device:
  - 1. Rigidly mount interior devices, instruments, and electrical equipment on sub-panels.
  - 2. Locate mounted devices installed inside enclosures and as facial features on enclosures so connections can be easily made and so ample room exists for servicing each item. Every component in and on enclosures shall be able to be removed individually without affecting other components and without need to move other components.
  - 3. Install components according to manufacturer's instructions.
  - 4. Fully install devices prior to terminating wire or tubing.
  - 5. Rigidly attach devices with properly sized stainless steel screws or bolts so they may be removed.
  - 6. Do not install devices on panel sides, except for cooling devices, receptacles, and lighting, devices, unless approved by Owner on case-by-case basis.
  - 7. Provide gaskets for devices penetrating panel exterior and seal in accordance with NEMA 4 standards on NEMA 4 or NEMA 4X panels. Entire enclosure shall meet NEMA standard after installation of required devices for panels designated as NEMA 4 or 4X.

- B. Cutouts:
1. No distortion of panels is permitted as result of machining cutouts or mounting instruments and devices.
  2. Cutouts shall be smooth and shall not have any irregularity from desired shape.
  3. Do not make openings by flame cutting or arc-cutting.
  4. Align cutouts, sub-panels, and drilling for mounting to keep devices grouped and in vertical and horizontal alignment.
  5. Provide rubber grommets in cutouts for wiring or tubing to prevent chaffing or scarring of insulation or jacketing of wiring or tubing.
  6. No field conduit knock outs may be cut at manufacturer's panel shop.

### 3.6 RACEWAY

- A. Install raceways along vertical or horizontal runs to present neat appearance. Angled runs are not allowed.
- B. Wireway:
1. Permanently fasten plastic wireways fastened into sub-panels using 10/32 screws.
  2. Support lower sidewall on horizontal runs of plastic wireway with bracing to avoid sagging. This bracing shall be at least 1/2 width of wireway with consideration given to space for wire egress. There will be no exceptions regardless of lack of sagging of newly installed wireway.

### 3.7 ELECTRICAL

- A. Wiring:
1. Install wiring between devices and terminal blocks in wireways except for dressing out to make terminations. Wireway fill shall not exceed 40% of wireway volume.
  2. Neatly arrange, bundle with nylon tie-wraps, and support with adhesive backed tie-wrap supports wiring which must be outside wireway. Provide flexible sleeves for protection of each wire bundle that passes across door hinge. Allow sufficient slack in wiring bundles so that door can fully open. Provide separate bundles for analog and discrete wiring crossing door hinges separated by > 6".
  3. Provide labels on wireway designating AC and DC wiring.
  4. Install wire and cabling so that any item may be removed without interrupting circuit power or other terminations.
  5. Use solderless spade-type compression lugs for wiring terminations except for pressure plate type terminations.
  6. Mark each wire at both ends with wire number typed on labels. Type device tag name on tag. Hand written labeling is not allowed. Properly identify power circuits.
  7. Install wiring along vertical or horizontal runs to present neat appearance. Angled runs are not allowed.
  8. Provide copper grounding lugs for electrical grounding of metal panels. Size lugs for system requirements but shall be less than #8.
  9. Neatly land and terminate stranded conductors in terminal blocks. Do not remove strands of stranded wire out to make wiring fit terminal.

10. Fuses or circuit breakers shall be readily accessible and easily identified. Properly label each fuse or circuit breaker. Install circuit breakers and fuses in clear space as required by NEC.
  11. Connect controller network cabling in accordance with manufacturer's connection practices and as shown on drawings.
  12. Connect 120 VAC or low voltage power, as required, to each I/O module and to processor rack power supply.
  13. Connect I/O to terminal blocks including controller I/O spares and spare I/O cards.
- B. Terminal Blocks:
1. Assure ease of accessibility of terminal blocks.
  2. Connect no more than 2 conductors under each terminal screw.
  3. For terminal blocks located between 3" deep or deeper wireway, install terminal blocks on raised channel to facilitate ease of connection to terminal block.
  4. Label terminal blocks with wire tag except for power wiring unless otherwise noted.
  5. Group terminal blocks in sequential manner following I/O type and device tag name.
  6. Grouping or placement shall not compromise NEC wiring classification.
- C. Lights and Receptacles:
1. Provide one incandescent light for each enclosure bay and one ground fault interrupt receptacle for floor mounted panel(s).
  2. Provide one ground fault interrupt receptacle for each wall mounted panel.

### **3.8 WIRE, CABLE, AND OPERATOR INTERFACE DEVICES**

- A. Provide wire and cable system in accordance with Section 25 3001CR - General Instrumentation Requirements and as described herein to complete electrical connections within panel.

### **3.9 OPERATOR INTERFACE/SWITCHING DEVICES**

- A. Provide operator interface devices (pilot lights, selector switches) and switching devices (control relays) to complete functions as shown on drawings or as detailed in specifications in accordance with Section 25 3001CR - General Instrumentation Requirements as described herein.

### **3.10 POWER SUPPLIES**

- A. Provide 24 VDC power supplies unless indicated in documents as furnished by others. Size power supplies to 175% of maximum load with 0 diversity.

### **3.11 CURRENT CONDITIONERS**

- A. Provide 24 VDC power supplies unless indicated in documents as furnished by others. Size power supplies to 150% of maximum load with 0 diversity.



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### **3.12 PNEUMATIC PIPING/TUBING**

- A. Provide piping/tubing system in accordance with Section 25 3526CR - Pneumatic Piping Tubing and as described herein to complete pneumatic connections within panel.
- B. Do not splice tubing within panel. Use bulkhead bars for circuit extensions.
- C. Mount tubing so that tubing run(s) do not interfere with removal of components.
- D. Terminate interior pneumatic components to bulkhead bars. Terminate incoming tubing to these bulkheads.
- E. Install tubing along vertical or horizontal runs to present neat appearance. Angled runs are not allowed.
- F. Mark each tube at both ends with tube number typed on self laminating wrap-on labels. Type device tag name on tag; hand written labeling is not allowed.

### **3.13 NAMEPLATES**

- A. Provide white laminated phenolic plates with black core color, with beveled edges in accordance Section 25 0553 - Instrumentation Tagging for tagging methods and installation.
- B. For NEMA 4 or 4X enclosures, properly seal screw holes after installation to maintain NEMA 4.
- C. Mount device nameplates, panel mounted instrument nameplates, and sub-panel mounted instrument nameplate next to device with adhesive or aluminum channel inside panel and as described herein on panel exterior. Do not install nameplates on removable covers.
- D. Provide nameplate for each panel with panel number and description as noted.
- E. Mount nameplates with adhesive on purged panels.

### **3.14 WIRE AND CABLE LABELS**

- A. Provide wire and cable labels on wire and cable. Refer to Section 25 0553CR - Instrumentation Tagging for wire and cable label requirements.

### **3.15 TESTING**

- A. Electrical:
  - 1. Test each fully assembled panel, console, or enclosure at factory prior to shipment.
  - 2. Notify Owner 10 business day's minimum prior to testing and make arrangements for Owner observation and testing.
  - 3. Testing in preparation for inspection shall include but not be limited to:
    - a. Test wiring and tubing for continuity and tightness of connections.
    - b. Energize electrical circuits within control panel.

- c. After energizing panel, check control circuits through simulated field inputs and outputs.
- d. Pressurize pneumatic circuits within control panel.

### 3.16 SHIPPING

- A. Protect external connections, fittings, hardware.
- B. Secure and restrain from movement loose materials and accessories and use appropriate blocking and cushioning for shipment and storage.
- C. Use interior protectors and braces as necessary.
- D. Cover panel with plastic or waterproof paper to prevent water damage during transit and on-site storage.
- E. Crating:
  1. Mount floor mounted or self-supporting panels on wood skid whose dimensions are not less than 6" (15.5 cm) greater than overall length and width of structure. Main wood supports shall be minimum of 4 x 4 inches (10 x 10 cm) solid wood. Nailing together two 2 x 4's is not allowed.
  2. Extension of skid supports shall be such that panel will not tip when inclined at angle of 15°. Consider panel's center of gravity with components installed when constructing and mounting skids to panel. Construct skid structure to allow panel to be moved by fork truck.
  3. Secure wall mount apparatus during shipment on wall-mounted panels.
  4. Transport panels in enclosed vans and secured to prevent shifting or over-turning during transport.
  5. Ship panel in air-ride type van.

### 3.17 INSTALLATION

- A. Location:
  1. Install control panels in locations as shown on drawings.
- B. Mounting fasteners:
  1. Minimum size for panel fastening anchors shall be 9/16" for floor anchors and 3/8" bolt for wall anchors. Increase anchor sizes as required for heavy panels.
- C. Floor Mounted Panels:
  1. Unless otherwise specified, install floor mounted control panel(s) on four 4" concrete equipment pad(s) with grout as required.
  2. Install two (2) anchors for each four (4) feet of equipment length or minimum of four (4) anchors. Decrease anchor spacing for heavy panels as required. Bolt equipment to pad using cap screws and washers.
  3. Do necessary grouting after equipment is installed and leveled. Grouting material shall be Owner approved cement grout; mixed and placed in accordance with manufacturer's recommendations. Remove leveling shims and wedges after grout has hardened. Re-grout Shim and wedge areas after shims or wedges are removed.

- D. Wall Mounted Panels:
  - 1. Provide one anchor for every 4'-0" of outside perimeter for wall mounted panels; minimum anchors for wall mounted panels shall be 4. Decrease anchor spacing for heavy panels as required.
  
- E. Field Connections:
  - 1. Provide clear space for dressing out wiring, cables and tubing entering panel. Provide 4"<sup>2</sup> unrestricted clear space for each inch of conduit size or each square inch of wireway size, with 4" x 4" being minimum area, in alignment with entering conduit or wireway, for bringing wiring into panel and routing to other locations. This space shall be sufficiently accessible to enable pulling wiring, cables, or tubing into panel for termination with initially installed equipment in place.
  
- F. Lifting Lugs:
  - 1. Remove lifting lugs after panels are set and use short, full-thread, hex-head machine screws to fill lug holes.

**END OF SECTION**



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## SECTION 25 1514CR

### PROCESS CONTROL APPLICATION SOFTWARE DESIGN

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Refer to Section 25 0901CR - Process Control System Integration
- B. Refer to Section 25 1524CR - Graphical User Interface Application Design
- C. Refer to Section 25 3001CR - General Instrumentation Requirements

##### 1.2 REFERENCE

- A. The Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

#### PART 2 PRODUCTS

##### 2.1 PROCESS CONTROL INSTRUMENTATION

- A. Refer to Section 25 3003CR - Process Instrumentation Device Specifications.

#### PART 3 EXECUTION

##### 3.1 PROGRAMMING TERMINAL SETUP:

- A. Install required software, Programmable Process Controllers, including operating system(s), programming software, etc. on programming terminal.

##### 3.2 GENERAL APPLICATION SOFTWARE REQUIREMENTS

- A. Control Sequence Setpoints:
  - 1. Setpoints listed in control sequences are values for initial application program development. Those setpoints may require field adjustment by start-up/commissioning group. This adjustment shall be included as part of application software development. Contractor shall be allowed to request extra payment for setpoint changes only after controller acceptance by Owner.
- B. Programming Software:
  - 1. Develop PLC application software using programming software developed for selected controlled PLC processor as specified.

- C. Failure Mode Output Configuration:
  - 1. In event of power failure, equipment shall enter shut down mode and outputs shall return to fail-safe position. As required by control sequence, equipment shall go to fail-safe position after failure. Control system shall not attempt to activate/actuate failed equipment until after operator reset.

### 3.3 APPLICATION PROGRAM STRUCTURE:

- A. Main Routines shall have one entry and one exit. Sub-routines and sub-programs shall have one entry and one exit except when routine detects device failure and invokes failure routine.
- B. Eliminate application program computer code, which does not execute in implementing control sequence or Software Functional Description ("dead code").
- C. Use data names or mnemonics for one purpose only in single controller. That is data name shall not be used to represent one entity in one area of program and redefined later within same controller.
- D. Construct application program to read top-to-bottom, or left to right, depending on syntax structure. That is first application module shall be processed first, second module second, third module third, etc.; not eighth module first, third module second, tenth module third, etc.
- E. Structure application program so that application program follows descending process/production flow by product, i.e. program function module referring to first part of process/production flow shall be at beginning of application, next function module would be second part of process/production flow and so on.
- F. Do not utilize indirect access without prior approval.

### 3.4 PROGRAM STRUCTURE

- A. Function Modules:
  - 1. Configure control sequences into logical function modules within program structure.
  - 2. Base Function modules on major equipment systems. At minimum, each major equipment system shall have its own module.
  - 3. Structure Text
    - a. Limit structured text function module statement lines to 500 lines.
  - 4. Graphic Programming
    - a. Limit graphic programming function module blocks to 15 blocks.
- B. Ladder Logic Program Structure:
  - 1. Construct logic so they may be displayed with their terminating element on 80 column CRT or within width of programming device screen, whichever is less.
  - 2. "Unfinished" rungs (or those which might be too wide for display) may be terminated with internal coil, which has contact beginning next rung to continue circuit.

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3. Avoid excessive parallel branches in rung. These requirements are intended to permit viewing entire rungs without using cursor control keys, and logic printouts on 8.5 x 11 paper without difficulty.
- C. Structured Text:
1. Implement Top-Down Structured Programming techniques when developing main routines and subroutines, with exception of many programs will be continuously processed (after routine is processed top to bottom, processing returns to top of routine and routine is re-processed, top to bottom). Main points of Top-Down Structured Programming are:
    - a. Routines are scanned top to bottom.
    - b. Routines have one entry and one exit.
    - c. Routines have no non-executed code.
    - d. Routines do not contain internal infinite loops.
  2. Develop initialization routine, which initializes internal variables and executes only on controller power-up.
  3. Do not use GOTO instructions in application software unless system software syntax does not contain subroutine call/return instruction. GOTO structure may be used in this exception only to return from and call subroutines.
  4. Do not redefine variables within controller. That is each variable shall have only one function within controller.
  5. Use descriptive variable names. For example use HEAT\_EXC\_TEMP1 not H1 for heat exchanger #1 temperature.
  6. Construct structured text so that entire line is displayed on-screen by using line continuation syntax and temporary variables.
  7. Limit number of variables used in one statement to 10 by using temporary variables in excessively long equations and string manipulation statements.
- D. Graphic Programming:
1. Construct modules to flow left-to-right, top-to-bottom. Function modules should fit on one graphic screen. Modules shall fit on three screens maximum.
  2. Minimize program flow control line crossings.
  3. Use major right-to-left and bottom-to-top program flow control lines only on main function modules to implement repetitive function module processing.
  4. Configure blocks to perform only one function per block.
- E. Subroutine or Child Routine Requirements:
1. Order Main Control Programs (MCP) or main subroutines sequentially to match process order or equipment numbering.
  2. Use subroutine for control operations/functions, which are used within program 3 or more times.
  3. Use "nested" subroutines as required by control sequence. However, do not nest subroutines more than 5 deep.
  4. Configure subroutines to include path to return to main program including during fault situations. No subroutine shall be configured to hold or stop program execution.

- F. Discrete Data Management:
1. Coils and outputs shall be in right-most rung column.
  2. Use relay logic or FIFO/LIFO stacks to determine scheduling or position tracking for multiple groups of parallel equipment. Do not use bit shifts or rotates.
  3. Word/register bit sequencer implementations of timing charts may be used to energize/de-energize discrete equipment outputs (on/off valves, motor driven equipment, etc.). Word/register shall be transferred to discrete output using "mask". If implemented, this technique shall be set-off from main application program in subroutine structure and timing chart representation shall be entered as rung/network comment associated with bit-shift. Use integer word/register for sequencer management.
  4. Structure sequencer using "step/next step" configuration. That is, another step is configured for each device state change (on/off - open/close) for devices being implemented.
  5. When same coil is used in multiple rungs, locate multiple rungs within 5 rungs of first usage of coil. Document each coil usage with other coil locations in element comment.
  6. When same coil is used in multiple rungs, list other rung occurrence at each rung location, which contains referenced coil. Use either rung or element comment depending as required to fully list each occurrence.
  7. Use 1 slot addressing for discrete inputs and outputs.
  8. Use 2 slot addressing if using 8 point discrete I/O.
  9. Use 1/2 slot addressing if using 32 point discrete I/O.
  10. Move discrete inputs and outputs to internal file(s)/register(s) at top of application software program. Use internal discrete file(s)/register(s) within application program and not real I/O.
- G. Setpoint Implementation:
1. Store setpoints and operational parameters in controller memory (backed-up as specified) and not in GUI memory.
- H. Switch Point Actuation:
1. Provide each switch/alarm trip point with an adjustable time delay to prevent nuisance tripping. These time delays apply to each switch point whether hardware or software and are for normal operation. Additional or longer delays may be necessary during start-up as noted herein.
  2. Nuisance alarms are not permitted (i.e. equipment status alarms should not be activated if equipment has been manually turned off by operator in control room).
  3. Unless specified otherwise, time delay shall be as follows:

<u>Process or Operation</u>	<u>Time Delay</u>
Flow	1 second
Motor Starter	1 second
Liquid Pressure	2 seconds
Level	5 seconds
Valve Limit Switch	20 seconds

- a. If above time delays are less than controller scan rate, minimum controller scan rate shall be time delay.



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- I. Alarm Management:
    - 1. Function module alarm management shall be second from end of module. Alarm switching shall be executed in controller. Alarms shall be latched within controller requiring operator acknowledgement either through GUI or panel mounted push-button.
    - 2. No alarm switching may be in GUI only system. Alarm logging, annunciation, acknowledgement, and printing shall be executed by GUI only system alarm task manager.
    - 3. Configure field device generated alarms normally-closed, alarm on open. Configure software generated alarms to alarm on true.
    - 4. Provide a dry contact for common fail signal for all fail alarms shown in Section 25 1524 - Graphical User Interface Application Design. Dry contact shall be electromechanical type relay. This signal shall be transmitted to the building automation system.
  
  - J. Diagnostic Alarm:
    - 1. Configure controller diagnostic word(s)/register(s) into coil type bits or virtual discrete points for alarming in GUI application.
  
  - K. Analog Data Management:
    - 1. Scale analog values to engineering units. Only analog values with specified accuracy error less than 1%, may be directly implemented in analog input register/word counts (e.g. pH meters and weigh cells).
    - 2. Move analog inputs to internal words/registers in separate program file or at beginning of function module.
    - 3. Use separate program file for applications with 10 or more block transfers. Applications with less than 10 block transfers, block transfer instruction may be either at beginning of function module, or in separate file.
    - 4. Scale analog inputs not used for PID blocks in Block Transfer Read instruction. Use integer files for analog value scaling; not binary files.
    - 5. Analog values may be scaled with offset to represent narrow range. For example pressure transmitter input with calibrated range of 0-2 psig may be scaled 0-2000 within controller to ensure resolution. If this technique is implemented, document offset used at each occurrence of scaled word/register.
    - 6. Monitor Block Transfer and Message instruction status word/register(s). If fault is detected, activate communication alarm (information only) and reset instruction to continue communication.

### 3.5 PID LOOP CONFIGURATION

- A. Provide PID loops that support proportional, integral, and derivative parameters. Configure PID block/instruction to support automatic and manual mode. In manual mode, operators will be able to directly adjust output. In automatic mode, operators will be able to directly adjust controller setpoint.
  
- B. PID outputs may be manually changed only when PID loop is in MANUAL.
  
- C. PID shall track manual operator controller/output changes while loop is in manual to provide bumpless transfer when operator switches loop from manual to automatic.

- D. Configure PID loops to prevent integral wind-up. Loop shall not be calculated when loop is in manual or when system of which loop is part, is not on-line. Integral component shall not contribute to PID output when output is less than 0% or greater than 100%.
- E. Tune PID loops for quarter amplitude decay.
- F. Tune PID loops using load upsets not setpoint changes unless load changes will result in major equipment damage or personnel injury.
- G. Scale input parameters used for PID control.

### 3.6 CONTROLLER LADDER LOGIC SOFTWARE DOCUMENTATION

- A. Controller Software Documentation shall be complete with following:
  - 1. Communication word(s)/register(s) shall be transferred on each communication network cycle 0.5Hz maximum.
  - 2. Annotation shall be in English.
- B. Title Block:
  - 1. Hard-copy documentation shall begin with Title Block, which includes as minimum: Control Contractor's name, controller type, and process function.
- C. Annotation:
  - 1. Annotate each contact or instruction element with its numeric controller address, device identification in form of address label or symbol, and functional description.
    - a. I/O Device identification in controller program shall be same as that appearing on drawings.
    - b. (Note: Where controller program displays and prints contact or instruction elements address automatically, it is not always necessary to repeat address in annotation.
- D. Unique Labels or Symbols:
  - 1. Do not use repetitive words such as LIGHT or SOLENOID or PUSHBUTTON for address labels or symbols.
  - 2. Avoid using labels or symbols to replace actual address appearing in instruction. For example, do not replace T4:8 in timer or counter with symbol, such as "PART TIMER."
- E. Wording of Descriptions:
  - 1. Break words entered into lines available for functional description only at their syllables. Functional descriptions for I/O contacts or coils shall be same as that on 70Z\* drawings and ID tags, to extent permitted by field lengths.
  - 2. Each internal contact or instruction element in rung shall have adjacent cross reference to line location of its parent "coil."

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- F. Consolidated Annotation for Register/Words:
1. Register/word or memory locations may be annotated in listing at end of controller program printout.
  2. Following additional information shall be included with controller program printout (or on drawings if software lacks capability):
    - a. Controller system configuration, consisting of:
      - 1) Actual Used and Maximum Available numbers of: coils, inputs, outputs, timers, register/word, and logic lines.
      - 2) Controller memory used, memory remaining, and total system memory.
      - 3) Data table utilization.
      - 4) Memory Map listing for controllers.
  3. Subroutine calls within process step file shall have rung comment detailing what subroutine is being executed, location of subroutine called, and parameters passed.

### **3.7 CROSS-REFERENCES**

- A. Show full cross references at each coil or output element and in summary (with descriptions) at end of controller programming printout.

### **3.8 RUNG COMMENTS**

- A. Attach line or rung comment to each rung containing controller elements beyond simple contacts and coils, or which is not easily understood. This includes, but is not limited to, rungs containing arithmetic functions, data manipulation such as block transfers or bit shifts, communications with peripherals, etc. Provide sufficient detail to fully describe action of rung.

### **3.9 NUMBERING OF LINE MARKERS**

- A. For those controllers where comment is attached to rung by means of arbitrarily numbered "line marker," line marker number shall be same as address of output element or coil on that rung. (This maintains one-to-one correspondence between comment and rung, regardless of later editing and restructuring of logic program).

### **3.10 DATA TRANSFERS FULLY DEFINED**

- A. Fully and clearly define data transfers and interlocks between controllers, or between controllers and peripheral devices, (timing, sequence, time duration and logic level, etc.). Include this information in both line or rung comments.

**END OF SECTION**



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## SECTION 25 1524CR

### GRAPHICAL USER INTERFACE APPLICATION DESIGN

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 25 0901CR - Process Control System Integration
- B. Section 25 1100CR - Programmable Process Controllers
- C. Section 25 1316CR - Control Panels
- D. Section 25 1514CR - Process Control Application Software Design
- E. Section 25 3003CR - Process Instrumentation Device Specifications
- F. Section 25 0993CR - Control Sequences

##### 1.2 REFERENCE

- A. The Work under this Section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 PURPOSE

- A. This specification defines Graphical User Interface (GUI) system using Human-Machine Interface (HMI) and SCADA in conjunction with Programmable Logic Controller (PLC). It is intended as guide for GUI design to maintain a consistent, user-friendly, and maintainable system.

##### 1.4 SUBMITTALS

- A. See submittal requirements in Section 25 0901CR - Process Control System Integration.
- B. Submit individual control system graphics and reports, printed after entered into GUI system, techniques employed by users to interact with system (e.g., function key usage and hierarchy layout), alarm lists, and other application specific GUI tasks.

#### PART 2 PRODUCTS

##### 2.1 GRAPHICAL USER INTERFACE (GUI) HARDWARE

- A. Laminated plastic nameplates shall be provided for each workstation. Each nameplate shall identify the function, network address and identifier of the workstation. Laminated plastic shall be 0.125 inch thick, white with black center core. Nameplates shall be a

minimum of 1 by 3 inches with minimum 0.25 inch high engraved block lettering. All nameplates shall be attached to the device in conspicuous location.

- B. GUI Hardware (workstation and server) shall be a standard unmodified digital desktop computer of modular design or a laptop as shown. The modular components of the desktop, or the laptop, shall be products of a single manufacturer which advertises service in all 48 contiguous states.
- C. Workstation hardware shall meet the following minimum requirements:
1. Case and 250 watt power supply.
  2. Processor speed: 150% the stated requirements of the software to be installed on the workstation.
  3. BIOS in Flash Memory.
  4. Sufficient expansion slots to be properly configured for its intended use.
  5. Random Access Memory (RAM): 150% the stated requirements of the software to be installed on the workstation.
  6. Video Output Card: Supports at least 32 bit color at a minimum resolution of 1280 by 1024 at a minimum refresh rate of 70 Hz.
  7. 101 key, keyboard with 12 function keys.
  8. 23-inch widescreen LCD monitor with a minimum resolution of 1024 by 768 pixels, non-interlaced, a maximum dot pitch of 0.28 millimeters, and a minimum refresh rate of 60Hz.
  9. Communication Ports: serial port, one enhanced parallel port and two USB ports in addition to any ports required for the keyboard and mouse.
  10. CD-RW/DVD ROM 24X Drive
  11. Hard Drive: 120 GB formatted disk space with an average seek time of 7 milliseconds or less.
  12. Network interface card: Integrated Gigabit Ethernet NIC with an RJ45 connector and associated hardware.
  13. All required cables for connecting to network and other remote devices.
  14. Mouse with mouse pad.
  15. UPS with 30 minute backup battery.
  16. The operating system (OS) shall fully support all installed software and peripherals and shall be able to obtain screen capture of the monitor display being viewed.
  17. Virus Protection Software shall consist of the project site's standard virus protection software complete with a virus definition update subscription.
  18. Latest version of Microsoft Office Professional
  19. Latest version of Adobe Acrobat.
- D. Server hardware shall meet the following minimum requirements.
1. Processor speed: Minimum 250% of the stated requirements of the software to be installed on the server.
  2. Random Access Memory (RAM): Minimum 250% of the stated requirements of the software to be installed on the server.
  3. Communications ports: One serial port, one enhanced parallel port and two USB port in addition to any ports required for the keyboard and mouse.
  4. Hard Drives and Controller: Controller and Drives shall provide a minimum of 250 percent of the usable disk space required for monitoring, control and data

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- archiving with an average seek time of 7 milliseconds or less using hardware RAID (Redundant Array of Inexpensive Disks) at level 5 (RAID-5).
  5. CD/DVD-RW Drive: Combo CD-RW with 32x read, 24x write and 16x rewrite and DVD-RW with 12x read; 4x re-write; 2x write.
  6. Video output card: Support at least 16 bit color at a minimum resolution of 1280 by 1024 at a minimum refresh rate of 70 Hz.
  7. Network Interface Card (NIC): Two (2) Gigabit Ethernet Network Interface Cards (NICs).
  8. Monitor: 21-inch LCD monitor with a minimum resolution of 1024 by 768 pixels, non-interlaced, a maximum dot pitch of 0.28 millimeters, and a minimum refresh rate of 70Hz.
  9. Keyboard: 101 key keyboard having a minimum 64 character standard ASCII character set based on ANSI INCITS 154.
  10. Mouse: 2-button mouse with a minimum resolution of 400 dots per inch.
  11. Hot-swappable redundant power supplies.
  12. Redundant Fans.
  13. UPS with 30 minute backup battery.
  14. The operating system (OS) shall fully support all installed software and peripherals.
  15. Virus Protection Software shall consist of the project site's standard virus protection software complete with a virus definition update subscription.
  16. Latest version of Microsoft Office Professional
  17. Latest version of Adobe Acrobat.
  18. Coordinate additional software requirements with Owner.
  19. All required cables for connecting to network and other remote devices
- E. Panel Mounted Operator Interface Touch Screens:
1. Provide operator interface touch screens in door of each HC900 PLC cabinet with the following minimum requirements:
    - a. Honeywell 900 Control Station, 10" w/ documents CD
    - b. Station Designer Software
    - c. Flash Memory Module (2GB)
    - d. 24vdc Power Supply
    - e. 900 Control Station Cable (USB Configuration, 10 ft.

## 2.2 PRINTERS

- A. Printers shall be local or network printers as shown. Local printers shall have a parallel or USB interface. Network printers shall have a 100Base-T interface with an RJ45 connection and shall have a firmware print spooler compatible with the Operating System print spooler.
1. The color printer shall use ink jet technology, shall be a full-color printer, and shall meet the following minimum requirements:
    - a. Resolution: 600 by 600 dots per inch.
    - b. Printing Time: 2 pages per minute.
    - c. Data Buffer Size: 16 Megabytes.
    - d. Colors: Printer shall have a separate replaceable black ink cartridge or print head.
    - e. Media Type: Paper and transparency film.

- f. Media Size: 8.5 by 11 inches and as shown.
- g. Paper Cassette: 250 sheet capacity.

### **2.3 GRAPHICAL USER INTERFACE (GUI) SOFTWARE**

- A. Honeywell Experion HS
- B. Provide 400 point SCADA capacity or 20% above required for project, whichever is greater.
- C. Software shall provide graphical control/monitoring interface for Clean Room HVAC systems, gas detection, environmental conditions, access control and video surveillance as indicated.
- D. Graphical displays shall also include alarm displays, scheduling displays, report displays and trending displays. Data associated with an active display shall be no more than 2 seconds out-of-date.
- E. GUI server shall be provided with all software applications and licenses required to provide access to minimum of 5 simultaneous clients.
- F. Graphical User Interface shall be interactive, fully prompted, menu driven and shall provide the following functionality as a minimum:
  - 1. HVAC Systems:
    - a. Graphical User Interface shall allow for hierarchical graphical navigation between individual control systems, graphical representations of systems, access to real-time data for each system, ability to override points in a system, and access to all supervisory monitoring and control functions. Each system display shall clearly distinguish between the following point data types and information: Real-time data, User-entered data, Overridden or operator-disabled points, Devices in alarm (unacknowledged), and Out-of-range, bad, or missing data. The software shall allow the user to create, modify, and delete displays and graphic symbols.
    - b. Operator shall be able to monitor/control all data points as shown on flow diagrams via graphic displays.
  - 2. Alarm and Event Management:
    - a. Graphical User Interface software shall generate alarm event notifications and manage system alarm/event notification and routing.
    - b. Software shall provide audible, visual, and printed means of alarm indication. The alarm dialog box shall always become the top dialog box regardless of the application(s) currently running.
    - c. Software shall provide log of alarm messages. Alarm log shall be archived to the hard disk of the web server. Each entry shall include a description of the event-initiating object generating the alarm. Description shall be an alarm message of at least 256 characters in length. Entry shall include time and date of alarm occurrence, time and date of object state return to normal time and date of alarm acknowledgment and identification of operator acknowledging alarm.
    - d. Alarm logs shall be maintained for a minimum of one year.



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- e. Operator shall be able to adjust alarm limits if logged on with the appropriate security access.
3. Trending & Data Archiving:
- a. Trend log files shall be appended with new sample data, allowing samples to be accumulated. Systems that write over archived data shall not be allowed, unless limited file size is specified.
  - b. Archived data shall be maintained for a minimum of two years.
  - c. All trend log information shall be displayed in standard engineering units.
  - d. Web interface shall provide ability to graphically view trend data using two-axis (x,y) graphs that display up to ten object types at the same time in different colors. Graphs shall show object values relative to time.
  - e. Operator shall be able to change trend log setup information if logged on with the appropriate security access. This includes the information to be logged as well as the interval at which it is to be logged. All input, output, and value object types in the system may be logged.
4. Report Generating:
- a. Software shall be provided with commands to generate and format reports for displaying on current Workstation, printing, and storing on disk.
  - b. Reports shall be stored by type, date, and time. The destination of each report shall be selectable by the operator.
  - c. Dynamic operation of the system shall not be interrupted to generate a report. The report generation mode, either automatic or requested, shall be operator assignable. The report shall contain the time and date when the samples were taken, and the time and date when the report was generated.
  - d. The software shall be capable of saving reports to a file. If the file format is not in a format compatible with standard Microsoft Office software, the Control Contractor shall provide a means to export or convert the file to a compatible format.
  - e. The software shall allow for automatic or manual generation of reports. For automatic reports, the operator shall be able to specify the time the initial report is to be generated, the time interval between reports, end of period, and the output format for the report. The operator shall be able to modify, or inhibit a periodic report.
  - f. Manual report generation shall allow for the operator to request at any time the output of any report.
  - g. The software shall have a report generation utility programmed for generating the following standard reports:
    - 1) Alarm Report: Outstanding alarms by building or unit, including time of occurrence.
    - 2) Override Report: Points overridden, including time overridden, and identification of operator overriding the point.
    - 3) Run Time Reports: A report totalizing the accumulated run time of individual pieces of equipment. The operator shall be able to define equipment groupings and shall be able to generate reports based on these groupings.
    - 4) Access Control System "Muster" Report: A report indicating all persons currently occupying clean room.

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- 5) Access Control System Entrance/Exit Report: A report indicating entry and exit operations over a specified period of time. Report shall include Entry/Exit Time, Entry/Exit Date, Badge Number and Badge Holder Name..
  - 6) Provide allowance for five (5) additional Owner defined custom reports.
5. Activity Logging:
- a. System shall maintain a historical file logging all activity of the system.
  - b. This file shall maintain, as a minimum, a record of all operators logged onto the system, alarm acknowledgments, commands issued and all database modifications. Passwords shall not be logged.
  - c. The activity log shall be maintained at the GUI server hardware. The system shall automatically provide a mechanism for archiving the log files for long term record storage.
  - d. The system shall maintain a minimum of two years of log files.
6. Honeywell Digital Video manager (DVM):
- a. Provide scalable, digital closed-circuit television (CCTV) video solution. Initial system shall provide for four (4) camera feeds.
  - b. Operators shall have ability to view and control video.
  - c. Experion HS alarms and events shall automatically trigger cameras to move to a predefined position and trigger video recordings to start.
  - d. All DVM alarms and events, including events detected using video analytics, shall appear within the Experion HS alarm summary display. The alarm summary display shall include a DVM icon that displays a pop-up with the recording control embedded.
  - e. Provide all configuration software, cables and adapters necessary for a fully functioning system.
- G. Graphics and Controls:
1. Graphics shall be configured for “point-and-click” operation to allow user to navigate through the building systems with ease. The user shall be able to define the action of control buttons configured on the graphics.
  2. Building systems and equipment drawings can be created from built-in image library or may be imported from a scanner, the Internet, CAD drawing, or other files such as bitmap (.BMP), JPEGs or Icon files.
  3. All symbols used by the contractor in the creation of graphic pages shall be saved to a library file for use by the Owner. Provide additional copy of library file on CD.
  4. Graphic Editor: The graphic editor shall enable the user to create, modify, and delete displays and graphic symbols. The primary use shall be for adding and modifying graphic displays, status displays, system summaries, and system directories, as new controllers, points, data, and other necessary changes are made.

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## **PART 3 EXECUTION**

### **3.1 GENERAL**

- A. Install system software, including configuration and application software required. Configure application software as defined herein. Result will be fully functional GUI system as specified.

### **3.2 INFORMATION PRESENTED**

- A. GUI should present only necessary information for control and monitoring. Information (measured or calculated values) available to GUI, but not immediately required for facility operation, will be accessible to users via subgraphics.

### **3.3 SYSTEM CONSISTENCY**

- A. Configure system graphics, such as controller performance screens, consistently. Text of same type should be same size; for instance, equipment designators should be same size.
- B. Another example is virtual controller faceplate implementation. Consistently color and locate process variable, setpoint, and output in same relative position for each faceplate.

### **3.4 SECURITY**

- A. Software shall manage user information and shall recognize at least 50 separate users and have at least 3 levels of security: Operator, Supervisor, and Configurer.
- B. Operator will have basic functionality. Operator may monitor graphics including system status graphics. Operator control is limited to switching device modes between AUTO, MANUAL, and REMOTE (if applicable), manually starting and stopping or opening and closing devices, manually changing valve positions, and adjusting setpoints within engineering defined ranges.
- C. Supervisor will have same capabilities as operator; with the ability to modify parameters, such as frequency of backwashing and simple system functions such as data back-up. Supervisor will not have access to any software modification graphics including permanent recipe changes.
- D. Configurer will have complete access to system functions including software configuration screens. After executing proper change control procedures, Configurer will be able to make any application software revision.
- E. Implement software passwords that, when properly entered, will allow access to corresponding area. Password will not be displayed while user is entering password. However, "X"s or "\*" may be used to represent number of characters entered.
- F. System shall provide an Auto Logout Feature that shall automatically logout user when there has been no keyboard or mouse activity for 5 minutes. Time period shall be adjustable by system administrator. Auto Logout may be enabled and disabled by system

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administrator. Operator terminal shall display message on screen that user is logged out after Auto Logout occurs.

### **3.5 SCREEN RESPONSE**

- A. Screen call-up times will be limited to 3 seconds by keeping quantity of graphic system links (e.g., zero page links, process parameter display, color-filled lines, and process equipment) and total graphic size to manageable levels even though this may require increase in quantity of static graphics.

### **3.6 OPERATOR ACTIONS**

- A. GUI hierarchy will be navigable.
- B. Operator input to control system should be straightforward and quick. By using dedicated function keys, operators will quickly and easily select or perform required tasks. For instance, operator should be able to adjust setpoint by selecting control loop, selecting setpoint, and either typing new setpoint or selecting setpoint ramp function.
- C. Configure keystroke responsiveness so that multiple or repeated control system actions will not occur after operator executes single keystroke.

### **3.7 OPERATOR NAVIGATION**

- A. Operator will be capable of navigating through GUI quickly and easily, employing standard actions to access or perform different tasks via control system and with minimum of operator keystrokes. Operator actions must be implemented to operate with fewest user entries possible.
- B. Implementation will be based on hierarchical format with each successive lower level revealing increasing detail in the following order:
  - 1. Top level will be Main Menu accessing Area graphics and other system displays.
  - 2. Area graphics will be accessible from Main Menus.
  - 3. Area graphics will display summarized major equipment and piping of Area. Area graphics will display important information of equipment group. No control will be possible from Area graphics.
  - 4. Units will be accessible from Area graphics.
  - 5. Unit, base segment, will consist of single equipment unit or single process function; e.g., storage tank with its associated valves, pump(s), analyzers, and chemical feed.
  - 6. Sub-Units will be accessible from Unit graphics.
  - 7. Sub-Unit will consist of detail graphics about Unit. For Example, storage tank and its associated instrumentation.

### **3.8 MAIN MENU**

- A. Main Menu will provide access to various Area Overviews, and other operator displays.
- B. Main Menu will have options logically grouped and uniquely colored representing like display types.

- C. Main Menu should be first displayed graphic after system start-up. It has password entry areas if password entry is not system defined.

### **3.9 AREA OVERVIEW**

- A. Area Overview graphic should display major systems/components and important information of area including:
  1. Status of Equipment.
  2. Critical process parameters.
- B. Area Overview will provide only monitoring capability and will not provide any manual control access.

### **3.10 UNIT GRAPHIC**

- A. Unit/System Graphic will provide complete operator access for unit/system monitoring and manual control. Unit/System Graphic will be designed for operator access to necessary information to determine state of system without having to leave that Unit/System Graphic.
- B. Provide individual unit graphics for the following systems, as a minimum:
  1. Each Air Handling Unit
  2. Each Exhaust System
  3. Glycol Heat Recovery System
  4. Process Chilled Water System
  5. Low Temperature Chilled Water System
  6. Clean Room AHU Chilled Water System
  7. Air Lock Gowning Room w/ associated fans and AHU
  8. Ultra Pure Water System
  9. Gas Detection System
- C. Monitoring functions will include:
  1. Status of control elements.
  2. Process parameters (e.g., pressure, level, conductivity) for each field instrument.
  3. Current process step.
  4. Interlock status and interlock verbal descriptions, as applicable.
  5. Unit Graphic will provide manual control access of automated control elements; (i.e., pumps and valves) and will provide AUTO/MANUAL mode changed of analog and discrete devices.
  6. Access to specific control and monitoring Sub-Unit graphics will be provided from Unit Graphic.

### **3.11 SUB-UNIT GRAPHIC**

- A. Sub-Unit graphics will include alarm displays, details of monitoring and control, and trend groups associated only with that unit.

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### **3.12 OTHER OPERATOR DISPLAYS**

- A. Overall Plan:
  - 1. This should simply be an overall view locating major process equipment units. Each process equipment unit, when selected, will take operator to corresponding Unit Graphic.
- B. Hierarchy:
  - 1. Hierarchy should be schematic flow tree representing various graphic levels accessible by operators. Each Operation Graphic will be displayed as boxed target which, when selected, will take operator to corresponding graphic.

### **3.13 VERTICAL GRAPHIC LEVEL CHANGES**

- A. Configure function key or graphic target at each hierarchical level that, upon selection, will return operator directly to Area Overview or Main Menu. This will be consistent throughout; either function key, target, or both on every graphic.
- B. Configure function key or graphic target for each graphic hierarchical level that, upon selection, will take operator to display level above or below current hierarchical viewing level.

### **3.14 HORIZONTAL GRAPHIC LEVEL CHANGES**

- A. Each graphic will have target on each side of graphic which takes user to next graphic horizontally in hierarchy; i.e., second Unit Graphic will have target on left that will take user to first Unit Graphic and target on right that will take user to third Unit Graphic.

### **3.15 TARGETS**

- A. Screen-selectable targets should have solid box outline designations. On overviews, process equipment symbol will serve as select target without outline designation. Interlocks should be diamond symbols. Other designators should be rectangles enclosing text description of target.
- B. Locate operator targets for input of analog values above digital display for that analog value.

### **3.16 DISCRETE DEVICE OPERATION**

- A. Method for software mode changes of discrete devices will be that operator selects device and then selects AUTO/MANUAL toggle. While discrete device is in MANUAL, operator will have full control of device and control system will have no control.
- B. After discrete devices are in MANUAL, operator will have the option of manually change device's operating or position state by toggling "State Change" toggle (i.e. ON/OFF for motor driven equipment, OPEN/CLOSE for valve type equipment).

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### **3.17 AUTO/MANUAL TOGGLE FOR DISCRETE DEVICES**

- A. AUTO/MANUAL will be target box as defined above. After operator selects device, AUTO/MANUAL target will appear. When discrete device is MANUAL, "STATE CHANGE" target box will appear. STATE CHANGE target box will be ON/OFF for motor driven equipment and like and will be OPEN/CLOSE for valve type equipment.
- B. Configure only one (1) AUTO/MANUAL toggle target pair on each graphic. Operator will select device as described above. Software then will correlate AUTO/MANUAL toggle with selected device.

### **3.18 ANALOG DEVICE OPERATION**

- A. Method for software mode changes of analog controllers will be that operator selects controller and then selects AUTO/MANUAL toggle for simple PID controllers.
- B. Refer to Section 25 1514 - Process Control Application Software Design for description of modes.
- C. While analog controller is in MANUAL, operator will have full control of device and control system will have no control.
- D. When loop is in AUTO, control system will calculate loop output (controlled variable) based on difference between input (process variable, or measured variable), setpoint, and operator configured tuning parameters.
- E. Analog controller outputs will be manually changed only when controller is in MANUAL.
- F. Locate critical analog device operator control on Unit Graphics. Non-critical analog device operator control will be on sub-graphics such as faceplates.
- G. Locate analog device on sub-graphics such as faceplates.
- H. Operator analog input will be graphical target/function keys configured as increase/decrease to analog values.

### **3.19 AUTO/MANUAL TOGGLE FOR ANALOG DEVICES**

- A. AUTO/MANUAL will be target box. After operator selects device AUTO/MANUAL target will appear. When analog device is MANUAL, display OUTPUT CHANGE graphical box to allow operator changes to analog outputs. When analog device is AUTO, display SETPOINT CHANGE graphical box to allow operator changes to loop setpoint.
- B. Configure only one (1) AUTO/MANUAL toggle target pair on each graphic. Operator will select device as described above. Software will correlate AUTO/MANUAL toggle with selected device.

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### 3.20 MENU SELECTIONS

- A. Configure operator inputs to control system that require repeated numeric strings on pop-up menus. Center pop-up menus on screen. Remove menu from screen after operator makes selection. Configure function (function key or graphical target) to remove menu from screen if operator chooses to not make selections.

### 3.21 TEXT

- A. Text should be standard block, CG Times, Universal Scaleable or Helvetica font. Use 3 sizes:
  1. Large: Approximately 3/4" tall, used only for graphic screen titles.
  2. Medium: Approximately 3/8" tall, used for equipment labels and general informational displays including batch information.
  3. Small: Approximately 1/4" tall, used for instrument tags and other detailed displays.

### 3.22 LABELS

- A. Label process equipment. Each process vessel or piece of major process equipment, such as storage tank, will have description above equipment that includes equipment number, brief description of equipment, and control system tag number. Locate these descriptions near graphic top boundary.
- B. Label automated final elements, such as pumps, with equipment number under device. Color label to designate interaction with control system will be as follows:
  1. Control Interaction Tag Color
  2. No interaction White
  3. Monitor Only White
  4. Monitor and Control Process Color
- C. Label analog loops with instrument tag number within instrument loop definition box.
- D. Indicating loop designators will be "XI"-0000 and control loop designators will be "XIC"-0000 (X represents loop function, e.g., F for flow, P for pressure, T for temperature, etc.). Label will be white and box will be green.

### 3.23 INSTRUMENT DISPLAYS

- A. Locate sensors with single pixel-wide or solid line connecting process to controller.
- B. Display each loop's process variable measurement, units (flow, pressure, temperature, etc.), ISA designators (TIC, PC, etc.), loop number, and mode (AUTO, MANUAL, REMOTE, etc.). Locate controller on graphic by rectangular box that contains ISA designator and tag number. Use dashed lines to connect elements of loops together (e.g., dashed line connects temperature transmitter to temperature controller and second dashed line connects controller to final control element). Line and rectangle will be green for normal operation and red when loop parameter is in alarm. Show loop process variable measurement near that box. Loop text and digital display will be white.



- C. Display each control system analog input (process variable) near sensor location. Depict location with white arrow pointing to sensor location. Display tag name, tag number, and process variable at opposite end of arrow.
- D. Display valve position in percent open regardless of valve position.
- E. Display valve position in percent of output signal detailing if the valve is fail open or fail closed.
- F. Show device mode as AUTO/MANUAL. Where both field HOA switch and software device controller exist, AUTO will be displayed only when both HOA and software modes are in AUTO. Otherwise, mode will be displayed as MANUAL.
 

1.	Loop or Letter	Background	Foreground	Border
2.	Device State	Designator	Color	Color Color
3.	Manual M	Yellow	Black	White
4.	Automatic A	Green	White	White
5.	Field F	Yellow	Black	White
6.	Remote Setpoint	R	Green	White White
7.	Local Setpoint on	L	Green	White White
8.	Remote Controller			
- G. Locate these icons close to device or loop.

### 3.24 ALARMS

- A. Alarms will be graphic flags to alert operator that abnormality has occurred or present limit has been exceeded in system. Only necessary alarms will be presented to avoid having operator process any unnecessary information.
- B. Configure four classes of alarms: hardware failure alarms, process critical alarms, process advisory alarms, and operator information messages listed by order or priority. Alarm task will be capable of sorting alarms by unit and priority. Alarm task will display only those alarms associated with unit when alarm target is selected from Unit Graphic. If required by application, alarm task will display area alarms when alarm target is selected from Area graphic.
  - 1. Hardware alarm will be where control system hardware failure as detected by control system diagnostics. Example would be failure of analog card.
  - 2. Process critical alarm will be an event that causes any environmental damage, personnel injury, major equipment damage, or significant production loss.
  - 3. Process advisory alarms will alert operator that process is not operating optimally or that process critical alarm is pending unless appropriate operator action is taken.
  - 4. Operator messages will alert operator that certain tasks are required or that process events have occurred. For instance, message for monthly data back-up would be operator message.
- C. Alarms should be color-coded as follows:
  - 1. Alarm Color
  - 2. Hardware Failure Magenta
  - 3. Process Critical Red

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- 4. Process Advisory      Yellow
  - 5. Operator Message      Green
  - 6. System Normal-No Message      White

D. Control system will store alarms on fixed disk in First-In-First-Out stack.

### **3.25 FACE-PLATES**

- A. Faceplate displays allow operator to:
  - 1. Monitor loop operation.
    - a. Switch loop modes between AUTO and MANUAL.
    - b. Manually enter changes to loop's setpoint or output.
  - 2. Graphic Programming.
    - a. Construct modules to flow left-to-right, top-to-bottom. Function modules should fit on one graphic screen. Modules should fit on three screens maximum.
  - 3. Minimize program flow control line crossings.
  - 4. Use major right-to-left and bottom-to-top program flow control lines only on main function modules to implement repetitive function module processing.
  - 5. Configure blocks to perform only one function per block.
  - 6. Limit graphic programming function module blocks to 15 blocks.

### **3.26 BRINGING SYSTEM ON-LINE**

- A. Taking GUI console on-line or off-line should not affect any controllers or variables that can be accessed and modified by GUI system. Upon start-up, system will read current analog and discrete values within controller to which GUI package writes and make GUI database values equal to current controller variables prior to enabling GUI write functions.

### **3.27 DOCUMENTATION**

- A. Each active GUI software module will have description detailing what module is doing and techniques employed to accomplish defined task. Documented modules include: graphic animation links and tasks, alarm tasks, graphical logic tasks, input/output tasks (if applicable), and other implemented tasks.

### **3.28 SYSTEM SOFTWARE**

- A. Provide static graphics meeting requirements of Unit graphics specified herein.
- B. Provide individual alarm acknowledgement.
- C. Provide screen selector function for operator menus.
- D. No command will be implemented if operator presses touchscreen area while screen saver is implemented.

**END OF SECTION**

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## SECTION 25 2005CR – CLEANROOM SPECIALTY GAS DETECTION SYSTEM

### PART 1 GENERAL

#### 1.1 SUMMARY

- A. Provide a complete specialty gas Toxic Gas Monitoring System (TGMS) for Hazardous Production Material (HPM) and Oxygen concentration including gas sensors and transmitters, PLC controllers, communication networks, Human-Machine Interface (HMI) touch screen displays, network PC workstation, UPS power back-up, alarm and notification devices, emergency shutdown (EMO) stations, conduit and wiring, and start-up and commissioning of system components.

#### 1.2 REFERENCES

- 1. Comply with national and local building and fire codes, OSHA, NFPA and SEMI standard requirements for the safe handling of hazardous gases.
- 2. All specialty gas detection system components shall meet Class 1 Division 2 requirements of the NEC for hazardous locations when required.

#### 1.3 RELATED SECTIONS

- A. General and Supplementary Conditions and Division 1
- B. Section 13 2100CR – Cleanroom Construction
- C. Section 13 2105CR – Cleanroom Construction Protocol
- D. Section 13 2110CR – Cleanroom Ceiling System
- E. Section 13 2120CR – Cleanroom Wall System
- F. Section 13 2130CR – Cleanroom Automatic Sliding Doors
- G. Section 13 2140CR – Cleanroom Chemical Fume Hood and Wet Processing Stations
- H. Division 21: Fire Suppression
- I. Division 22: Plumbing
- J. Division 23: HVAC
- K. Division 25: Cleanroom Controls
- L. Division 26: Electrical

#### 1.4 DESCRIPTION

- A. Specialty Gas Detection System:
  - 1. Provide gas detection system for specialty gases classified as toxic, highly-toxic, flammable, pyrophoric, and corrosive located in cylinder gas cabinets and at point of use tool locations.

2. TGMS shall include but is not limited to controllers and control enclosures; computer hardware, software, and peripherals; annunciation devices; conduit and wiring; emergency shutdown switches; global alarm relays; communications ports; integration to the building fire alarm system; and capabilities for remote monitoring and programming.
  3. The specialty gas detection system shall be capable of monitoring a minimum of 96 satellite gas detection sensors locations on the communication network. The system shall be expandable with the addition of network equipment in the future by the Owner.
- B. Oxygen Depletion Detection System:
1. Provide complete Oxygen (O<sub>2</sub>) depletion detection system at locations indicated in the drawings.
  2. Oxygen depletion systems shall include but are not limited to gas detection sensors, wiring, emergency shutdown switches, global alarm relays, communications ports, integration to the building fire alarm system, and capabilities for remote monitoring and programming.
- C. Basis of Design: The design for the gas detection system is a distributed network of gas detector transmitters residing on an open-protocol communication network with a central monitoring microprocessor based computer display panel. Acceptable open-protocol communications are IP, LonWorks and BacNet. This design shall meet the design intent in all aspects and shall be demonstrated for each requirement of this specification prior to acceptance by the Owner and Architect. This demonstration in the form of a written narrative of the systems shall be approved prior to the submittal process.

## 1.5 COORDINATION

- A. Work of this section requires close coordination with work of Divisions 22, 23 and 26 as well as installation of Owner furnished (OF) components and work specified in other sections. Sequence all work to ensure an orderly progress in the project without removal of previously installed work and so as to prevent damage to finishes and products.
- B. The exact sensing location of gas detectors at tool locations shall be carefully coordinated with Owner's equipment to ensure adequate detection of a gas leak based on the most probable location of tool gas leakage. The locations shall take into account the geometry of the tool and airflow patterns within the room and around the tool. In some cases, the best location of the sensor may be below the raised floor system. Contractor shall be responsible for coordinating this work with the Owner including necessary field investigation of existing tools at the Owner's facilities and any required testing of airflow patterns around tool in the operational cleanroom environment.

## 1.6 SUBMITTALS

- A. Materials List/Product Data: Submit complete materials list, including catalog data of all materials, equipment, and products for work specified in this section.
- B. Shop Drawings: Submit complete shop fabrication and installation drawings, including plans, elevations, sections, details, schedules, and 3-dimensional layouts (as necessary). Show relationship to adjoining materials and construction. Shop drawings shall depict final product design and installation. Shop drawings shall be prepared electronically and submitted in the form of reproducible or photocopies, prepared in standard Architectural drawing formats and scaled to defined dimensions.
- C. Sequence of Operations: Submit a complete written description for all sequence of operations for the gas detection system as a basis for testing and commissioning the systems.

- D. Testing Procedures: Submit a complete and comprehensive testing procedure to be followed to demonstrate proper operation of all components and sequence of operations for the gas detection systems.
- E. Operations/Maintenance Manuals: Submit under provisions of Division 1 "Closeout Procedures" for Owner's use, complete operating and maintenance manuals that describe proper operating procedures, maintenance and replacement schedules, component parts list, and factory representative contacts information for components and service.

## 1.7 QUALIFICATIONS

- A. Work in this Section shall be performed by a firm having a minimum five (5) years documented experience, and an established organization and production facilities including all tools, equipment and special machinery necessary for specializing in the fabrication and installation of the type of equipment required with skilled personnel, factory trained workmen and an experienced engineering department. Each shall have the demonstrated knowledge, ability and the proven capability to produce the specified equipment of the required quality and the proven capacity to complete an installation of this size and type within the required time limits.

## PART 2 PRODUCTS

### 2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - 1. Analytical Technologies Inc.
  - 2. Honeywell
  - 3. DOD Technologies Inc.
  - 4. Approved equal.

### 2.2 CONTROLLERS

- A. PLC Equipment: Modular in style with backplane bussing, comprising of processor modules, I/O modules, network and communications cards including Ethernet 10/100, Power Supplies, and auxiliary modules and components. Several processors can be mounted in one chassis and all modules are capable of removal and insertion under power without faulting the processor.
  - 1. Units monitor or control each input/output point; process information; execute commands from other control units, devices, and operator stations, and download or upload to operator stations.
  - 2. Provide stand-alone mode control functions for major pieces of equipment and system functionality regardless of network status. Functions shall include the following:
    - a. Global communications.
    - b. Discrete/digital, analog, and pulse input/output types.
    - c. Monitoring, controlling, or addressing data points.
    - d. Testing and development of control algorithms without disrupting field hardware and controlled environment.
  - 3. Logic Controller:
    - a. Tasks: 32 tasks support all event trigger tasks.
    - b. User memory: 1.5 Mbytes or greater.
    - c. Built-in communication ports: 1 port RS-232 serial.
    - d. Communication options: Ethernet IP, Control Net, DeviceNet, Modbus, Universal Remote I/O, serial.

- e. Connections: 128 over Ethernet IP.
  - f. Controller redundancy: Full redundancy support.
  - g. Native I/O: ControlLogix I/O.
  - h. Mounting: Chassis or DIN rail panel mount.
  - i. Programming Languages: Relay ladder, structured text, function block, and sequential function chart.
4. Digital I/O Modules:
- a. Chassis digital input and output modules that can support direct voltage interface to devices.
  - b. Individually isolated inputs or outputs.
  - c. Point-level status and output fault states.
  - d. Direct-connect or rack-optimized communications.
  - e. Field-side diagnostics.
  - f. Electronic fusing both internal and externally mounted.
5. Analog I/O Modules:
- a. Local chassis analog input and output modules to support voltage and or current interface to devices.
  - b. Individually isolated inputs or outputs.
  - c. On-board data alarming.
  - d. Direct connect or rack optimized communications.
  - e. Internal scaling to engineering units.
  - f. Real-time channel sampling.
  - g. IEEE 32-bit floating point or 16-bit integer data formats.
6. Ethernet IP Communications Module:
- a. Functions as an adapter for distributed I/O on remote Ethernet IP links.
  - b. Provide routing messages to devices on other networks.
  - c. Communications Rate 10/100 Mbps
  - d. Connections: Supports a maximum of 64 TCP/IP 10/100 connections, 5000 messages per second. Multiple cards per rack are allowed.

### 2.3 GRAPHICAL USER INTERFACE (GUI)

- A. Data Display and Programming:
- 1. Display and programming shall be through a color touchscreen, graphical user interface panel. Minimum size shall be 15-inch. Display shall provide main alarm screen indicated the status and level of all monitored gases and include layered graphics to allow user to select individual gas detection devices for monitoring and programming.
  - 2. Manufacturer: Allen-Bradley model PanelView Plus 1500 or approved equal.
- B. Power supply:
- 1. Voltage input shall be self regulating between 90 and 264 VAC.
  - 2. Provide uninterruptable power supply (UPS) battery backup module to operate the system for up to 30 minutes.
- C. Communication Ports:
- 1. Communication shall be on LONworks or BACnet network.
- D. Enclosure: The GUI shall be mounted in a NEMA 4x wall mount enclosure, color white, with keyed locked cylinder.

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## 2.4 COMPUTER HARDWARE, SOFTWARE, AND PERIPHERALS

- A. Workstation Personal Computer (PC): Tower PC with minimum Dual Core processor with 2 GB RAM (minimum), 250 GB hard drive (minimum), DVD-R/CDRW optical drive, 256 MB graphics card (minimum), internal PCI modem, internal 10/100 PCI Ethernet card.
- B. Workstation Monitor: 22-inch (550 mm)(minimum size) LCD display monitor with built-in audio speakers.
- C. Software:
  - 1. Data Visualization Software (DVS): Basis of Design: Wonderware software.
  - 2. LonMaker for Windows (when LONworks communication based system is utilized).
  - 3. PC Anywhere host/remote.
  - 4. MS Office 2007 suite.
- D. Printer: Desktop color laser printer for report printing.
- E. Uninterruptable Power Supply (UPS): UPS sized to provide 30 minute of PC and monitor run-time during loss of electrical power.

## 2.5 NETWORK GAS SENSORS AND TRANSMITTERS

- A. Specialty gas sensors and transmitters for specialty gases are to be furnished in the future by the Owner based upon specific requirements for Cleanroom tools and processes. The following requirements shall be used as a basis of design for the TGMS system.
- B. The gas transmitters shall be provided to monitor ambient gas concentration of the monitored gas.
- C. Sensor Location:
  - 1. Specialty Gases: (To be provide by Owner upon Cleanroom tool installation)
    - a. The sensors shall be placed at the following locations:
      - 1). One sensor on the wall inside the gas storage cabinet or in the exhaust air duct immediately above the gas cabinet.
      - 2). One sensor on or adjacent to the gas cabinet (outside cabinet) inside the gas cylinder room.
      - 3). One sensor per tool area location within the Cleanroom. The sensor(s) shall be placed within immediate proximity of point of use connection.
    - b. Provide cabling in conduit to transmitter location as required.
  - 2. Oxygen Depletion:
    - a. The sensors shall be placed at the following locations: Wall-mounted sensors on the room wall at 12-inch above finished floor and within 12-inch of finished ceiling.
- D. Sensor Transmitter:
  - 1. General: Universal transmitter platform with wall-mounted enclosure designed for replaceable and exchangeable sensor cartridge.
  - 2. Enclosure: Painted steel case with mounting holes on rear chassis. Design shall be immune to RF interference.
  - 3. Power: 36 – 57 vdc power-over-Ethernet (POE) communication and power platform.
  - 4. Interface: Keypad touch button membrane interface and remote Web Browser interface. Password protected menu levels.
  - 5. Display: Bright LED status lights and backlit alpha-numeric LCD display.

6. Outputs: Isolated 0-22mA analog output. RJ45 connector port for shielded CAT 5 network cable. Discrete relay outputs for alarm and fault.
  7. Communication: Modbus/TCP Ethernet connectivity.
  8. Sample Pump: Extractive pump system and sample tubing to sample gas up to 100-feet away and exhaust sample gas up to 100-feet away. Pump flow rate shall be self-regulating and provide a sampling transport time of 30 seconds or less. Pump system shall have a minimum expected life span of 2-years of continuous operation.
  9. Event logging to review sensor history.
  10. Basis of Design: Honeywell Analytics Midas gas monitoring system.
- E. Sensor Cartridge:
1. Gas sensor cartridge shall use specific gas type sensor technology to measure the gas level in ppm.
  2. Gas sensor cartridge shall be replaceable and exchangeable for transmitter and provide auto-calibration upon installation.

## 2.6 ACCESSORIES

- A. Alarm LED Lamp Module:
1. Description: Modular vertical column indicating light system to allow up to five (5) lamp units with a base power unit. Provide three (3) lamps modules – amber, red and blue along with base unit and wall mount bracket.
  2. Basis of Design: Federal Signal Litestak Model LSLD with LSB base or approved equal:
  3. Features:
    - a. Multiple LED cluster reflected form double parabolic inner reflector.
    - b. 24 vdc or 120 vac/60 Hz.
    - c. 1000,000 hour light source life.
    - d. NEMA 1 enclosure.
    - e. Selectable steady burn or flash mode.
    - f. Shatter resistant polycarbonate lens.
    - g. UL listed.
    - h. Dimensions: 4-inch diameter x 3-1/4-inch high nominal each lamp/base.
  4. Accessories:
    - a. Wall Mount Bracket: Heavy-duty construction of cast aluminum sealed with powder coat paint (color white) for mounting to outside corner or walls with electrical back box.
  5. Hazardous Locations: Provide Class 1 Division 2 Type 4X enclosure multi-color, LED, single-high status indicator to provide amber and red colors from a single light source; surface mounted; selectable flash patterns; 24 vdc or 120vac/60 Hz. Manufacturer: Federal Signal model USIX or approved equal.
- B. Alarm Sound Module:
1. Description: Microprocessor based audible signaling device compatible with modular vertical column indicating light system.
  2. Basis of Design: Federal Signal Litestak Sound Module Model LSS or approved equal:
  3. Features:
    - a. Solid-state circuitry.
    - b. 24 vdc or 120 vac/60 Hz.
    - c. Selectable one of 18 tones. Coordinate uniform tone selection with Owner's representative.
    - d. Produces 59 dB to 69 dB @ 3-meter (10-feet).
    - e. NEMA 1 enclosure
    - f. UL listed.



4. Hazardous Locations: Provide Class 1 Division 2 Type 4X electro-mechanical vibrations horn; surface mounted; selectable coded or sustained tones; 120vac/60 Hz. Manufacturer: Federal Signal Vibratone model 350WBX or approved equal.
- C. Ethernet Switch: Rack-mounted, managed stackable power-over-Ethernet (POE) switch, 48-port, auto-sensing 10/100 ports. Provide two switches to meet system design capacity for sensors. 100 – 240vac/60 Hz universal input power.

## **2.7 WIRING**

- A. Provide wiring from sensor/transmitters to network as required.
- B. Provide dedicated electrical supply circuit for gas detection devices and alarm system components.
- C. All wiring shall be inside dedicated metal conduit. Conduit shall be painted with a unique color such as white, blue, or other (Red color not allowed). Conduit shall be labeled “Warning - TGMS” at intervals not exceeding 10-feet.

## **PART 3 EXECUTION**

### **3.1 SITE CONDITIONS**

- A. Prior to installation of the work of this Section, carefully inspect the installed work specified in other sections and verify that all such work is complete to the point where this installation may properly commence.
- B. Verify that all work has been installed in complete accordance with the original design, received submittals, and the manufacturer's recommendations.
- C. In the event of discrepancy, immediately notify the Architect. Do not proceed with installation in areas of discrepancy until all such discrepancies have been fully resolved.

### **3.2 INSTALLATION**

- A. Coordinate location and alignment of sensors and equipment with other trades and Owner furnished equipment.
- B. Coordinate power requirements with Division 26. Extend power from designated sources as required to provide power to equipment locations.
- C. Install all equipment in accordance with applicable codes and regulations, accepted shop drawings, and as necessary for a complete operating system.
- D. All power and signal wiring shall be installed in EMT conduit. All conduits shall be uniquely identified by solid color (other than red) and/or permanent identification labels affixed to the conduit at intervals not exceeding 3- meter (10-feet). Labels shall indicate gas detection system.

### **3.3 SYSTEM TESTING**

1. Test system operation and performance. A complete operational testing procedure shall be performed to demonstrate proper performance of all components and sequence of operations for the systems.

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2. Testing procedures shall be witnessed by the Commissioning Agent and Owner's designated representatives. Provide written notification to the Architect of testing dates and times a minimum of ten (10) working days prior to test.
  3. Sensor exposure to each gas during test should not exceed TLV limits. Each sensor shall be tested with approved gases or exposure shall be simulated to demonstrate system response.
  4. Repair or remove and replace defective work or components.
  5. Provide a copy of the completed testing procedures with the O&M's.

**END OF SECTION 25 2005CR**

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## SECTION 25 3001CR

### GENERAL INSTRUMENTATION REQUIREMENTS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Refer to Section 20 0000CR - General HVAC Requirements
- B. Refer to Section 25 0993CR - Control Sequences
- C. Refer to Section 25 0192CR - Instrument Calibration
- D. Refer to Section 25 0553CR - Instrumentation Tagging
- E. Refer to Section 25 1316CR - Control Panels
- F. Refer to Section 25 3003CR - Instrument Device Specifications
- G. Refer to Section 25 3526CR - Pneumatic Piping Tubing
- H. Refer to Section 26 0519 - Low-Voltage Electrical Power Conductors and Cables
- I. Refer to Section 26 0533 - Raceways and Boxes for Electrical Systems

##### 1.2 REFERENCE

- A. The Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 DESCRIPTION

- A. This Section defines general instrument installation requirements related to instrumentation and control valves in this Contract. Related sections to this Section further define specific instrumentation aspects.

##### 1.4 DEFINITIONS

- A. Field: Areas where production occur (e.g.; plant floor) exclusive of control rooms, administration areas, and welfare areas.
- B. Instrument: Device used directly or indirectly to measure, monitor, record or control variable. Term includes primary elements, transmitters, analyzers, controllers, recorders, transducers, final control elements, signal converting or conditioning devices, computing devices, and electrical devices such as annunciators, switches, and push-buttons. Term does not apply to parts (e.g.; receiver bellows or resistor) that are internal components of instrument.

- C. Instrument Piping/Tubing: Piping, tubing, tubing bundles, tube track and channel, valves, air supply filters and regulators, fittings, supports, hardware, and supplies required for Impulse Lines and Process Connections, for Pneumatic Signals and Interconnections, and for Air Supplies shall constitute instrument piping/tubing system.
- D. PCS - Process Control System: Control systems primarily used for production facilities. PCS may include Programmable Logic Controllers (PLC), Distributed Control Systems (DCS), or Stand-alone Single Loop Controllers (SSLC).
- E. Remote Mounted Instruments: Instruments or components of instruments, which are not mounted directly into process or utility piping systems. (e.g., pressure instruments, remote transmitters/totalizers, and analyzers.)
  - 1. Actuator: Control device to provide motion of valve or damper in response to control signal.
  - 2. Analog: Continuously variable state over stated range of values.
  - 3. AI: Analog Input.
  - 4. AO: Analog Output.
  - 5. Discrete: Binary or digital state.
  - 6. DI: Discrete Input.
  - 7. DO: Discrete Output.
  - 8. FC: Fail Closed position of control device or actuator. Device moves to closed position on loss of control signal or energy source.
  - 9. FO: Fail Open position of control device or actuator. Device moves to open position on loss of control signal or energy source.
  - 10. I/P: Current to pneumatic transducer.
  - 11. Modulating: Movement of control device through entire range of values proportional to infinitely variable input value.
  - 12. P/I: Pneumatic to current transducer.
  - 13. PID: Proportional - Integral - Derivative control, control mode with continuous correction of final controlled output element versus input signal based on proportional error, its time history (reset/integral), and rate at which its changing (derivative/rate).

## 1.5 GENERAL

- A. Control Room and Field Instruments:
  - 1. Furnish all instruments indicated on P&ID's as system inputs/outputs and as required to accomplish control sequences per section 25 0993 – Control Sequences in accordance with Section 25 3003 - Process Instrumentation Device Specifications.
  - 2. Instruments shall have factory applied prime and final finish, unless otherwise noted.
- B. Receipt and Inspection of Instrumentation Equipment:
  - 1. Receive and inspect instruments and equipment furnished for conformance with Specifications and in accordance with Division 01.
- C. Prefabricated Equipment:
  - 1. Inspect Prefabricated Equipment, (i.e.; control panels), for damage and, if furnished by others, inform Owner of damage found.

2. Remove shipping stops.
  3. Re-install devices (i.e.; controller equipment) removed for shipment and inspect completed assembly for compliance with Documents and manufacturer's recommended installation practice.
- D. Instrument Storage:
1. Store Instruments and Equipment, including those furnished by others, in accordance with Division 01.
  2. Store Instruments in accordance with manufacturer's recommendations. In no case shall storage or transportation environment be colder than 0°F or hotter than 120°F.
- E. Spool Pieces:
1. Contractor will not be required to furnish temporary spool pieces, blanks, inserts, or like items for line or equipment cleaning and testing unless such are specifically defined in Contract Documents.

## 1.6 SUBMITTALS

- A. Refer to Section 20 0000CR - General HVAC Requirements.
- B. Calibration Records:
1. Provide Calibration Records for Instruments in accordance with Section 25 0192CR - Instrument Calibration.

## PART 2 PRODUCTS

### 2.1 INSTRUMENT MOUNTING

- A. In-Line Pipe Mounting:
1. Manufacturers: Foxboro or approved alternate.
  2. In-line pipe mounting stand shall be saddle type with leveling mechanism for leveling the vertical support pipe in the same plane as the pipe. Leveling mechanism shall allow support to be raised or lowered on each end 1/4" minimum. Saddle shall be cast iron and sized to be mounted on the pipeline.
- B. Snubbers:
1. Snubbers shall be used to dampen pressure noise in piping systems due to the pulsations of pumps. Snubbers shall be rated for 1500 psig and expected process temperature. Brass snubbers may be used only if piping is copper, carbon steel, or cast iron. Otherwise, use same material as pipe and approved for process exposure.
- C. Siphon Pigtail:
1. Pigtails shall be carbon steel and shall have 1/2" connections or be provided with reducers/enlargers to match the process take-off and pressure instrument measurement port.
    - a. Maximum Pressure/Temperature: 2000 psi @ 650°F or  
1000 psi @ 900°F

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## 2.2 ELECTRICAL

- A. 120 VAC Instrument Power Wiring:
  - 1. Power wiring shall be stranded copper wire with THHN insulation and shall be sized for load with #12 AWG being minimum size.
  
- B. 120 VAC Discrete Signal Wiring:
  - 1. Discrete signal wiring shall be #14 AWG stranded copper wire with THHN insulation unless otherwise stated on drawings.
  
- C. 24 VDC Discrete Signal Wiring:
  - 1. Discrete signal wiring shall be #14 AWG stranded copper wire with THHN insulation unless otherwise stated on drawings.
  
- D. Analog Signal Wiring:
  - 1. Manufacturer: Belden, Dekoron, Alpha or approved alternate.
  - 2. Analog instrument signal wiring shall be concentric stranded, tinned copper, twisted, shielded pair with shield drain wire.
    - a. Wire Size: #16 AWG
    - b. Insulation: Polyethylene
    - c. Jacket: PVC or Teflon (Teflon is required for plenum installed cable)
    - d. Jacket Color: Black unless otherwise noted.
    - e. Shield Material: Aluminum
    - f. Capacitance: 30pF max per ft.
    - g. Voltage Rating: 300V unless routed to electrical equipment (motor control centers, switchgear, etc.) in which case voltage rating shall be greater than voltage rating of equipment.
    - h. Temperature Rating: 80°C minimum
  - 3. Cable installed in cable tray shall be rated for cable tray (TC) installation.
  
- E. RTD Signal Wiring:
  - 1. Manufacturer: Belden, Dekoron, Alpha or approved alternate.
  - 2. RTD signal wiring shall be concentric stranded, tinned copper twisted / shielded conductor with shield drain wire.
    - a. Wire Size: #18 AWG minimum
    - b. Insulation: Polyethylene
    - c. Jacket: PVC or Teflon (Teflon is required for plenum installed cables)
    - d. Jacket Color: Black
    - e. Shield Material: Aluminum
    - f. Capacitance: 60pF max per foot
    - g. Voltage Rating: 300V unless routed to electrical equipment in which case voltage rating shall be greater than voltage rating of equipment.
    - h. Temperature Rating: 80°C minimum

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3. Cable installed in cable tray shall be rated for cable tray (TC) installation.
    - a. Wire Size: #16 AWG minimum
    - b. Insulation: PVC, teflon, or polyethylene
    - c. Jacket: PVC or teflon
    - d. Shield Material: Aluminum
    - e. Temperature Rating: 80°C minimum
  4. Cable installed in cable tray shall be rated for cable tray (TC) installation.
- F. Thermocouple Signal Wiring:
1. Manufacturer: Belden, Omega or approved alternate
  2. Thermocouple signal wiring shall be solid, shielded two conductor with shield drain wire. Wire colors shall be per ANSI guidelines.
  3. Material of Construction: Same as associated Thermocouple
    - a. Wire Size: #16 AWG
    - b. Insulation: PVC, teflon or polyethylene
    - c. Jacket: PVC or teflon
    - d. Shield Material: Aluminum
    - e. Temperature Rating: 80°C minimum
  4. Cable installed in cable tray shall be rated for cable tray (TC) installation.
- G. Instrument Specific Cable:
1. Instrument specific cable for connecting sensors to converters / transmitters shall be in accordance with manufacturer's recommendations.
- H. Communication Cable:
1. Cable not concealed in raceway shall have UL Listed plenum rated insulation.
  2. Interior LAN Communication Cable: Interior Copper LAN cable shall meet or exceed all requirements of Category 6 cable as specified in TIA/EIA-568-B.2.
- I. Terminal Blocks:
1. Manufacturers: Allen Bradley, Entrelec, Phoenix Contact, Weidmuller or approved alternate.
  2. Terminal blocks shall be IEC style double density feed through finger safe type rated for 15A, UL listed, DIN style rail mounted, and capable of accepting #22 to #12 AWG wire. Insulation shall be rated for 0°C to 85°C continuous operating temperature. Voltage rating shall be greater than or equal to voltage rating of cables served by terminal block.
  3. Control system output terminal blocks shall be same construction as IEC style single density terminal blocks with interconnecting fuses. Blocks shall include either neon or LED blown fuse indicator, which is illuminated upon fuse failure. Replacement of fuse shall not require removal of block's wires or removal of block from mounting device. Fuse shall be sized for 175% of expected load with 0 diversity unless otherwise noted. Controller discrete outputs with integral fused outputs do not require fused terminal blocks.
- J. Panel Power Terminal Blocks:
1. Manufacturers: Allen Bradley, Entrelec, Phoenix Contact, Weidmuller or approved alternate.
  2. Terminal blocks shall be IEC style single density feed through finger safe type rated for 20A/600 VAC, UL listed, DIN style rail mounted, and capable of accepting

- #18 to #10 AWG wire. Insulation shall be rated for 90°C continuous operating temperature.
3. Terminal blocks shall be high density single height style feed through finger safe type, UL listed, rail mounted and capable of accepting #22 to #12 AWG wire. Insulation shall be rated for 80°C continuous operating temperature.
  4. Power requirements are as follows:

<u>Use</u>	<u>Fuse</u>	<u>Current</u>	<u>Voltage</u>
Analog I/O and Discrete Input	No	15A	300V or rating of served cable whichever is greater
Discrete	Yes	15A	300V or rating of served cable whichever is greater
Power	Yes	20A	600V

5. Fuses, if required, shall have neon or LED style blown fuse indicators. Fuses shall be rated for 175% of expected load unless otherwise noted.

<u>I/O Type</u>	<u>Voltage</u>	<u>Fused</u>	<u>Manufacturer</u>	<u>Model Number</u>
Discrete In	300	No	Allen Bradley	1492H1
Discrete Out	300	No	Allen Bradley	1492H1
Discrete Out	300	Yes	Allen Bradley	1492H5
Analog In	300	No	Allen Bradley	1492H1
Analog Out	300	No	Allen Bradley	1492H1
Power	600	No	Allen Bradley	1492CA1

K. Thermocouple Terminal Blocks:

1. Manufacturers: Allen Bradley, Phoenix Contact, Omega Engineering or approved alternate.
2. Terminal blocks shall be IEC style feed through, finger safe type, DIN style rail mounted, and capable of accepting #24 to #14 AWG wire. Insulation shall be rated for 80°C continuous operating temperature. Voltage shall be greater than or equal to voltage rating of cable served by terminal block. Interconnecting bar shall be of same material as thermocouple or extension wire. Each block shall accept both circuit sides and be clearly marked with wire material.

L. Alternate to Dedicated Thermocouple Block Type:

1. Manufacturer: Entrelec type MTL6.
2. Terminal blocks shall be IEC style finger safe type constructed to allow thermocouple/extension wire to complete circuit without an interconnecting bar. Block shall include shield conductor.

M. DIN Rail Circuit Breakers:

1. Manufacturer: Allen Bradley, Entrelec or approved alternate.
2. Circuit breakers for switching panel power shall be magnetic, energy limiting, handle style, single-pole finger safe type DIN rail mounted with visual fault trip indication and capable of accepting #16 to #6 AWG wire.



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- N. Dropping Resistors:
1. Voltage dropping resistors used to obtain 1 to 5 volt input signal in 24 VDC powered 420mA loops shall be 250 ohms, 5 watts, with 1/10 of 1 percent tolerance.
- O. Power Supplies:
1. Manufacturer: Acopian, Sola, Lambda, Idec or approved alternate.
  2. Regulated type with short circuit protection shall be used for analog control loop power.
    - a. Input Power: 105 to 125 VAC 60 Hz
    - b. Output Power: 24 VDC unless otherwise noted with error  $\pm 1.5\%$ . Contractor shall select current range to provide 100% spare capacity for initial installation.
    - c. Regulation Error: Line:  $\pm 0.07\%$   
Load:  $\pm 0.12\%$
    - d. Output Polarity: Negative terminal tied to earth ground.
    - e. Mounting: Direct to panel or bracket. Socket mounting is not allowed.
    - f. Temperature Coefficient: Error  $< 0.05\%/^{\circ}\text{C}$
    - g. Operating Temperature:  $32^{\circ}\text{F}$  to  $120^{\circ}\text{F}$  ( $0^{\circ}\text{C}$  to  $50^{\circ}\text{C}$ )
- P. DIN Rail Mounted Power Supplies:
1. Manufacturer: Phoenix Contact, Sola, Lambda, Idec, or approved alternate.
  2. Regulated type with short circuit protection shall be used for analog control loop power.
    - a. Input Power: 105 to 125 VAC 60 Hz
    - b. Output Power: 24 VDC unless otherwise noted with error  $< 1.5\%$ . Contractor shall select current range to provide 100% spare capacity for initial installation.
    - c. Regulation Error: Line:  $< 0.07\%$   
Load:  $< 0.12\%$
    - d. Residual Ripple:  $< 25\text{ mV}$
    - e. Residual Ripple:  $< 25\text{ mV}$
    - f. Operating Temperature:  $32^{\circ}\text{F}$  to  $120^{\circ}\text{F}$  ( $0^{\circ}\text{C}$  to  $50^{\circ}\text{C}$ )
- Q. Uninterruptible Power Supply (Server Rack):
1. Provide rack mounted dual/double conversion UPS for backup power for Server Rack. UPS shall maintain power to Server Rack upon loss of normal power and until emergency power supply is brought on line.
  2. Select UPS for minimum of 20 minutes backup time for load connected. This will allow emergency power sources to come on line.
  3. UPS shall be provided with power management software and communication cable for interfacing with Server.
  4. Upon sensing loss of normal power, transfer time shall be 8 milliseconds maximum.
  5. Operating Parameters:
    - a. Operating Temperature: 0 to  $40^{\circ}\text{C}$
    - b. Relative Humidity: 0 to 95% RH, non-condensing

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- c. Recharge Time: 8 hours, typical
- R. PLC Uninterruptible Power Supply
1. Manufacturers: Siemens, Sola, Phoenix Contact or approved equal.
  2. Provide DIN rail mount UPS for backup power for PLC's and remote I/O cabinets required for control of emergency powered equipment. UPS shall maintain control upon loss of normal power and until emergency power supply is brought on line.
  3. Select UPS for minimum of 5 minutes backup time for load connected. This will allow emergency power sources to come on line and provide backup power to emergency powered equipment.
  4. Upon sensing loss of normal power, transfer time shall be 8 milliseconds maximum.
  5. UPS shall include N.O./N.C. form "C" contact. Relay contact shall signal for "Low Battery" alarm.
  6. Operating Parameters:
    - a. Operating Temperature: 0 to 40°C
    - b. Relative Humidity: 0 to 95% RH, non-condensing
    - c. Recharge Time: 8 hours, typical
- S. Signal Conditioners:
1. Manufacturers: Acromag, Action Instruments, Absolute Process Instruments or approved alternate.
  2. Signal Isolators shall be DC Input Field Configurable type and shall be surface or DIN rail mounted and use 120 VAC 60 Hz input power. Contractor shall select signal conditioner to required signal interface between systems.
- T. Current/Power Conditioners:
1. Manufacturer: Sola or approved alternate.
  2. Current conditioners shall produce 120 VAC 60 Hz true sine waveform with 120 VAC 60 Hz input.
    - a. Input Voltage: 120 VAC 60 Hz nominal  $\pm$  3% input variation
    - b. Output Voltage: 120 VAC 60 Hz error  $\pm$  1%
    - c. Noise Rejection: > 30 dB common mode  
> 30 dB transverse mode
    - d. Efficiency: > 85% at full load
    - e. Operating Temperature: 32°F to 120°F (0°C to 50°C)
- U. 120 VAC General Purpose Relays:
1. Manufacturers: Allen Bradley, IDEC, Potter & Brumfield, Square D or approved alternate.
  2. General purpose control relays shall be miniature type for control logic switching.
    - a. Operating Temperature: 32° to 120°F (0° to 50°C)
    - b. Coil Voltage: 120 VAC / 60 Hz
    - c. Dielectric Withstand Voltage: 1000 V for 1 minute
    - d. Mechanical Switch Operating Life: 5,000,000 cycles
    - e. Contact Material: Silver Cadmium Oxide
    - f. Contact Rating: 10 Amps continuous at 120 VAC/60 Hz or 24 VDC

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- g. Contact Type: Doublethrow (Normally Open and Normally Closed with same common)
- h. Relay Dust Cover: Polycarbonate or equal.
- i. Socket Style: Rectangular Blade type plugin terminals (Not Octal)
- j. Socket Wire Connection: Screw
- k. Socket Mounting: DIN style rail
3. Contractor shall select contact quantity to best meet required control function, 2 sets minimum, unless otherwise noted.
- V. 24 VDC General Purpose Relays:
1. Manufacturers: IDEC type RH2BU, Potter Brumfield type KUP11D15-24, Allen Bradley Type 700-HB or approved alternate.
2. Pilot control relays shall be miniature type for control logic switching.
- a. Operating Temperature: 32° to 120°F (0° to 50°C)
- b. Coil Voltage: 24 VDC with maximum current burden of 50 milliamps
- c. Dielectric Withstand Voltage: 1000 V for 1 minute
- d. Mechanical Switch Operating Life: 5,000,000 cycles
- e. Contact Material: Silver Cadmium Oxide
- f. Contact Rating: 10 Amps continuous at 120 VAC/ 60 Hz or at 24 VDC
- g. Contact Type: Doublethrow (Normally Open and Normally Closed with same common)
- h. Relay Dust Cover: Polycarbonate or equal.
- i. Socket Style: Rectangular Blade type plugin terminals (Not Octal)
- j. Socket Wire Connection: Screw
- k. Socket Mounting: DIN style rail
3. Contractor shall select contact quantity to best meet required control function 2 sets minimum, unless otherwise noted.
- W. Shunt Diodes:
1. Shunt diodes shall be 1N4005 or equal.
- X. Timed Delay Relays:
1. Manufacturers: Allen Bradley, IDEC, Square D, or approved alternate.
2. Electronic timed delay type control relays shall be used for time delay logic switching.
- a. Operating Temperature: 32° to 120°F (0° to 50°C)
- b. Coil Voltage: 120VAC / 60 Hz
- c. Dielectric Withstand Voltage: 1000 V for 1 minute
- d. Mechanical Switch Operating Life: 1,000,000 cycles
- e. Contact Material: Silver Cadmium Oxide
- f. Contact Rating: 10 Amps continuous at 120 VAC/ 60 Hz or at 24 VDC

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- g. Contact Type: Doublethrow (Normally Open and Normally Closed with same common)
- h. Relay Dust Cover: Polycarbonate or equal.
- i. Socket Style: Rectangular Blade type plugin terminals (Not Octal)
- j. Socket Wire Connection: Screw
- k. Socket Mounting: DIN style rail
3. Contractor shall select contact quantity to best meet required control function, 2 sets minimum, unless otherwise noted.
- Y. Master Control Relays:
1. Manufacturer and Type: Allen Bradley, Square D, or approved alternate.
2. Heavy-duty control relays for switching power to outputs "OFF" when Emergency Stop button is activated shall be used to deenergize controller output when emergency stop is initiated.
- a. Operating Temperature: 32° to 104°F (0° to 40°C)
- b. Coil Voltage: 120VAC / 60 Hz
- c. Dielectric Withstand Voltage: 1000 V for 1 minute
- d. Mechanical Switch Operating Life: 1,000,000 cycles
- e. Contact Material: Silver Cadmium Oxide
- f. Contact Rating: 20 Amps continuous at 120 VAC/ 60 Hz or 24 VDC
- g. Contact Type: Doublethrow (Normally Open and Normally Closed with same common)
3. Contractor shall select contact quantity to best meet required control function, 2 sets minimum, unless otherwise noted.
- Z. Push Buttons:
1. Manufacturer and Type: Allen Bradley, IDEC, Square D, or approved alternate.
2. Heavy-duty nonilluminated flush push buttons with same or better NEMA rating as panel enclosure shall be used for control panel operator interface switching.
- a. Contact Type: Contractor shall select based on drawings or as required to meet intended control function.
- b. Voltage: 120 VAC/60 Hz or 24 VDC unless otherwise noted. (Contractor to match to required application.)
- c. Current: 5 amp continuous.
- d. Mechanical Switch Actuation Life: 500,000 cycles minimum.
- e. Dielectric Strength: 2000 V for 1 minute.
- f. Vibration: 6 G minimum without false trip or switch damage.
- g. Shock: 1/2 cycle sine wave for 8 milliseconds without switch actuation.
- AA. Pilot Lights:
1. Manufacturer and Type: Allen Bradley Bulletin 800T, IDEC, Square D, or approved alternate.

2. Heavy-duty illuminating pilot lights with same NEMA rating as panel enclosure shall be used for operator interface indication. Include power module to match control system voltage to lamp.
    - a. Lamp Type: Incandescent, High Visibility LED, or Diode
    - b. Voltage: 120 VAC/60 Hz
    - c. Voltage: 24 VDC
  3. Pilot lights shall include push-to-test feature.
- BB. Pneumatic Thread Sealant:
1. Thread sealant shall be teflon based paste for applying thread sealant by brush. Products shall be nontoxic, chemically inert, nonhardening rated for 250°F to 500°F, meeting Military Specification T27730A.
  2. Teflon tapes or cords are not allowed.
  3. Thread sealant shall be PTFE Teflon tape, 0.0035" thickness Military Specification T27730A, tape for fitting thread sealant.

### 2.3 ACCESS CONTROL

- A. Card Access and Door Control Panels
1. The Access Control Panel shall be listed for Underwriters Laboratory (UL):
    - a. UL294 (Access Control System)
    - b. UL1076 (Proprietary Alarm Monitoring System)
  2. Provide apS power supplies as necessary for 4 hours of backup minimum.
- B. Card Reader
1. Where indicated on project drawings, this Contractor shall provide and install proximity type card readers.
  2. Agency Approvals and Compliance:
    - a. The reader shall be FCC Part 15, UL 294 listed, and CE approved.
    - b. The reader shall support GE Proximity with F/2F intelligent supervision, HID Proximity (including HID Corporate 1000), MIFARE CSN ISO 14443A, MIFARE/DESFire CSN, and Vicinity CSN ISO 15693 communication protocols for physical access credentials (cards, key fobs, and adhesive-patch technologies).
  3. Color: Charcoal
  4. Construction: The reader shall be sealed and compliant with UL-approved rating for indoor and outdoor applications.
  5. All card readers shall be HID Proximity Reader Type.
- C. Access Cards
1. Provide 100 access cards.
- D. Cable Types by Use
1. For all access control doors, this contractor shall provide and install required cable.
  2. Follow manufacturer's recommendations for all systems cabling.
  3. Cable shall be CMP rated for installation in ceiling plenum.
  4. The contractor shall provide a 10-foot service loop of cable slack, neatly secured in accessible ceiling above each door.

5. Cable for card reader doors shall be an 'All-in-one' bundled Belden #658AFS or Convergent #725116, or pre-approved equal.

## **2.4 ELECTRONIC VIDEO SURVEILLANCE**

- A. IP Video Cameras
  1. Interior Day/Night Fixed dome. Camera shall be Sony SNC-DF80N PoE powered Single Cat 5E Connection.
- B. Power Cabline
  1. Provide power cabling from power supply. Cable shall be sized to handle camera, heater, and blower and shall be adjusted to accommodate for voltage drop (18 gauge minimum).

## **PART 3 EXECUTION**

### **3.1 GENERAL**

- A. Frequently clean installation and termination debris from project. This includes, but not limited to, instrument shipping protective devices, cable termination debris, tubing termination debris, etc.

### **3.2 FIRE STOPPING**

- A. Fire stopping of openings between floors, fire-rated walls, and smoke-rated walls, created by others for this contractor to pass cable through, shall be the responsibility of this contractor. Sealing material and application of this material shall be accomplished in such a manner that is acceptable to the local fire and building authorities having jurisdiction over this work.
- B. Any openings created by or for Contractor and left unused shall be sealed up as part of this work.

### **3.3 INSTRUMENT INSTALLATION**

- A. Install instruments as noted in accordance with Instrument Installation Details. If installation detail is not provided for instrument, follow Owner or manufacturer's instructions.
- B. Ensure that proper connections are provided in process lines for instrument connections.
- C. Install instruments which could be damaged during line or vessel cleaning or pressure testing, i.e.: orifice plates, turbine meters, positive displacement meters, pitot tubes, and pressure gauges, into piping system or vessels only after cleaning and testing is complete.
- D. Repair or replace to Owner's satisfaction equipment for which this Contractor is responsible which is damaged during course of Contract.

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- E. Sloping of Impulse Lines:
1. Run gas filled instrument impulse lines with slope, not less than 1/4" per 12" of horizontal run, downward from instrument to process connection unless otherwise noted.
  2. Run liquid filled instrument impulse lines run with slope, not less than 1/4" per 12" of horizontal run, upward from instrument to process connection unless otherwise noted.
- F. Miscellaneous Pressure Instruments:
1. Install screened vents facing downward.
  2. Protect instrument capillary tubing from stress and from contact with other equipment by installation in channel supports. Coil excess capillary into 6" to 9" coils and secure with nylon tiewraps.
- G. Vent Fittings:
1. Provide screened vent fittings for threaded vents of instruments, which are not connected to process or exposed to ambient environment conditions. These shall not be sintered filters.
- H. Snubbers:
1. Provide snubbers on pressure switches and pressure gauges located at pump discharge.
- I. Siphon Pigtail:
1. Provide siphon pigtails on steam service pressure instruments, which are to be mounted locally to piping system.
- J. Mounting:
1. Provide mounting and supports for remote mounted instruments in accordance with instrument installation details.
  2. Wall, ceiling, and building steel instrument supports are preferred for mounting remote mounted instruments. Use pipe stands for instrument supports when walls, ceilings or building steel are not within approximately 20' from process connection.
  3. Mount remote mounted instruments on pipestands with tops at 4'6" above grade level. Deviations from this requirement must be approved by Owner.
  4. Do not use process piping to support instruments. This is not in reference to inline components.
  5. Do not use process piping to support instruments which are not specified to withstand vibration with less than 0.3% error per g of acceleration or specified to meet SAMA PMC 31,1, Level 2. This is not in reference to inline components. Mount pressure instrumentation, meeting these specifications, on process piping with diaphragm perpendicular to piping centerline.
  6. Do not use hand rails to support instruments or equipment.
- K. Process Connections:
1. Provide materials required to complete instrument process connections, sensing lines, and sensor installations in accordance with installation details. This shall include required:
    - a. Piping

- b. Tubing
  - c. Fittings
  - d. Isolation Manifolds
  - e. Hardware and Supports
  - f. Valves After First TakeOff Valve
- 2. Process wetted materials shall meet or exceed corrosion, pressure, and temperature requirements of process. Be aware that construction and design of some instruments requires better corrosion, pressure, and temperature ratings than is required by piping or vessel and shall assure that these requirements are satisfied; with consideration that impulse line connected instruments may operate at lower temperature than process.
  - 3. Provide other items required to complete instrumentation installation.
- L. Thread Sealant:
- 1. Provide thread sealant when assembling threaded type connections. Apply so that no thread sealant will be intrapped inside piping or pneumatic systems.
- M. Rivets:
- 1. Do not use rivets for fastening or installation of instruments.

### **3.4 INSTRUMENT TAGGING**

- A. Provide instrument tagging in accordance with Section 25 0553CR - Instrumentation Tagging.

### **3.5 ELECTRICAL**

- A. Install instrument electrical systems in accordance with requirements of NEC, Local Electrical Codes, Electrical Hazard Classification, housekeeping requirements, and corrosion resistance requirements for location.
- B. Install and connect instrumentation wiring to I/O terminations inside Motor Control Center (MCC) panels as defined in Documents. MCC installation and power connections are not part of Contract.
- C. Run DC signal conductors in separate conduit from AC conductors. AC conductors shall not be routed in same wireway or cable tray (without proper barriers) as DC conductors. AC DC route crossings shall be at 90°.
- D. Match wiring terminations to terminals. For connection to screw terminals, use spade-tongue crimping type insulated terminal connectors as approved by Owner. Terminate to tubular terminals using bare stripped wire.
- E. Make circuit extensions, if required, using specified terminal strips. Use wingnuts only for connecting cable system to instruments with permanently potted leads. Wire splices or tee taps are not allowed.
- F. Install terminal strips so that each terminal connection may be easily reached without moving other wires. Do not stack terminal strips. Stacked terminal blocks not including double density terminal blocks are not allowed.



- G. Install special sensor to convertor cables in accordance with manufacturer's instructions.

### 3.6 WIRE AND CABLE

A. Standard Wire and Cable:

1. Provide instrument wiring and instrument signal cable in raceways or cable tray as required by documents in accordance with this Section and Section 26 0519 - Low-Voltage Electrical Power Conductors and Cables.
2. Wiring and cables shall not have mechanical stress or strain.
3. Do not splice instrument/control wiring and cables. Make connections in Junction Boxes using terminal blocks.
4. Do not cut out strands of stranded wire to make wiring fit terminal.
5. Wire color code shall be as follows:

<u>Type</u>	<u>Color</u>
120 VAC control signal	Red
120 VAC line power	Black
120 VAC line neutral	White
Grounds	Green
+ 24 VDC analog or discrete	Black
- 24 VDC analog or discrete	White or clear
RTD V+	Black
RTD V	White
RTD compensation	Red
Intrinsic Safe Cable Jacket	Light Blue

6. Continuously shield analog signal cables. Ground shields as shown in Wiring Details and Installation Details. Pay particular attention to requirement for floating shields through termination points, maintaining only one single grounding point, and insulating from ground at other points. Refer to Wiring Drawings to determine single grounding point.
7. Continuously shield analog signal cables. Ground shields at point instrument power supply enters loop. Carry shields through terminal blocks and float/insulate (cut back and tape to electrically insulate) shields at opposite wire/cable end(s) from power supply.
8. Continuously shield analog signal cables. Ground shields at point instrument power supply enters loop. Carry shields through terminal blocks and float/insulate shields at opposite wire/cable end(s) from power supply. Insulate shield by applying heat shrink tubing over shield at cable end.
9. Maximum distance for shield cut and terminate shall be 3/4" from cable end. That is shield shall be continuous except for last 3/4" at each cable end.
10. Using cable shields to carry signal current, except noise signal current, (that is using shield as signal common or signal return) is not allowed. This is not in reference to RG59 or RG6 coaxial cable.
11. Install instruments with sufficient flexible conduit length to allow for instrument removal without electrically disconnecting instrument. Flexible conduit length shall not exceed 3' except in cases where instrument is suspended into pit or sump.

- B. Terminal Blocks:
1. Provide minimum of 20% spare capacity for both analog and discrete (calculated separately) terminal blocks above spare I/O (if applicable).
  2. Provide thermocouple terminal blocks for thermocouple extension cable terminations. Install per manufacturers requirements ensuring wire overlap within terminal block. Carry shield through terminal block.
- C. Shunt Diodes:
1. Provide shunt diodes across motor starter coils when coil is connected to control system or other open collector transistor controller output.
  2. Provide shunt diodes across size 3 or larger motor starter coils when coil is connected to control system or other open collector transistor controller output.
  3. Provide shunt diodes across control relay coils and motor starter coils when coil is connected to control system or other open collector transistor controller output.
- D. Pilot Light Standard Colors:
1. Provide following colors for pilot light indication, unless otherwise noted:
- | <u>Function</u>              | <u>Color</u>        |
|------------------------------|---------------------|
| Alarm/Emergency Indication   | Red                 |
| Normal Operating Status      | Green               |
| Warning Condition Indication | Yellow              |
| Other Status Indication      | Blue or White/Clear |
- E. Pilot Light PushToTest:
1. Provide push-to-test pilot lights with test circuit connected so that light will illuminate if pushed bypassing control functionality as allowed by NEC and NFPA.
- F. Raceways:
1. Provide complete raceways as required by documents in accordance with Section 26 0533 - Raceways and Boxes for Electrical Systems.
- G. Instrument Ground:
1. Provide conductors, busbars, insulating standoffs, and components for isolated instrument ground system. Connect main ground conductor directly to building steel ground and not through MCC or Unit Sub ground.
  2. Provide conductors, busbars, insulating standoffs, and components for isolated instrument ground system. Connect main ground conductor directly to facility ground grid and not through building steel, MCC, or Unit Sub ground.
  3. Connect instrument ground to isolated ground bus in star configuration and not in series connection. Connect 4 devices maximum to 1 home run to bus.

### 3.7 PIPING AND TUBING

- A. Provide piping/tubing system in accordance with Section 25 3526CR - Pneumatic Piping Tubing.

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### **3.8 CONTROL PANELS, ENCLOSURES, FIELD PANELS, AND HOUSINGS**

- A. Provide control panels, Field Panels (i.e.: marshalling panels), enclosures, and housings, which are shown in documents in accordance with Section 25 1316CR - Control Panels.

### **3.9 PAINTING**

- A. Painting of equipment will be done by others unless hereinafter specified to be furnished with factory applied finish coats.
- B. If factory finish on any instrument furnished by this Contractor is damaged in shipment or during construction of building, refinish instrument to satisfaction of Owner.
- C. Furnish one can of touch-up paint for each different color factory finish, which is to be final finished surface of product.
- D. Paint ferrous supports, hangers, enclosures, etc.
- E. Paint hidden surfaces, prior to installation. Painted device shall be fully dry before it may be installed.
- F. Do not paint prepainted Equipment.
- G. Do not paint non-ferrous metals except as area requirement.
- H. Do not paint, cover, or deface instrument or equipment nameplates.

### **3.10 ACCESS CONTROL**

- A. Coordinate cardholder database programming with Owner. Provide programming services for 50 cardholders.
- B. Refer to specification section 27 6100 – Premise Security Access Control for additional requirements.

### **3.11 ELECTRONIC VIDEO SURVEILLANCE**

- A. Refer to specification section 27 6200 – Electronic Video Surveillance for additional requirements.

### **3.12 CALIBRATION, FUNCTIONAL CHECKS AND COMMISSIONING OF INSTRUMENTS**

- A. Calibration:
  - 1. Calibrate instruments in accordance with Section 25 0192CR - Instrument Calibration.
- B. Commissioning:
  - 1. Check calibrations and settings of instrument items and systems and recalibrate and adjust as required to assure proper operation of each instrument, instrument

loop, and complete control system, except such items specifically identified as to be checked by others.

### 3.13 CHECKOUT AND STARTUP

- A. Provide labor, tools, and equipment required to commission and startup instrumentation.
- B. Test and inspect wiring for proper connections, for correct polarity, for shorts, and for continuity to verify that items function properly.
- C. Test and inspect tubing for proper connections, for open lines, and for continuity to verify that items function properly.
- D. Check instruments requiring fill fluid to ensure instrument is fully filled with proper fluid and checked for gas bubbles per manufacturer's recommendations. Remove gas bubbles.
- E. Checkout pneumatic instruments using facility's instrument air system.
- F. Test instrument loops and control loops to ensure response to input signals, output signals, alarms, interlocks, interconnections, and signal processing. These tests shall be performed by teams of combined Owner and Contractor personnel, or as stated by Documents.
- G. Stroke valves fully open and fully closed. Operate manual switches to ensure correct function.
- H. Record calibrations performed during this phase in accordance with Section 25 0192CR - Instrument Calibration.
- I. Correct errors or faulty workmanship discovered during testing to satisfaction of Owner.
- J. Loop Checks:
  - 1. Provide checkout master listing, checkout record (COR) to document field loop checkouts. Form shall include loop tag identifier, description of loop function, associated major equipment, and blank lines for Contractor and Owner to initial and date after loop has been successfully checked out.
  - 2. Test instrument loops and control loops to ensure response to input signals, output signals, alarms, interlocks, interconnections, and signal processing. These tests shall be performed by, teams of combined Owner and Contractor personnel; or as noted. Test smart instrumentation using manufacturer's configuration terminal.
  - 3. Document fully functional loops by initialing and dating COR and having Owner initial and date his observation. If instrument loop is disturbed after having been checked out, reverify loop using this procedure and record change in COR.
  - 4. Provide checkout master listing, Check Out Record (COR) to document field loop checkouts. Form shall include loop tag identifier, description of loop function, associated major equipment, and blank lines for Contractor to initial and date after loop has been successfully checked out.
  - 5. Test instrument loops and control loops to ensure response to input signals, output signals, alarms, interlocks, interconnections, and signal processing.

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6. Document fully functional loops by initialing and dating COR in black ink.
- K. Smart Instrument Analog Inputs:
    1. Test smart instrumentation using manufacturer's configuration terminal and employ following procedure:
      - a. Open loop at panel terminal strip.
      - b. Connect voltmeter positive to loop positive on panel side of terminal strip.
      - c. Connect voltmeter negative to loop negative on panel side of terminal strip.
      - d. Check voltage. Voltage should read 24 to 26 VDC.
      - e. Connect milliamp meter negative to loop positive on field side of terminal.
      - f. Connect milliamp meter positive to loop negative on field side of terminal.
      - g. Verify proper loop operation.
      - h. Connect manufacturer's smart instrument configuration unit positive to loop positive on panel side of terminal strip.
      - i. Connect manufacturer's smart instrument configuration unit negative to loop negative on panel side of terminal strip.
      - j. Verify proper communication of transmitter.
      - k. Close loop at panel terminal strip.
  - L. NonSmart Instrument Analog Inputs:
    1. For nonsmart type analog inputs, employ following procedure.
      - a. Open loop at panel terminal strip.
      - b. Connect voltmeter positive to loop positive on panel side of terminal strip.
      - c. Connect voltmeter negative to loop negative on panel side of terminal strip.
      - d. Check voltage. Voltage should read 24 to 26 VDC.
      - e. Connect milliamp meter negative to loop positive on field side of terminal.
      - f. Connect milliamp meter positive to loop negative on field side of terminal.
      - g. Verify proper loop operation.
      - h. Close loop at panel terminal strip.
  - M. Analog Outputs to Field Devices:
    1. For analog outputs, employ following procedure:
      - a. Open loop at panel terminal strip.
      - b. Connect milliamp meter positive to panel side loop positive terminal.
      - c. Connect milliamp meter negative to panel side loop negative terminal.
      - d. Generate milliamp output at 0, 25, 50, 75, 100 percent of span through control system.
      - e. Verify proper output at milliamp meter and proper final control element operation.
      - f. Verify proper fail position if applicable.
      - g. Close loop at panel terminal strip.
  - N. Discrete Inputs From Field Devices:
    1. For discrete inputs from field or panel devices, employ following procedure.
      - a. Manually operate field device, which actuates status switch contacts to verify that valid data is received by control system.

- b. Verify field device matches tag number to which it is wired.
  - c. Verify proper normal switch position agrees with drawings.
- O. Discrete Outputs To Field Devices:
- 1. For discrete outputs to field or panel devices, employ following procedure.
    - a. Open loop at panel terminal strip.
    - b. Connect milliamp meter positive to panel side top terminal test socket screw.
    - c. Connect milliamp meter negative to field side top terminal test socket screw.
    - d. Energize output through control system.
    - e. Verify loop current is between 30 and 50 milliamps.
    - f. Verify full field device operation. It is not sufficient to verify that solenoid on On/Off Valve energizes but valve must actuate using final connected air supply.

**END OF SECTION**

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## SECTION 25 3002CR

### PROCESS CONTROL VALVES AND DAMPERS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Refer to Section 25 0993CR - Control Sequences
- B. Refer to Section 25 3001CR - General Instrumentation Requirements

##### 1.2 REFERENCE

- A. The Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 DESCRIPTION

- A. This Section, in conjunction with above referenced sections, defines procurement requirements for instruments, which are included in this Work.

##### 1.4 VALVE SELECTION AND SIZING

- A. General:
  - 1. Provide and connect control valves as listed in Control Valve Schedule as specified under this Section.
  - 2. Provide and connect instruments as shown in drawings and required to fully accomplish control sequences as defined in Section 25 0993CR - Control Sequences.
  - 3. Furnish instruments of same type by same manufacturer; for instance, water service butterflies shall be of same manufacturer.
  - 4. Electronic control valve accessories in normal operation shall have no more than 1% span error from 5 watt source of EMI/RFI at distance of 3' operating at frequencies of 20 Hz to 1 GHz when properly installed, connected, and with covers and housings in place. On/Off devices shall not false trip if more than 1% from trip point.
  - 5. Manufacturer shall furnish each control damper with stainless steel tag, stamped with tag number as shown in listing, permanently affixed to device with stainless steel screws, stainless steel chain, or stainless steel wire.
  - 6. Provide valves and accessories with factory applied prime and final finish, unless otherwise specified.
  - 7. Each device shall be fully crated for protection during shipment with end covers protecting connections.
  - 8. Control valves shall have of 85 dBA at five feet maximum sound power.
  - 9. Valves shall be fully factory assembled with components, lubricated, and tested prior to shipment by Manufacturer as shown on drawings.

10. Ensure flashing/cavitation does not occur or provide cavitation control devices to fully eliminate flashing/cavitation effects.
11. Modulating valves shall be selected so that minimum and maximum required  $C_v$  is approximately 30% and 85% respectively of valve's  $C_v$  regardless of piping line size. Valve's  $C_v$  shall not be below 10% or exceed 90% of process's  $C_v$  without Owner/Engineer's approval.
12. On/off valves shall be line size unless otherwise noted.
13. Select control valves and actuators for 100% shut-off against system maximum differential pressure.
14. Select control valves and actuators to fail safe by spring return, in a normally open, normally closed, or fail last position as indicated in documents. Refer to 25 0993CR – Control Sequences or schedules.
15. Valve body ratings indicated in Part 2 are minimum required. Valve body, trim and packing selected shall be designed to withstand maximum pressure and temperature encountered in system.
16. Submit engineering calculations for sizing modulating control valves unless valves are scheduled. Control valves serving terminal devices may be sized based on flow ranges for each pump system.
17. Required device accuracy shall include effects of hysteresis, linearity, repeatability, and drift. Accuracy validation test shall comply with 3 statistical analysis.

**B. Instrumentation Valves:**

1. Unless otherwise noted, instrumentation shut-off valves for isolation of gauges, switches, transmitters, etc., shall be as follows:
  - a. Compressed air/instrumentation air systems: ball or plug-type valves
  - b. Water systems: ball valves
  - c. Steam and condensate systems: gate-type valves
  - d. Ductwork, air handling unit or air terminal device penetrations: ball or plug-type valves

**1.5 DAMPER SELECTION AND SIZING**

- A. Submit engineering calculations for sizing modulating control dampers including outside, return, and relief air dampers of air handling units unless dampers are scheduled.
- B. Calculations for sizing dampers shall be based on actual characteristics of ductwork system being installed. Opposed blade dampers shall be sized for minimum of 10% of duct system pressure drop. Parallel blade dampers shall be sized for minimum of 30% of duct system pressure drop. Duct section is defined as ductwork containing flow control damper starting with inlet or branch tee and ending with outlet or branch tee. Calculate actual duct pressure drops for each duct section containing modulating damper using latest version of ASHRAE Handbook of Fundamentals. If control systems fixes pressure drop, use those pressure setpoints. Use balance damper to provide additional pressure drop as required for obtaining linear damper response.
- C. Contractor is responsible for obtaining adequate system information necessary for sizing.
- D. Two position dampers to be sized as close as possible to duct size, but in no case is damper size to be less than duct area.



- E. Submit leakage and flow characteristic data for control dampers along with shop drawings. Leakage ratings shall be based on AMCA Standard 500 and dampers shall bear AMCA Air Leakage Seals.

## 1.6 SUBMITTALS

- A. Submit shop drawings in accordance with Division 01 requirements and Section 25 3001 - General Instrumentation Requirements.
- B. Shop drawings shall include:
1. Manufacturer's specification sheets marked with supplied features specific for Project.
  2. Wiring and tubing diagrams (as appropriate).
- C. Valve Data:
1. Tag Number:
  2. Manufacturer/Model Number:
  3. Body Size:
  4. Body Type/Style (globe, butterfly, ball, etc.):
  5. Body Material:
  6. Port configuration (2 port, 3 port, etc):
  7. Body Pressure Rating:
  8. Body ANSI Pressure Class:
  9. Body Orientation (if not standard):
  10. End Connections:
  11. Packing/Gasket Material:
  12. Trim Characteristics (equal %, linear, etc.):
  13. Trim Type (plug, cage, disk, ball, etc.):
  14.  $C_{v1}$ ,  $C_{g1}$ , or  $C_s$  @ 10%, 20%, 40%, 60%, 80%, 100% Flow:
  15. Seat/Guide/Stem Material:
  16. Full Stroke Stem Length (linear type only):
  17. Bonnet Configuration (Bolted or union glove or gate only):
  18. Maximum Operating Pressure/Temperature:
  19. Maximum Delta Pressure before Flashing, Cavitation, or Choked Flow:
  20. Maximum Shut-Off Differential Pressure:
  21. Required Actuation Force at Maximum Shut-off Pressure and Maximum Operating Pressure:
  22. ANSI Shut-off Class (with actuator):
  23. Valve Recovery Constants:
  24. Noise Level (dBA at 3 ft):
- D. Actuator Data:
1. Manufacturer/Model Number:
  2. Motive Force/Output Power (force):
  3. Size/Style (rack and pinion, diaphragm, linear piston, etc.):
  4. Bench Range (3-15 psi, etc., pneumatic only)/Input Signal:
  5. Open/Close vs Full-Flow Fail:
  6. Stroke Speed (coupled with valve at maximum delta pressure):
  7. Enclosure NEMA Rating (electric/electronic only):
  8. NEMA Rating Manufacturer/Model Number:

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9. Limit (end) Switch Manufacturer/Model Number (if provided):
- E. Damper Data:
1. Tag Number:
  2. Manufacturer/Model Number:
  3. Service (Outside Air, Return, Exhaust, Smoke, Fume Hood, etc.):
  4. Type (butterfly, opposed blade, parallel blade, etc.):
  5. Shape (round, rectangle, etc.):
  6. Dimensions/Number of Sections:
  7. Frame Material/Gauge and Coating or Finish:
  8. End Connections (flange, slip joint):
  9. Blade width and Blade Material/Gauge:
  10. Blade Orientation (horizontal/vertical):
  11. Blade Type (air foil, v-notch, butterfly, etc.):
  12. Blade Seal Material/Side (edge) Seal Material:
  13. Bearing Type Material (ball, sleeve, etc.):
  14. Shaft Size (cross section)/Material:
  15. Operating Flow (if contractor-sized):
  16. Sizing Equation (if contractor-size):
  17. Maximum Operating Pressure/Temperature:
  18. Maximum Differential Pressure Drop:
  19. Approach Velocity/Maximum Velocity:
  20. Leakage at Rated Differential Pressure:
  21. Leakage Class (smoke only):
  22. Duct Size:
  23. Actuator Mounting Location:
  24. Required Actuation Force Minimum/Maximum:
- F. Submittals will be returned not reviewed if each item for each instrument/valve/damper is not included in submittal.

## **PART 2 PRODUCTS**

### **2.1 CONTROL VALVES**

- A. General:
1. If control valves are not scheduled, refer to Part 1 of this Section for sizing criteria.
  2. Use 2 or 3 port normally open globe type control valves with equal percentage contoured throttling plugs for water applications, except as otherwise noted.
  3. Use 2 port modulating straight-through magnetic type valves with linear characteristics for 90% of closing stroke and equal-percentage for final 10% for steam applications, except as otherwise noted.
  4. Butterfly valves may be used for water system control valves 6" and larger provided that valves meet pressure and temperature requirements. High performance butterfly valves shall be used for modulating applications. General purpose butterfly valves may be used for 2 position control.

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- B. Magnetic Valves – AHU coil control and humidifier steam control:
1. Manufacturers: Siemens
  2. Valves use magnetic actuation to enhance response time and provide stability. Large signal changes switch the actuator to the large signal band, allowing high-gain response to quickly position the valve element. Small signal changes switch the actuator to the small signal band to provide loop stability and precise positioning.
  3. Valves shall be two-way straight-thru or three-way mixing as indicated on flow diagrams and selected for intended service.
  4. Valves shall be iron or steel body, Female NPT (2" and smaller) or flanged (larger than 2"), 150 psi rating.
  5. Valves shall have stainless steel stems, spring-loaded Teflon or Ethylene Propylene (EP) packing, replaceable metal seats and discs. Provide valve trim to limit audible sound levels to 85 dBA or less when measured at 5 ft.
  6. ANSI Class IV shutoff. Valves shall conform to ANSI B16.10, ISA SP-75.
- C. Globe Valves:
1. Manufacturers: DeZurik/K&M, Fisher, Spirax Sarco, Samson Controls, Warren Controls or Valtek
  2. Valves shall be iron or steel body, flanged, 150 psi rating.
  3. Valves for standard use 2" and smaller shall be unguided, unbalanced equal percentage plug type. Valves 2-1/2" and larger shall be guided plug type with either top and bottom guides or cage restrained plugs. Valves with pressure drops greater than 50% of upstream pressure shall be cage type valves with sound reduction trim.
  4. Valves shall have stainless steel stems, spring-loaded Teflon or Ethylene Propylene (EP) packing, replaceable metal seats and discs. Provide valve trim to limit audible sound levels to 85 dBA or less when measured at 5 ft.
  5. ANSI Class IV shutoff. Valves shall conform to ANSI B16.10, ISA SP-75.
- D. General Purpose Butterfly Valves:
1. Refer to Section 23 2118 - Valves. Refer to Damper and Valve Actuators in this Section for valve actuators.
  2. Valves and actuators shall be manufactured by valve manufacturer. Valve assembly including actuator and limit switches, if used, shall be assembled by, valve manufacturer.
  3. Used for shut-off and two position control only.
- E. High Performance Butterfly Valves:
1. Manufacturers: DeZurik, Xomox, Jamesbury, Posi-Seal, Bray/McCannalok or Fisher
  2. Carbon steel body, lugged style, ANSI Class 150, adjustable PTFE packing, PTFE seat with suitable metal back-up ring, upper and lower shaft thrust bearings, 316 stainless steel one piece shaft and 316 stainless steel disc with offset shaft/disc design.
  3. Normal and dead end (without downstream flanging) pressure rating shall be 275 psi.

4. Valves and actuators shall be manufactured by, valve manufacturer. Valve assembly including actuator and limit switches, if used, shall be assembled by valve manufacturer.
- F. Ball Control Valve
1. Manufacturer: Jamesbury, Fisher, Worcester (Invensys), Masoneilan, Apollo or approved alternate
  2. Valve:
    - a. These shall be ball type valves with upper thrust bearing and resilient seat.
    - b. Valve type: 3-piece standard port
    - c. Port Configuration: 2 way
    - d. Maximum Continuous Temperature: 300°F
    - e. Maximum Pressure: 175 PSIG at maximum temperature
    - f. Materials of Construction:
      - 1) Body and Bonnet: Carbon Steel
      - 2) Ball and Stem: Stainless Steel unless otherwise noted.
      - 3) Seat: TFE
      - 4) Fasteners: Carbon Steel or Stainless Steel if body is Stainless Steel
    - g. Connections:
      - 1) Linesize < = 2": Female NPT
      - 2) Linesize > 2" : ANSI Class #150 Raised Face Flange

## 2.2 CONTROL DAMPERS

- A. General:
1. If control damper sizes are not shown or scheduled, refer to Part 1 of this Section for sizing criteria.
  2. Unless otherwise indicated, modulating control dampers shall be opposed blade or parallel blade type and 2-position (open/close) dampers shall be parallel blade type.
  3. Blade linkage hardware shall have corrosion-resistant finish and be readily accessible for maintenance.
- B. Fume Exhaust Fan Shut-off Dampers:
1. Manufacturers: Swartwout 902 or Ruskin CDR92.
  2. 304 stainless steel construction, flanged connection, grease lubricated ball bearings, continuous shaft with seal, suitable for maximum temperature 250°F, approach velocity 6000 fpm, and differential pressure of 13" WC.
  3. Furnish dampers with neoprene blade seals.
  4. Furnish with 2" outboard grease lubricated ball bearings and shaft seals.
  5. Damper actuators shall be fail-open, electric 120 V AC, heavy duty industrial quality similar to Valvcon, Rotork, Limitorque or Automax.
- C. Exhaust System Outside Air Bypass Dampers:
1. Manufacturers: Ruskin Model CD80AF2 or American Warming and Ventilating Model VC-423

2. 304 stainless steel construction, suitable for maximum temperature 250°F, approach velocity 6000 fpm and differential pressure of 13.5" WC.
3. Air foil blade design, 16 ga minimum and 12" maximum width.
4. Furnish with flexible jamb seals, EPDM, silicone or neoprene blade seals and pneumatic damper actuators with pilot positioners.
5. Damper actuators shall be fail-open, electric 120 V AC, heavy duty industrial quality similar to Valvcon, Rotork, Limitorque or Automax.

### 2.3 DAMPER AND VALVE ACTUATORS

- A. Provide following actuators on control valves specified below as shown on drawings or unless otherwise noted. Manufacturer shall size actuator and shall match actuator characteristic (yoke size, stem size, required shut-off, operational thrust, actuator action, etc.) to required valve.
- B. Analog Electronic (Fan Coil Units):
  1. Manufacturers: Belimo, Honeywell, Johnson Controls, Siemens Building Technologies or TAC
  2. Actuators shall be hydraulic or electric motor/gear drives that respond proportionally to analog voltage or current input. Stroke time for major equipment shall be 90 seconds or less for 90° rotation. Stroke time for terminal equipment shall be compatible with associated local controller, but no more than 6 minutes.
  3. Provide spring return feature for fail open or closed positions, as required by control sequence, for critical applications such as outside, return, or exhaust dampers, heating and cooling coils on major air handling units, humidifiers, heat exchangers, flow control for major equipment items such as chillers, cooling towers, boilers, etc.
  4. Provide position feedback potentiometers connected to controller for closed loop control on major equipment analog control loops.
  5. Actuators for terminal heating/cooling equipment do not require spring return feature.
- C. Quarter-Turn Electric
  1. Manufacturer: Rotork, Limitorque, Valvcon, Belimo, or Same As Valve Manufacturer.
  2. These shall be quarter-turn electric rotary type actuators and shall be sized to guarantee valve operation at specified delta pressures with 1.2 safety factor and shall have adjustable operating speed. Motor thermal protection shall be provided.
  3. Actuator shall be reversing type such that it strokes 0° to 90° rotation. Actuators, which stroke full 360°, are not allowed.
  4. Actuators applied to butterfly valves, modified ball valves (eccentric disk, V-Notch, segmented ball, etc.), or modulating ball valves shall be reversing type such that it strokes 0° to 90° rotation. Actuators for these valve types, which stroke full 360°, are not allowed. This does not apply to full ball valves in on/off service.
  5. Drive: Worm or Gear
    - a. Operating Voltage: 120 VAC, 60 Hz, 1 Phase
    - b. Ambient Temperature: 0° to 120°F

- c. Motor Insulation Class: F or H with 15 min time rating
- d. Torque and Limit Switch: One required in each direction
- e. Lubrication: Permanent
- f. Housing: Aluminum or Steel
- g. Actuation Signal:
  - 1) On/Off Contact Closure
  - 2) Modulating: 4-20 mA, 24 VDC
- h. Actuator Type: Spring Return
- i. Speed of response disconnected from load: Valve shall travel 100% of stroke within 5 seconds

D. Linear Electric

- 1. Manufacturer: Jordan Controls, Belimo, or Same as Valve Manufacturer
- 2. These shall be synchronous, motor drive type actuators, which provide floating control. 3-wire, 24 VAC signal from controller energizes UP drive or DOWN drive motion of actuator. When input signal is removed, valve remains in place (Non-Spring Return).
- 3. Stroke Time:
  - a. 1/2" stroke: 80 seconds maximum
  - b. 3/4" stroke: 110 seconds maximum
  - c. Shutoff Force: 50 lb Force minimum
- 4. Ambient Temperature:
  - a. Operating: 0 to 140°F, 10-90% RH
  - b. Storage: -40 to 150°F
- 5. Maximum Fluid Temperature:
  - a. Liquid Service: 190°F minimum
  - b. Steam Service: 280°F minimum
- 6. Limit Switches: Integral to Actuator. OPEN and CLOSE Limit Switches
- 7. Actuation Signal:
  - a. On/Off: Contact Closure
  - b. Modulating: 4-20 mA, 24 VDC
- 8. Actuator Type: Spring Return
- 9. Speed of response disconnected from load: valve shall travel 100% of stroke within 5 seconds.

E. Electric Damper

- 1. Manufacturer: Belimo, Andover, Honeywell, Johnson Controls, Siemens Building Technologies, Invensys Building Systems, or same as Damper Manufacturer
- 2. These shall be quarter-turn electric rotary type actuators and shall be sized to guarantee damper operation at specified delta pressures with 1.75 safety factor and shall have adjustable operating speed. Motor thermal protection shall be provided.
- 3. Actuator shall be reversing type such that it strokes 0° to 90° rotation. Actuators, which stroke full 360°, are not allowed.
- 4. Contractor shall match stroke length and torque requirements to damper.
  - a. Drive: Worm or Gear
  - b. Operating Voltage: 120 VAC, 60 Hz, 1 Phase
  - c. Ambient temperature: 0° to 120°F
  - d. Motor insulation class: F or H with 15 min time rating
  - e. Torque & Limit Switch: One required in each direction.

- f. Lubrication: Permanent
- g. Housing: Aluminum or Steel
- h. Actuator Type: Spring Return
- i. Actuation Signal:
  - 1) On/Off: Contact Closure
  - 2) Modulating: 4-20 mA, 24VDC
- j. Speed of response connected to damper: Damper shall travel 100% of stroke within 15 seconds.

## 2.4 CONTROL DAMPER ACCESSORIES

- A. Provide following accessories on dampers (valve and actuator specified below) as shown on drawings or unless otherwise noted.
- B. Limit (End) Switches
  - 1. Manufacturer: Kele and Associates or approved alternate.
  - 2. These shall be encapsulated ball bearing switches mounted on a 1/2" damper jack-shaft to give indication of opened or closed damper position.
  - 3. Switch actuates when cable end drops below horizontal position and resets at horizontal or above positions.
  - 4. Switch Action: SPDT (Single-Pole-Double-Throw)
  - 5. Switch Rating:
    - a. 2 A @ 120 VAC, 60 Hz
    - b. 1 A @ 240 VAC, 60 Hz
  - 6. Switch Angle: 15° Below Horizontal Switch Makes

## 2.5 CONTROL VALVE ACCESSORIES

- A. Visual Position Indicator (Rotary Actuator)
  - 1. Manufacturer: Westlock (Tyco Flow), Worcester (Invensys), ASCO, or approved alternate.
  - 2. These shall be top-hat two color type position indicators with rotating inner-sleeve attached to actuator, limit switch, or positioner knuckle. Inner-sleeve shall change color as actuator rotates through its full stroke.
- B. Limit Switches
  - 1. Manufacturer: Westlock (Tyco-Flow), Worcester (Invensys), ASCO, or same as valve manufacturer.
  - 2. Limit switches shall be adjustable through full valve actuator stroke. Switches shall be factory wired to terminal strip.
  - 3. Switch Action: SPDT (Single-Pole-Double-Throw)
  - 4. Switch Rating: 5 Amps, 120 VAC/60 Hz
  - 5. Minimum Enclosure Rating: NEMA 4
  - 6. Conduit Connection: 1/2" NPT
- C. Visual Position Indicator (Rotary Actuator)
  - 1. Manufacturer: Westlock (Tyco Flow), Worcester (Invensys), ASCO, or approved alternate.

2. These shall be top-hat two color type position indicators with rotating inner-sleeve attached to actuator, limit switch, or positioner knuckle. Inner-sleeve shall change color as actuator rotates through its full stroke.
3. These valves shall be ball type valves with upper thrust bearing and resilient seat.

### **PART 3 EXECUTION**

#### **3.1 CONTROL VALVES**

- A. Provide valves with necks with sufficient neck length to clear any insulation, where valve is to be installed into insulated piping system.
- B. Provide Fail (Normally) closed actuators on steam service valves, which supply steam to pressure rated vessels.

#### **3.2 CONTROL DAMPERS**

- A. Valve and damper operating speeds shall be selected or adjusted so operators will remain in step with controller without hunting regardless of load variations. Operators acting in sequence with other operators shall have adjustment of control sequence as required by operating characteristics of system.
- B. Provide proper linkage and brackets for mounting and attaching actuators to devices. Provide mounting and support such that damper has no more than 2% hysteresis error in either direction (actual movement of valve stem/damper shaft/ideal movement) due to deflection of actuator mounting.
- C. Calibrate position feedback potentiometers where specified with range and gain factors as required for proper operation.

**END OF SECTION**



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## SECTION 25 3003CR

### PROCESS INSTRUMENTATION DEVICE SPECIFICATIONS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Refer to Section 25 0993 - Control Sequences
- B. Refer to Section 25 3001 - General Instrumentation Requirements

##### 1.2 REFERENCE

- A. The Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 DESCRIPTION

- A. This Section, in conjunction with above referenced sections, define procurement requirements for instruments, which are included in this Work.

##### 1.4 SUBMITTALS

- A. Submit shop drawings in accordance with Division 01 requirements and Section 25 3001 - General Instrumentation Requirements.
- B. Product data sheets shall include construction materials and assembly methods, maximum design parameters (temperature, pressure, velocity, etc.), and performance data for full range of instrument span. Product data sheets shall include charts, graphics or similar items used in making selections. Sheets shall be marked with supplied features specific for project. Include wiring and tubing diagrams (as appropriate).
- C. Submit following information for each instrument:
  - 1. Tag Number
  - 2. Equipment Served
  - 3. Process Fluid
  - 4. Instrument Range
  - 5. Calibrated Span
  - 6. Input/Output Signal
  - 7. Power Required (i.e., loop powered 120 VAC)
  - 8. Wetted Parts
  - 9. Housing Construction/NEMA Rating
  - 10. Mounting Orientation and Method
  - 11. Process Connection
  - 12. Agency Approval(s)
  - 13. Min/Max Operating Temperature
  - 14. Min/Max Operating Pressure

15. Accuracy
  16. Drift per Time Period
  17. Repeatability
  18. Pressure Drop (in-line devices only)
- D. Temperature Instruments Only:
1. Insert Length
  2. Thermowell Type
  3. Union
- E. Pressure Instruments Only:
1. Overpressure
  2. Seal/Capillary Type
  3. Gauge
- F. Submittals will be returned not reviewed if each item for each instrument is not included with submittal.

## **PART 2 PRODUCTS**

### **2.1 GENERAL**

- A. Instruments of same type shall be by same manufacturer, for instance, pressure transmitters, gauge, absolute, and differential pressure shall be of same manufacturer.
- B. Instruments in normal operation shall have no more than 1% span error from 5 watt source of EMI/RFI at distance of 3' operating at frequencies of 20 Hz to 1 GHz when properly installed, connected, and with covers and housings in place. On/Off devices shall not false trip if more than 1% from trip point.
- C. Manufacturer shall furnish each instrument with stainless steel tag, stamped with tag number as shown in listing, permanently affixed to device with stainless steel screws or drive pins. There shall be no deviation from this requirement except by owner approval on item-by-item basis.
- D. Instruments with potted leads shall have sufficient lead length to allow for instrument removal without disconnecting instrument.
- E. Instrument zero shall be  $20\% < \text{expected measured range}$ , unless parameter's minimum measurable value is 0 in which case instrument zero shall be 0 instrument upper calibrated span shall be  $20\% > \text{expected measured range}$  unless otherwise noted. i.e. instrument span shall be  $0 < \text{instrument span} < 120\%$  of highest expected instrument measured value or instrument minimum expected measurement -  $20\%$  instrument span  $< 120\%$  of highest expected instrument measured value.
- F. Furnish manufacturer's certified factory calibration sheet for each instrument that is each instrument receives individual calibration and manufacturer's calibration sheet is supplied for each device. Furnish one NIST certified calibration sheet for each manufacturer's reference instrument used in this project's field instrument calibration or manufacturer's

standard operating practice for reference instrument calibration if primary standard is used.

- G. Instruments shall have factory applied prime and final finish, unless otherwise specified.
- H. Each instrument shall be fully crated for protection during shipment with end covers protecting instrument connections.
- I. Probe type instruments with permanently attached sensor leads shall have leads with sufficient length to remove probe without disconnecting leads from signal cable.
- J. Required instrument accuracy shall include affects of hysteresis, linearity, repeatability, and drift.

## 2.2 DISCRETE INSTRUMENTS

- A. General:
  - 1. Discrete inputs to controller shall meet following:
  - 2. Normal operating voltage shall be either non-isolated 5 vdc logic level signal or 24 vdc opto-isolated logic level signal. Source of this signal shall be control system. Current draw shall be less than 1 milliamp in case of non-isolated and 10 milliamps in case of opto-isolated inputs. Maximum transient voltage shall be  $\pm 30$  vdc. As minimum, field indication device shall have contacts rated for "dry circuit" applications. If this is not feasible, contractor shall provide 120 VAC circuit to energize status relay.
- B. Current Switches - Constant Load, Constant Speed:
  - 1. Manufacturers: Veris Industries, N-K Technologies, Absolute Process Instruments, Kele & Associates, R-K Electronics or approved equal.
  - 2. These shall be Induction type sensors clamped over single phase conductor of AC electrical power and shall be solid-state sensors with adjustable threshold and normally open contacts. Each current switch shall be selected for proper operating range of current.
    - a. Output: Solid state relay or relay contacts
    - b. Trip Setpoint: Adjustable by multi-turn potentiometer
    - c. Operating Temperature: 0 to 55°C (32 to 131°F)
    - d. Response Time: < 0.5 seconds
- C. Current Switches - Variable Load, Variable Speed
  - 1. Manufacturers: Veris Industries, N-K Technologies or approved equal.
  - 2. These shall be induction type sensors clamped over single-phase conductor of AC electrical power and shall consist of solid-state sensors with self-calibrating threshold and normally open contacts. Each current switch shall be selected for proper operating range of current.
    - a. Output: Solid state relay or relay contacts
    - b. Trip Setpoint: Self-calibrating through microprocessor
    - c. Operating Temperature: 0 to 55°C (32 to 131°F)
    - d. Response Time: < 0.5 seconds

- D. Pressure Differential Switches (Air Systems):
1. Manufacturers: Cleveland Controls, Dwyer, Honeywell, Johnson Controls/Penn, Siemens Building Technologies, or TAC.
  2. Adjustable set point, differential pressure type. Select switches for accuracy, ranges (20 to 80% of operating range) and dead-band to match process conditions, electrical requirements and to implement intended functions.
  3. Pressure differential switches for air systems shall have pressure rating of at least 10" WG.
  4. Pressure indicating differential switches for air systems shall be equal to Dwyer Series 3000 photohelic gauge.
    - a. Maximum Temperature Rating: 180°F
    - b. Repeatability: ± 1%
- E. Temperature Low Limit Switches (Freezestats):
1. Electric 2-position type with temperature sensing element and automatic reset. Controls shall be capable of opening circuit if any one foot length of sensing element is subject to temperature below setting.
  2. Sensing element shall not be less than one lineal foot per square foot of coil surface areas. Unless otherwise indicated, calibrate temperature switch setpoint to 38°F.
  3. Provide adjustable time delay relay for 0.5 to 5 minutes. Time delay relay shall be wired between freezestats and controller to allow air handling unit mixed air to stabilize upon startup or transition from unoccupied to occupied mode to prevent spurious trips from occurring when outside air damper(s) opens and cold outside air enters air handling unit.
- F. Temperature Switch:
1. Manufacturers: SOR, Ashcroft, United Electric, Allen Bradley, or approved alternate.
  2. These shall be vapor pressure temperature type switches.
  3. Switches shall be selected, to operate between 20 and 80 percent of switch range.
  4. Switches operating over 175°F shall have switches rated for high temperature (300°F minimum).
  5. Setpoint: Adjustable through switch range
  6. Repeatability: Error ± 1.0%
  7. Contact Rating: 5 Amp non-inductive 120 VAC dry contacts
  8. Contact Type: SPDT
  9. Remote Bulb Type Switches:
    - a. All remote bulb type switches shall have 0.375 diameter bulb with 3 inches sensitive length and associated thermo-bulb shall be bored 0.385 inches.
    - b. Bulb/capillary shall have union connection for bulb retention in thermo-bulb thermowell and shall have bendable extension of sufficient length for thermo-bulb.
    - c. Capillary shall be armor jacketed copper.
  10. Thermo-bulbs:
    - a. Bore shall be as described for switch portion. Thermowells shall be welded construction.
    - b. Manufacturer shall select correct stem or bulb size for thermo-bulb.

## 2.3 ANALOG INSTRUMENTS:

- A. Magnetic Flow Transmitter
1. Manufacturer: Rosemount, Onicon, Yokogawa or approved alternate.
  2. The flow meter shall be an insertion style meter installed in either the supply or return pipe of the system to be measured following the manufacturer's installation instructions. Flow meters shall be installed through a full port ball valve to enable insertion and removal of the meter without system shutdown. Flow meters shall be hand-insertable up to 400 psi.
  3. These shall be electromagnetic induction type flow measuring and transmitting instruments, which provide linear output signal proportional to flow rate. System shall utilize principle of electromagnetic induction to provide linear output signal proportional to flow rate.
  4. Maximum instrument span shall not be greater than twice process range.
  5. Maximum Measurable Flow Rate: 20 foot/second
  6. Minimum Measurable Flow Rate: 0.8 foot/second
  7. Minimum Accuracy: Error  $\pm$  1% total of full range
  8. Minimum Enclosure Rating: NEMA 4
  9. Transmitter/Totalizer:
    - a. Remote mounted indicator/transmitter/totalizer shall be microprocessor based. It shall be fully field configurable.
- B. Combination Temperature/Humidity Transmitter:
1. Manufacturers: Automation Components Inc., Veris Industries, Vaisala, Minco or General Eastern.
  2. Combination Temperature and Humidity sensor/transmitter shall meet the following minimum requirements:
    - a. Temperature:
      - 1) Temperature Sensor: 100 or 1000 Ohm Pt RTD
      - 2) Temperature Coefficient: .00385 ohm/ohm/ $^{\circ}$ C
      - 3) Accuracy:  $\pm$  0.36 $^{\circ}$ F (0.2 $^{\circ}$ C)
      - 4) Operating Range: -10 to 160 $^{\circ}$ F
      - 5) Supply Voltage: 18 to 36 VDC / VAC
      - 6) Output Ranges: 2-wire, 4 to 20 mA or 3-wire, 0 to 5, 0 to 10 VDC or 4 to 20 mA (24 VAC)
    - b. Humidity:
      - 1) Temperature Compensated: Full range of RH signal
      - 2) Response Time: 30 seconds for 63% step
      - 3) Accuracy Range:  $\pm$ 1% RH between 20 to 95% RH Span (including hysteresis, linearity repeatability).
      - 4) Sensing Element: Resistance or Capacitance humidity sensor
      - 5) Operating RH Range: 0 to 100%RH(non-condensing)
      - 6) Supply Voltage: 24 VDC (current or voltage output) 24 VAC (contact factory)
      - 7) Output Ranges: 4 to 20mA, 0 to 5V, 0 to 10V
      - 8) Long Term Stability: Less than 2% RH drift per year

- C. Chilled Mirror Moisture/Dewpoint Analyzer
1. Manufacturer: Michell Instruments, General Eastern or approved alternate.
  2. These shall be chilled mirror type moisture analyzers and shall provide linear output signal proportional to moisture (humidity) content in measured air stream. System shall have automatic correction for mirror contaminants. System shall include programmable automatic restandardization of measurement.
  3. Accuracy: Error  $\pm 0.36^{\circ}\text{F}$  ( $0.2^{\circ}\text{C}$ ) Dew Point
  4. Operating Temperature:  $-40^{\circ}\text{F}$  to  $+140^{\circ}\text{F}$  ( $-40^{\circ}\text{C}$  to  $60^{\circ}\text{C}$ )
  5. Sample Pressure: 0 to 200 psia (0 to 14 kg/cms<sup>2</sup>)
  6. Depression:  $81^{\circ}\text{F}$  ( $45^{\circ}\text{C}$ )
  7. Operating Temperature:  $-58^{\circ}\text{F}$  to  $+212^{\circ}\text{F}$  ( $-50^{\circ}\text{C}$  to  $100^{\circ}\text{C}$ )
  8. Temperature Measurement: 3 wire IEC 751 100  $\Omega$  RTD
  9. Maximum Sample Rate:  $4^{\circ}\text{F}$  ( $2.2^{\circ}\text{C}$ )/second minimum above  $0^{\circ}\text{C}$
  10. Outputs:
    - a. Analog: 4-20mA
    - b. Discrete: 2 SPDT form C contacts rated @ 3A 120 VAC.
  11. Supply Voltage: 120VAC / 60 Hz
  12. Display: LED 3-1/2 digit
  13. Sensor Mounting: Remote up to 75 feet
  14. Analyzer Mounting: Panel
  15. Analyzer Housing: NEMA 4 Wall Mounted
- D. Dew Point Temperature Transmitter (Compressed Air) :
1. Manufacturers: General Eastern, Vaisala or Approved Alternate.
  2. Microprocessor type primary dew point temperature measurement using platinum RTD, 4 wire, 100 ohm temperature sensing element with 4-20 mA transmitter.
    - a. Accuracy:  $\pm 3.6^{\circ}\text{F}$
    - b. Sensor Range (minimum):  $-50^{\circ}\text{F}$  to  $+50^{\circ}\text{F}$  dew point;  $32^{\circ}\text{F}$  to  $140^{\circ}\text{F}$  ambient
  3. Unit shall be selected for mounting in instrument air piping.
- E. Ducted Air System Static Pressure and Differential Pressure (Velocity) Transmitters:
1. Manufacturers: GE Modus, Setra, Invensys.
  2. Provide transducers/transmitters to convert velocity pressure differential or static duct pressure relative to sensor location into electronic signal.
  3. Unit shall be capable of transmitting linear 4 - 20 mA DC output signal proportional to differential (total minus static or static minus ambient) pressure input signals with the following minimum performance and application criteria:
    - a. Span: Not greater than twice duct static or velocity pressure at maximum flow rate, or more than 16 times velocity pressure at minimum flow rate.
    - b. Accuracy:  $\pm 1.0\%$  of span or  $\pm 1.0\%$  of full scale
    - c. Dead Band: Less than 0.5% of output
    - d. Hysteresis: Within 0.5% of span or within 0.5% of full scale
    - e. Linearity: Within 1.0% of span or within 0.5% of full scale
    - f. Repeatability: Within 0.5% of output
    - g. Response: Less than 1 second for full span input
  4. Return and exhaust air system static pressure transducers/transmitters shall be furnished with protective integral air filters on pressure sensing lines from static

pressure sensing stations and with static air probes to prevent migration of moisture and particulate matter into transducers. If inputs to pressure transducers/transmitters are dead-ended, integral air filters are not required. Supply air system sensors do not require integral air filters.

- F. Pressure/Differential Pressure Transmitter (Water):
1. Differential pressure water sensors shall be Dwyer Series 632, Setra 228, Robinson Halpern Series 152 or approved equal.
  2. Gauge pressure sensors shall be Setra C206, Ashcroft Model K1 thin film pressure transmitter or approved equal.
  3. Pressure sensor and integral 4-20 mA VDC transmitter. Select instrument for intended usage, range, maximum pressure/temperature. Sensor shall be capacitance or strain gauge type. Enclosure to be NEMA 4.
  4. Differential pressure transmitters shall have 5-valve manifold for servicing.
    - a. Diaphragm Material: Stainless Steel or Hastelloy
    - b. Process Connection: 1/2" NPT Stainless Steel
    - c. Power Supply Voltage: 13 - 35 VDC unregulated
    - d. Over Pressure: 1000 psig or 2 times maximum operating pressure whichever is greater.
    - e. Performance:
      - 1) Zero: Zero control shall be continuously adjustable between  $\pm 50\%$  of upper range limit. Total calibrated span and zero adjustment cannot exceed upper range limit. Zero span shall be independently field-adjustable with no interaction.
      - 2) Accuracy:  $\pm 0.25\%$  of calibrated span, including effects of linearity, hysteresis, repeatability dead band.
      - 3) Drift:  $\pm 0.1\%$  of upper limit for 6 months.
      - 4) Power Supply Effect: Less than 0.01% of output span per volt.
      - 5) Static Pressure Effect: Zero Error:  $\pm 0.1\%$  of upper range limit per 1000 psi.
      - 6) Span Error:  $\pm 0.2\%$  of reading per 1000 psi.
      - 7) Temperature Effect:  $\pm (0.025\%$  upper range limit plus 0.125% span) per 50°F.
- G. Room Pressure Differential Transmitter:
1. Manufacturers: Setra, Dwyer or approved equal.
  2. Provide ultra low differential pressure transmitter connected to passive pressure probes located in each space to be monitored.
  3. Room pressure differential transmitter shall have the following minimum characteristics:
    - a. Pressure Range:  $\pm 0.1$  inches WC
    - b. Accuracy:  $\pm 1\%$  of Full Scale Range
    - c. Resolution:  $\pm 5\%$  of reading
    - d. Operating Temperature Range: 32° to 120°F
    - e. Output Signal: 0-10 VDC or 4-20 mA
    - f. Operating Power: 24 VAC, 60 Hz
  4. Provide space static pressure sensors as follows:
    - a. Manufacturers: Air Monitor Corporation, Tek-Air or Thermo Electron Corporation

- b. Space static pressure probe shall be brushed aluminum with anodized finish or stainless steel with polished or painted finish selected by Architect.
  - c. Shielded static air probe shall be similar to Air Monitor Corporation Model 3 for flush ceiling mounting, complete with multiple sensing ports, pressure impulse suppression chamber, air flow shielding, and 3/8" FPT take-off fitting. Sensor shall be capable of sensing static pressure within 1% of actual pressure value while being subjected to maximum air flow of 100 fpm from radial source.
- H. Space Monitoring RTD Temperature Elements
- 1. Manufacturer: Minco, Burns Engineering or approved alternate.
  - 2. These shall be 3 lead 100  $\Omega$  platinum RTD ambient air monitoring direct mounted to 316 Stainless Steel plate. Plate shall be suitable for flush mounting to single-gang electrical box.
  - 3. Self-heating (Joule) error shall be less than 0.1°C with 0 to 1.0 mADC excitation current and shall have minimum 100 mW/°C heat dissipation factor. Conditions for specification: Potable water at 82°F (28°C) flowing at 1 ft/sec (0.3 m/s) transverse to sensor sheath.
  - 4. Temperature Span: -50 to 200°C
  - 5. Conformance: IEC 751/DIN 43760 unless otherwise noted.
  - 6. Temperature Coefficient: 0.00385  $\Omega/\Omega^\circ\text{C}$
  - 7. Accuracy Class: Class A Error  $\pm$  0.06% at 0°C
- I. Insertion RTD
- 1. Manufacturer: Pyromation or approved alternate.
  - 2. These shall be 100 $\Omega$  platinum RTD type temperature instruments for process immersion or air duct mounting.
  - 3. Sensors mounted in air streams, such as air handling units, supply ducts, exhaust ducts or return ducts, shall be averaging type. Mount averaging sensor across duct area in a "Z" pattern using mounting clips specific for averaging temperature sensor probes.
  - 4. Sheath shall be full welded construction, 316 Stainless Steel, and 0.250" diameter. Minimum lead length shall be 18". Sensitive portion of RTD shall not exceed 1" from sensor tip.
  - 5. Instrument leads shall terminate in junction "head".
    - a. Temperature Span: -50 to 200°C
    - b. Lead Quantity: 3 Lead
    - c. Conformance: IEC 751/DIN 43760 unless otherwise noted.
    - d. Temperature Coefficient: 0.00385  $\Omega/\Omega^\circ\text{C}$
    - e. Accuracy:  $\pm$  0.01% at 0°C
- J. RTD w/ Temperature Transmitter
- 1. Manufacturer: Minco, Rosemount, Burns, Moore Products, Foxboro, or approved alternate.
  - 2. These shall be 100 $\Omega$  platinum RTD type temperature instruments for process immersion or air duct mounting.
  - 3. RTD & transmitters shall be provided as a matched set and calibrated to the actual resistance of the RTD (traceable to NIST).



4. RTD:
  - a. Sensors mounted in air streams, such as air handling units, supply ducts, exhaust ducts or return ducts, shall be averaging type. Mount averaging sensor across duct area in a "Z" pattern using mounting clips specific for averaging temperature sensor probes.
  - b. Sheath shall be full welded construction, 316 Stainless Steel, and 0.250" diameter. Minimum lead length shall be 18". Sensitive portion of RTD shall not exceed 1" from sensor tip.
  - c. Self-heating (Joule) error shall be less than 0.1°C with 0 to 1.0 mADC excitation current and shall have minimum 100 mW/°C heat dissipation factor. Conditions for specification: Potable water at 82°F (28°C) flowing at 1 ft/sec (0.3 m/s) transverse to sensor sheath.
  - d. Instrument leads shall terminate in junction "head".
    - 1) Temperature Span: -50 to 200°C
    - 2) Lead Quantity: 3 Lead
    - 3) Conformance: IEC 751/DIN 43760 unless otherwise noted.
    - 4) Temperature Coefficient: 0.00385  $\Omega/\Omega C$
    - 5) Accuracy Class: Class A Error  $\pm$  0.06% at 0°C
5. Transmitter:
  - a. Instrument shall provide linear output signal proportional to process temperature input from 100 $\Omega$  platinum RTD and shall be matched to specified RTD.
  - b. Calibrate transmitter to the actual resistance of the RTD (traceable to NIST).
  - c. Instrument shall have configurable fail mode (Fail High or Fail Low).
  - d. Power Supply Voltage: 13 - 35 vdc unregulated
  - e. Output Signal: 4-20 mA 24 VDC two-wire
  - f. Operating Temperature: - 20 to +180°F
  - g. Accuracy: Error  $\pm$  0.1% of calibrated span
  - h. Minimum Span: 12  $\Omega$
  - i. Ambient Operating Range: -15 to 160°F, 0-99% RH non-condensing
6. Thermowell (liquid systems):
  - a. Manufacturer: Same as RTD manufacturer, Alloy Engineering, Burns, or approved alternate.
  - b. Thermowells shall be stepped configuration. Upper diameter of step shall be 3/4", tip diameter shall be 1/2". 1/2" section shall be approximately 2-1/2". Bore shall match sensor and shall be 1/4" short of tip. Thermowell assembly minimum insertion length, minimum measured fluid contact, shall be 6" or 1/3 of pipe diameter whichever is greater. Thermowells inserted into tanks shall be 15" minimum length.
  - c. Assembly shall include union between thermowell and connection head.
  - d. Thermowells shall be seamless 316 stainless steel and shall be of welded construction. Internal threads shall be 1/2" NPSM. Process connection shall be 3/4" NPSM.
  - e. Manufacturer shall determine RTD length when thermowell is required. Sensors installed in thermowells shall be spring loaded providing positive contact between sensor and thermowell bottom. Spring loading mechanism shall allow sensor to be removed from thermowell without disconnecting or twisting sensor leads.

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## PART 3 EXECUTION

### 3.1 GENERAL

- A. Provide and connect instruments as shown in drawings and required to fully accomplish control sequences as defined in Section 23 0993 - Control Sequences.

### 3.2 DISCRETE INSTRUMENTS

- A. Current Switches
1. To set current switch actuation point on gas or air moving equipment, block fan inlet(s) and outlet(s) and measure no load current draw with fan running at minimum speed. Set switch at 110% of no load current draw.
  2. To set current switch actuation point on liquid or water moving equipment, block fan inlet(s) and outlet(s) and measure no load current draw with pump running at minimum speed. Set switch at 110% of no load current draw.

- B. Air Handling Equipment Filter Pressure Drop
1. Unless otherwise noted, span for filter differential pressure instruments shall be:

<u>Filter Type</u>	<u>Scale Range (in wc)</u>
Throwaway Filter	0-0.5
Filters with 25% to 30% efficiency	0-1.0 (based on atmospheric dust spot test)
Filters with 31% to 99% efficiency	0-2.0 (based on atmospheric dust spot test)

2. Instruments on other filters shall be selected to match filter conditions.

- C. Low Limit Temperature Switches (Freeze Stats):
1. Install low limit controls where indicated on drawings or as specified. Unless otherwise indicated, install sensing element on upstream face of cooling coil where cooling coil is provided, or at downstream side of heating coils where no cooling coil is provided.
  2. Distribute sensing element across entire area of medium being sensed. Install controls at accessible location with suitable mounting brackets and element duct collars where required.
- D. Temperature Switches:
1. Provide properly sized thermowells for switches in liquid (water) processes and in gas (air) processes operating at 3 psig or greater.
  2. Capillaries shall not be excessively long (more than 3' then required length) on remote bulb switches.

### 3.3 ANALOG INSTRUMENTS

- A. Space Pressure Differential Transmitter
1. If within 6 ft of air distribution duct or within 1 ft of door, mount protective shroud over sensor.

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- B. Thermowells:
1. Thermowells shall not be subjected to flow velocities greater than manufacturer's recommended limit.
  2. Install thermowells with tip pointing downstream. Thermowells shall not be installed pointing upstream without approval by engineer. Thermowells shall not be installed pointing upstream in high velocities ( $> 10$  FPS).
  3. For line sizes less than 6", thermowell "U" dimension shall be 4" minimum and installed in elbow. If line size is 2" or less provide increaser/reducer to install thermowell in 2" pipe.
  4. For line sizes 6" and greater, size thermowell so that tip of thermowell extends into pipe  $1/3$  of pipe diameter.
  5. For insulated pipe installations, provide thermowells with 3" lag extension.
  6. Thermowells in high velocity fluid streams ( $> 15$  FPS for liquid) shall be tapered.
  7. For thermowells used with RTD's or thermocouples, provide unions connecting temperature instrument head to thermowell lagging extension.
- C. RTD'S
1. Provide properly sized thermowells for RTD's in liquid (water) processes and in gas (air) processes operating at 3 psig or greater.
  2. For air duct applications, size RTD so that tip of RTD extends into duct  $1/3$  of duct diameter/depth.
- D. Averaging RTD'S
1. Use averaging RTD's for each duct measuring application. Install with 6" minimum bend radius.

**END OF SECTION**



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## SECTION 26 0000CR

### GENERAL ELECTRICAL REQUIREMENTS

#### PART 1 GENERAL

##### 1.1 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.2 DESCRIPTION

- A. Intent of drawings and Specifications is to obtain complete systems tested, adjusted, and ready for operation.
- B. Except as otherwise defined in greater detail, the terms "provide", "furnish" and "install" as used in Division 26 Contract Documents shall have the following meanings:
  - 1. "Provide" or "provided" shall mean "furnish and install".
  - 2. "Furnish" or "furnished" does not include installation.
  - 3. "Install" or "installed" does not include furnishing.
- C. Include incidental details not usually shown or specified, but necessary for proper installation and operation.
- D. Check, verify and coordinate work with drawings and specifications prepared for other trades. Include modifications, relocations or adjustments necessary to complete work or to avoid interference with other trades.
- E. Included in this Contract are electrical connections to equipment provided by others. Refer to Architectural, Mechanical, Plumbing, and final shop drawings for equipment being furnished under other sections for exact locations of electrical outlets and various connections required.
- F. Information given herein and on drawings is as exact as could be secured but is not guaranteed. Do not scale drawings for dimensions.
- G. Where architectural features govern location of work, refer to Architectural Drawings.
- H. Perform work in "neat and workmanlike" manner as defined in ANSI/NECA 1, Standard Practices for Good Workmanship in Electrical Contracting.

##### 1.3 RELATED WORK

- A. Utility Services:
  - 1. Include costs for temporary service, temporary routing of service or other requirements of temporary nature associated with utility service.
  - 2. The contractor shall furnish and install ductbanks from the project site boundary and existing manholes and existing buildings to the new building.

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- B. Temporary Services:
1. Refer to Division 01 – Temporary Facilities and Controls
  2. Provide temporary exterior lighting with 0.3 footcandles around perimeter fence line of construction or higher levels as required by Division 01.
- C. Continuity of Service:
1. No service shall be interrupted or changed without permission from Architect and Owner. Obtain written permission before work is started.
  2. When interruption of services is required, Architect, Owner and other concerned parties shall be notified and shall determine a time.
  3. All outages to the electrical system shall occur at night and/or on weekends or holidays. Contractor shall include appropriate costs in his bid. No extra charges associated with outages will be accepted.
- D. Demolition:
1. Division 02 – Site Demolition and Structure Demolition
  2. Perform required demolition to accomplish new work.
    - a. Remove abandoned wiring to source of supply.
    - b. Remove exposed abandoned conduit, including abandoned conduit above accessible ceiling finishes. Cut conduit flush with walls and floors, and patch surfaces.
    - c. Disconnect abandoned outlets and remove devices.
    - d. Remove abandoned outlets if conduit servicing them is abandoned and removed.
    - e. Provide blank cover for abandoned outlets that are not removed.
    - f. Disconnect and remove electrical devices and equipment serving utilization equipment that has been removed.
    - g. Disconnect and remove abandoned luminaries. Remove brackets, stems, hangers, and other accessories.
    - h. Disconnect electrical systems in walls, floors, and ceilings scheduled for removal.
  3. Accomplish work in neat workmanlike manner to minimize interference; annoyance or inconvenience such work might impose on Owner or other Contractors.
  4. Unless otherwise noted, remove from premises materials and equipment removed in demolition work.
  5. Equipment noted to be removed and turned over to Owner, shall be delivered to Owner at place and time Owner designates.
  6. Where materials are to be turned over to Owner or reused and installed by Contractor, it shall be Contractor's responsibility to maintain condition of materials and equipment equal to that existing before work began. Repair or replace damaged materials or equipment at no additional cost to Owner.
  7. Where demolition work interferes with Owner's use of premises, schedule work through Architect, Owner and with other Contractors to minimize inconvenience to Owner. Architect must approve schedule before Contractor begins such work.
- E. Cleaning and Repair
1. Panelboards.
    - a. Clean exposed surfaces and check tightness of electrical connections.
    - b. Replace damaged circuit breakers and provide closure plates for vacant positions.

- c. Provide typed circuit directory showing revised circuiting arrangement.
- F. Concrete Work:
- 1. Provide cast-in-place concrete as required by Contract Documents unless otherwise noted.
  - 2. Concrete shall comply with Division 03 - Concrete.
  - 3. Provide anchor bolts, metal shapes and templates to be cast in concrete or used to form concrete as required for anchoring and supporting electrical equipment.
- G. Painting:
- 1. Furnish equipment with factory-applied finish coats or paint equipment per Division 09 – Finishes unless specified otherwise.
  - 2. Furnish equipment with factory applied prime finish unless otherwise specified.
  - 3. If factory finish on equipment furnished by Contractor is damaged in shipment or during construction, refinish equipment to satisfaction of Architect.
  - 4. Furnish one can of touch up paint for each product equipped with a final factory-applied finish coat.

#### 1.4 REQUIREMENTS OF REGULATORY AGENCIES

- A. Rules and regulations of Federal, State and local authorities and utility companies, in force at time of execution of Contract shall become part of this specification.

#### 1.5 REFERENCE STANDARDS

- A. Agencies or publications referenced herein refer to the following:
  - 1. AEIC Association of Edison Illuminating Companies
  - 2. ANSI American National Standards Institute
  - 3. ASME American Society of Mechanical Engineers
  - 4. ASTM American Society for Testing and Materials
  - 5. BICSI Building Industry Consulting Services International
  - 6. EIA Electronic Industries Association
  - 7. FIPS Federal Information Processing Standards
  - 8. FCC Federal Communications Commission
  - 9. ICEA Insulated Cable Engineers Association
  - 10. IEEE Institute of Electrical & Electronics Engineers
  - 11. IESNA Illuminating Engineering Society of North America
  - 12. NEC National Electrical Code
  - 13. NECA National Electrical Contractors Association
  - 14. NEMA National Electrical Manufacturers Association
  - 15. NESC National Electrical Safety Code
  - 16. NETA National Electrical Testing Association
  - 17. NFPA National Fire Protection Association
  - 18. NIST National Institute of Standards & Technology
  - 19. OSHA Occupational Safety and Health Administration
  - 20. TIA Telecommunications Industries Association
  - 21. UL Underwriters Laboratories, Inc.

- B. Work shall be in accordance with latest edition of codes, standards or specifications unless noted otherwise.

## 1.6 LISTING

- A. Install materials bearing UL label or UL listing, unless UL label or listing is not available for that type of material.
- B. Other nationally recognized testing agencies, acceptable to AHJ, are approved.

## 1.7 ENCLOSURES

- A. Typical NEMA Enclosures and Usage
  1. NEMA 1 - Indoors. Falling dirt.
  2. NEMA 2 - Indoors. Falling dirt. Falling liquids. Light splashing.
  3. NEMA 3 - Outdoors. Sleet, snow, rain. Windblown dust.
  4. NEMA 3X - Same as NEMA 3 plus corrosion resistant.
  5. NEMA 3S - Same as NEMA 3 plus mechanism operable when ice covered.
  6. NEMA 3SX - Same as NEMA 3S plus corrosion resistant.
  7. NEMA 3R - Outdoors. Rain, snow, sleet.
  8. NEMA 3RX - Same as NEMA 3R plus corrosion resistant.
  9. NEMA 4 - Indoors. Falling dirt. Falling and light splashing liquids. Flying dust, lint and fibers. Hose down.
  10. NEMA 4X - Same as NEMA 4 - Indoors plus corrosion resistant.
  11. NEMA 4 - Outdoors. Rain, sleet, snow. Wind blown dust. Hose down.
  12. NEMA 4X - Same as NEMA 4 - Outdoors plus corrosion resistant.
  13. NEMA 5 - Indoors. Falling Dirt. Falling Liquids. Settling dust, lint and fibers.
  14. NEMA 6 - Indoors. Falling dirt. Falling and light splashing liquids. Flying dust, lint and fibers. Hose down. Temporary submersion.
  15. NEMA 6P - Same as NEMA 6 - Indoors plus corrosion resistant. Prolonged submersion.
  16. NEMA 6 - Outdoors. Rain, snow, sleet. Windblown dust. Hose down. Temporary submersion.
  17. NEMA 6P - Same as NEMA 6 - Outdoors plus corrosion resistant. Prolonged Submersion.
  18. NEMA 7 - Indoors. Class I, Division 1 or 2, Groups A, B, C or D. (Flammable gas).
  19. NEMA 9 - Indoors. Class II, Division 1 or 2. Groups E, R, or G. (Combustible dust).
  20. NEMA 12 - Indoors. Falling Dirt. Falling liquids. Flying dust, lint and fibers. Oil or coolant seepage.
  21. NEMA 13 - Same as NEMA 12 plus oil or coolant spraying or splashing.

## 1.8 SUBMITTALS

- A. Submit shop drawings for equipment provided under this Division:
  1. Refer to Division 01 - Submittal Procedures.
  2. Note that for satisfying submittal requirements for Division 26, "Product Data" is usually more appropriate than true "Shop Drawings" as defined in Division 01. However, the expression "Shop Drawings" is generally used throughout Specification.



3. Submit shop drawings for equipment and systems as requested in respective specification sections. Submittals which are not requested may not be reviewed.
  4. Specifically mark general catalog sheets and drawings to indicate specific items submitted and its correlation to specific designation for product in drawings.
  5. Specifically indicate proper identification of equipment by name and/or number, as indicated in specification and shown on drawings.
  6. When manufacturer's reference numbers are different from those specified, provide correct cross-reference number for each item. Clearly mark and note submittal accordingly.
  7. Submit complete record of required components when luminaires, equipment and items specified include accessories, parts and additional items under one designation.
  8. Include wiring diagrams for electrically powered or controlled equipment.
  9. Submit electrical equipment room layouts drawn to scale, including equipment, raceways, accessories and required working clearances. Submit electrical equipment room layouts concurrently with electrical distribution equipment submittals.
  10. Where submittals cover products containing non-metallic materials, include "Material Safety Data Sheet" (MSDS) from manufacturer stating physical and chemical properties of components and precautionary considerations required.
  11. Submit shop drawings or product data as soon as practicable after signing contracts. Submittals must be approved before installation of materials and equipment.
  12. Submittals that are not complete, not permanent, or not properly checked by Contractor, will be returned without review.
  13. "Coordination Drawings", which are normally prepared by Contractor to coordinate work among various trades and to facilitate installation, shall not be submitted for Division 26 work unless specifically requested in technical sections. These types of drawings typically include dimensioned piping, ductwork or electrical raceway layouts.
  14. Unless specifically requested in Division 26 technical sections, submittals of coordination drawings will be returned without review.
- B. Certificates and Inspections:
1. Obtain and pay for inspections required by authorities having jurisdiction and deliver certificates approving installations to Owner unless otherwise directed.
- C. Operation and Maintenance Manuals:
1. Refer to Division 01 - Operation and Maintenance Data.
  2. Upon completion of work but before final acceptance of system, submit to Architect for approval 3 copies of operation and maintenance manuals in loose-leaf binders. If "one copy" is larger than 2" thick or consists of multiple volumes, submit only one set initially for review. After securing approval, submit 3 copies to Owner.
  3. Organize manuals by specification section number and furnish table of contents and tabs for each piece of equipment or system.
  4. Include the following:
    - a. Copies of shop drawings

- b. Manufacturer's operating and maintenance instructions. Include parts lists of items or equipment. Where manufacturer's data includes several types or models, designate applicable type or model.
  - c. CD ROM's of O&M data with exploded parts lists where available
  - d. Phone numbers and addresses of local parts suppliers and service companies
  - e. Internet/Web page addresses where applicable
  - f. Wiring diagrams
  - g. Start up and shut down procedure
  - h. Factory and field test records
  - i. Additional information, diagrams or explanations as designated under respective equipment or systems specification section
5. Instruct Owner's representative in operation and maintenance of equipment. Instruction shall include complete operating cycle on all apparatus.
  6. Furnish O&M manuals and instructions to Owner prior to request for final payment.
  7. Once the final paper copies of the O&M manuals are approved, contractor shall create a CD-Rom containing PDF files of all paper copy O&M manual sheets, organized by subject, and submit.
- D. Record Documents:
1. Refer to General Conditions of Contract and Section 01 7700 - Closeout Procedures. Prepare complete set of record drawings in accordance with Section 01 7700.
  2. Use designated set of prints of Contract Documents as prepared by Architect to mark-up for record drawing purposes.
  3. As-build drawings shall be on same AutoCAD system version as used by University of Minnesota at time of substantial completion.

## 1.9 JOB CONDITIONS

- A. Building Access:
1. Arrange for necessary openings in building to allow for admittance of all apparatus.
- B. Coordination:
1. Equipment provided under other Divisions of these specifications.
    - a. Motors
    - b. Electrically powered equipment
    - c. Electrically controlled equipment
    - d. Starters, where specified
    - e. Variable frequency drives, where specified
    - f. Control devices, where specified
    - g. Temperature Control wiring
  2. Provide the following devices required for control of motors or electrical equipment, unless noted otherwise:
    - a. Starters
    - b. Disconnect devices
    - c. Control devices:
      - 1) Pushbuttons
      - 2) Pilot lights
      - 3) Contacts

- d. Conduit, boxes and wiring for Power wiring
  - e. Conduit, boxes and wiring for Control wiring, except temperature control wiring
  3. Connect and wire equipment complete and ready to operate according to wiring diagrams furnished by various trades.
  4. Wire starters or other similar control devices furnished by others.
  5. This contractor's drawings and/or specifications show number and hp rating of motors furnished by others, together with their actuating devices. Should any change in size, hp rating, voltage, or means of control be made to any motor or other electrical equipment after Contracts are awarded, Contractor responsible for change shall immediately notify this Contractor. Additional costs due to these changes shall be responsibility of Contractor initiating change.
  6. Equipment and wiring shall be selected and installed for conditions in which it will be required to perform. (i.e., general purpose, weatherproof, rain tight, explosion proof, dust tight, or any other special type as required.)
  7. Comply with local utility motor starting requirements and provide starters for motors furnished by others as specified herein or under various trade sections of those specifications.
- C. Cutting and Patching:
1. Refer to General Conditions of the Contract.
  2. Perform cutting and patching required for complete installation of systems unless otherwise noted. Patch and restore work cut or damaged to original condition. This includes openings remaining from removal or relocation of existing system components.
  3. Provide materials required for patching unless otherwise noted.
  4. Do not pierce beams or columns without permission of Architect and then only as directed. If openings are required through walls or floors where no sleeve has been provided, hole shall be core drilled to avoid unnecessary damage and structural weakening.
  5. Where alterations disturb lawns, paving, walks, etc., replace, repair or refinish surfaces to condition existing prior to commencement of work. This may include areas beyond construction limits.
- D. Housekeeping and Cleanup:
1. Refer to Division 01 - Closeout Procedures.
  2. As work progresses or as directed by Architect, periodically remove waste materials from building and leave area of work broom clean. Upon completion of work, remove tools, scaffolding, broken and waste materials, etc. from site.

## 1.10 WARRANTY

- A. Refer to Division 01 for general Warranty requirements.
- B. Refer to technical sections for Warranty requirement for each system.
  1. Where no warranty requirements are called out, warrant for 1 year after acceptance by Owner equipment, materials, and workmanship to be free from defect.
- C. Repair, replace, or alter systems or parts of systems found defective at no extra cost to Owner.

- D. In any case, wherein fulfilling requirements of any guarantee, if Contractor disturbs any work guaranteed under another contract, restore such disturbed work to condition satisfactory to Architect and guarantee such restored work to same extent as it was guaranteed under such other contract.
- E. Warranty shall include labor, material, and travel time.

## **PART 2 PRODUCTS**

### **2.1 PRODUCT SUBSTITUTIONS**

- A. Refer to Division 01 - Product Requirements.

## **PART 3 EXECUTION**

### **3.1 GENERAL**

- A. Verify elevations and dimensions prior to installation of materials.

### **3.2 DELIVERY, STORAGE, AND HANDLING**

- A. Deliver products to the site under provisions of Division 01.
- B. Store and protect products under provisions of Division 01
- C. Store in clean, dry space.
- D. Maintain factory wrapping or provide cover to protect units from dirt, water, construction debris, and traffic.
- E. Handle in accordance with manufacturer's written instructions.
- F. Handle carefully to avoid damage to components, enclosure, and finish. Lift only with lugs provided for the purpose.
- G. Provide supplemental heat if required to prevent moisture contamination.

### **3.3 FLOOR, WALL, ROOF AND CEILING OPENINGS**

- A. Coordinate location of openings, chases, furred spaces, etc. with appropriate Contractors. Provide sleeves and inserts that are to be built into structure during progress of construction.
- B. Remove temporary sleeves, if used to form wall openings, prior to installation of permanent materials. Provide minimum 24 ga galvanized sheet metal for permanent wall penetration sleeves unless otherwise noted.
- C. Provide Schedule 40 carbon steel pipe with integral water stop for steel sleeves required below grade or to exterior.

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- D. Submit to Structural Engineer for review and approval the size and location of core-drilled holes prior to execution.
  - E. Submit product data and installation details for penetrations of building structure. Include schedule indicating penetrating materials, (steel conduit, PVC conduit, cables, cable tray, etc.), sizes of each, opening sizes and sealant products intended for use.
  - F. Where penetrations of fire-rated assemblies are involved, seal penetrations with appropriate firestopping systems as specified in Section 26 0593CR - Electrical Systems Firestopping.
  - G. Submit complete penetration layout drawings showing openings in building structural members including floor slabs, bearing walls, shear walls, etc. Indicate and locate, by dimension, required openings including those sleeved, formed or core drilled. Submit drawings for approval prior to preparing openings in structural member.
  - H. Provide 1/2" clearance around penetration openings intended for raceways and cables. Where fire resistant penetrations are required, size openings in accordance with written recommendations of firestopping systems manufacturer.
  - I. Seal non fire-rated floor penetrations with non-shrink grout equal to Embeco by Master Builders, or urethane caulk, as appropriate.
  - J. Seal non-rated wall openings with urethane caulk.
  - K. Where penetrations occur through exterior walls into building spaces, use steel sleeves with integral water stop, similar to type "WS" wall sleeves by Thunderline Corporation. Seal annular space between sleeves and pipe with "Link-Seal" modular wall and casing seals by Thunderline Corporation, or sealing system by another manufacturer approved as equal by Architect. Sealing system shall utilize Type 316 stainless steel bolts, washers and nuts.
  - L. Finish and trim penetrations as shown on details and as specified hereinafter.
  - M. Provide chrome or nickel plated escutcheons where raceways pass through walls, floors or ceilings and are exposed in finished areas. Size escutcheons to fit raceways for finished appearance. Finished areas shall not include mechanical/electrical rooms, janitor's closets, storage rooms, etc., unless suspended ceilings are specified.
  - N. In Clean Room areas:
    - 1. Exposed conduit penetrations shall be sealed as follows:
      - a. Escutcheons shall not be used when conduits are exposed in finished areas and penetrate finished surfaces.
      - b. Cut and patch penetration to within 1/4" of conduit.
      - c. Seal openings around conduit and patch work with sealants specified in Division 07 – Joint Sealants. If not sealants are listed, provide sprayable, flexible, liquid polyvinyl chloride coating equal to ANDEK "COCOON® 72634-USDA". Sealant shall be installed per manufacturer's application requirements.
    - 2. Penetrations other than conduits (junction boxes, light fixtures, etc.) including wiring devices shall be sealed as follows:
      - a. Seal non-rated opening with silicone sealant.

- b. See drawings for details.
- c. Confirm selected sealant is compatible with paint provided by others prior to application.
- d. Product: One-Part Mildew-Resistant Silicone Sealant: Type S; Grade NS; Class 25; Uses NT, G, A, and as applicable to nonporous joint substances indicated, O; formulated with fungicide; intended for sealing interior joints with nonporous substrates and subject to in-service exposure to conditions of high humidity and temperature extremes; subject to compliance with requirements. Provide one of the following:
  - 1) 786 Mildew Resistant Silicone Sealant; Dow Corning Corp.
  - 2) Sanitary 1700 Silicone Sealant; General Electric Co.
  - 3) 898 Silicone Sanitary Sealant; Pecora Corp.
  - 4) Tremsil 600; Tremco Corp.
  - 5) OmniPlus; Sonneborn Building Products Div., Rexnord Chemical Products, Inc.

### 3.4 EQUIPMENT ACCESS

- A. Install raceways, junction and pull boxes, and accessories to permit access to equipment for maintenance. Relocate raceways or accessories to provide maintenance access at no additional cost to Owner.
- B. Install equipment with ample maintenance space for removal, repair or changes to equipment. Provide ready accessibility to equipment and wiring without moving other future or installed equipment.
- C. Provide access doors in walls, chases or inaccessible ceilings for equipment requiring access for servicing, repairs and maintenance, unless otherwise noted. Access frames and doors shall be as manufactured by Milcor, Incorporated, or similar, of style applicable to surface. Provide access doors used in fire-rated construction with UL label. Provide steel, prime-coated access doors in dry locations. Provide stainless steel access doors for use in ceramic tile walls, toilet rooms, locker rooms, and in areas subject to excessive moisture. Provide access doors of sufficient size to allow complete maintenance. Coordinate location of access doors with General Contractor and rough-in equipment accordingly.
- D. Locate electrical outlets and equipment to fit details, panels, decorating or finish at space. Architect reserves right to make minor position changes of outlet locations before work has been installed.
- E. Verify door swings before installing room light switch boxes. Install boxes on latch side of door unless otherwise noted.

### 3.5 EQUIPMENT SUPPORTS

- A. Provide supporting steel not indicated on drawings as required for installation of equipment and materials including angles, channels, beams, hangers, etc.
- B. Provide steel shell with plug type concrete anchors for attaching equipment to concrete. Plastic, rawhide or anchors using lead are not allowed.

- C. Do not support equipment or luminaires from metal roof decking.

### **3.6 CLEANING**

- A. Clean systems after installation is complete.
- B. Clean luminaire lenses and lamps at time of installation and clean lens exteriors just prior to final inspection.
- C. Thoroughly clean equipment of stains, paint spots, dirt and dust. Remove temporary labels not used for instruction or operation

### **3.7 SUPPORT PROTECTION**

- A. In occupied areas, mechanical and electrical rooms and areas requiring normal maintenance access, guard certain equipment to protect personnel from injury.
- B. Provide minimum 1/2" thick Armstrong Armaflex insulation or similar product applied with Armstrong 520 adhesive on lower edges of equipment, including bus duct, cable tray, pull boxes and electrical supporting devices suspended less than 7 ft above floors, platforms or catwalks in these areas.
- C. Protect threaded rods or bolts at supporting elements as described above. Trim threaded rods or bolts such that they do not extend beyond supporting element.

### **3.8 LEAD, RF, EMI SHIELDING**

- A. Wherever installation of this contractor's equipment destroys radiological integrity of wall, floor, or ceiling, this contractor shall be responsible to provide suitable shielding to restore that integrity. Coordinate these requirements with General Contractor.

### **3.9 REPORTS**

- A. Wherever this specification section or any other specification section requires a paper report to be made, test data to be recorded, or information to be submitted to Owner or Engineer, one electronic copy shall be made of the same data contained in the paper copy. This electronic copy shall be one copy of the same paper data, organized by subject, submitted in PDF format on CD-Rom.

### **3.10 ELECTRICAL SYSTEMS IDENTIFICATION**

- A. Refer to Section 26 0553CR – Electrical Systems Identification.

### **3.11 ACCEPTANCE TESTING**

- A. Contractor shall engage testing and inspection agency to perform acceptance tests. Equipment to be tested is noted as "Testing by Testing Agency" in technical specification sections. Perform in accordance with Section 26 0800CR – Commissioning of Electrical Systems
- B. When testing is to be witnessed by Architect/Engineer or Inspector, notify them at least 10 days prior to testing date.

- C. When equipment or systems fail to meet minimum test requirements, replace or repair defective work or materials as necessary and repeat inspection and test. Make repairs with new materials.
- D. Contractor is responsible for certifying in writing equipment and system test results. Certification shall include identification of portion of system tested, date, time, test criteria and name and title of person signing test certification documents.
- E. Maintain copies of certified tests, including those for any failed tests, at project site. At completion of project, include copies of test records and certifications in O&M Manuals.

### **3.12 START-UP**

- A. Systems and equipment shall be started, tested, adjusted, and turned over to Owner ready for operation. This includes "Owner-Furnished, Contractor-Installed" (OFICI) and "Contractor-Furnished, Contractor-Installed" (CFCI) systems and equipment.
- B. Follow manufacturer's pre-start-up checkout, start-up, trouble shooting and adjustment procedures.
- C. Contractor shall provide services of technician/mechanic knowledgeable in start-up and checkout of types of systems and equipment on project.
- D. Provide start-up services by manufacturer's representative where specified or where Contractor does not have qualified personnel.
- E. Coordinate start-up with all trades.

### **3.13 CLEANING**

- A. Clean systems after installation is complete.
- B. Vacuum debris from panelboards, switchboards, motor starter and disconnect switch enclosures, junction boxes and pull boxes two weeks before energization and again prior to completion.
- C. Delete non-applicable equipment.
- D. Where louvers are provided in switchgear or transformer enclosures, vacuum louvers free of dust and dirt.
- E. Clean luminaire lenses and lamps at time of installation and clean lens exteriors just prior to final inspection.
- F. Thoroughly clean equipment of stains, paint spots, dirt and dust. Remove temporary labels not used for instruction or operation.

**END OF SECTION**



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**SECTION 26 0516CR**

**OWNER-FURNISHED EQUIPMENT**

**PART 1 GENERAL**

**1.1 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.2 DESCRIPTION**

- A. Section includes electrical connection(s) to Owner-purchased pieces of equipment, which are required in construction.
- B. Owner-furnished equipment requiring work by Contractor is specified in the following Sections:
- C. Contractor shall be responsible for receipt of equipment from Owner, storage after receipt, installation, and electrical connection.
- D. Owner-furnished equipment requiring work by the Contractor is shown on the drawings and schedules.
- E. Owner-furnished, Contractor-installed equipment is labeled OFCI.

**1.3 SUBMITTALS**

- A. Shop Drawings: Owner-supplied shop drawings of equipment furnished by Owner.
- B. Manufacturer's Installation Instructions:
  - 1. Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of product.

**1.4 QUALITY ASSURANCE**

- A. Regulatory Requirements:
  - 1. Comply with NFPA 70 for components and installation.
  - 2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

**1.5 DELIVERY, STORAGE, AND HANDLING**

- A. Store in clean, dry space. Maintain factory unopened packaging until ready for installation.

## **1.6 WARRANTY**

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr written warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.
- C. Contractor shall guarantee work performed to install equipment.
- D. Contractor shall have right and authority to request replacement of Owner-furnished equipment as if Contractor had purchased equipment.

## **PART 2 PRODUCTS**

### **2.1 NOT APPLICABLE TO THIS SECTION**

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Provide labor, materials and electrical connections for Owner-furnished equipment in accordance with contract drawings.
- B. Install and connect Owner-furnished equipment as though it had been purchased by Contractor.
  - 1. This shall include:
    - a. Receiving equipment at jobsite
    - b. Rigging and setting equipment in place
    - c. Making electrical connections
    - d. Starting
    - e. Testing
- C. Install equipment in accordance with manufacturer's installation instructions.
- D. Maintain equipment until facility is accepted by Owner.
- E. Review Owner-supplied shop drawings of Owner-furnished equipment to ascertain that necessary labor and materials have been provided to install equipment and complete the system it serves.

**END OF SECTION**

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**SECTION 26 0519CR**

**LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 26 0529CR - Hangers and Supports for Electrical Systems
- B. Section 26 0533.13CR - Surface Raceway System
- C. Section 26 0553CR - Electrical Systems Identification
- D. Section 26 0593CR - Electrical Systems Firestopping
- E. Section 26 0800CR – Commissioning of Electrical Systems

**1.2 REFERENCE**

- A. Work under this section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. Section includes conductors and cables rated 600 V and less, connectors, splices, and terminations rated 600 V and less, sleeves and sleeve seals for cables.
- B. Conductor and conduit sizes in these contract documents are based on copper wire, and only copper wire shall be used.
- C. All branch circuits shall be provided with a dedicated neutral conductor. No neutrals shall be shared between circuits or phases.

**1.4 REFERENCE STANDARDS**

- A. ASTM A 53/A 53M – Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless.
- B. ASTM B 1 – Standard Specification for Hand-Drawn Copper Wire.
- C. ASTM B 8 – Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.
- D. NEMA WC 3 – Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-19-81).
- E. NEMA WC 5 – Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-61-402).

- F. NEMA WC 70 – Non-Shielded Power Cable 2000 V or less for the Distribution of Electrical Energy (ICEA S-95-668).
- G. NFPA 70 – National Electrical Code.
- H. UL 44 – Thermoset-Insulated Wires and Cables.
- I. UL 83 – Thermoplastic-Insulated Wires and Cables.
- J. UL 486A-486B – Wire Connectors.
- K. UL 486C – Splicing Wire Connectors.
- L. UL 486D – Standard for Insulated Wire Connector Systems for Underground Use or in Damp or Wet Locations.
- M. UL 486E – Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors.
- N. UL 1569 – Standard for Metal-Clad Cables.

## 1.5 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Manufacturer's Installation Instructions: Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, and installation.
- C. Test Reports: Indicate field test and inspection procedures and interpret test results and corrective action taken for compliance with specification requirements.
- D. Closeout Submittals:
  - 1. Project Record Documents:
    - a. Record actual locations of components and circuits.
  - 2. Operation and Maintenance Data:
    - a. Include manufacturer's recommended operating instructions, maintenance procedures and intervals, and preventive maintenance instructions.

## 1.6 QUALITY ASSURANCE

- A. Regulatory Requirements:
  - 1. Comply with NFPA 70 for components and installation.
  - 2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.
- B. Wire and cable boxes and reels shall bear the date of manufacture.
  - 1. Date of manufacture shall not precede contract date by more than one year.

## **1.7 DELIVERY, STORAGE, AND HANDLING**

- A. Store in clean, dry space. Protect from dirt, fumes, water, corrosive substances, and construction debris.

## **1.8 WARRANTY**

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Alcan Products Corporation; Alcan Cable Division
- B. American Insulated Wire Corp.; a Leviton Company
- C. General Cable Corporation
- D. Southwire Company

### **2.2 DESCRIPTION**

- A. NEMA WC 70; single copper conductor insulated wire; 600 V rated insulation; 90°C maximum operating temperature for dry and wet or damp locations.
  - 1. Thermoplastic-insulated wires and cables: NEMA WC 5, UL 83; Type dual rated THHN/THWN-2.
  - 2. Thermoset-insulated wires and cables: NEMA WC 3, UL 44; Type USE.
- B. Multi-conductor Cable: UL Listed, NEMA WC 70; for metal-clad cable, Type MC with ground wire.
- C. Metal-clad cable, Type MC; UL 1569:
  - 1. Impervious, corrugated, continuous, seam welded metal sheath.
  - 2. Single grounding conductor.

### **2.3 REMOTE CONTROL AND SIGNAL CIRCUITS**

- A. Class 1
  - 1. Copper conductor, single insulated wire.
  - 2. Insulation type THHN/THWN-2 rated 90°C, 600 V insulation class.
  - 3. UL 83 listed, ASTM B 1 for solid conductors; ASTM B 8 for stranded conductors.

- B. Classes 2 and 3
  - 1. Copper conductor, multiple twisted conductors covered with an overall non-metallic jacket unless otherwise noted.
  - 2. Insulation type XLE, rated 105°C, 300 V insulation class.
  - 3. UL listed for use in space in which circuits will be installed.

## **2.4 CONNECTORS, SPLICES, AND TERMINALS**

- A. Manufacturers:
  - 1. AFC Cable Systems, Inc.
  - 2. Hubbell Power Systems, Inc.
  - 3. O-Z/Gedney; EGS Electrical Group LLC.
  - 4. 3M; Electrical Products Division
  - 5. Tyco Electronics Corp.
- B. Description: UL 486A-486B, UL 486C, UL 486D, UL 486E; factory-fabricated connectors, splices, and terminals of size, ampacity rating, material, type, and class for application and service indicated.

## **2.5 TERMINATIONS**

- A. Compression set, bolted or screw type lug, or direct to bolted or screw type terminal.

## **2.6 PLASTIC CABLE TIES**

- A. Nylon or approved; locking type; metallic ties not permitted.

# **PART 3 EXECUTION**

## **3.1 INSTALLATION OF CONDUCTORS AND CABLES**

- A. Install conductors in a raceway system, unless otherwise specified or indicated.
- B. All branch circuits shall be provided with a dedicated neutral conductor. No neutrals shall be shared between circuits or phases.
- C. Install conductors only after:
  - 1. Building interior is enclosed and weather tight
  - 2. Mechanical work likely to damage conductors has been completed
  - 3. Raceway installation is complete and supported
- D. Pull conductors into raceway at same time.
- E. Wires shall not be drawn into conduit until plastering and tile work are complete. Thoroughly swab out all conduits before wire is pulled.
- F. Neatly train and lace conductors inside boxes, equipment, and panelboards.
- G. Conceal cables in finished walls, ceilings, and floors, unless otherwise indicated.

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- H. Use manufacturer-approved pulling compound or lubricant where necessary; compound used must not deteriorate conductor or insulation. Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values.
  - I. Use pulling means, including fish tape, cable, rope, and basket-weave wire/cable grips, that will not damage cables or raceway.
  - J. Install exposed cables parallel and perpendicular to surfaces of exposed structural members, and follow surface contours where possible. Protect exposed cables from damage.
  - K. Support cables above accessible ceiling using plastic cable ties to support cables from structure or ceiling suspension system. Do not rest cable on ceiling panels.
  - L. Support cables and conductors in vertical raceways per requirements in Section 26 0529CR - Hangers and Supports for Electrical Systems.
  - M. Identify and color-code conductors and cables according to Section 26 0553CR - Electrical Systems Identification.
    - 1. 208Y/120 volt, 3 phase, 4 wire: phase A-black, phase B-red, phase C-blue, neutral-white ground conductor-green.
    - 2. 480Y/277 volt, 3 phase, 4 wire: phase A-brown, phase B-orange, phase C-yellow, neutral-gray ground conductor-green.
    - 3. Phase conductors, grounds, and neutral conductors shall be identified by color specified being the color of the conductor insulation along the entire length of the conductor.
    - 4. Neutral shall be identified with the circuit numbers of the associated phase conductors.
  - N. Wiring at Outlets: Install conductor at each outlet, with minimum 6" of slack.
  - O. Limit conduit fill to a maximum of 9 current-carrying conductors. Neutral conductors shall be considered current carrying.
  - P. Install stranded conductors where conductors terminate in crimp type lugs. Do not place bare stranded conductors directly under screws.
  - Q. At no time shall the conductors of the emergency, life safety, or standby power branches occupy the same boxes or raceways as the normal power system or each other.
  - R. 208/120V conductors shall not occupy the same raceway as 480V/277V conductors.
  - S. Where specific wire sizes are not indicated on drawings, size branch circuit conductors and ground wire based on overcurrent protective device per NEC. Ground wires shall be increased in size proportional to phase conductor increase when
  - T. De-rate conductors as required by NEC for voltage drop, conduit fill or ambient temperature. Provide increase in conductors and conduit size as needed due to de-rating or voltage drop calculation.

### 3.2 CONDUCTOR MATERIAL APPLICATIONS

- A. Feeders: Stranded copper.
- B. Branch Circuits: Stranded copper for size #8AWG and larger. Solid copper for size #10AWG and smaller except that #10AWG and smaller which is installed in flexible conduit at terminal connections of rotating, vibrating, or moveable equipment shall be stranded. Contractor may use stranded wire for #10AWG and smaller at their own discretion provided that proper compression connectors are used and terminated for all devices and equipment. See 3.1.P.
- C. Minimum conductor sizes shall be as follows:
  - 1. No. 12 AWG – Branch circuits of any kind.
  - 2. No. 14 AWG – Remote control and signal systems, fire alarm system.
- D. Branch wiring length limitations:
  - 1. 208Y/120 V circuits over 65 ft in length: Increase wire size one size for each 65 ft of length. Increase conduit size as required. Increase ground wire size as required by NEC.
  - 2. 480Y/277 V circuits over 150 ft in length: Increase wire size one size for each 150 ft of length. Increase conduit size as required. Increase ground wire size as required by NEC.

### 3.3 CONDUCTOR INSULATIONS AND MULTICONDUCTOR CABLE APPLICATIONS AND WIRING METHODS

- A. Service Entrance: Type THHN/THWN-2.
- B. Exposed Feeders: Type THHN/THWN-2.
- C. Feeders Concealed in Ceilings, Walls, Partitions, and Crawlspace: Type THHN/THWN-2.
- D. Feeders Concealed in Concrete, below Slabs-on-Grade, and Underground: Type THHN/THWN-2
- E. Exposed Branch Circuits, Including in Crawl Spaces: Type THHN/THWN-2.
- F. Branch Circuits Concealed in Concrete, below Slabs-on-Grade, and Underground (where specifically allowed or shown): Type THHN/THWN-2.
- G. Motor Circuit Branch Wiring and Associated Control Wiring: Type THHN/THWN-2.
- H. Wiring in Fluorescent Fixture Channels: Type THHN, rated 90°C for dry and damp locations, single conductors.
- I. Branch circuits for exterior lighting circuits: Type XHHW.
- J. Cord Drops and Portable Appliance Connections: Type SO, hard service cord with stainless-steel, wire-mesh, strain relief device at terminations to suit application.



### 3.4 REMOTE CONTROL AND SIGNAL CIRCUITS

- A. Sizing - #14 AWG minimum.
- B. Installation:
  - 1. Install cables in cable tray and cable rings.
  - 2. Provide protection for exposed cables where subject to damage.
  - 3. Support cables above accessible ceilings; do not rest on ceiling tiles.
  - 4. Use suitable cable fittings and connectors.

### 3.5 CONNECTORS, SPLICES, AND TERMINALS

- A. Connectors:
  - 1. Except where equipment is furnished with bolted or screw type lug, use compression set pressure connectors with insulating covers. Use compression tools and die compatible with connectors being installed.
  - 2. Use bolt or compression-set type with application of insulating tape, pre-stretched or heat-shrinkable insulating tubing for splices and taps of #8 AWG conductors and larger. Install with hydraulic compression tool.
  - 3. Use pre-insulated "twist-on" connectors with integral spring for splices and taps of #10 AWG conductors and smaller.
  - 4. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A-486B.
  - 5. Terminate aluminum conductors with tin-plated, aluminum-bodied compression connectors only.
  - 6. Install suitable reducing connectors or mechanical connector adaptors for connecting aluminum conductors to copper conductors.
- B. Splices:
  - 1. Splice wires and cable only in accessible locations such as within junction boxes.
  - 2. Make splices to carry full capacity of conductors with no perceptible temperature rise.
  - 3. Make below-grade splices in manholes and handholes watertight with pre-stretched or heat-shrinkable insulating tubing, or resin-filled insulator.
  - 4. Use electrical tape to build up insulation level equivalent to cable insulation and cover with not less than two half-lapped layers of plastic electrical tape, for joints, taps, and splices of #1 AWG conductors and larger.
  - 5. Plastic snap-on splice insulators are not allowed.
  - 6. Make splices and taps that are compatible with conductor material and that possess equivalent or better mechanical strength and insulation ratings than unspliced conductors.
  - 7. Use oxide inhibitor in each splice and tap conductor for aluminum conductors.
- C. Terminals:
  - 1. Insulate ends of spare conductors with electrical tape and identify spare circuit number where appropriate.
  - 2. Eye type crimped terminal for removable screw type terminal. Forked torque terminal when screw terminal cannot be removed.

3. Train wires to eliminate fanning of strands, crimp with proper tool and die.
4. Torque screw termination per manufacturer's recommended values.

### **3.6 CABLE TIES**

- A. Neatly bundle conductors and cables together for support. Size cable ties sufficiently to accommodate the multiple cables being supported.

### **3.7 FIELD QUALITY CONTROL**

- A. Test 600 volt conductors and cables per requirements in Sections 26 0800CR – Commissioning of Electrical Systems
- B. Interpret test results in writing and submit to Engineer.
- C. Replace conductors and cables that are found defective, at no expense to Owner.

**END OF SECTION**

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**SECTION 26 0526CR**

**GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 26 0000CR – General Electrical Requirements
- B. Section 26 0800CR – Commissioning of Electrical Systems

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. Section includes methods and materials for grounding systems and equipment, as required by State Codes, NFPA 70, applicable portions of other NFPA codes, as indicated herein, plus the following special applications:
  - 1. Underground distribution grounding.
- B. Maximum resistance to ground shall be less than 5 ohms.
- C. Refer to Grounding Riser Diagram.
- D. All branch circuits shall be provided with a dedicated neutral conductor. No neutrals shall be shared between circuits or phases.

**1.4 REFERENCE STANDARDS**

- A. ANSI J-STD-607-A – Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications
- B. ASTM B 3 – Specification for Soft or Annealed Copper Wire
- C. ASTM B 8 – Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard or Soft
- D. ASTM B 33 – Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
- E. IEEE C2 – National Electrical Safety Code (ANSI)
- F. IEEE 857 – Standard for Qualifying Permanent Connections Used in Substation Grounding

- G. NETA ATS – Acceptance Testing Specifications
- H. NFPA 70 – National Electrical Code
- I. NFPA 70B – Recommended Practice for Electrical Equipment Maintenance
- J. UL 467 – Grounding and Bonding Equipment
- K. IEEE 80 – Guide for Safety in AC Substation Grounding

## 1.5 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Closeout Submittals:
  - 1. Operation and Maintenance Manuals: Include the following:
    - a. Instructions for periodic testing and inspection of grounding features at test wells, ground rings, grounding connections for separately derived systems, NETA ATS.
      - 1) Instructions to perform tests to determine if ground resistance or impedance values remain within specified maximums, and instructions shall recommend corrective action if they do not.
      - 2) Include recommended testing intervals.
- C. Other Informational Submittals: Plans showing dimensioned as-built locations of grounding features, including the following:
  - 1. Test wells
  - 2. Ground rods
  - 3. Ground rings
  - 4. Grounding arrangements and connections for separately derived systems
  - 5. Grounding for sensitive electronic equipment
- D. Field Quality-Control Test Reports:
  - 1. Indicate field test and inspection procedures and interpret test results and corrective action taken for compliance with specification requirements.
  - 2. Test reports of resistance to earth. Each test report shall include:
    - a. Date of test, soil moisture content, and soil temperature
    - b. Test operator
    - c. Instrument or other test equipment used
    - d. Electrode designation or location
    - e. Ground impedance in ohms
    - f. Assumptions made - if required

## 1.6 QUALITY ASSURANCE

- A. Regulatory Requirements:
  - 1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70.
  - 2. Comply with UL 467 for grounding and bonding materials and equipment.

## **1.7 DELIVERY, STORAGE, AND HANDLING**

- A. Store products in clean, dry space. Protect from dirt, fumes, water, corrosive substances, and construction debris.

## **1.8 WARRANTY**

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr written warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

## **PART 2 PRODUCTS**

### **2.1 CONDUCTORS**

- A. Insulated Conductors: Copper wire or cable insulated for 600 V unless otherwise required by applicable Code or authorities having jurisdiction, insulation color: green.
- B. Bare Copper Conductors:
  - 1. Solid Conductors: ASTM B 3.
  - 2. Stranded Conductors: ASTM B 8.
  - 3. Tinned Conductors: ASTM B 33.
  - 4. Bonding Cable: 28 kcmil, 14 strands of No. 17 AWG conductor, 1/4" in diameter.
  - 5. Bonding Conductor: No. 4 or No. 6 AWG, stranded conductor.
  - 6. Bonding Jumper: Copper tape, braided conductors, terminated with copper ferrules; 1-5/8" wide and 1/16" thick.
  - 7. Tinned Bonding Jumper: Tinned-copper tape, braided conductors, terminated with copper ferrules; 1-5/8" wide and 1/16" thick.
  - 8. Grounding Grid Conductors: #4/0 bare copper.
- C. Grounding Bus: Horizontal rectangular bars of annealed copper, as indicated on drawings.

### **2.2 CONNECTORS**

- A. Listed and labeled by a nationally recognized testing laboratory acceptable to authorities having jurisdiction for applications in which used, and for specific types, sizes, and combinations of conductors and other items connected.
- B. Welded Connectors: Exothermic-welding kits of types recommended by kit manufacturer for materials being joined and installation conditions.
- C. Compression Connectors: Irreversible type.

### **2.3 GROUNDING ELECTRODES**

- A. Ground Rods: Copper-clad steel ; 3/4" in diameter by 10 ft in length

## 2.4 MANHOLE GROUNDING BUSBARS

- A. Material: Annealed Copper
  - 1. ¼" Thick
- B. Size
  - 1. Horizontal rectangular bar
  - 2. 24"Lx4"H pre-drilled with ½" holes and NEMA 2-hole spacing.
- C. Insulators and stand-off brackets shall isolate busbar from wall surface.

## PART 3 EXECUTION

### 3.1 APPLICATIONS

- A. Conductors: Install stranded conductors.
- B. All branch circuits shall be provided with a dedicated neutral conductor. No neutrals shall be shared between circuits or phases.
- C. Underground Grounding Conductors: Install bare copper conductor. Sized as indicated on drawings.
  - 1. Bury at least 24" below grade.
  - 2. Ductbank Grounding Conductor: Bury 12" above ductbank when indicated as part of ductbank installation.
- D. Isolated Grounding Conductors: Green-colored insulation with continuous yellow stripe. On feeders with isolated ground, identify grounding conductor where visible to normal inspection, with alternating bands of green and yellow tape, with at least three bands of green and two bands of yellow.
- E. Conductor Terminations and Connections:
  - 1. Pipe and Equipment Grounding Conductor Terminations: Bolted connectors
  - 2. Underground Connections: Welded connectors, except at test wells and as otherwise indicated
  - 3. Connections in Manholes: Compression connectors or Welded connections
  - 4. Connections to Ground Rods at Test Wells: Bolted connectors
  - 5. Connections to Structural Steel: Welded connectors

### 3.2 EQUIPMENT GROUNDING

- A. Install grounding for service entrance equipment room consisting of ground bus, ground conductors, and ¾" x 10'-0" copperweld grounding rods arranged as indicated on drawings.
  - 1. Ground bus shall be horizontal copper bar as indicated on drawings. Bolt to wall at 10-foot intervals with 1" stand-offs at each bus support.
  - 2. Install ground bus and copper ground conductor from bus to each ground rod per details on drawings.
  - 3. Direct buried conduit shall be Schedule 80 PVC.
  - 4. Direct buried conduit beneath buildings shall be Schedule 40 PVC.

5. Exterior conduit above grade shall be rigid galvanized steel with cast fittings and boxes.
- B. Install insulated equipment grounding conductors with feeders and branch circuits. Install a common equipment ground for every (3) branch circuit phase conductors (or portion thereof) originating from panelboards.
- C. Air-Duct Equipment Circuits: Install a separate insulated equipment grounding conductor to duct-mounted electrical devices operating at 120 V and more, including air cleaners, heaters, dampers, humidifiers, and other duct electrical equipment. Bond conductor to each unit and to air duct and connected metallic piping. Ground ductwork of fans serving flammable liquid storage rooms or fume hoods. Install continuous ground around any flexible connections in this ductwork system. Bond lower end of exhaust ducts, vent stacks, etc., which pass through roof.
- D. Water Heater, Heat-Tracing, and Antifrost Heating Cables: Install a separate insulated equipment grounding conductor to each electric water heater and heat-tracing cable. Bond conductor to heater units, piping, connected equipment, and components.
- E. Duplex receptacles of any amperage: Install separate jumper between grounding terminal on device and metallic box.
- F. Isolated Grounding Receptacle Circuits: Install an insulated equipment grounding conductor connected to the receptacle grounding terminal. Isolate conductor from raceway and from panelboard grounding terminals. Terminate at equipment grounding conductor terminal of the applicable derived system or service, unless otherwise indicated.
- G. Isolated Equipment Enclosure Circuits: For designated equipment supplied by a branch circuit or feeder, isolate equipment enclosure from supply circuit raceway with a nonmetallic raceway fitting listed for the purpose. Install fitting where raceway enters enclosure, and install a separate insulated equipment grounding conductor. Isolate conductor from raceway and from panelboard grounding terminals. Terminate at equipment grounding conductor terminal of the applicable derived system or service, unless otherwise indicated.
- H. Size of equipment grounding conductors for branch circuits: As indicated in NEC-70, except minimum size shall be No. 12 AWG.
- I. Metal Poles Supporting Outdoor Lighting Fixtures: Install grounding electrode and a separate insulated equipment grounding conductor in addition to grounding conductor installed with branch-circuit conductors to pole base. Grounding Conductor: Same size as phase conductors, but not smaller than No. 10 AWG.
  1. Install at each pole or standard a concealed driven 1/2" x 8'-0" ground rod, ground clamp and No. 3 stranded copper conductor concealed and attached to pole and base.

### 3.3 SEQUENCING, SCHEDULING

- A. Permanently attach service grounds before permanent building service is energized.

- B. Permanently attach equipment grounds prior to energizing equipment.

### 3.4 INSTALLATION

- A. Connections: Exposed and visible for inspection at all times. Do not install insulation over ground connections.
- B. Identify all grounding conductors by system and room number of termination at building grounding electrode point.
- C. Grounding Conductors: Route along shortest and straightest paths possible, unless otherwise indicated or required by Code. Avoid obstructing access or placing conductors where they may be subjected to strain, impact, or damage.
- D. Common Ground Bonding with Lightning Protection System: Comply with NFPA 780 and UL 96 when interconnecting with lightning protection system. Bond electrical power system ground directly to lightning protection system grounding conductor at closest point to electrical service grounding electrode. Use bonding conductor sized same as system grounding electrode conductor, and install in conduit.
- E. Ground Rods: Install ground rods with the top 1 ft minimum below finished grade.
  - 1. Interconnect ground rods with grounding electrode conductor below grade and as otherwise indicated. Make connections without exposing steel or damaging coating, if any.
  - 2. For grounding electrode system, install at least 3 rods spaced at least one rod length from each other and located at least the same distance from other grounding electrodes, and connect to the service grounding electrode conductor.
- F. Test Wells: Ground rod driven through drilled hole in bottom of handhole. Handholes shall be at least 12" deep, with cover.
  - 1. Test Wells: Install at least one test well for each service, unless otherwise indicated. Install at the ground rod electrically closest to service entrance. Set top of test well flush with finished grade or floor.
- G. Bonding Straps and Jumpers: Install in locations accessible for inspection and maintenance, except where routed through short lengths of conduit.
  - 1. Bonding to Structure: Bond straps directly to basic structure, taking care not to penetrate any adjacent parts.
  - 2. Bonding to Equipment Mounted on Vibration Isolation Hangers and Supports: Install so vibration is not transmitted to rigidly mounted equipment.
  - 3. Use exothermic-welded connectors for outdoor locations, but if a disconnect-type connection is required, use a bolted clamp.
- H. Grounding and Bonding for Piping:
  - 1. Metal Water Service Pipe: Install insulated copper grounding conductors, in conduit, from building's main service equipment, or grounding bus, to main metal water service entrances to building. Connect grounding conductors to main metal water service pipes, using a bolted clamp connector or by bolting a lug-type connector to a pipe flange, using one of the lug bolts of the flange. Where a dielectric main water fitting is installed, connect grounding conductor



- on street side of fitting. Bond metal grounding conductor conduit or sleeve to conductor at each end. Water pipe, by itself, is not an adequate grounding electrode and must be supplemented by another electrode system. Bond system together.
2. Water Meter Piping: Use braided-type bonding jumpers to electrically bypass water meters. Connect to pipe with a bolted connector.
  3. Bond each aboveground portion of gas piping system downstream from equipment shutoff valve.
- I. Grounding for Steel Building Structure: Bond the ground grid to the reinforcing steel or building structural steel at maximum 50' intervals.
- J. Bond steel columns at bases using copper conductor to column footing rebar as indicated on drawings..
- K. Make grounding connections on surface that has been cleaned of paint, dirt, oil, etc., so that connections are bare metal to bare metal contact.
- L. Make grounding connections tight with UL listed grounding devices, fittings, bushings, etc.
- M. Ground Ring: Install a grounding conductor, electrically connected to building structure ground rod and to each steel column, extending around the perimeter of building.
1. Install tinned-copper conductor as indicated on drawings.
  2. Bury ground ring not less than 24" from building foundation.
- N. Concrete-Encased Grounding Electrode: Fabricate according to NFPA 70, using a minimum of 20 ft of bare copper conductor not smaller than No. 4 AWG.
1. If concrete foundation is less than 20 ft long, coil excess conductor within base of foundation.
  2. Bond grounding conductor to reinforcing steel in at least four locations and to anchor bolts. Extend grounding conductor below grade and connect to building grounding grid or to grounding electrode external to concrete.
- O. Multiple Conductors on Single Lug: Not permitted. Terminate each grounding conductor on its own terminal lug.
- P. Bond steel columns at bases using #4/0 copper conductor to column footing rebar.
- Q. Equipment Grounding Conductor: Terminate in panelboard at green wire ground bus.
- R. Flexible Metallic Conduit, Non-Metallic Rigid Conduit, or Liquid Tight Flexible Conduit: Install green wire grounding conductor with phase conductors in conduit.

### 3.5 FIELD QUALITY CONTROL

- A. After installing grounding system but before permanent electrical circuits have been energized, test for compliance with requirements.
1. Test completed grounding system at each location where a maximum ground-resistance level is specified, at service disconnect enclosure grounding

terminal, at ground test wells , and at individual ground rods. Make tests at ground rods before any conductors are connected.

- B. Test grounding systems per requirements in Section 26 0800CR – Commissioning of Electrical Systems
- C. Interpret test results in writing and submit to Engineer.
- D. Inspect completed system by commissioning authority, prior to backfilling.

**END OF SECTION**

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## SECTION 26 0529CR

### HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 26 0533CR – Raceway and Boxes for Electrical Systems

##### 1.2 REFERENCE

- A. Work under this section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions and sections under Division 01 General Requirements.

##### 1.3 DESCRIPTION

- A. Section includes the following:
  - 1. Manufactured hangers and supports for individual raceways and cables, and most electrical equipment that is not floor mounted.

##### 1.4 REFERENCE STANDARDS

- A. AWS D1.1/D1.1M – Structural Welding Code-Steel.
- B. ASTM A 36/A 36M – Carbon Structural Steel.
- C. ASTM A 325 – Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.
- D. ASTM A 780 – Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
- E. MSS SP-58 – Pipe Hangers and Supports - Materials, Design and Manufacture.
- F. MSS SP-69 – Pipe Hangers and Supports - Selection and Application.
- G. MFMA-4 – Metal Framing Standards Publication.
- H. NECA 1 – Standard Practices for Good Workmanship in Electrical Construction.
- I. NECA 101 – Standard for Installing Steel Conduits (Rigid, IMC, EMT).
- J. NFPA 70 – National Electrical Code.
- K. SSPC-PA 1 – Paint Application Specification No. 1: Shop, Field, and Maintenance Painting of Steel.

## 1.5 SUBMITTALS

- A. Product Data: For the following:
  - 1. Raceway and cable supports.
  - 2. Steel slotted support systems.
  - 3. Structural steel for fabricated supports and restraints.
  - 4. Support for conductors in vertical raceways.
  - 5. Mounting, anchoring, and attachment components:
    - a. Mechanical-expansion anchors.
    - b. Concrete inserts.
    - c. Clamps for attachment to structural steel.
    - d. Through bolts.
    - e. Toggle bolts.
    - f. Hanger rods.
- B. Shop Drawings: Signed and sealed by an Engineer registered and licensed in the State of Minnesota. Include concrete anchors application, size, and placement. Include concrete inserts application, size, loading, and placement. Show fabrications and installation details and include calculations for the following:
  - 1. Fabricated metal equipment support assemblies.
  - 2. Trapeze hangers.
- C. Welding certificates.
- D. Schedule of hangers and support devices with support spacing.

## 1.6 QUALITY ASSURANCE

- A. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code – Steel."
- B. Comply with NFPA 70.

## PART 2 PRODUCTS

### 2.1 SUPPORT, ANCHORAGE, AND ATTACHMENT COMPONENTS

- A. Rated Strength: Adequate in tension, shear, and pullout force to resist maximum loads calculated or imposed for this Project, with a minimum structural safety factor of 5 times the applied force.
- B. Raceway and Cable Supports: As described in NECA 1 and NECA 101.
- C. Raceway and Cable Support Devices: Steel hangers, clamps, and associated fittings, designed for types and sizes of raceway or cable to be supported.

- D. Mounting, Anchoring, and Attachment Components: Items for fastening electrical items or their supports to building surfaces include the following:
1. Mechanical-Expansion Anchors: Insert-wedge-type, stainless steel, for use in hardened portland cement concrete with tension, shear, and pullout capacities appropriate for supported loads and building materials in which used.
    - a. Manufacturers:
      - 1) Cooper B-Line, Inc.; A division of Cooper Industries
      - 2) Empire Tool and Manufacturing Co., Inc.
      - 3) Hilti Inc.
      - 4) ITW Ramset/Red Head; A division of Illinois Tool Works, Inc.
      - 5) MKT Fastening, LLC.
      - 6) Approved equal
  2. Concrete Inserts: Steel or malleable-iron, slotted support system units similar to MSS Type 18; complying with MFMA-4 or MSS SP-58.
  3. Clamps for Attachment to Steel Structural Elements: MSS SP-58, type suitable for attached structural element.
  4. Through Bolts: Structural type, hex head, and high strength. Comply with ASTM A 325.
  5. Toggle Bolts: All-steel springhead type.
  6. Hanger Rods:
    - a. MSS SP-58; threaded steel, with adjusting and lock nuts; hot-dipped galvanized finish.

## 2.2 FABRICATED METAL FRAMING EQUIPMENT SUPPORT ASSEMBLIES

- A. Description: Welded or bolted, structural steel shapes, shop or field fabricated to fit dimensions of supported equipment.
- B. Materials: Comply with requirements in Division 05 Section "Metal Fabrications" for steel shapes and plates; not be lighter than 12 AWG.
- C. Finish: Electro-galvanized
- D. Manufacturers: Same as in paragraph 2.1.D.3 above.
- E. Steel Slotted Support Systems: Comply with MFMA-4, factory-fabricated components for field assembly.
1. Finishes
    - a. Metallic Coatings:
      - 1) Factory standard primed, galvanized or electroplated finish and applied according to MFMA-4, for indoor applications.
      - 2) Hot-dip galvanized after fabrication and applied according to MFMA-4, for outdoor applications.
    - b. Nonmetallic Coatings: Manufacturer's standard PVC, polyurethane, or polyester coating applied according to MFMA-4, for corrosive environments.
    - c. Painted Coatings: Manufacturer's standard painted coating applied according to MFMA-4.
  2. Channel Dimensions: Selected for applicable load criteria.

3. Manufacturers:
  - a. Allied Support Systems; Power-Strut Unit.
  - b. Cooper B-Line, Inc.; A division of Cooper Industries.
  - c. ERICO International Corporation.
  - d. GS Metals Corporation.
  - e. Thomas & Betts Corporation.
  - f. Unistrut; Tyco International, Ltd.
  - g. Wesanco, Inc.
  - h. National Pipe Hanger Corporation.
  - i. Michigan Hanger Co., Inc.; O-Strut Division..

### PART 3 EXECUTION

#### 3.1 APPLICATION

- A. Comply with NECA 1 and NECA 101 for application of hangers and supports for electrical equipment and systems except if requirements in this Section are stricter.
- B. Maximum Support Spacing and Minimum Hanger Rod Size for Raceway: Space supports for EMT, IMC, and RMC as required by NFPA 70.
  1. Size steel hanger rods for individual hangers and trapeze supports as indicated in the following schedule. Total weight of equipment shall not exceed limits indicated.

<u>Maximum Loads (lbs)</u>	<u>Rod Diameter (")</u>	<u>Maximum Pipe Size With Single Rod</u>
730	3/8	2"
1130	1/2	3"
1818	5/8	5"

#### 3.2 SUPPORT INSTALLATION

- A. Comply with NECA 1 and NECA 101 for installation requirements, except as specified in paragraphs below.
- B. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb.
- C. Mounting and Anchorage of Surface-Mounted Equipment and Components: Anchor and fasten electrical items and their supports to building structural elements by the following methods unless otherwise indicated by code:
  1. To Wood: Fasten with lag screws or through bolts.
  2. To New Concrete: Bolt to concrete inserts.
  3. To Masonry: Approved toggle-type bolts on hollow masonry units and expansion anchor fasteners on solid masonry units.
  4. To Existing Concrete: Expansion anchor fasteners.
  5. To Steel: Welded threaded studs complying with AWS D1.1/D1.1M, with lock washers and nuts.
  6. To Light Steel: Sheet metal screws.

- 7. Items Mounted on Hollow Walls and Nonstructural Building Surfaces: Mount pull and junction boxes, and other devices on slotted-channel racks attached to substrate by means that meet seismic-restraint strength and anchorage requirements.
- D. Drill holes for expansion anchors in concrete at locations and to depths that avoid reinforcing bars.
- E. Do not support raceway by other raceway.
- F. Do not support equipment or raceway from metal roof decking or floor decking.
- G. Do not impose weight of electrical equipment, raceways, or lighting fixtures on support provided for other trades or systems.
- H. Do not support loads from bottom chord member of trusses or open web chord.
- I. Minimize use of concrete anchors and inserts after concrete pour.
- J. Punching, drilling, welding of building structural steel or welding attachment to building structural steel is not allowed, unless approved by structural engineer.

### **3.3 INSTALLATION OF FABRICATED METAL SUPPORTS**

- A. Comply with installation requirements in Division 05 Section "Metal Fabrications" for site-fabricated metal supports.
- B. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor electrical materials and equipment.
- C. Field Welding: Comply with AWS D1.1/D1.1M.

### **3.4 CONCRETE HOUSEKEEPING PADS**

- A. Construct concrete housekeeping pads for all floor-mounted electrical equipment.
- B. Dimensions: 3.5" high and not less than 2" larger in both directions than supported equipment, so anchors will be a minimum of 10 bolt diameters from edge of the base.
- C. Use 3000 psi, 28-day compressive-strength concrete. Concrete materials, reinforcement, and placement requirements are specified in Division 03 Section "Cast-in-Place Concrete."
- D. Anchor equipment to concrete housekeeping pad.
  - 1. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
  - 2. Install anchor bolts to elevations required for proper attachment to supported equipment.
  - 3. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

- E. Coordinate with Architect installation of housekeeping pads on roof.

### **3.5 PAINTING**

- A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
  - 1. Apply paint by brush or spray to provide minimum dry film thickness of 2.0 mils.
- B. Touchup: Comply with requirements in Division 09 for cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal.
- C. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

**END OF SECTION**



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**SECTION 26 0533CR**

**RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 26 0526CR – Grounding and Bonding for Electrical Systems
- B. Section 26 0529CR – Hangers and Supports for Electrical Systems
- C. Section 26 0553CR – Electrical Systems Identification
- D. Section 26 0593CR – Electrical Systems Firestopping
- E. Section 26 2726CR – Wiring Devices

**1.2 REFERENCE**

- A. Work under this section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. Section includes raceways, fittings, wireways, wall ducts, outlet boxes, pull and junction boxes, floor boxes, tap boxes and raceway seals.

**1.4 REFERENCE STANDARDS**

- A. ANSI/NECA 1 – Standard Practices for Good Workmanship in Electrical Contracting
- B. ANSI C80-1 – Rigid Steel Conduit-Zinc Coated (GRS or GRC)
- C. ANSI C80-6 – Intermediate Metal Conduit-Zinc Coated (IMC)
- D. ANSI C80-3 – Electrical Metallic Tubing-Zinc Coated (EMT)
- E. ASTM A 53/A 53M – Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
- F. BICSI TDMM – Telecommunications Distribution Methods Manual, Latest Edition
- G. NEMA 250 – Enclosures for Electrical Equipment (1000 V Maximum)
- H. NEMA FB 1 – Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit, Electrical Metallic Tubing and Cable
- I. NEMA OS 1 – Sheet-Steel Outlet Boxes, Device Boxes, Covers, and Box Supports

- J. NEMA OS 2 – Nonmetallic Outlet Boxes, Device Boxes, Covers, and Box Supports
- K. NEMA TC 2 – Electrical Polyvinyl Chloride (PVC) Conduit
- L. NEMA TC 3 – PVC Fittings for Use with Rigid PVC Conduit and Tubing
- M. NEMA TC 13 – Electrical Nonmetallic Tubing (ENT)
- N. NFPA 70 – National Electrical Code
- O. TIA-569-B – Commercial Building Standard for Telecommunications Pathways and Spaces
- P. UL 6 – Electrical Rigid Metallic Conduit-Steel
- Q. UL 6A – Electrical Rigid Metallic Conduit-Aluminum and Stainless Steel
- R. UL 514A – Metallic Outlet Boxes
- S. UL 1 – Flexible Metal Conduit
- T. UL 360 – Liquid-Tight Flexible Steel Conduit
- U. UL 514A – Metallic Outlet Boxes
- V. UL 797 – Electrical Metallic Tubing-Steel
- W. UL 1242 – Electrical Intermediate Metal Conduit-Steel
- X. UL 1242 – Electrical Intermediate Metal Conduit-Steel
- Y. UL 514B – Conduit, Tubing, and Cable Fittings
- Z. UL 514C – Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers
- AA. UL 651 – Schedule 40 and 80 Rigid PVC Conduit and Fittings
- BB. UL 870 – Wireways, Auxiliary Gutters, and Associated Fittings
- CC. UL 1242 – Electrical Intermediate Metal Conduit-Steel

## 1.5 SUBMITTALS

- A. Product Data:
  - 1. Raceways
  - 2. Fittings
  - 3. Wireways
  - 4. Outlet boxes
  - 5. Floor boxes/Poke-through
  - 6. Pull and junction boxes

7. Floor boxes
  8. Raceway seals
- B. Manufacturer's Installation Instructions:
1. Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation and installation of product.
- C. Closeout Submittals:
1. Project Record Documents:
    - a. Record actual routing of all feeder conduits.
    - b. Record actual location and mounting heights of wireways, wall ducts, outlet, pull and junction boxes.
  2. Operation and Maintenance Data:
    - a. Include manufacturer's recommended operating instructions, maintenance procedures and intervals, and preventive maintenance instructions.
    - b. Include spare parts data listing, source, and current prices of replacement parts and supplies.

## 1.6 QUALITY ASSURANCE

- A. Regulatory Requirements:
1. Comply with NFPA 70.
  2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

## 1.7 DELIVERY, STORAGE, AND HANDLING

- A. Store in clean, dry space. Maintain factory wrapping or provide additional canvas or plastic cover to protect from dirt, water, construction debris, and traffic.
- B. Protect PVC conduit from sunlight.
- C. Comply with manufacturer's written instructions.

## 1.8 WARRANTY

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr written warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

## PART 2 PRODUCTS

### 2.1 RIGID METAL CONDUIT (RMC)

- A. Rigid Steel Conduit (RSC or GRC): ANSI C80.1, UL 6; heavy wall galvanized steel

- B. Intermediate Metal Conduit (IMC): ANSI C80.6, UL 1242; thinner wall, galvanized steel
- C. Fittings (couplings, conduit bodies, connectors and bushings): NEMA FB 1, UL 514B; steel; threaded; connectors with double locknuts and steel insulating bushings, ; conduit bodies cover: caststeel, with stainless steel screws and neoprene gaskets; PVC coated to match conduit.
- D. Fittings Manufacturers: Cooper Crouse-Hinds; Carlon Electric Products; O-Z/Gedney; Appleton; Hubbell.

## **2.2 ELECTRICAL METALLIC TUBING (EMT)**

- A. ANSI C80.3, UL 797; galvanized steel tubing
- B. Fittings (couplings, conduit bodies, and connectors): NEMA FB I, UL 514B; steel, steel concrete-tight set-screw type connectors with double locknuts and insulated throat; conduit bodies cover: caststeel, with stainless steel screws and neoprene gaskets. Indentor, drive-on, die-cast, slip-on, or pressure cast fittings shall not be permitted.
- C. Fittings Manufacturers: Same as manufacturers listed in 2.1.D.

## **2.3 FLEXIBLE METAL CONDUIT (FMC)**

- A. UL 1; interlocked steel
- B. Fittings: NEMA FB I, UL 514B; steel

## **2.4 LIQUIDTIGHT FLEXIBLE METAL CONDUIT (LFMC)**

- A. UL 360; interlocked steel, with PVC jacket
- B. Fittings: NEMA FB 1, UL 514B; steel

## **2.5 RIGID NONMETALLIC CONDUIT (RNC)**

- A. NEMA TC 2, UL 651; Schedule 80 PVC or Schedule 40 PVC as indicated
- B. Fittings: NEMA TC 3, UL 651

## **2.6 OUTLET BOXES**

- A. Sheet Metal Outlet Boxes: NEMA OS 1, UL 514A; galvanized steel with stamped knockouts.
  - 1. Luminaire and Equipment Supporting Boxes: Rated for weight of equipment supported; 1/2" male fixture studs, where required.
  - 2. Concrete Ceiling Boxes: Concrete type
- B. Cast-Metal Outlet Boxes: NEMA FB 1, ferrous alloy, Type FD, with gasketed cover and threaded hubs
- C. Minimum switch, pull, junction, and outlet box size shall be 4" square by 2-1/8" deep.

- D. Gangable type boxes are not allowed.
- E. Manufacturers: O-Z/Gedney; Raco; Cooper Crouse-Hinds

## **2.7 PULL AND JUNCTION BOXES**

- A. Small Sheet Metal Pull and Junction Boxes: NEMA OS 1; galvanized steel
- B. Cast-Metal, Pull, and Junction Boxes: NEMA FB 1; galvanized with ground flange, gasketed cover and stainless steel cover screws
- C. Minimum size: 4" square by 2-1/8" deep for use with 1" conduit and smaller; 4-11/16" square by 2-1/8" deep for use with 1-1/4" conduit and larger
- D. Sheet Metal Boxes Larger Than 12" in any direction: Hinged cover or a chain installed between box and cover
- E. Field-fabricated boxes not allowed without prior approval of local authority having jurisdiction.
- F. Manufacturers: same as manufacturers listed in 2.6.E

## **2.8 FLOOR BOXES**

- A. Combination Flush Floor Boxes
  - 1. As indicated on drawings.

## **2.9 EXPANSION FITTINGS**

- A. Malleable iron, hot dip galvanized allowing 4" ( $\pm 2$ ") raceway movement.
- B. Manufacturers: OZ/Gedney AX Series or equivalent by manufacturer listed in 2.1.D.

## **2.10 RACEWAY PENETRATION SEALS**

- A. Thruwall and Floor Seals.
- B. Manufacturers: New construction – OZ/Gedney FSK Series; existing construction – OZ/Gedney CSM Series; or equivalent by manufacturer listed in 2.1.D.

## **2.11 RACEWAY SEALING FITTINGS**

- A. For one through four conductors: Manufacturers: OZ/Gedney CSB Series
- B. For greater than four conductors: Manufacturers: OZ/Gedney EYA Series with sealing compound
- C. Low-temperature or hazardous locations: Manufacturers: OZ/Gedney EYA Series with sealing compound

## **2.12 CABLE SUPPORTS**

- A. Manufacturers: OZ/Gedney Type S or equivalent by manufacturer listed in 2.1.D.

## **2.13 SLEEVES FOR RACEWAYS**

- A. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends, with integral water stop.
- B. Sleeves for Rectangular Openings: Galvanized sheet steel with minimum 0.052" or 0.138" thickness and of length to suit application.

## **2.14 OUTLET BOXES FOR COMMUNICATIONS**

- A. Minimum outlet box size: 4" square by 2-1/8" deep minimum, with two-gang trim ring, unless otherwise noted on drawings.
  - 1. Total depth of the assembly including the trim ring shall not be less than 2-1/2".

## **2.15 PULL AND JUNCTION BOXES FOR COMMUNICATIONS**

- A. Size: Per TIA-569-B, unless otherwise noted on drawings.
- B. Minimum pull box size: 4-11/16" square by 2-1/8" deep, where pull box is used with raceway(s) smaller than 1-1/4" trade size, unless otherwise noted on drawings.
- C. Minimum pull box size, where pull box is used with raceway(s) 1-1/4" trade size or larger:
  - 1. For straight pull through: Length of at least 8 times trade-size diameter of largest raceway.
  - 2. For angle and U pulls:
    - a. Have distance between each raceway entry inside box and opposite wall of box of at least 6 times trade-size diameter of largest raceway, this distance being increased by sum of trade-size diameters of other raceways on same wall of box; and
    - b. Have distance between nearest edges of each raceway entry enclosing same conductor of at least:
      - 1) Six times trade-size diameter of raceway; or
      - 2) Six times trade-size diameter of larger raceway if raceways are of different sizes.
    - c. For raceway entering wall of pull box opposite to removable cover, have distance from wall to cover of not less than trade-size diameter of largest raceway plus 6 times diameter of largest conductor.

## **PART 3 EXECUTION**

### **3.1 COORDINATION**

- A. Coordinate with Architect/Engineer size and location of required built-in openings in building structure, including those sleeved, formed or core drilled.

- B. Coordinate with Architect/Engineer cutting, removing, or piercing general or mechanical insulation, fire-rated walls, ceilings or steelwork.
- C. Coordinate with Architect/Engineer exact locations of floor boxes and poke-throughs, where shown on drawings, prior to rough-in.
- D. Coordinate with Architect and lab programming drawings on all surface raceway installations.
- E. Coordinate routing of through-roof conduits.
- F. Coordinate sleeve selection and application with selection and application of firestopping specified in Section 26 0593CR – Electrical Systems Firestopping.
- G. Verify that exterior wall or wet location boxes are gasketed type cast boxes with matching cover. Boxes shall be rated for outdoor use and weather-tight.
- H. Verify with manufacturer that “touch-up” paint kit and PVC-coating kit are available for use.

### **3.2 EXAMINATION**

- A. Examine surfaces to receive raceways and boxes for compliance with installation tolerances and other conditions affecting performance of raceway’s installation. Do not proceed with installation until unsatisfactory conditions have been corrected.

### **3.3 INSTALLATION**

- A. Raceways:
  - 1. Comply with ANSI/NECA 1 and NFPA 70 for installation requirements applicable to products specified in Part 2 except where requirements on drawings or in this Section are stricter.
  - 2. Arrange raceways to maintain headroom and present neat appearance.
  - 3. Raceway routing is shown in approximate locations, unless dimensioned. Route to complete raceway installation before starting conductor installation.
  - 4. Keep raceways at least 12” away from parallel runs of fuels, steam, or hot-water pipes. Install horizontal raceway runs above water and steam piping. Install raceways level and square. Do not block access to junction boxes.
  - 5. Run raceways concealed in construction to avoid adverse conditions such as heat and moisture, to permit drainage, and to avoid materials and equipment of other trades, except where noted otherwise.
  - 6. Avoid exposed raceway runs. Run raceways exposed where impractical or impossible to conceal or where specific approval is obtained. Run exposed raceways grouped and parallel or perpendicular to construction. Do not route exposed raceways over boilers or other high-temperature machinery or in contact with such equipment. Offset exposed raceways at boxes.
  - 7. Route raceways installed above accessible ceilings parallel or perpendicular to construction.

8. Do not install raceways in structural or topping floor slabs or below slab on grade, except where specifically noted on the plans. Conduit shall not be installed inside slab on grade, but may be run below slab on grade where specifically indicated on plans. Install raceway in structural or topping floor slabs, where specifically noted on plans, only as follows:
  - a. Center raceways in structural slabs clear of reinforcing steel, except where crossing same, and spaced on centers equal or exceeding 3 times the raceway diameter. Secure raceways to reinforcing rods to prevent sagging or shifting during concrete placement. Space raceways laterally to prevent voids in concrete.
  - b. Outside diameter of raceway shall not exceed 1/3 the structural slab thickness.
  - c. Obtain approval from Engineer for each run of raceway 1" or larger.
  - d. Do not install raceways in topping slabs of 2" or less.
  - e. Locate raceways to avoid conflict with equipment, door bucks, partitions and other equipment bolted to floor.
  - f. Arrange stub-ups so curved portions of bends are not visible above finished slab. Install with an adjustable top or coupling threaded inside for plugs set flush with finished floor. Extend conductors to equipment with rigid steel conduit; use flexible metal conduit 6" above the floor. Install threaded plugs flush with floor for future equipment connections.
  - g. Change from nonmetallic raceway to RMC before rising above floor.
9. Cut raceways square using saw or pipecutter.
10. Use hydraulic one-shot raceway bender or factory elbows for bends in raceway larger than 2", unless sweep elbows required. Bend raceways according to manufacturer's recommendations. Do not use torches or open flame to aid in bend of PVC conduit.
11. Use raceway fittings compatible with raceways and suitable for use and environment.
12. Provide insulated bushings on all raceways.
13. Raceways minimum sizes:
  - a. Minimum raceway size 3/4", except as noted on drawings.
  - b. Minimum home run size: 3/4", except as noted on drawings. Verify conduit fill per NEC based on quantity of conductors and grounds installed. Increase size as required.
  - c. Minimum size for flexible metal conduit is 1/2" except 3/8" for luminaires.
14. Install empty raceways 2-1/2" and larger with No. 10 galvanized fishwire; install 200 lb nylon pull cord in raceways smaller than 2-1/2"; leave at least 12" of slack at each end of pull wire. Cap raceways at both ends.
15. Raceways Supports:
  - a. Independently support or attach raceway system to structural parts of construction. Suspended ceiling systems shall not be considered as structural parts of construction for raceway support. Do not attach raceways to piping system.
  - b. Raceway supports for horizontal or vertical single runs:
    - 1) Hot dipped galvanized heavy-duty sheet steel straps, mineralac clamps or steel slotted support channel system with appropriate components.
  - c. Raceway supports for horizontal and vertical multiple runs:



- 1) Trapeze-type supports fabricated with steel slotted channel systems with appropriate components.
- 2) Support horizontal runs with appropriately sized rods.
- 3) Anchor vertical runs to structure.
- 4) Spring-steel type pressure clamps for raceways 3/4" and smaller.
- d. Do not support raceways with wire, perforated pipe straps or plastic tie-wrap. Remove wires used for temporary support.
- e. Arrange raceway supports to prevent misalignment during wiring installation.
- f. Vertical raceway runs 1-1/4" and larger passing through floors: Support at each floor with pipe riser clamps.
- g. Secure raceways in metal stud walls to prevent rattling.
- h. Do not fasten raceways to corrugated metal roof deck.
- i. For fasteners and supports, support devices, support spacing, and hanger rod size, refer to Section 26 0529CR – Hangers and Supports for Electrical Systems and NFPA 70.
16. Identify raceways per requirements in Section 26 0553CR – Electrical Systems Identification.
17. Ground raceways per requirements in Section 26 0526CR – Grounding and Bonding for Electrical Systems.
18. Flexible Conduit Connections: Use maximum of 72" of flexible conduit for recessed and semi-recessed lighting fixtures, equipment subject to vibration, noise transmission, or movement; and for transformers and motors.
  - a. Use LFMC in damp or wet locations subject to severe physical damage.
  - b. Use LFMC or LFNC in damp or wet locations not subject to severe physical damage.
  - c. All electrical connections to rotating or reciprocating equipment and respective housings, as well as equipment and ductwork mounted on vibration isolators, shall be made with a suitable length of flexible conduit to provide a 'slack' connection; with a 1' loop in the flexible conduit.
19. Install stainless steel raceway clamps, mounting hardware, supports, hangers, etc., when located in "wet" or "wash-down" areas.
20. Communications Raceways:
  - a. Minimum communications raceway size: 1" unless otherwise noted on drawings.
  - b. Install one raceway from each communications outlet box. Horizontal raceway runs between wall outlet boxes are not allowed.
  - c. Terminate raceway on cable tray.
  - d. Install insulated bushings on end of each raceway.
  - e. Use UL listed metallic grounding clamps and provide a #8 bonding jumper from clamp to tray, when terminating raceway on cable tray.
  - f. Install with no more than 180 degrees of bends between pull or junction boxes or terminations at distribution frames or cabinets where necessary to comply with these requirements.
  - g. Conduit bend radii (minimum) shall be:
    - 1) Six (6) times internal conduit diameter for conduit 2" or less internal diameter.
    - 2) Ten (10) times internal conduit diameter for conduit greater than 2" internal diameter.

- h. Conduit bends shall be smooth, even, and free of kinks or other discontinuities that may have detrimental effects on pulling tension or cable integrity during or after installation.
  - i. Do not install 90-degree condulets. Install continuous radius sweeps of 45° minimum for 90-degree bends.
  - j. Do not install continuous sections longer than 100 ft.
  - k. Install nylon pull cord in empty raceways. Leave at least 12" of slack at each end of pull wire. Cap raceways at both ends.
  - l. To reduce EMI, contractor shall maintain conduit clearance of 5" from any 2 kVA power lines, 18" from lighting, 39" from any 5 kVA power lines, and 47" from transformers and motors.
- B. Boxes:
- 1. Install boxes to accommodate device indicated by symbol, in conformance with code requirements, number and size of conductors and splices and consistent with type of construction.
  - 2. Install the appropriate cover on surface-mounted boxes:
    - a. Raised device covers on 4" square and 4-11/16" boxes and handy box covers on handy boxes, etc.
  - 3. Set outlet boxes parallel to construction and independently attached to same.
  - 4. Install multi-ganged boxes where 2 or more devices are in same location, unless otherwise noted.
  - 5. Box Support:
    - a. Mount boxes straight.
    - b. Install horizontal bracing at top or bottom of box for 3 or more gang device boxes in stud walls.
    - c. Install stud support one side, with short piece of stud, for up to 2 gang device boxes.
    - d. Do not support boxes with tie-wire.
    - e. For one and two gang box support, manufactured bracket supports shall be accepted alternate.
    - f. Support boxes independently of raceways.
    - g. Install adjustable steel channel fasteners for hung ceiling outlet box.
    - h. Install stamped steel bridges to fasten flush-mounted outlet box between studs.
    - i. Do not install boxes to ceiling support wires or piping systems.
  - 6. Pull and junction boxes: Install as shown, or as necessary to facilitate pulling of wire and to limit number of bends within code requirements.
  - 7. Install boxes to be permanently accessible.
  - 8. Do not intermix conductors from more than one system in same junction box or pull box, unless shown or specifically authorized otherwise.
  - 9. Adjust box location up to 10 ft prior to rough-in to accommodate intended purpose.
  - 10. Orient boxes to accommodate wiring devices oriented as specified in Section 26 2726CR – Wiring Devices.
  - 11. The drawings do not necessarily show every outlet, pull or junction box required. Add all required boxes as necessary.
  - 12. Inaccessible Ceiling Areas: Install outlet and junction boxes no more than 6" from ceiling access panel or from removable recessed luminaire.
  - 13. Install partitions in multi-ganged boxes where different types of devices are installed, or devices installed operate at different voltages.

14. Mount boxes in block walls at block joint nearest to indicated height.
  15. Recessed Boxes in Masonry Walls: Saw-cut opening for box in center of cell of masonry block, and install box flush with surface of wall.
  16. When boxes are installed in fire-resistive walls and partitions, provide 24" horizontal separation between boxes on opposite sides of a wall. In addition, limit penetrations to 16 sq in per penetration and not to exceed a total of 100 sq in per 100 sq ft of wall area. Apply fire stop putty pads acceptable to the AHJ.
- C. Outlet Boxes for Communications:
1. Install communications outlet boxes for each communications outlet, or as noted on drawings.
- D. Pull and Junction Boxes for Communications:
1. Provide Communications Pull and Junction Boxes:
    - a. In any section of conduit longer than 100 ft
    - b. Where there are bends totaling more than 180 degrees between pull points or pull boxes
    - c. Wherever there is a reverse bend in run
  2. Do not use pull boxes in place of bends on straight section of raceway, unless otherwise shown on drawings.
- E. Floor Boxes:
1. Set metal floor boxes level and flush with finished floor surface.
  2. Set nonmetallic floor boxes level. Trim after installation to fit flush with finished floor surface.
  3. Use cast floor boxes for installations in slab on grade.
  4. Install floor boxes and fittings to preserve fire-resistant rating of slabs and other elements, using materials and methods specified in Section 26 0593CR – Electrical Systems Firestopping.
- F. Expansion Fittings:
1. Install raceway expansion and deflection fittings in all raceway runs embedded in or penetrating concrete where movement perpendicular to axis of the raceway may be encountered.
  2. Install raceway expansion fittings complete with bonding jumpers in raceway runs that cross expansion joints in structure and raceway runs mechanically attached to 2 separate structures.
  3. Use couplings and flexible connection made up of 24" length of flexible metal conduit, where EMT runs across expansion joints in ceiling spaces.
  4. Install fitting(s) that provide expansion and contraction for at least 0.0004" per ft of length of straight run per °F of temperature change.
  5. Install each expansion-joint fitting with position, mounting, and piston setting selected according to manufacturer's written instructions for conditions at specific location at time of installation.
- G. Raceway Penetration Seals:
1. Seal space outside of sleeves with grout for penetrations of concrete and masonry and with approved joint compound for gypsum board assemblies.
  2. Interior Penetrations of Non-Fire-Rated Walls and Floors: Seal annular space between sleeve and raceway, using joint sealant appropriate for size, depth,

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- and location of joint. Refer to Division 07 Section "Maintenance of Joint Protection" for materials and installation.
3. Fire-Rated-Assembly Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at raceway penetrations. Install sleeves and seal with firestop materials. Comply with Section 26 0593CR – Electrical Systems Firestopping.
  4. Roof-Penetration Sleeves: Seal penetration of individual raceways with flexible, boot-type flashing units applied in coordination with roofing work.
  5. Aboveground, Exterior-Wall Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1" annual clear space between pipe and sleeve for installing mechanical sleeve seals.
  6. Underground, Exterior-Wall Penetrations: Install cast-iron "wall pipes" for sleeves. Size sleeves to allow for 1" annual clear space between raceway and sleeve for installing mechanical sleeve seals.
  7. Sleeve-Seal Installation: Use type and number of sealing elements recommended by manufacturer for raceway material and size. Position raceway in center of sleeve. Assemble mechanical sleeve seals and install in annular space between raceway and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.
  8. Provide chrome- or nickel-plated escutcheons where raceways pass through walls, floors or ceilings and are exposed in finished areas. Size escutcheons to fit raceways for finished appearance. Finished areas shall not include mechanical/electrical rooms, janitor's closets, storage rooms, etc., unless suspended ceilings are specified.
  9. Remove temporary sleeves, if used for form wall openings, prior to installation of permanent materials.
- H. Raceway Sealing Fittings:
1. Install listed watertight seals to prevent the passage of moisture and water vapor through raceway, where raceway passes from interior to exterior of the building, where raceway passes between areas of different temperatures such as into or out of cold rooms or freezers, where raceway enters room which at any time is subject to low or high temperatures and where raceway enters a room which at any time is subject to internal air pressures above or below normal.
  2. Install watertight seals in interior of all raceways passing through ground floor slab (when the raceway does not extend beyond building footprint), or through outside walls of building above or below grade. Seal on the end inside building, using raceway sealing fittings manufactured for the purpose. Locate fittings at suitable accessible locations. For concealed raceways install each fitting in flush steel box with blank coverplate to match finish of adjacent plates or surfaces.
  3. Seal raceways entering or passing through "hazardous (classified) areas" as defined in NFPA 70.
- I. Sleeve Installation for Electrical Penetrations:
1. Coordinate sleeve selection and application with selection and application of firestopping specified in Section 26 0593CR – Electrical Systems Firestopping.
  2. Concrete Slabs and Walls: Install sleeves for penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of slabs and walls.

3. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
4. Rectangular Sleeve Minimum Metal Thickness:
  - a. For sleeve cross-section rectangle perimeter less than 50" and no side greater than 16", thickness shall be 0.052".
  - b. For sleeve cross-section rectangle perimeter equal to, or greater than, 50" and 1 or more sides equal to, or greater than, 16", thickness shall be 0.138".
5. Fire-Rated Assemblies: Install sleeves for penetrations of fire-rated floor and wall assemblies, unless openings compatible with firestop system used are fabricated during construction of floor or wall.
6. Cut sleeves to length for mounting flush with both surfaces of walls.
7. Extend sleeves installed in floors 2" above finished floor level.
8. Size pipe sleeves to provide 1/4" annular clear space between sleeve and raceway, unless sleeve seal is to be installed or unless seismic criteria require different clearance.

### 3.4 APPLICATION

- A. Raceway uses permitted and not permitted per NFPA 70 requirements and as described below.
- B. Rigid Metal Conduit (GRS or GRC) permitted to be installed as follows:
  1. All locations except corrosive atmospheres
  2. Installations below grade and in or under concrete slabs (where specifically permitted)
  3. Hazardous locations
  4. Locations requiring mechanical protection
  5. Only cast boxes shall be used with GRC conduit.
- C. Intermediate Metallic Conduit (IMC) permitted to be installed as follows:
  1. All locations, except corrosive atmospheres
  2. Hazardous locations
  3. Locations requiring mechanical protection
- D. Electrical Metallic Tubing (EMT) permitted to be installed as follows:
  1. Interior partitions
  2. Above suspended ceilings
  3. 6 ft AFF and higher in exposed areas of mechanical equipment rooms
  4. Sizes 4" and smaller
- E. Rigid Nonmetallic Conduit (RNC) permitted to be installed as follows:
  1. Direct burial, concrete encased (Schedule 40)
  2. Direct burial, in sand fill on bottom and top (Schedule 40)
  3. Use manufacturer recommended glue, primer and cleaner for PVC conduit runs.
  4. Use steel elbow in concrete encased runs
  5. Where specifically permitted to be run in floor slabs
  6. RNC shall not be used for interior raceways.

- F. Flexible Metal Conduit (FMC) permitted to be installed as follows:
  - 1. Use flexible metal conduit not over 4 ft in length for final connections for:
    - a. Vibrating equipment (including transformers and hydraulic, pneumatic, electric solenoid, or motor-driven equipment) in dry locations.
    - b. Final connections to recessed luminaires in lengths not to exceed 6 ft.
    - c. All electrical connections to rotating or reciprocating equipment and respective housings, as well as equipment and ductwork mounted on vibration isolators, shall be made with a suitable length of flexible conduit to provide a 'slack' connection; with a 1' loop in the flexible conduit.
- G. Liquid Tight Flexible Metal Conduit (LFMC) permitted to be installed as follows:
  - 1. Use liquid tight flexible conduit, not over 4 ft in length, for final connections to:
    - a. Vibrating equipment (including transformers and hydraulic, pneumatic, electric solenoid, or motor-driven equipment) in wet locations.
    - b. Instruments and control devices.
    - c. All electrical connections to rotating or reciprocating equipment and respective housings, as well as equipment and ductwork mounted on vibration isolators, shall be made with a suitable length of flexible conduit to provide a 'slack' connection; with a 1' loop in the flexible conduit.
- H. One-half inch raceway permitted:
  - 1. Between controller and its control or pilot device
  - 2. Between lighting switch and nearest outlet for luminaire
  - 3. Control wiring where mounted on equipment where conduit must follow contour of equipment
  - 4. Protective and signal systems where noted
  - 5. Where shown on plans
- I. Outdoor Locations, Above Grade: Install GRC conduit; install gasketed cast metal outlet, pull, and junction boxes.

### **3.5 RACEWAY WIRING METHODS**

- A. Underground More than 5 ft outside Foundation Wall: Install thickwall nonmetallic conduit; install cast metal boxes or nonmetallic handholes. Refer to plans for specific requirements.
- B. Underground Within 5 ft from Foundation Wall: Install rigid steel conduit; install cast metal or nonmetallic boxes.
- C. In or Under Slab on Grade Where specifically permitted: Install rigid steel conduit or PVC; install cast or nonmetallic metal boxes.
- D. In Slab Above Grade Where specifically permitted: Install rigid steel conduit or thickwall nonmetallic conduit; install cast boxes.

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### **3.6 FIELD QUALITY CONTROL**

- A. Inspect raceway, boxes, indoor service poles, and wireways for physical damage, proper alignment, supports and seismic restraints, where applicable.
- B. Replace any damaged component of the raceway system, or install new raceway system.
- C. Inspect components, wiring, connections and grounding.

### **3.7 REPAINTING**

- A. Repair damage to galvanized finishes with manufacturer-supplied zinc-rich paint kit. Leave remaining paint with Owner.
- B. Repair damage to PVC or paint finishes with manufacturer-supplied touch-up coating. Leave remaining coating with Owner.
- C. Wireways, indoor service poles: Remove paint splatters and other marks from surface; touch-up chips, scratches, or marred finishes to match original finish using manufacturer-supplied paint kit. Leave remaining paint with Owner.

### **3.8 ADJUSTING**

- A. Adjust flush-mounted boxes pre-pour and after-pour to be flush with finished materials.
- B. Install knockout closures in unused openings in boxes.
- C. Align adjacent wall-mounted outlet boxes for switches and similar devices.

### **3.9 CLEANING**

- A. Clean interior and exterior of boxes, wireways, and indoor poles to remove dust, debris and other material.

**END OF SECTION**





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**SECTION 26 0533.13CR**

**SURFACE RACEWAY SYSTEM**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables
- B. Section 26 0526CR – Grounding and Bonding for Electrical Systems
- C. Section 26 0553CR – Electrical Systems Identification
- D. Section 26 2726CR – Wiring Devices

**1.2 REFERENCE**

- A. Work under this section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. Section includes surface metallic raceway system for branch circuits.
- B. Surface raceway system shall consist of raceway bases, appropriate fittings, and device mounting plates necessary for a complete installation.
- C. The lengths of the raceways shown on drawings are illustrative and diagrammatic only and are not accurate. Raceways shall be provided completely installed to match lengths of cabinets and shelving as indicated on (laboratory) casework shop drawings or as indicated on drawings.

**1.4 REFERENCE STANDARDS**

- A. ANSI/NECA 1 – Standard Practices for Good Workmanship in Electrical Contracting.
- B. NFPA 70 – National Electrical Code.
- C. UL 5 - Surface Metal Raceways and Fittings.
- D. UL 94 – Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.

**1.5 SUBMITTALS**

- A. Product Data: Catalog cuts of components.

- B. Shop Drawings:
  - 1. Complete layout, with locations of raceway components.
  - 2. Grounding, branch circuiting, and wiring including locations of service entrances.
  - 3. Receptacle types, manufacturers, and spacing.
  - 4. Receptacle labeling with proper voltage, phase, circuit and panelboard designations, as indicated on drawings.
- C. Manufacturer's Installation Instructions:
  - 1. Indicate application conditions and limitations of use. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of product.
- D. Closeout Submittals:
  - 1. Project Record Documents
    - a. Record actual locations of surface raceways with receptacle types, locations and circuits identified.
  - 2. Operation and Maintenance Data:
    - a. Include manufacturer's recommended operating instructions, maintenance procedures and intervals, and preventive maintenance instructions.
    - b. Include spare parts data listing, source, and current prices of replacement parts and supplies.

## 1.6 QUALITY ASSURANCE

- A. Obtain surface raceways from one source and by single manufacturer.
- B. Regulatory Requirements:
  - 1. Comply with NFPA 70 for components and installation.
  - 2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

## 1.7 DELIVERY, STORAGE, AND HANDLING

- A. Store in clean, dry space. Maintain factory unopened packaging until ready for installation.
- B. Comply with manufacturer's written instructions.

## 1.8 WARRANTY

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr written warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

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## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Metallic Raceways:
  - 1. Mono-Systems
  - 2. Square D
  - 3. Wiremold

### **2.2 FABRICATION**

- A. UL 5
- B. Fabrication:
  - 1. Aluminum
  - 2. Suitable for use in dry interior locations only.
  - 3. Two-piece with base and snap-on cover.
  - 4. Base: single compartment where required for power only, two compartments with dividers where required for power and data, as indicated on drawings.
  - 5. Two-compartment raceway with separate cover for each compartment.
  - 6. Single compartment – same size and construction as Wiremold ALA 3800 series, Two compartments - same size as Wiremold Isoduct ALA 4800 Series.
  - 7. Covers with cutouts for device plates as shown on drawings.
  - 8. 6” and 12” long device plates with flange to overlap joint of adjacent cover.
- C. Material:
  - 1. Aluminum Raceways: Alloy 6063-T5 extruded aluminum, minimum thickness 0.060”.
  - 2. Fittings: Same material and metal thickness as linear raceway components.
- D. Finish:
  - 1. Aluminum Raceways:
    - a. Clear anodized aluminum.
  - 2. Fittings: Color to match linear raceway components.
- E. Accessories:
  - 1. Fittings: Available as standard accessories, including external corner units, internal corner units, flat units, blank end units, internal and external elbows, coupling for joining raceway sections, and device mounting brackets and plates.
  - 2. Wire Clips: One for every 2 linear ft of indicated raceway configuration.
  - 3. Corner elbows and tee fittings, to maintain 2” cable bend radius that meets requirements for communications pathways and specifications for fiber optic, coaxial, and high-performance twisted-pair cabling.
  - 4. Device Mounting Brackets and Plates: Plastic device mounting brackets and trim plates allowing installation of indicated wiring devices, and communications outlets horizontally in raceways; trim cover sized to overlap device cut-out in raceway, concealing seams; finished to match linear raceway components; plastic compatible with UL 94; brackets and plates, to match raceway width, and with device mounting holes.

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## **PART 3 EXECUTION**

### **3.1 COORDINATION**

- A. Coordinate cover plate openings with the wiring devices contained within.
- B. Coordinate surface raceways installation with (laboratory) casework shop drawings and architectural to match lengths of cabinets and shelving.
- C. Verify location of raceways with architectural interior elevation drawings.

### **3.2 EXAMINATION**

- A. Do not begin installation until substrates have been properly prepared.
- B. If substrate preparation is the responsibility of another installer, notify Architect/Engineer of unsatisfactory preparation before proceeding.

### **3.3 INSTALLATION**

- A. Install in accordance with ANSI/NECA 1 and manufacturer's instructions.
- B. Install flathead screws, clips and straps to fasten surface raceways to substrates, ensuring they are permanently and mechanically anchored. Double-sided adhesive is not acceptable. Mount plumb and level. Use suitable insulating bushings and inserts at connections to outlets and corner fittings.
- C. Install wiring devices and communications outlets of type, quantity and spacing as indicated on drawings.
- D. Mount raceways on wall and casework parallel to or at right angles to structure and casework.
- E. Feed raceways mounted on walls, casework or modular casework from a backbox through a wall box connector. Determine point of feed in field and complete wiring connections.
- F. Maintain ground continuity throughout entire raceway length per requirements in Section 26 0526CR – Grounding and Bonding for Electrical Systems.
- G. Raceways shall not be pre-wired. All wiring and devices shall be installed in the field.
- H. Install appropriate backbox extension rings where raceway is mounted to steel slotted channel or by some other method, stood off from wall.
- I. Raceway receptacle faceplates shall be labeled with adhesive labels with 1/4" high lettering, per requirements in Section 26 0553 – Electrical Systems Identification, indicating receptacle voltage, phase, and amperage (i.e., 120V, 1-phase, 20A) at top of receptacle, and panel and circuit designation (i.e., NLP-D2-2/12) at bottom of receptacle, in accordance with requirements in Section 26 0553CR – Electrical Systems Identification, for 15A, 20A and 30A receptacles.

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- J. Reinforce each cover section for every 30A receptacle in raceway with two 4-40 Phillips counter-sunk steel screws attached to enclosure near top and bottom of receptacle.
  - K. Raceway base shall be secured using screws. Securing with double-sided adhesive is not acceptable.

### **3.4 FIELD QUALITY CONTROL**

- A. Inspect surface raceways for physical damage and proper alignment.
- B. Inspect components, wiring, connections, installation, and grounding.

### **3.5 CLEANING**

- A. Vacuum dirt and construction debris from interior and exterior of equipment; do not use compressed air to assist in cleaning.

**END OF SECTION**



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## SECTION 26 0536CR

### CABLE TRAYS FOR ELECTRICAL SYSTEMS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 26 0000CR - General Electrical Requirements
- B. Section 26 0526CR - Grounding and Bonding
- C. Section 26 0529CR - Hangers and Supports for Electrical Systems
- D. Section 26 0533CR - Raceway and Boxes for Electrical Systems
- E. Section 26 0593CR - Electrical System Firestopping

##### 1.2 REFERENCE

- A. Work under this section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 DESCRIPTION

- A. Provide complete cable tray system including straight tray sections, fittings such as horizontal elbows, vertical risers, crosses, tees, wyes, reducers and coupling accessories, splice plates, and cable tray supports to support cable systems in locations as indicated on drawings.
- B. Cable tray system is intended to carry telephone, data and communications cable only; power wiring and fire alarm system cabling not allowed.

##### 1.4 REFERENCE STANDARDS

- A. ASTM A 123 - Specification for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and forged Steel Shapes, Plates, Bars, and Strip.
- B. ASTM A 446 - Specification for Zinc-Coated (Galvanized) by Hot-Dip Process, Structural (Physical) Quality.
- C. ASTM A 525 - Specification for Steel Sheet, Zinc-Coated Galvanized by Hot Dip Process.
- D. ASTM A 607 - Specification for Steel Sheet and Strip, Hot-rolled and Cold-Rolled, High Strength, Low Alloy Columbium or Vanadium.
- E. ASTM B 633 - Specification for Electro-deposited Coatings of Zinc on Iron and Steel.
- F. NEMA VE 1 - Metal Cable Tray Systems.

## 1.5 SUBMITTALS

- A. Submit shop drawings for equipment provided under this Section.
- B. Submit as-built drawings showing floor plan location, elevation changes, and conduit drops.
- C. A sample of cable tray, tees, fittings, crosses, and dropouts shall be provided to Owner for review prior to approval, purchase, and installation of cable tray.

## PART 2 PRODUCTS

### 2.1 MATERIALS

- A. Acceptable Manufacturers: Chatsworth, B-Line, Chalfant, Globe, Mono Systems, Inc.

### 2.2 FABRICATION AND MANUFACTURER

- A. Materials of Construction:
  - 1. Materials shall be adequately protected against corrosion or made of corrosion resistant material.
- B. Aluminum Ladder Trays:
  - 1. Straight section and fitting side rails shall be extruded aluminum. Other components shall be aluminum.
  - 2. Rung spacing shall be 9" on center.
- C. Wire Plated Mesh-Basket:
  - 1. Mono Tray Mono-Mesh or equal which may be approved prior to bid.
  - 2. Cable Tray system to be constructed in U shape of longitudinal round wires, supported by intersecting transverse wires welded, at each intersection to form a mesh.
  - 3. Provide mesh system allowing for support, ventilation of cables, and maximum heat dissipation.
  - 4. Cable tray system to be manufactured from high strength steel wires, utilizing a patented welding method. Wire to be welded, bent, and zinc plated after manufacture. All welds and edges to be smooth and free of burrs and sharp edges.
  - 5. All tray sections to be electro-plated zinc.
  - 6. Mesh size to be no larger than 2 inches by 4 inches.
  - 7. Straight sections to be provided in 99 inch lengths.
  - 8. All cable exits from tray shall utilize a waterfall style dropout system which allows for smooth radius cable and wire drops from both directions.
  - 9. Fittings: All tees, crosses, IVR's, OVR's, reducers or other required fittings which may or may not provide a specific radius shall be assembled in the field utilizing straight tray sections, hardware, and instructions provided by manufacturer.
  - 10. Tray coupling hardware shall provide a union which equals or exceed strength of cable tray itself, allowing for splices to be located anywhere in support span.



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11. Installation: Install cable tray system utilizing splice connectors and support hardware as supplied by manufacturer, and in accordance with recognized industry practices, applicable portions of NEC and all applicable codes.
- D. Unless otherwise shown on drawings, tray system shall be basket type, width as indicated in documents by 6" deep with minimum usable loading depth 1" less than overall nominal tray depth.
- E. Ladder type trays:  
1. Shall consist of 2 longitudinal members (side rails) with transverse members (rungs) welded to side rails. Tray rung spacing shall be designed to prevent cable sagging as follows:
- F. Rungs shall have minimum cable bearing surface of 7/8" with radiused edges. No portion of rungs shall protrude below bottom plane of side rails.
- G. Tray system shall not present sharp edges, burrs or projections injurious to wiring. Upper flanges shall be rolled out and downward for safety.
- H. Provide splice plates with straight sections and fittings.
- I. Splice plates shall be bolted type.
- J. Splice plate construction shall be designed to permit splice to be located at any point within support span without diminishing cable tray rated loading capacity.
- K. Splice plates for aluminum tray systems shall be aluminum and attached with minimum of 4 rib neck carriage bolts, lock washers, and nuts.
- L. Tray System shall be side rail hung.
- M. Supports for Aluminum Tray:  
1. Aluminum or painted carbon steel.
- N. Supports for Mesh Tray:  
1. Galvanized steel or painted carbon steel.
- O. Minimum bending radius of cross-ties and elbows shall be 24".
- P. Trapeze hangers shall be supported by 1/2" minimum diameter rods.
- Q. Aluminum and galvanized steel cable trays shall be UL classified as equipment grounding conductors.

## **PART 3 EXECUTION**

### **3.1 INSTALLATION**

- A. Tray system shall be accessible, with sufficient space provided about cable trays to permit side access for installation and maintenance of cables. Maintain 6" clearance

- from any portion of the cable tray from all non-cable tray related devices including, but not limited to, structural, mechanical, piping, architectural components and features of the building. Maintain 5" clear from all light fixtures to any portion of the cable tray.
- B. To reduce EMI, contractor shall maintain tray clearance of 5" from any 2 kVA power lines, 18" from lighting, 39" from any 5 kVA power lines, and 47" from transformers and motors.
  - C. Provide blind end plates for trays that dead end.
  - D. Provide full-width dropouts where cables exit from tray.
  - E. Join cable tray system sections at ends using manufacturer prefabricated splice plates.
  - F. Provide prefabricated expansion splice plates at intervals of 48 ft in straight runs and where cable tray systems cross building expansion joints.
  - G. Provide minimum of 1 expansion splice plate in straight runs, which exceed 12 ft for tray installations in exterior areas.
  - H. Support cable tray system utilizing trapeze hangers from building or other structural steel members, angle brackets from vertical structural steel members, upright angle brackets on pipe racks, or directly upon horizontal structural steel members of the building or pipe racks.
  - I. Size, anchor, and space supports to sustain weight of cable tray system, cable, and tubes that are to be installed into cable tray, and 200 lbs excess on any individual ladder rung or section, with safety factor of 1.5 minimum when supported as simple span and tested per NEMA requirements. Load and safety factors are applicable to both, rung or section and side rails.
  - J. Calculate supports based on 100lbs/ft load of cables and tubes.
  - K. Total vertical tray deflection shall not exceed 1-1/2" between supports.
  - L. Include dynamic loads in calculations for outside area installations.
  - M. Make intersections, bends, and tees, using fittings of same type and model series as straight run sections.
  - N. Place barriers to obtain size of each raceway as noted on drawings.
  - O. Secure barriers into cable tray system using prefabricated barrier strip clips. Barriers shall not be secured using screws tapped into ladder rungs or sections. Join barriers at ends using manufacturer prefabricated barrier strip splices.
  - P. Cable tray systems shall be electrically continuous.

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- Q. Connect each cable tray system subassembly to building ground system using grounding clamps and grounding conductors. Provide 3.0 ohm maximum resistance to building ground connection.
  - R. Copper grounding conductors shall not be installed on aluminum tray systems.
  - S. Cable tray shall not be connected to instrumentation grounding system.
  - T. Structural side members shall not be punched or drilled except for splice-plate and fastener bolt holes.
  - U. Cable tray system components shall not be flame-cut or arc-cut. Make cuts using a saw and remove burrs.
  - V. Drill or punch holes for splice-plates and fasteners and remove burrs.
  - W. Nicks and scratches and ends of cut sections with galvanized coatings shall be coated with approved galvanizing coating after tray installation.
  - X. Conductor Installation:
    - 1. Provide metallic grounding conduit clamps to attach conduits to cable tray system.
    - 2. Provide bushings on conduit ends where cables enter conduit to protect insulation.
    - 3. Make multiple drops at ends of sections using manufacturer prefabricated ladder drops.
    - 4. Provide sufficient slack in cables to allow for unequal expansion coefficients of cable tray and cables. This requirement is in addition to slack required at cable tray expansion joints.

**END OF SECTION**



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## **SECTION 26 0553CR**

### **ELECTRICAL SYSTEMS IDENTIFICATION**

#### **PART 1 GENERAL**

##### **1.1 RELATED WORK**

- A. Section 26 0000CR – General Electrical Requirements
- B. Section 26 0533CR – Raceways and Boxes for Electrical Systems
- C. Section 26 2726CR – Wiring Devices

##### **1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 - General Requirements.

##### **1.3 DESCRIPTION**

- A. Section includes the following:
  - 1. Underground-line warning tape.
  - 2. Warning labels and signs.
  - 3. Wiring devices identification.
  - 4. Miscellaneous identification products.
- B. Refer to the respective Division 26 Sections, and Sections in other Divisions that specify electrical components, for additional electrical identification requirements.

##### **1.4 REFERENCE STANDARDS**

- A. ANSI A13.1 – Scheme for the Identification of Piping Systems
- B. ANSI C2 – National Electrical Safety Code
- C. ANSI Z535.4 – National Standards for Product Safety Signs and Labels
- D. 29 CFR – Labor, Part 1910 – Occupational Safety and Health Standards, Section 1910.145 – Specifications for Accident Prevention Signs and Tags
- E. NFPA 70 – National Electrical Code

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## 1.5 SUBMITTALS

- A. Product Data: For each electrical identification product indicated.
- B. Nameplate Schedule: Prior to making nameplates, submit a complete schedule to Architect for approval indicating nameplate size, lettering size, color and actual nameplate information.
- C. Samples: For each type of label and sign to illustrate size, colors, lettering style, mounting provisions, and graphic features of identification products.

## 1.6 QUALITY ASSURANCE

- A. Comply with ANSI A13.1 and ANSI C2.
- B. Comply with NFPA 70.
- C. Comply with 29 CFR 1910.145.

## 1.7 COORDINATION

- A. Coordinate identification names, abbreviations, colors, and other features with requirements in Contract Documents, Shop Drawings, manufacturer's wiring diagrams, and Operation and Maintenance Manual, and with those required by codes, standards, and 29 CFR 1910.145. Use consistent designations throughout project.
- B. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.

## PART 2 PRODUCTS

### 2.1 UNDERGROUND-LINE WARNING TAPE

- A. Manufacturers: Brady USA, Ideal, Marking Services, Inc. (MRI), Seton, or approved equal.
- B. Description: Permanent, bright-colored, continuous-printed, polyethylene tape.
  - 1. Not less than 6" wide by 4 mils thick.
  - 2. Compounded for permanent direct-burial service.
  - 3. Embedded continuous metallic strip or core.
  - 4. Printed legend shall indicate type of underground line.

### 2.2 RACEWAY AND METAL-CLAD CABLE IDENTIFICATION MATERIALS

- A. Comply with ANSI A13.1 for minimum size of letters for legend and for minimum length of color field for each raceway and cable size.
- B. Manufacturers: Brady USA, Ideal, Marking Services, Inc. (MSI), Seton, or approved equal.
- C. Color for Printed Legend:
  - 1. Legend: Indicate system or service and voltage, if applicable.

- D. Snap-Around Labels: Slit, pretensioned, flexible, preprinted, color-coded acrylic sleeves, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action when placed in position.
- E. Snap-Around, Color-Coding Bands: Slit, pretensioned, flexible, solid-colored acrylic sleeves, 2" long, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action when placed in position.
- F. Outdoor use.

### **2.3 CONDUCTOR AND COMMUNICATION- AND CONTROL-CABLE IDENTIFICATION MATERIALS**

- A. Comply with ANSI A13.1 for minimum size of letters for legend.
- B. Manufacturers: Brady USA, Ideal, Marking Services, Inc. (MRI), Seton, or approved equal.
- C. Color-Coding Conductor Tape: Colored, self-adhesive vinyl tape not less than 3 mils thick by 1 to 2" wide.
- D. Marker Tapes: Vinyl or vinyl-cloth, self-adhesive wraparound type, with circuit identification legend machine printed by thermal transfer or equivalent process.
- E. Aluminum Wraparound Marker Labels: Cut from 0.014" thick aluminum sheet, with stamped, embossed, or scribed legend, and fitted with tabs and matching slots for permanently securing around wire or cable jacket or around groups of conductors.
- F. Metal Tags: Brass or aluminum, 2" x 2" x 0.05", with stamped legend, punched for use with self-locking nylon tie fastener.
- G. Write-On Tags: Polyester tag, 0.010" thick, with corrosion-resistant grommet and polyester or nylon tie for attachment to conductor or cable.
  - 1. Marker for Tags: Permanent, waterproof, black ink marker recommended by tag manufacturer.
- H. Plasticized Card-Stock Tags: Vinyl cloth with preprinted and field-printed legends. Orange background, unless otherwise indicated, with eyelet for fastener.

### **2.4 UNDERGROUND-LINE WARNING TAPE**

- A. Manufacturers: Brady USA, Ideal, Marking Services, Inc. (MRI), Seton, or approved equal.
- B. Description: Permanent, bright-colored, continuous-printed, polyethylene tape.
  - 1. Not less than 6" wide by 4 mils thick.
  - 2. Compounded for permanent direct-burial service.
  - 3. Embedded continuous metallic strip or core.
  - 4. Printed legend shall indicate type of underground line.

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## 2.5 EQUIPMENT IDENTIFICATION NAMEPLATES

- A. Laminated Plastic Nameplates:
1. ASTM D 709, Type I, cellulose, phenolic-resin-laminate engraving stock; Grade ES-2, black surface, black phenolic core, with white melamine subcore.
  2. Nameplates shall have 1/2" high lettering, except where space is limited letters may be 1/4" high.
  3. Face of nameplate to be black and letters to be white, except emergency, life safety, or standby power equipment nameplates are to have white face with red letters.
  4. Fasteners shall be small metal screws or pop rivets.
  5. Nameplate thickness shall be 1/8"
  6. Nameplates shall indicate equipment name indicated on contract documents.
  7. For all panelboards, switchboards, switchgear, distribution panels, and transformers, nameplate shall be installed on exterior of cabinet and shall indicate equipment name and voltage on the first line and where equipment is SERVED FROM (upstream equipment name and room number) on the second line.

## 2.6 WIRING DEVICES IDENTIFICATION

- A. Refer to Section 26 2726CR – Wiring Devices for requirements.

## 2.7 MISCELLANEOUS IDENTIFICATION PRODUCTS

- A. Cable Ties: Fungus-inert, self-extinguishing, 1-piece, self-locking, type 6/6 nylon cable ties.
1. Minimum Width: 3/16"
  2. Tensile Strength: 50 lb minimum
  3. Temperature Range: -40 to +185°F
  4. Color: Black, except where used for color-coding
- B. Paint: Paint materials and application requirements are specified in Division 09 – Finishes painting Sections.
- C. Fasteners for Labels and Signs: Self-tapping, stainless-steel screws or stainless-steel machine screws with nuts and flat and lock washers.

## PART 3 EXECUTION

### 3.1 APPLICATION

- A. Accessible Raceways and Metal-Clad Cables, 600 V or Less, for Service, Feeder, and Branch Circuits More Than 30A: Identify with blue snap around labels.
1. Identify junction and pullboxes concealed above ceiling or exposed with neat lettering on cover with permanent black marking pen. Identify source, circuit number, phase, and control circuit number.



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- B. Accessible Raceways and Cables of Auxiliary Electrical Systems: Identify the following systems with color-coded, snap-around, color-coding bands:
    - 1. Fire Alarm System (including covers of pull and junction boxes): Red
    - 2. Security System: Blue and yellow
    - 3. Telecommunication System: Green and yellow
  - C. Power-Circuit Conductor Identification: For conductors in vaults, pull and junction boxes, manholes, and handholes use color-coding conductor tape. Identify source and circuit number of each set of conductors or other appropriate number or letter to expedite future tracing and troubleshooting. For single conductor cables, identify phase in addition to the above. Phase identification shall be consistent throughout the system.
  - D. Branch-Circuit Conductor Identification: Where there are conductors for more than three branch circuits in same junction or pull box, use color-coding conductor tape. Identify each ungrounded conductor according to source and circuit number.
  - E. Locations of Underground Lines: Identify with underground-line warning tape for power, lighting, communication, and control wiring and optical fiber cable.
  - F. Conduit and boxes shall be identified with snap-around color coded bands and paint on junction boxes. Conduit shall be identified to within 6" of box or enclosure. The following colors shall be used:
    - 1. Fire Alarm System: Red
    - 2. Telecommunication System: Green and yellow
    - 1. Security System: Blue and yellow
  - G. Motor starter nameplates shall include motor designation as identified by Division 23 contractor.

### 3.2 IDENTIFICATION

- A. Nameplates shall be securely attached to non-concealed junction box covers of the following:
  - 1. Telephone Distribution System
  - 2. Electrical Distribution System
  - 3. Fire Alarm System
  - 4. Access Control System
  - 5. Closed Circuit Television System
- B. Engraved plastic nameplates shall be securely attached to:
  - 1. Panelboards
  - 2. Switchboards
  - 3. Switchgear
  - 4. Motor Starters
  - 5. Each separately mounted circuit breaker or disconnect switch
  - 6. Each device in Main Distribution
  - 7. Each device in Switchboards
  - 8. Each device in Motor Control Centers
  - 9. Transformers
  - 10. Automatic Transfer Switches
  - 11. Medium Voltage Switches

- 12. Substations
- 13. Switchgear
- 14. Busway

C.4" round, 4" square and 4-11/16" junction boxes concealed above ceilings may be identified with neat lettering on cover with permanent type black marking pen.

D. Nameplate labels shall identify the equipment designation and operating voltage on the first line, and the name of upstream equipment and room number location of the device or source supplying the equipment on the second line.

### **3.3 INSTALLATION**

- A. Verify identity of each item before installing identification products.
- B. Location: Install identification materials and devices at locations for most convenient viewing without interference with operation and maintenance of equipment.
- C. Apply identification devices to surfaces that require finish after completing finish work.
- D. Self-Adhesive Identification Products: Clean surfaces before application, using materials and methods recommended by manufacturer of identification device.
- E. Install non-adhesive signs and plastic nameplates parallel to equipment lines; attach with screws and auxiliary hardware appropriate to the location and substrate. Secure to inside surface of door or panelboard that is recessed in finished locations.
- F. System Identification Color Banding for Raceways and Cables: Each color band shall completely encircle cable or conduit. Place adjacent bands of two-color markings in contact, side by side. Locate bands at changes in direction, at penetrations of walls and floors, at 50 ft maximum intervals in straight runs, and at 25 ft maximum intervals in congested areas.
- G. Underground-Line Warning Tape: During backfilling of trenches install continuous underground-line warning tape directly above line at 6 to 8" below finished grade. Use multiple tapes where width of multiple lines installed in a common trench or concrete envelope exceeds 16" overall.
- H. Painted Identification: Prepare surface and apply paint according to Division 09 – Finishes painting Sections.

**END OF SECTION**

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## **SECTION 260573**

### **OVERCURRENT PROTECTIVE DEVICE COORDINATION AND ARC FLASH STUDY**

#### **PART 1 GENERAL**

##### **1.1 RELATED WORK**

- A. Section 260800 – Commissioning of Electrical Systems
- B. Section 261113 – Primary Unit Substations
- C. Section 261216 – Dry-Type, Medium-Voltage Transformers
- D. Section 261316 – Medium-Voltage Non-Fused Interrupter Switchgear
- E. Section 262200 – Low-Voltage Transformers
- F. Section 262413 – Switchboards
- G. Section 262416.13 – Lighting and Appliance Panelboards
- H. Section 262416.16 – Distribution Panelboards
- I. Section 262813 – Fuses
- J. Section 262816 – Enclosed Switches and Circuit Breakers
- K. Section 262913 – Enclosed Controllers
- L. Section 263623 – Automatic Transfer Switches

##### **1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### **1.3 DESCRIPTION**

- A. Project electrical contractor shall supply pertinent information to electrical design engineer for use in short-circuit analysis and coordination study, protective device setting calculations, and arc flash protection study. Project electrical contractor shall supply arc-flash protection labeling of equipment as required by NEC and as calculated by NFPA 70E based on results of electrical design team arc flash protection evaluation. Labeling shall indicate level of protection required. All switchboard, distribution panelboards, lighting and appliance panelboards, and industrial control panels shall be marked as required by NEC and NFPA 70E.

- B. Electrical design team will perform study using "SKM System Analysis, Inc.," Power Tools Electrical Engineering Software.
- C. Electrical contractor shall furnish field information and data needed for the studies in a bound format.
- D. Available fault current and electrical equipment interrupting capacity indicated on drawings are based on the short circuit study performed during design as part of the construction documents.
- E. Arc flash labels shall be installed prior to energizing equipment.

#### 1.4 REFERENCE STANDARDS

- A. ANSI C57.12.10 – American National Standard for Transformers-230 kV and Below 833/958-8333/10 417 kVA, Single-Phase, and 750/862-60 000/80 000/100 000 kVA, Three-Phase, w/o Load Tap Changing; and 3750/4687-60 000/80 000 kVA with Load Tap Changing-Safety Requirements
- B. ANSI C57.96 – Distribution and Power Transformers, Guide for Loading Dry-Type (Appendix to ANSI C57.12 Standards)
- C. IEEE 141 – Recommended Practice for Electric Power Distribution for Industrial Plants
- D. IEEE 241 – Recommended Practice for Electric Power Systems in Commercial Buildings
- E. IEEE 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
- F. IEEE 399 – Recommended Practice for Power System Analysis
- G. IEEE 620 – Guide for the Presentation of Thermal Limit Curves for Squirrel Cage Induction Machines
- H. IEEE 1015 – Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems
- I. IEEE 1584 – Guide for Performing Arc-Flash Hazard Calculations
- J. IEEE C37.010 – Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- K. IEEE C37.20.1 – IEEE Standard for Metal-Enclosed, Low-Voltage Power Circuit Breaker Switchgear
- L. IEEE 37.46 – American National Standard Specifications for Power Fuses and Fuse-Disconnecting Switches
- M. IEEE C57.96 – IEEE Guide for Loading Dry-Type Distribution and Power Transformers
- N. ICEA P-32-382 – Short-Circuit Characteristics of Insulated Cable

- O. ICEA P-45-482 – Short-Circuit Performance of Metallic Shielding and Sheaths of Insulated Cable
- P. NEMA MG 1 – Motors and Generators
- Q. NFPA 70 – National Electrical Code (NEC)
- R. NFPA 70C – Hazardous Locations Classification
- S. NFPA 70E – Standard for Electrical Safety in Workplace

### **1.5 SUBMITTALS**

- A. Electrical design engineer and electrical contractor shall work together to provide short-circuit, arc flash, and protective device coordination studies based on actual installed conditions.
- B. Final report shall be included in O&M manuals.

## **PART 2 PRODUCTS**

### **2.1 NOT APPLICABLE TO THIS SECTION**

## **PART 3 EXECUTION**

### **3.1 EXAMINATION**

- A. Examine project overcurrent protective device submittals for compliance with electrical distribution system coordination requirements and other conditions affecting performance. Devices for coordination are indicated on drawings.

### **3.2 POWER SYSTEM DATA**

- A. Electrical contractor shall provide to the electrical design engineer all required information and tabulate the following input data to support coordination study:
  - 1. Product Data for overcurrent protective devices specified in other Division 26 Sections and involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with power riser diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
  - 2. Impedance of utility service entrance.
  - 3. Floor plan drawings of electrical rooms and panel, switchboard, and switchgear locations.

4. Power Riser Diagrams: In hard copy and electronic copy formats, showing the following:
  - a. Circuit breaker and fuse-current ratings and types
  - b. Relays and associated power and current transformer ratings and ratios
  - c. Transformer kilovolt amperes, primary and secondary voltages, connection type, impedance, and X/R ratios
  - d. Generator kilovolt amperes, size, voltage, and source impedance
  - e. Cables: Indicate conduit material, sizes of conductors, conductor material, insulation, and total length
  - f. Busway ampacity and impedance
  - g. Motor horsepower and code letter designation according to NEMA MG 1
  - h. Load current that is the basis for sizing continuous ratings of circuits for cables and equipment
5. Data sheets to supplement power riser diagrams, cross-referenced with tag numbers on diagrams, showing the following:
  - a. Special load considerations, including starting inrush currents and frequent starting and stopping
  - b. Transformer characteristics, including primary protective device, magnetic inrush current, and overload capability
  - c. Motor full-load current, locked-rotor current, service factor, starting time, type of start, and thermal-damage curve
  - d. Generator thermal-damage curve
  - e. Ratings, types, and settings of utility company's overcurrent protective devices
  - f. Special overcurrent protective device settings or types stipulated by utility company
  - g. Time-current characteristic curves of devices indicated to be coordinated
  - h. Manufacturer, frame size, interrupting rating in amperes rms symmetrical, ampere or current sensor rating, long-time adjustment range, short-time adjustment range, and instantaneous adjustment range for circuit breakers
  - i. Manufacturer and type, ampere-tap adjustment range, time-delay adjustment range, instantaneous attachment adjustment range, and current transformer ratio for overcurrent relays
  - j. Panelboards, switchboards, and switchgear ampacity, and interrupting rating in amperes rms symmetrical

### **3.3 FIELD QUALITY CONTROL**

- A. Inspect, set, test, and calibrate the protective relays, circuit breakers, fuses, and other applicable devices per requirements in Section 260800 – Commissioning of Electrical.

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- B. Upon final approval of study, provide weatherproof vinyl or polyester arc flash label for all electrical equipment defined above. Label shall include calculated flash protection boundary, incident energy at working distance of 18", required PPE level, limited approach, restricted approach, and prohibited approach boundaries, equipment name, overcurrent device settings if applicable, and date label was produced.
1. PPE label shall be color coded as follows:
    - a. Category 0 or 1 – Green
    - b. Category 2 – Yellow
    - c. Category 3 – Orange
    - d. Category 4 – Red

### **3.4 ADJUSTING**

- A. Make modifications to equipment, as required, to accomplish conformance with equipment evaluation study.
- B. Adjust relay and overcurrent protective device settings according to recommended settings table provided by overcurrent protective device coordination study.
- C. Notify Owner/Engineer in writing of any required major modifications.

### **3.5 INSTALLATION**

- A. Install PPE labels on each piece of equipment prior to energizing equipment.
- B. PPE labels shall be protected by clear plastic cover, weatherproof type material or laminated and mounted on front of equipment. Taping of PPE label to front of equipment is unacceptable.
- C. PPE label shall be clearly visible upon approach to equipment.
- D. For large pieces of equipment, label shall be placed near main overcurrent device or incoming feeder to equipment.
- E. Label shall be mounted at a minimum of 42" to bottom and maximum 66" to top above finished floor.

**END OF SECTION**





**SECTION 26 0593CR**

**ELECTRICAL SYSTEMS FIRESTOPPING**

**PART 1 GENERAL**

- 1.1** Refer to 07 8400 - Firestopping for electrical systems firestopping requirements.

**END OF SECTION**



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## **SECTION 26 0800CR**

### **POWER DISTRIBUTION ACCEPTANCE TESTS**

#### **PART 1 GENERAL**

##### **1.1 RELATED WORK**

- A. Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables
- B. Section 26 0526CR – Grounding and Bonding for Electrical Systems
- C. Section 26 2200CR – Low-Voltage Transformers
- D. Section 26 2413CR – Switchboards
- E. Section 26 2816CR – Enclosed Switches and Circuit Breakers
- F. Section 26 2913CR – Enclosed Controllers

##### **1.2 REFERENCE**

- A. Work under this section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions and sections under Division 01 General Requirements.

##### **1.3 DESCRIPTION**

- A. All acceptance type testing will be performed by the Owner's commissioning agent. The Division 26 contractor shall be responsible for standard electrical equipment checkout, testing, and installation in accordance with each individual Division 26 specification section.
- B. All electrical equipment shall be installed in accordance with all industry and NECA standards for electrical equipment.
- C. Equipment shall be installed and provided in a condition ready for acceptance testing by the commissioning agent.
- D. Division 26 contractor shall provide assistance to and work with the Owner, commissioning agent, and test agency in obtaining access to, information about, and repair of all equipment as required by commissioning agent's testing contractor findings.
- E. Owner's commissioning agent will independently hire testing contractor.
- F. Section includes acceptance testing requirements for assessing the suitability for service and reliability of the power distribution system.

- G. It is the purpose of this specification to assure all tested electrical equipment, both contractor and Owner supplied, is operational and within industry and manufacturer's tolerances and is installed in accordance with design specifications.
- H. Tests and inspections shall be performed after installation
- I. Typical items expected to be tested include but are not limited as follows. Contractor shall coordinate with Owner and commissioning agent for complete list:
  - 1. 600-volt conductors and cables
  - 2. Dry type transformers (small)
  - 3. Switchboard
  - 4. Low-voltage power circuit breakers
  - 5. Low-voltage insulated-case/molded-case circuit breakers
  - 6. Low-voltage disconnect switches
  - 7. Ground fault protection systems
  - 8. Grounding systems

#### 1.4 REFERENCE STANDARDS

- A. ANSI/IEEE C2 – National Electrical Safety Code
- B. ANSI/IEEE C37 – Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses
- C. ANSI/IEEE C37.04 – Standard Rating Structure for AC High Voltage Circuit Breaker
- D. ANSI/IEEE C57 – Distribution, Power, and Regulating Transformers
- E. ANSI/IEEE C57.13.1 – Guide for Field Testing of Relaying Current Transformers
- F. ANSI/IEEE C57.13.3 – Grounding of Instrument Transformer Secondary Circuits and Gases
- G. ANSI/IEEE C57.104 – Guide for the Interpretation of Gases Generated in Oil-immersed Transformers
- H. ANSI/IEEE C62 – Surge Protection
- I. ANSI/IEEE Std. 43 – IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery
- J. ANSI/IEEE Std. 48 – Standard Test Procedure and Requirements for High-Voltage Alternating-Current Cable Terminations
- K. ANSI/IEEE Std. 81 – Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
- L. ANSI/IEEE Std. 141 – IEEE Recommended Practice for Electrical/Power Distribution for Industrial Plants (IEEE Red Book)

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- M. ANSI/IEEE Std. 142 – IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)
  - N. ANSI/IEEE Std. 241 – IEEE Recommended Practice for Electrical Power Systems in Commercial Buildings (IEEE Gray Book)
  - O. ANSI/IEEE Std. 242 – IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book)
  - P. ANSI/IEEE Std. 399 – IEEE Recommended Practice for Power Systems Analysis (IEEE Brown Book)
  - Q. ANSI/IEEE Std. 400 – Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field
  - R. ANSI/IEEE Std. 446 – IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book)
  - S. ANSI/IEEE Std. 493 – IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book)
  - T. ANSI/IEEE Std. 1100 – IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book)
  - U. ASTM D877 – Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
  - V. ASTM D823 – Standard Practices for Sampling Electrical Insulating Liquids
  - W. ASTM D924 – Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
  - X. ASTM D971 – Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Methods
  - Y. ASTM D974 – Standard Test Method for Acid and Base Number by Color-Indicator Titration
  - Z. ASTM D1298 – Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
  - AA. ASTM 1500 – Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
  - BB. ASTM D1524 – Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field
  - CC. ASTM D1816 – Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes

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- DD. ASTM D2285 – Standard Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin Against Water by the Drop-Weight Method
  - EE. ASTM D3612 – Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography
  - FF. ASTM D3613 – Standard Practice for Sampling Insulating Liquids for Gas Analysis and Determination of Water Content
  - GG. NETA – Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems
  - HH. NEMA AB 4 – Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications
  - II. NEMA MG1 – Motors and Generators
  - JJ. NFPA 70 – National Electrical Code
  - KK. NFPA 70B – Recommended Practice for Electrical Equipment Maintenance
  - LL. NFPA 70E – Electrical Safety Requirements for Employee Workplaces
  - MM. NFPA 101 – Life Safety Code
  - NN. NFPA 110 – Emergency and Standby Power Systems
  - OO. NIST – National Institute of Standards and Technology
  - PP. OSHA – Part 1910 – Subpart S – 1910.308 – Special Systems

## **PART 2 PRODUCTS**

### **2.1 NOT APPLICABLE TO THIS SECTION.**

## **PART 3 EXECUTION**

### **3.1 PREPARATION**

- A. Documentation: Deliver the following to testing firm, minimum two weeks prior to commencement of testing:
  - 1. Complete set of electrical plans and specifications.
  - 2. Approved submittals and shop drawings of equipment being tested.
  - 3. Pertinent change orders.
- B. Schedule: Notify Owner and Engineer 10 working days prior to performance of any tests.

- C. Coordination: Coordinate with Construction Manager/Owner/Engineer the testing schedule and availability of equipment ready for testing.
- D. Test Power: Provide test power (including specialized) for equipment testing before and after service energizing.
- E. Contractor shall coordinate with the University of Minnesota Energy Management in the development and completion of all University Commissioning Checklists and test procedures developed for this project.

### 3.2 FIELD QUALITY CONTROL

- A. Inspection and Test Procedures: Comply with NETA.
  - 1. 600 V Conductors and Cables:
    - a. Visual and Mechanical Inspection:
      - 1) Compare cable data with drawing and specifications.
      - 2) Inspect exposed sections of cables for physical damage.
      - 3) Verify tightness of accessible bolted electrical connections by calibrated torque wrench in accordance with manufacturer's published data or Table 12.
      - 4) Perform thermographic survey of bolted electrical connections in accordance with paragraph "Thermographic Survey."
      - 5) Inspect compression-applied connectors for correct cable match and indentation.
      - 6) Verify visible cable bends meet or exceed ICEA and manufacturer's minimum allowable bending radius.
      - 7) Inspect for correct identification and arrangements.
      - 8) Inspect jacket and insulation condition.
    - b. Electrical Tests:
      - 1) Perform insulation-resistance test using megohm meter. Applied potential to be 1000 VDC. Individually test each conductor with other conductors grounded. Test duration shall be one minute.
      - 2) Perform continuity tests to insure correct cable connection.
    - c. Test Values:
      - 1) Insulation-resistance values should not be less than 50 megohms.
  - 2. Dry Type Transformers (Small):
    - a. Visual and Mechanical Inspection:
      - 1) Compare equipment nameplate data with drawings and specifications.
      - 2) Inspect physical and mechanical condition.
      - 3) Inspect anchorage, alignment, and grounding.
      - 4) Verify that resilient mounts are free and that any shipping brackets have been removed.
      - 5) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
      - 6) Perform thermographic survey of bolted electrical connections, in accordance with paragraph "Thermographic Survey."

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- 7) Verify that as-lift tap connections are as specified.
    - b. Test Values:
      - 1) Bolt-torque levels should be in accordance specified by manufacturer.
  3. Low-Voltage Switchgear and Switchboard Assemblies:
    - a. Visual and Mechanical Inspection:
      - 1) Compare equipment nameplate data with drawings and specifications.
      - 2) Inspect physical and mechanical condition.
      - 3) Confirm correct application of manufacturer's recommended lubricants.
      - 4) Verify appropriate anchorage, required area clearances, grounding and correct alignment.
      - 5) Inspect doors, panels, and sections for paint, dents, scratches, fit, and missing hardware.
      - 6) Verify fuse and/or circuit breaker sizes and types correspond to drawings and coordination study as well as to circuit breaker's address for microprocessor-communication packages.
      - 7) Verify that current and potential transformer ratios correspond to drawings.
      - 8) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench. Refer to manufacturer's published data for proper torque values.
      - 9) Confirm correct operation and sequencing of electrical and mechanical interlock systems.
        - a) Attempt closure on locked-open devices. Attempt to open locked-closed devices.
        - b) Make key exchange with devices operated in off-normal positions.
      - 10) Inspect insulators for evidence of physical damage or contaminated surfaces.
      - 11) Verify correct barrier and shutter installation and operation.
      - 12) Exercise active components.
      - 13) Inspect mechanical indicating devices for correct operation.
      - 14) Verify filters are in place and/or vents are clear.
    - b. Test Values:
      - 1) Bolt-torque levels shall be in accordance specified by manufacturer.
  4. Low-Voltage Power Circuit Breakers:
    - a. Visual and Mechanical Inspection:
      - 1) Compare nameplate data with drawings and specifications.
      - 2) Inspect physical and mechanical conditions.
      - 3) Confirm correct application of manufacturer's recommended lubricants.
      - 4) Inspect anchorage, alignment, and grounding.
      - 5) Inspect arc chutes.
      - 6) Inspect moving and stationary contacts for condition, wear, and alignment.
      - 7) Verify maintenance devices are available for serving and operating breaker.



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- 8) Verify primary and secondary contact wipe and other dimensions vital to satisfactory operation of breaker are correct.
  - 9) Perform mechanical operator and contact alignment tests on breaker and its operating mechanism.
  - 10) Verify tightness of accessible bolted bus connections by calibrated torque-wrench method. Refer to manufacturer's instructions for correct torque levels.
  - 11) Check cell fit and element alignment.
  - 12) Check racking mechanism.
  - 13) Record as-found and as-left operation-counter readings.
- b. Test Values:
- 1) Bolt-torque levels shall be in accordance specified by manufacturer.
5. Low-Voltage Insulated-Case/Molded-Case Circuit Breakers, 225A and Larger:
- a. Visual and Mechanical Inspection:
- 1) Compare nameplate data with drawings and specifications.
  - 2) Inspect circuit breaker for correct mounting.
  - 3) Check cell fit, element alignment and racking mechanism for draw-out breakers.
  - 4) Operate circuit breaker to insure smooth operation.
  - 5) Inspect case for cracks or other defects.
  - 6) Verify tightness of accessible bolted electrical connections and/or cable connections by calibrated torque-wrench method in accordance with manufacturer's published data.
  - 7) Inspect mechanism contacts and arc chutes in unsealed units.
- b. Test Values:
- 1) Bolt-torque levels shall be in accordance specified by manufacturer.
6. Low-Voltage Disconnect Switches:
- a. Visual and Mechanical Inspection:
- 1) Compare equipment nameplate data with drawings and specifications.
  - 2) Inspect physical and mechanical condition.
  - 3) Inspect anchorage, alignment, grounding, and required clearances.
  - 4) Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
  - 5) Verify that fuse sizes and types are in accordance with drawings, short-circuit and overcurrent protective device coordination studies.
  - 6) Verify that each fuse has adequate mechanical support and contact integrity.
  - 7) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
  - 8) Verify operation and sequencing of interlocking systems.
  - 9) Verify correct phase barrier installation.
  - 10) Verify correct operation of all indicating and control devices.
  - 11) Confirm correct application of manufacturer's recommended lubricants.

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- b. Test Values:
    - 1) Compare bolted connection resistances to values of similar connections.
    - 2) Bolt-torque levels should be in accordance specified by the manufacturer.
  - 7. Motor Control and Motor Control Center:
    - a. Visual and Mechanical Inspection:
      - 1) Compare equipment nameplate data with drawings and specifications.
      - 2) Inspect physical and mechanical condition.
      - 3) Inspect anchorage, alignment and grounding.
      - 4) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
      - 5) Verify controller mechanical operations. Inspect gap, wipe, alignment, and pressure are in accordance with manufacturer's published data.
      - 6) Verify motor running protection installed and properly sized.
      - 7) Confirm correct application of manufacturer's recommended lubricants.
    - b. Test Values:
      - 1) Bolt-torque levels shall be in accordance specified by manufacturer.
  - 8. Ground Fault Protection Systems:
    - a. Visual and Mechanical Inspection:
      - 1) Compare equipment nameplate data with drawings and specifications.
      - 2) Visually inspect components for damage and errors in polarity or conductor routing:
        - a) Verify ground connection is made ahead of neutral disconnect link and on line side of any ground fault sensor.
        - b) Verify neutral sensors are connected with correct polarity on both primary and secondary.
        - c) Verify all phase conductors and neutral pass through sensor in same direction for zero sequence systems.
        - d) Verify grounding conductors do not pass through zero sequence sensors.
        - e) Verify grounded conductor is solidly grounded.
      - 3) Verify tightness of accessible bolted electrical connections, including control circuits, by calibrated torque-wrench method in accordance with manufacturer's published data.
      - 4) Verify correct operation of self-test panel.
      - 5) Set pickup and time-delay settings in accordance with settings provided on drawings and in specifications. Record operation and test sequences as required by NFPA 70.
      - 6) Verify the control power transformer has adequate capacity for the system.
    - b. Test Values:
      - 1) Bus bolt-torque levels shall be in accordance specified by manufacturer.

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9. Grounding Systems:
- a. Visual and Mechanical Inspection:
    - 1) Verify ground system is in compliance with drawings, specifications, and NFPA 70.
    - 2) Inspect physical and mechanical condition.
    - 3) Inspect anchorage.
  - b. Electrical Tests:
    - 1) Perform fall-of-potential or alternative test in accordance with ANSI/IEEE 81 on the main grounding electrode or system.
    - 2) Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and/or derived neutral points.
    - 3) Make resistance measurements in dry weather not earlier than 48 hours after rainfall.
  - c. Test Values:
    - 1) The resistance between the main grounding electrode and ground should be no greater than five ohms. (Reference ANSI/IEEE 142.) Investigate any values above five ohms and notify Engineer immediately for further instructions.
    - 2) Investigate point-to-point resistance values that exceed 0.5 ohm.
  - d. Control Verification:
    - 1) Verify each relay contact performs its intended function in control scheme including breaker trip tests, close inhibit tests, 86 lockout tests, and alarm functions.
    - 2) For microprocessor-based relays, verify all inputs, outputs, internal logic, and timing elements used in protection, metering, and control functions.
  - e. Systems Tests:
    - 1) After the equipment is energized, measure magnitude and phase angle of inputs and compare to expected values.
  - f. Test Values:
    - 1) When not otherwise specified, use manufacturer's recommended tolerances.
    - 2) When critical test points are specified, relay should be calibrated to those points even though other test points may be out of tolerance.
- B. Test Reports:
- 1. Contractor shall do the following:
    - a. Investigate, replace, or repair any fault in material or in any part of the installation revealed by the tests performed by the contractor and the Owner's testing agent.

**END OF SECTION**



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**SECTION 26 0923CR**  
**LIGHTING CONTROL DEVICES**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 26 0000CR - General Electrical Requirements
- B. Section 26 5100CR - Lighting

**1.2 REFERENCE**

- A. The Work under this Section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION OF SYSTEM**

- A. Provide devices such as wall box dimmers, wall and ceiling mounted occupancy sensors, ambient light sensors, sensor power packs, etc., as shown on drawings.
- B. Openings shall be covered with devices and matching plates.
- C. Devices of same type shall be from same manufacturer.

**1.4 REFERENCE STANDARDS**

- A. UL20 - General Use Snap Switches.
- B. UL773A - Non-Industrial Photoelectric Switches for Lighting Control.
- C. NEMA WD 7 - Occupancy Motion Sensors.

**1.5 SUBMITTALS**

- A. Submit shop drawings for equipment provided under this Section.
- B. Device color samples.

**PART 2 PRODUCTS**

**2.1 MANUFACTURERS**

- A. Manufacturers:
  - 1. Wall Box Dimmers: Hubbell, Levitan, Lutron, Lightolier (Sunrise and Momentum Series), Prescolite, Unenco

2. Ceiling Sensors:
    - a. Dual Technology Occupancy Sensors, PIR and Ultrasonic: Hubbell, MyTech, Unenco, Wattstopper (DT Series)
    - b. Ambient Light Sensors: Hubbell, MyTech, Leviton, Lightolier (Insight Series), Uneco, Wattstopper
  3. Wall Sensors:
    - a. Dual Technical Occupancy Sensors, PIR and Ultrasonic, Switched: Hubbell, Wattstopper
  4. Power Packs: Light-O-Matic, Lightolier, Leviton, MyTech, Novitas, Tork, Unenco, Wattstopper
  5. Photocells: Intermatic, Paragon, Tork
  6. Timeclocks: Intermatic, Paragon, Tork
- B. It is the responsibility of Electrical Contractor to ensure devices submitted meet or exceed functional intent and design quality standards.

## 2.2 FABRICATION AND MANUFACTURE

- A. Devices shall be UL listed for loads and voltages as shown on drawings.

## 2.3 WALL BOX DIMMERS

- A. Dimmers shall:
1. Be stainless steel.
  2. Operate in ambient temperature range of 0°C (32°F) to 40°C (104°F).
  3. Be linear slide preset dimmers with power-failure memory.
  4. Incorporate separate control of intensity and on/off.
  5. Include voltage compensation circuitry that adjusts firing angle of dimmer to compensate light output for variations in AC line voltage. Dimmers in which firing angle is held constant with varying AC line voltage shall not be acceptable.
  6. Provide smooth and continuous IESNA Square Law Dimming Curve throughout entire dimming range.
  7. Incorporate filter network to minimize interference (RFI) with radio, audio, and video equipment.
  8. Incorporate air-gap switch to meet requirements of UL 20 for air-gap switches in incandescent dimmers.
- B. Fluorescent dimmers shall be:
1. Rated to control 430 mA rapid start, 800 mA high output or 265 mA lamps.
  2. Be approved by ballast manufacturer for control of ballasts provided.
  3. Contain relay to automatically remove power to circuit feeding dimming ballast when dimmer is off.
  4. Incorporate circuitry to prevent lights from momentarily "flashing" when dimmer is turned on or off.
  5. Different lamp lengths or one and two lamp ballasts on same circuit shall track evenly with no perceptible difference in light levels for same type of lamps.
  6. Dimmers and lamps shall have a dimming range from 100% down to 1% light output.
  7. Refer to Section 26 5100CR- Lighting for solid state dimming ballast specification.

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## 2.4 OCCUPANCY SENSORS

- A. Occupancy Sensor shall:
  - 1. Be gray colored.
  - 2. Operate with all lamp and ballast combinations, including magnetic, hybrid, and solid-state ballasts.
  - 3. Have LED to indicate occupant detection.
  - 4. Have adjustable time delays from 30 seconds to 15 minutes and adjustable sensitivity.
  
- B. Ultrasonic circuit shall be:
  - 1. Solid-state crystal controlled.
  - 2. 32 kHz minimum.
  
- C. Ceiling ultrasonic portion of dual technology occupancy sensors shall:
  - 1. Have 360° coverage with ceiling height of 12 ft.
  - 2. Be low voltage wired in parallel to common power pack.
  - 3. Incorporate by-pass switch to enable lighting to be turned on if sensor fails.
  
- D. Passive infrared portion of dual technology occupancy sensors shall:
  - 1. Incorporate temperature compensated dual element sensor and multi element fresnel lens.
  - 2. Have daylight filter to ensure sensor is insensitive to short-wave length waves emitted by sun.
  
- E. Ceiling passive infrared portion of dual technology occupancy sensors shall:
  - 1. Have round, square, or long rectangular coverage patterns to match floor plan layout.
  - 2. Operate within ceiling height of 12 ft.
  - 3. Be low voltage wired in parallel to common power pack.
  
- F. Dual technology occupancy sensors shall:
  - 1. Include both ultrasonic and passive infrared sensors. Each sensing technology shall have independent sensitivity adjustments and LED to indicate detection.
  - 2. Be designed to be either wall or ceiling mounted as indicated on drawings.
  - 3. Sense motion from both technologies to turn lighting on, but maintained detection from either technology will hold lighting on for set time delay.
  - 4. Be low voltage wired to sensor power packs.
  - 5. Contain isolated relay with normally open, normally closed, and common outputs for use with EMCS system, data logging, or other system control options.
  
- G. Wall dual technology occupancy sensors shall:
  - a. Incorporate all features and performance of ceiling ultrasonic and passive infrared sensors except include switching.
  - b. Have switch for either off or auto for normal operation.
  - c. Be completely self contained to replace standard toggle switches.
    - 1) Switching mechanism shall be latching air gap relay.
    - 2) Units may be low voltage devices with sensor power packs similar to ceiling mounted devices.
    - 3) Power supply shall be internal transformer.

- 4) Include switch or switches as required to control bi-level room lighting indicated on drawings.
  - d. Incorporate by-pass switch to enable lighting to be turned on if sensor fails.
  - e. Have 170° radial spread pattern with minimum of 20 ft axial sensor coverage.
  - f. Be user adjustable for normal operation.
    - 1) Sensor shall operate similar to toggle switch, tap on and tap off, with sensor maintaining lighting during detection and time delay lights off.
    - 2) Alternate operation shall be sensor detection lights on, with sensor maintaining lighting during detection and time delay off.
  - g. With ambient light sensor shall incorporate all features and performance of passive infrared sensors and ambient light sensors.
  - h. Ambient light sensor shall be internal with range of 5 to 300 footcandles.
  - i. Ambient light sensing component shall not permit lighting systems to be turned on if enough daylight is present.
  - j. Contain isolated relay with NO, NC, and common auxiliary output.
- H. Ambient light sensors shall:
- 1. Incorporate photoconductive cell to measure light levels between 10 and 1,000 footcandles.
  - 2. Be adjustable with deadband feature to prevent cycling of lighting from minor changes in cloud cover.
  - 3. Have adjustable time delay range from 15 seconds to 5 minutes.
  - 4. Not permit lighting systems to be turned on if enough daylight is present.
  - 5. Incorporate by-pass switch to enable lighting to be turned on if sensor fails.
  - 6. Be low voltage wired in parallel to power packs.
- I. Sensor power packs shall:
- 1. Be self-contained transformer relay modules.
  - 2. Have dry contacts capable of switching 20 amp load at either 120VAC or 277VAC.
  - 3. Provide 24VDC output capable of controlling ultrasonic or passive infrared occupancy sensors.

## 2.5 PHOTOCELLS

- A. Photocells shall:
- 1. Be rated 2,000 watts tungsten at 120, 240, or 277 volts.
  - 2. Have cadmium sulfide, 1" diameter cell.
  - 3. Have SPST normally closed contacts.
  - 4. Have delay of up to 2 minutes to prevent false switching.
  - 5. Have 5-year warranty.
- B. ON/OFF adjustment shall be done by moving light selector with range from 2 to 50 footcandles.
- C. Operational temperature range shall be -40 to 140°F (-40 to +60°C).



- D. Enclosure shall be die cast zinc, gasketed for maximum weatherproofing.
- E. Enclosure shall include positioning lug on top.
- F. Mounting shall be for 1/2" conduit nipple.

## 2.6 TIMECLOCKS

- A. Timeclocks shall:
  - 1. Be multi-purpose, 7-day, 365-day advance single and skip a day, combination 2-channel electronic time clock with SPDT switching configuration and astronomic dial.
  - 2. Be rated for 30 VDC, 120 VAC, 250 VAC and 277 VAC.
  - 3. Be capable of programming in AM/PM or 24-hour format by jumper selection, in one-minute resolution, using 2 buttons for basic settings.
  - 4. Have 365-day and/or holiday selection capabilities, with 16 single date and 5 holiday selection options and user selectable daylight savings/standard time functions.
  - 5. Have 72-hour memory backup with rechargeable battery and charger.
  - 6. Be capable of manual override, ON and OFF to the next scheduled event, using one button for each channel.
  - 7. Have operational temperature range of -40 to 150°F.
- B. Contacts shall be rated 10 amp resistive at 120/250 VAC, 7.5 amps inductive at 120/250 VAC, 5 amps inductive at 30 VDC and up to 1/2 hp at 250 VAC.
- C. Display shall be LED type.
- D. Enclosure shall be rated for indoor or outdoor installation.

## PART 3 EXECUTION

### 3.1 INSTALLATION

- A. Install devices at heights scheduled, and as indicated on drawings.
- B. Install wall devices vertically on latch side of door within 6" of frame edge, unless otherwise noted.
- C. Install ceiling devices as shown on drawings and as recommended by device manufacturer.
- D. Ceiling mounted occupancy sensors shall be located minimum of 6 ft from supply air diffusers.
- E. Install devices plumb, level with finished surfaces and free from blemishes.
- F. Verify device locations prior to rough in.

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- G. Control wiring shall be low voltage, Class II wiring, electrically isolated from power wiring by a Class II transformer.
  - H. Provide separate neutral conductor for each dimmer.
  - I. Wiring shall be in conduit.
  - J. Electrical Contractor shall be responsible for final adjustment and testing of all devices.

### **3.2 TESTING**

- A. Check dimmer preset control for proper operation.
- B. Verify dimmers function without producing lamp flicker or audible noise.
- C. Verify dimmers function without interference of audio and visual equipment.
- D. Adjust occupancy sensors for a 15 minute time delay.
- E. Verify proper operation of occupancy sensor switches and by-pass switches.
- F. Adjust occupancy sensor sensitivity such that movement outside range of coverage shall not trigger sensor.

**END OF SECTION**

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**SECTION 26 2200CR**  
**LOW-VOLTAGE TRANSFORMERS**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables
- B. Section 26 0526CR – Grounding and Bonding for Electrical Systems
- C. Section 26 0529CR – Hangers and Supports for Electrical Systems
- D. Section 26 0533CR – Raceway and Boxes for Electrical Systems
- E. Section 26 0553CR – Electrical Systems Identification
- F. Section 26 0800CR – Commissioning for Electrical Systems

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. Section includes dry type distribution and buck-boost transformers rated 600V and less, with capacities up to 500 kVA.

**1.4 REFERENCE STANDARDS**

- A. ANSI/NECA 1 – Standard Practices for Good Workmanship in Electrical Contracting
- B. IEE C57.12.91 – Test Code for Dry Type Distribution and Power Transformers
- C. NEMA 250 – Enclosures for Electrical Equipment (1000 Volts Maximum)
- D. NEMA ST 1 – Specialty Transformers (except General Purpose Type)
- E. NEMA ST 20 – Dry-Type Transformers for General Applications
- F. NEMA TP 1 – Guide for Determining Energy Efficiency for Distribution Transformers
- G. NEMA TP 2 – Test Method for Measuring the Energy Consumption of Distribution Transformers
- H. NEMA TP 3 – Standard for the Labeling of Distribution Transformer Efficiency

- I. NFPA 70 – National Electrical Code
- J. UL 506 – Specialty Transformers
- K. UL 1561 – Dry-Type General Purpose and Power Transformers

## 1.5 SUBMITTALS

- A. Product Data:
  - 1. Include rated nameplate data, capacities, minimum clearances, installed devices and features, and performance for each type and size of transformer indicated.
- B. Shop Drawings:
  - 1. For each transformer size and type:
    - a. Physical dimensions, including bolting templates, weight, and center of gravity
    - b. Loads, method of field assembly, components, and location and size of each field connection
    - c. Wiring Diagrams: Power, signal, and control wiring
    - d. kVA rating
    - e. Primary taps
    - f. Insulation class and temperature rise
    - g. Efficiency values measured at 0, 25, 50, 75, and 100% load
    - h. Impedance value – X/R and %Z
    - i. Sound level
    - j. “K” factor listing, where applicable
- C. Submit 1/4" scale electrical room floor plans with transformer locations.
- D. Manufacturer’s Installation Instructions:
  - 1. Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of product.
- E. Test Reports: Indicate field test and inspection procedures and interpret test results and corrective action taken for compliance with specification requirements.
- F. Output Settings Report: Record output voltages and tap settings.
- G. Closeout Submittals:
  - 1. Project Record Documents:
    - a. Record actual locations of transformers.
  - 2. Operation and Maintenance Data:
    - a. Include manufacturer’s recommended operating instructions, maintenance procedures and intervals, and preventive maintenance instructions.
    - b. Include spare parts data listing, source, and current prices of replacement parts and supplies.
    - c. Include in emergency, operation and maintenance manuals.

## 1.6 QUALITY ASSURANCE

- A. Obtain transformers from one source and by single manufacturer.
- B. Regulatory Requirements:
  - 1. Comply with NFPA 70 for components and installation.
  - 2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

## 1.7 DELIVERY, STORAGE, AND HANDLING

- A. Store in clean, dry space. Maintain factory wrapping or provide additional canvas or plastic cover to protect from dirt, water, construction debris, and traffic.
- B. Temporary Heating: Apply temporary heat according to manufacturer's written instructions within the enclosure of each ventilated-type unit, throughout periods during which equipment is not energized and when transformer is not in a space that is continuously under normal control of temperature and humidity.

## 1.8 WARRANTY

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr written warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

## PART 2 PRODUCTS

### 2.1 MANUFACTURERS

- A. Square D
- B. Cutler-Hammer
- C. Siemens

### 2.2 DISTRIBUTION TRANSFORMERS

- A. Fabrication:
  - 1. NEMA ST 20, UL 1561
  - 2. Factory assembled and tested
  - 3. Air-cooled, for 60 Hz service
  - 4. Two winding dry type
  - 5. Coils:
    - a. Continuous wound construction and impregnated with non-hydroscopic, thermosetting varnish.
    - b. Conductors: Continuous windings without splices, except for taps, and encapsulated wire resin compound to seal out moisture and air.
    - c. Materials: Aluminum

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- d. Separate primary and secondary
  - e. Internal Connections: Braised or pressure type
  - 6. Cores: High-grade silicon steel, non-aging, with high magnetic permeability, low eddy current losses and low hysteresis. Magnetic flux densities below saturation point. Core laminations clamped with steel members, one leg per phase.
  - 7. Rubber vibration absorbing mounts to isolate base of enclosure from core and coil assembly.
  - 8. Transformer neutral visibly grounded to enclosures with flexible grounding conductor.
- B. Enclosure:
- 1. NEMA 250
  - 2. Type 1, unless otherwise indicated to comply with environmental conditions at installed location.
  - 3. Code-gauge steel panel over core and coil.
  - 4. Ventilated (air-cooled): Louvered openings for convection cooling.
  - 5. Cooling and terminal chamber access with both sides and rear obstructed.
  - 6. Manufacturer's lifting eyes or brackets.
  - 7. Finish: Manufacturer's standard gray enamel over prime coat after being degreased, cleaned, and phosphatized.
- C. Ratings:
- 1. KVA Rating: 500 kVA maximum
  - 2. Primary Voltage: 480V, 3-phase, 3 wires.
  - 3. Secondary Voltage: 208Y/120V, 3-phase, 4 wires.
  - 4. Insulation Class and Winding Temperature Rise:
    - a. Transformers 5kVA – 500kVA : Class 220°C, with 150°C temperature rise above 40°C ambient temperature, capable of carrying 15% continuous overload without exceeding 150°C.
  - 5. Top of Enclosure Temperature: Maximum 35°C above 40°C ambient temperature at warmest point at full load.
  - 6. K-Factor Rating: UL 1561, as indicated.
  - 7. Impedance %Z: 3 to 5%
- D. Primary Taps:
- 1. 15kVA and larger transformers: Two 2.5% above and two 2.5% below normal full capacity, minimum of four taps.
- E. Energy Efficiency:
- 1. Transformers:
    - a. NEMA TP 1-2002, Class 1 efficiency level.
- F. Sound Levels:
- 1. NEMA ST 20, maximum average sound levels as follows:
    - a. 45 dB for general-purpose transformer sizes less than 51kVA.
    - b. 50 dB for general-purpose transformer sizes 51-150kVA.
    - c. 55 dB for general-purpose transformer sizes 151-500kVA.
- G. Electrostatic Shielding, where indicated: Each winding with an independent, single, full-width copper electrostatic shield arranged to minimize interwinding capacitance.

1. Coil leads and terminal strips arranged to minimize capacitive coupling between input and output terminals.
2. Special terminal included for grounding the shield.
3. Shield Effectiveness:
  - a. Capacitance between Primary and Secondary Windings: Not to exceed 33 picofarads over a frequency range of 20 Hz to 1 MHz.
  - b. Common-Mode Noise Attenuation: Minimum of minus 120 dBA at 0.5 to 1.5 kHz; minimum of minus 65 dBA at 1.5 to 100 kHz.
  - c. Normal-Mode Noise Attenuation: Minimum of minus 52 dBA at 1.5 to 10 kHz.

### **2.3 BUCK-BOOST TRANSFORMERS**

- A. Description: NEMA ST 1, UL 506, UL 1561, same as distribution transformers, except rated for continuous duty and with wiring terminals suitable for connection as autotransformer.
- B. Enclosure: Ventilated, NEMA 250, Type 2.
  1. Finish Color: Gray enamel over prime coat.

### **2.4 LUGS**

- A. Manufacturer's primary and secondary bolted lugs: labeled for 75°C copper and aluminum conductors for ventilated enclosures and labeled for 90°C copper and aluminum conductors for non-ventilated enclosures.
- B. Connections at sides near bottom, accessible from front of cabinet.

## **PART 3 EXECUTION**

### **3.1 EXAMINATION**

- A. Examine conditions for compliance with enclosure and ambient temperature requirements for each transformer.
- B. Examine areas and surface to receive transformers for compliance with requirements, installation tolerances, and other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.
- C. Verify space indicated for transformers' mounting meets code-required working clearances.
- D. Notify Architect/Engineer of any discrepancies prior to submittal of product data and shop drawings.
- E. Verify that ground connections are in place and requirements in Section 26 0526CR – Grounding and Bonding for Electrical Systems have been met.
- F. Verify with manufacturer that “touch-up” paint kit is available for repainting.

### 3.2 INSTALLATION

- A. Install transformers in accordance with ANSI/NECA 1.
- B. Install level and plumb within 1/2 degree, and at least 6" from the adjacent wall or structure to insure proper ventilation, in accordance with manufacturer's written instruction, and in compliance with recognized industry practices.
- C. Transformer mounting, and vibration control:
  - 1. Mount transformers as indicated.
  - 2. Floor mounting:
    - a. Secure to floor via isolation pads between floor brackets (fabricated by manufacturer) and transformer.
    - b. Mount on spring isolator.
  - 3. Wall mounting:
    - a. Secure to concrete-and-block wall via isolation pads between wall brackets (fabricated by manufacturer) and transformer.
    - b. Secure to gypsum walls with independent steel slotted channel supports, secured to floor via isolation pads between wall brackets (fabricated by manufacturer) and transformer.
    - c. Mount on spring isolator.
  - 4. Suspended mounting:
    - a. Suspend transformer enclosures designed for floor mounting, where suspended from structural ceiling, via trapeze constructed of steel slotted channel support system hung via 3/8" minimum steel threaded hanger rods attached to structural members or inserts in structural slab. Each rod to contain spring isolator ceiling hanger. Use locking type nuts in assembly.
    - b. Install restraint cables sway bracing sized to resist a horizontal force of 162% of the operating weight acting in any direction for normal power transformers and 212% of the operating weight for emergency/standby power transformers.
    - c. Anchor and fasten transformers and their supports to building structural elements by the methods described in Section 26 0529CR – Hangers and Supports for Electrical Systems.
- D. Install engraved plastic nameplates under provisions of Section 26 0553CR – Electrical Systems Identification. Attach nameplate to transformer using small, corrosion-resistant metal screws or rivets. Do not use contact adhesive.
  - 1. Indicate kVA rating, voltage/phase rating, taps, insulation class and temperature rise, impedance value, sound level, and K-factor listing.
- E. Connect each transformer to rigid conduit system with maximum 36" of flexible liquid-tight metal conduit. Install conduit per requirements in Section 26 0533CR – Raceway and Boxes for Electrical Systems.
- F. Install transformer in dedicated electrical space per NFPA 70 and as shown on drawings. Coordinate with miscellaneous trades for equipment foreign to the electrical installation to be outside of dedicated electrical space.



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### **3.3 CONNECTIONS**

- A. Ground transformers according to Section 26 0526CR – Grounding and Bonding for Electrical Systems.
- B. Connect wiring according to Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables.

### **3.4 FIELD QUALITY CONTROL**

- A. Inspect transformers for physical damage, proper alignment, anchorage, grounding, connections, and installation.
- B. Test transformers per requirements in Sections 26 0800CR – Commissioning of Electrical.
- C. Interpret test results in writing and submit to Engineer.
- D. Output Settings Report: Prepare a written report recording output voltages and tap settings and submit to Engineer.

### **3.5 REPAINTING**

- A. Remove paint splatters and other marks from surface of equipment.
- B. Touch-up chips, scratches, or marred finishes to match original finish, using manufacturer-supplied paint kit. Leave remaining paint with Owner.

### **3.6 ADJUSTING**

- A. Record transformer secondary voltage at each unit for at least 48 hours of typical occupancy period. Adjust transformer taps to provide optimum voltage conditions at secondary terminals. Optimum is defined as not exceeding nameplate voltage plus 10% and not being lower than nameplate voltage minus 3% at maximum load conditions.
- B. Connect buck-boost transformers to provide nameplate voltage of equipment being served, plus or minus 5%, at secondary terminals.

### **3.7 CLEANING**

- A. Vacuum dirt and construction debris from interior and exterior of equipment; do not use compressed air to assist in cleaning.

**END OF SECTION**



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## **SECTION 26 2413CR**

### **SWITCHBOARDS**

#### **PART 1 GENERAL**

##### **1.1 RELATED WORK**

- A. Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables
- B. Section 26 0526CR – Grounding and Bonding for Electrical Systems
- C. Section 26 0529CR – Hangers and Supports for Electrical Systems
- D. Section 26 0553CR – Electrical Systems Identification
- E. Section 26 0573CR – Overcurrent Protective Device Coordination Study
- F. Section 26 0800CR – Commissioning of Electrical Systems
- G.
- H. Section 26 2813CR – Fuses
- I. Section 26 4300 – Transient Voltage Suppression

##### **1.2 REFERENCE**

- A. Work under this section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### **1.3 DESCRIPTION**

- A. Section includes free-standing, dead-front type low-voltage distribution switchboards.

##### **1.4 REFERENCE STANDARDS**

- A. ANSI/IEEE C37.13 – Low-Voltage AC Power Circuit Breakers Used in Enclosures
- B. ANSI/NECA 400 – Recommended Practice for Installing and Maintaining Switchboards
- C. IEEE C62.11 – Metal-Oxide Surge Arresters for Alternating Current Power Circuits
- D. IEEE C62.41 – Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits
- E. NFPA 70 – National Electrical Code

- F. NEMA AB 1 – Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures
- G. NEMA AB 3 – Molded-Case Circuit Breakers and Their Applications
- H. NEMA FU 1 – Low-Voltage Cartridge Fuses
- I. NEMA KS 1 – Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)
- J. NEMA LA 1 – Surge Arresters
- K. NEMA PB 2 – Dead-Front Distribution Switchboards
- L. NEMA PB 2.1 – General Instructions for Proper Handling, Installation and Maintenance of Dead-Front Distribution Switchboards Rated 600 Volts or Less
- M. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum)
- N. UL 98 – Enclosed and Dead-Front Switches
- O. UL 486A-486B – Wire Connectors
- P. UL 489 – Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
- Q. UL 869A – Reference Standard for Service Equipment
- R. UL 891 – Dead-Front Switchboards
- S. UL 1053 – Ground-Fault Sensing and Relaying Equipment
- T. UL 1066 – Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures

## 1.5 SUBMITTALS

- A. Product Data: For each switchboard, components and accessories indicated:
  - 1. Include data on features and components and complete description; submit catalog cut sheets showing voltage, size, rating and size of transient voltage suppression device, switching and overcurrent protective devices.
  - 2. Features, characteristics, factory settings and time-current curves of individual protective devices, auxiliary components and ground fault relaying.
- B. Shop Drawings:
  - 1. For each switchboard specified in this Section:
    - a. General Arrangement:
      - 1) Indicate front, plan, and side views of switchboards; access requirements (front, side, rear); overall dimensions and components list; shipping splits and weights.
      - 2) Front elevation indicating location of devices and instruments.

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- 3) Sections through switchboard showing space available for conduits.
    - b. Conduit entrance locations and requirements.
    - c. Nameplate legends.
    - d. Configuration, size and number of bus bars for each phase and current rating of buses.
    - e. Ground bus.
    - f. Neutral bus.
    - g. Short circuit ratings of switchboards and overcurrent protective devices, and bus withstand rating.
    - h. Instrument details; enclosure types and details.
    - i. Wiring diagrams: power, signal and control wiring.
    - j. Descriptive documentation of optional barriers specified for electrical insulation and isolation.
  2. Contractor to submit 1/4" scale floor plans with switchboard locations and required clearances and service space around equipment.
- C. Manufacturer's Installation Instructions:
1. Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of product.
- D. Test Reports: Indicate field test and inspection procedures and interpret test results and corrective action taken for compliance with specification requirements.
- E. Complete review of this specification noting for each paragraph whether proposed equipment complies with project specifications or deviates. Justification must be given for each deviation.
- F. Closeout Submittals:
1. Project Record Documents:
    - a. Record actual locations, configurations, and ratings of switchboard and major components on single-line diagrams and plan layouts.
  2. Operation and Maintenance Data:
    - a. Include manufacturer's recommended operating instructions, maintenance procedures and intervals, and preventive maintenance instructions.
    - b. Include manufacturer's written instructions for testing and adjusting overcurrent protective devices.
    - c. Include spare parts data listing, source, and current prices of replacement parts and supplies.
    - d. Include Manufacturer Seismic Qualification Certification and Installation Seismic Qualification Certification.
    - e. Include time-current curves, including selectable ranges for each type of overcurrent protective device.

## 1.6 QUALITY ASSURANCE

- A. Obtain switchboards from one source and by single manufacturer.
- B. Regulatory Requirements:
  1. Comply with NFPA 70 for components and installation.

2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

## **1.7 DELIVERY, STORAGE, AND HANDLING**

- A. Store in clean, dry space. Maintain factory wrapping or provide additional canvas or plastic cover to protect units from dirt, fumes, water, corrosive substances, construction debris, and traffic. Provide temporary heaters in switchboards as required to prevent condensation.
- B. Deliver switchboards in shipping splits of length that can be moved in delivery path, as indicated, individually wrapped for protection, and mounted on shipping skids. Mark crates, boxes, and cartons clearly to identify equipment. Show crate, box, or carton identification number on shipping invoices.
- C. Handle switchboards in accordance with NEMA PB 2.1 and ANSI/NECA 400. Use factory-installed lifting provisions. Handle carefully to avoid damage to switchboard internal components, enclosure, and finish.

## **1.8 WARRANTY**

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

## **1.9 MAINTENANCE**

- A. Extra Materials: Furnish extra materials described below that match product installed, are packaged with protective covering for storage, and are identified with labels describing contents.
  1. Potential Transformer Fuses: Equal to 10% of amount installed for each size and type, but no fewer than 2 of each size and type.
  2. Control-Power Fuses: Equal to 10% of amount installed for each size and type, but no fewer than 2 of each size and type.
  3. Fuses for Fused Switches and for Fused Circuit Breakers: Equal to 10% of amount installed for each size and type, but no fewer than 3 of each size and type.
  4. Indicating Lights: Furnish 6 of each type required. Equal to 10% of amount installed for each size and type, but no fewer than 2 of each size and type.

## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Square D
- B. EatonSiemens

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## 2.2 RATINGS

- A. Nominal system voltage: As indicated on the drawings or scheduled.
- B. Maximum system voltage: 600V.
- C. Main bus continuous amp: As indicated on the drawings or scheduled.
- D. Short circuit current rating: As indicated on drawings. Brace switchboard components to withstand mechanical forces for symmetrical fault current shown. Fully rated. Series rating shall not be acceptable.

## 2.3 CONSTRUCTION

- A. NEMA PB 2, UL 891
- B. Free-standing, dead-front type; vertical sections bolted together; sides and rear covered with removable bolt-on covers; adequate ventilation within enclosure; supporting frame: steel channels rigidly fastened together, with same outside dimensions as the enclosure.
- C. Adequate strength and rigidity necessary to resist conditions of use to which it may be subjected and to support equipment, devices and appurtenances contained therein.
- D. Incoming lug locations: as applicable per drawings.
- E. Environmental Limitations:
  - 1. Ambient temperatures: Not exceeding 40°C.
  - 2. Altitude: Not exceeding 6600 ft
- F. Device Mounting and Type:
  - 1. Front accessible only switchboard: Front and rear aligned for placement against the wall:
    - a. Main device: Fixed (individually) mounted molded-case circuit breaker.
    - b. Feeder devices: Panel mounted molded-case circuit breakers.
    - c. Devices: Front removable; load connections: Front accessible.
- G. Bus:
  - 1. Material: Copper with silver plating; copper: 98% conductivity. The bus bars shall have sufficient cross-sectional area to meet UL 891 temperature rise requirements through actual tests.
  - 2. Connections:
    - a. Bolted:
      - 1) Not fewer than 4 bolts for each 4" x 4" contact.
      - 2) Not fewer than 2 bolts for each 2" x 2" contact.
      - 3) Grade 5 bolts and conical spring-type washers.
      - 4) Clamp joints are not allowed.
  - 3. Sizing: Standard size, based on 65°C over 40°C.

4. Main Phase Buses: Three phase, 4 or 3 wire as indicated on drawings; fully rated; uniform capacity for entire length of switchboard; ampacity as indicated on drawings; rated for the main protective device frame size or main incoming conductors.
  5. All feeder device line and load connection straps: Rated to carry current rating of device frame (not trip rating).
  6. Support for Buses: Mounted on high-impact, non-tracking insulated supports; joints in the vertical bus are not permitted.
  7. Bus arrangement: A-B-C (left to right, top to bottom, front to rear) as viewed from front.
- H. Ground Bus: extend length of switchboard.
1. 1/4" x 2" minimum-size, hard-drawn copper of 98 percent conductivity, equipped with pressure connectors for feeder ground conductors. For busway feeders, extend insulated equipment grounding cable to busway ground connection.
  2. Provide with bolted pressure clamp type lugs.
- I. Neutral Bus: 100% of the ampacity of phase buses, equipped with pressure connectors for outgoing circuit neutral cables. Bus extensions for busway feeder neutral bus are braced.
- J. Buswork shall have 30 cycles withstand rating.
- K. Hinged Front Doors: Allow access to circuit breaker, metering, accessory and blank compartments.
- L. Cable Supports: For each vertical section.
- M. Pull Box on Top of Switchboard:
1. Adequate ventilation to maintain temperature in pull box within same limits as switchboard.
  2. Removable top, front, and sides, same construction as switchboard.
  3. Insulating, fire-resistive bottom with separate holes for cable drops into switchboard.
  4. Cable supports shall be arranged to facilitate cabling and adequate to support cables indicated, including those for future installation.
- N. Future Provisions: Fully equip spaces for future devices with bussing, mounting brackets, supports, and appurtenances, insulated and braced for short circuit currents, with continuous current rating as indicated on drawings. Extension of phase, neutral, and ground buses from both ends.
- O. Adequate lifting means.
- P. Dimensions: 90" maximum height, excluding floor sills, lifting members and pull boxes. Length and depth indicated scaled on the drawing are maximum allowed.
- Q. Line and Load Terminations: Mechanical type accessible from front only of switchboard, suitable for conductor materials and sizes as indicated on drawings suitable for number, size and trip ratings.



- R. Enclosure: Steel, NEMA 250, Type 1:
  - 1. Enclosure Finish for Indoor Units: Factory-applied finish in manufacturer's standard gray finish over a rust-inhibiting primer on treated metal surface.

## 2.4 SHORT CIRCUIT CURRENT RATING

- A. Each switchboard with minimum short circuit current rating as indicated on drawings.
- B. Switchboards: Marked with their maximum short circuit current rating at supply voltage.
- C. Switchboards: Fully rated. Series rated switchboards are not acceptable.

## 2.5 TRANSIENT VOLTAGE SURGE SUPPRESSION (TVSS)

- A. By switchboard manufacturer
- B. IEEE C62.41; integrally mounted, plug-in style, solid-state, parallel-connected, suppression and filtering modules
- C. Per requirements in Section 26 4300 – Transient Voltage Suppression

## 2.6 OVERCURRENT PROTECTIVE DEVICES

- A. Molded-Case Circuit Breaker: NEMA AB 1, NEMA AB 3, UL 489; lockable handle; interrupting capacity to meet available fault current.
  - 1. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit breaker frame sizes 225 A and below.
  - 2. Electronic (solid-state microprocessor based) trip unit circuit breakers: digital true RMS sensing trip units; interchangeable in the field within the frame size (field-replaceable rating plug to determine the breaker trip rating), field-adjustable settings and the following trip functions for circuit breaker frame sizes 250 A - 1200 A:
    - a. Instantaneous trip
    - b. Long- and short-time pickup levels
    - c. Long- and short-time time delay adjustments with  $I^2t$  response
    - d. Ground-fault pickup level, time delay, and  $I^2t$  response (Where Ground Fault indicated on plans)
  - 3. Refer to plans for additional locations of Long time, short time, instantaneous and ground fault settings on breakers of various sizes.
- B. Molded-Case Circuit Breaker Features and Accessories: Standard frame sizes, trip ratings, and number of poles.
  - 1. Auxiliary Contacts: Two SPDT switches with "a" and "b" contacts; "a" contacts mimic circuit breaker contacts, "b" contacts operate in reverse of circuit breaker contacts.

- C. Circuit Breaker Electronic Trip Units general characteristics:
1. Circuit breakers, with solid-state microprocessor based trip units:
    - a. Unit shall consist of current sensors, solid-state trip device, and solid-state adjustable time/current curve shaping elements.
    - b. Trip units shall be removable to allow for field upgrades.
    - c. Trip units shall incorporate "True RMS Sensing."
  2. Solid-state elements shall provide functions as indicated above.
  3. Adjustments shall be made using non-removable, discrete steps.
  4. Sealable transparent cover shall be provided over adjustments.
  5. Adjustable long-time pickup ( $I_r$ ) and delay shall be available in an adjustable rating plug that is UL listed as field-replaceable. Adjustable rating plug shall allow for five minimum long-time pickup settings from 0.4 to 1.0 times the sensor plug ( $I_n$ ). Other adjustable rating plugs shall be available for more precise settings to match the application. Long-time delay settings shall be at least three bands.
  6. Short-time pickup shall allow for five minimum settings from 1.5 to 10 times  $I_r$ . Short-time delay shall be at least three bands with  $I^2t$  ON and OFF.
  7. Instantaneous settings on the trip units shall be available in five minimum bands from 2 to 15 times  $I_n$ . The instantaneous settings shall also have an OFF setting when short-time pickup is provided.
  8. Trip units shall have the capability to electronically adjust the settings locally and remotely to fine increments below the switch settings. Fine increments for pickup adjustments are to be one ampere. Fine increments for delay adjustments are to be one second.
  9. Trip unit shall indicate:
    - a. Long-time fault
    - b. Short-time fault
    - c. Instantaneous fault
    - d. Ground fault, where indicated on plans
  10. Trip unit shall provide local trip indication and capability to indicate local and remote reason for trip, i.e., overload, short circuit or ground fault.
  11. Trip unit shall contain means to conduct circuit breaker test, or via separate test kit.
  12. Breaker shall be equipped with externally accessible test points to be used for field testing.
  13. Trip units shall be available to provide real time metering. Metering functions include current, voltage, power and frequency.
  14. Trip devices with digital ammeter shall be provided with control power connected to supply power to each unit so display operates at all current levels.
  15. Trip units shall be provided with the following standard features:
    - a. True RMS sensing
    - b. LSIG/Ground-fault trip (where ground fault indicated on plans)
    - c. Adjustable rating plugs
    - d. LCD or LED – Long-time pickup
    - e. LCD or LED – Trip indication
    - f. Digital Ammeter
    - g. Phase loading bar graph
    - h. Communications
    - i. LCD dot matrix display
    - j. Advanced user interface
    - k. Protective relay functions

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- l. Thermal imaging
  - m. Neutral protection
  - n. Contact wear indication
  - o. Temperature indication
  - p. Incremental fine tuning of settings
  - q. Selectable long-time delay bands
  - r. Power measurement
  - s. Maximum peak demand (measure of average power over a 15-minute period) continuously recorded over a one-year period
  - t. Data logging
- D. Ground Fault protection equipment on breakers, where indicated: Integrally mounted relay and trip unit, push-to-test feature and ground fault indicator:
1. Ground-fault protection with at least three adjustable short-time delay settings and three trip-time delay bands; adjustable current pickup with maximum setting of 1200 amps. Arrange to provide protection for the following:
    - a. Three-wire circuit or system
    - b. Four-wire circuit or system
    - c. Four-wire, double-ended substation
  2. Trip units shall be capable of the following types of ground-fault protection: residual and zero sequence. Ground fault sensing systems shall be changed in the field.
  3. Neutral current transformers shall be provided for 4-wire system.
  4. Ground-fault settings for circuit breaker sensor sizes 1200 A or below shall be in nine bands from 0.2 to 1.0 times  $I_n$ . The ground-fault settings for circuit breakers above 1200 A shall be in minimum three bands up to 1200 A.

## 2.7 CONTROL POWER, COMPONENTS IDENTIFICATION, AND CONTROL WIRING

- A. Control Circuits: 120 V, supplied through secondary disconnecting devices from control-power transformer.
- B. Control-Power Fuses: Primary and secondary fuses for current-limiting and overload protection of transformer and fuses for protection of control circuits.
- C. Control components mounted within assembly, such as relays, pushbuttons, switches, etc.: Suitably marked for identification, corresponding to appropriate designations on manufacturer's wiring diagrams.
- D. Control Wiring: Factory installed, with bundling, lacing, and protection included; flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units; insulated locking spade terminals for all control connections, except where saddle type terminals, integral to a device; current transformer secondary leads, connected to short circuit terminal blocks; terminal blocks with suitable numbering strips for group of control wires leaving switchboard, with wire markers at each end of control wiring.

## 2.8 ACCESSORY COMPONENTS AND FEATURES

- A. Furnish portable test set to test functions of solid-state trip devices without removal from switchboard. Include relay and meter test plugs suitable for testing switchboard meters and switchboard class relays.

- B. Lockout Devices: Provide circuit breakers with integral, lockout/tagout devices.

### **PART 3 EXECUTION**

#### **3.1 COORDINATION**

- A. Instruct manufacturer about the location of incoming lugs, i.e., top or bottom feed based on incoming feeder entrance location.
- B. Coordinate installation of housekeeping concrete pad based on actual equipment supplied:
  - 1. Concrete: Per requirements in Division 03 – Concrete.
  - 2. Dimensions: Per requirements in Section 26 0529CR – Hangers and Supports for Electrical Systems.
- C. Coordinate with miscellaneous trades for equipment foreign to the electrical installation to be outside of dedicated electrical space.
- D. Verify with manufacturer that “touch-up” paint kit is available for repainting.

#### **3.2 EXAMINATION**

- A. Examine areas and surface to receive switchboards for compliance with requirements, installation tolerances, and other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.
- B. Verify that space indicated for switchboard mounting meets code-required working clearances.
- C. Notify Architect/Engineer of any discrepancies prior to submittal of product data and shop drawings.

#### **3.3 INSTALLATION**

- A. Install switchboard in accordance with NEMA PB 2.1 and ANSI/NECA 400.
- B. Switchboard mounting:
  - 1. Bolt switchboards to concrete housekeeping pads, using anchor bolts in accordance with Section 26 0529CR – Hangers and Supports for Electrical Systems. Cast anchor bolt inserts into pads.
- C. Install engraved plastic nameplates under provisions of Section 26 0553 – Electrical Systems Identification for each switchboard, every instrument, overcurrent protective device and disconnect device. Attach nameplate to exterior of [each] switchboard using small corrosion-resistant metal screws and rivets. Do not use contact adhesive. Indicate switchboard manufacturer’s name and drawing number, name, amperage, voltage, phase, number of wires, short circuit current rating (amp, RMS symmetrical and MVA 3-phase symmetrical) and momentary and fault-closing ratings (amp, RMS asymmetrical). For each overcurrent protective device and disconnect device, include

circuit, load and area served, voltage/phase rating, and fuse size and type, when applicable.

- D. Provide framed, printed operating instructions for switchboards, including control and key interlocking sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of switchboards.
- E. Install switchboards in dedicated electrical space per NFPA 70, and as indicated on drawings.
- F. Tighten electrical connectors and terminal according to equipment manufacturer's published torque-tightening values. Where manufacturer's torque values are not indicated, use those specified in UL 486A-486B.
- G. Tighten electrical connectors and terminals according to equipment manufacturer's published torque-tightening values. Where manufacturer's torque values are not indicated, use those specified in UL 486A-486B.
- H. Apply temporary heat to maintain temperature according to manufacturer's written instructions.

### **3.4 CONNECTIONS**

- A. Ground switchboards according to Section 26 0526CR – Grounding and Bonding for Electrical Systems.
- B. Connect power and control wiring according to Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables.

### **3.5 FIELD QUALITY CONTROL**

- A. Inspect switchboards for physical damage, proper alignment, connections, anchorage, seismic restraints and grounding.
- B. Test continuity of each circuit.
- C. Test switchboards per requirements in Sections 26 0800CR – Commissioning of Electrical.
- D. Interpret test results in writing and submit to Engineer.
- E. Test switch operators once after energizing.

### **3.6 REPAINTING**

- A. Remove paint splatters and other marks from surface of equipment.
- B. Touch-up chips, scratches or marred finishes to match original finish, using manufacturer-supplied paint kit. Leave remaining paint with Owner.

### **3.7 ADJUSTING**

- A. Set field-adjustable circuit breakers trip settings or change the trip settings to values indicated on drawings or recommended by the overcurrent protective device coordination study per Section 26 0573CR – Overcurrent Protective Device Coordination Study.
- B. Field adjustments or changing of trip setting and adjustment or replacement of equipment to comply with Section 26 0573CR – Overcurrent Protective Device Coordination Study; no additional cost to Owner.

### **3.8 CLEANING**

- A. Vacuum dirt and construction debris from interior and exterior of equipment; do not use compressed air to assist in cleaning.

### **3.9 DEMONSTRATION**

- A. Provide training session by manufacturer for one workday at a job location, to train the Owner's personnel in the operation and maintenance of switchboards.

**END OF SECTION**

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**SECTION 26 2416.13CR**

**LIGHTING AND APPLIANCE PANELBOARDS**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables
- B. Section 26 0526CR – Grounding and Bonding for Electrical Systems
- C. Section 26 0529CR – Hangers and Supports for Electrical Systems
- D. Section 26 0533CR – Raceway and Boxes for Electrical Systems
- E. Section 26 0553CR – Electrical Systems Identification
- F. Section 26 0800CR – Commissioning of Electrical Systems

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. Section includes circuit breaker type lighting and appliance branch circuit panelboards as shown on drawings and as scheduled.

**1.4 REFERENCE STANDARDS**

- A. NECA 407 - Recommended Practice for Installing and Maintaining Panelboards
- B. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum)
- C. NEMA AB 1 - Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures
- D. NEMA PB 1 - Panelboards
- E. NEMA PB 1.1 - General Instructions for Proper Installation, Operation, and Maintenance of Panelboards Rated 600 Volts or Less
- F. NFPA 70 - National Electrical Code
- G. UL 50 - Cabinets and Boxes

- H. UL 67 - Panelboards
- I. UL 486A-486B - Wire Connectors
- J. UL 489 - Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures
- K. UL 869A - Reference Standard for Service Equipment

## 1.5 SUBMITTALS

- A. Product Data:
  - 1. Submit catalog data showing specified features of standard products. Eliminate extraneous catalog data.
- B. Shop Drawings:
  - 1. Submit for review prior to manufacture. Include complete description, front view, dimensions, voltage, main bus ampacity, circuit breaker arrangement and sizes, short circuit current rating, and factory settings of individual protective devices.
  - 2. Submit 1/4" scale electrical room floor plans with panelboard locations.
  - 3. Submit features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
- C. Partial Submittals:
  - 1. Panelboards shall be submitted for review together. Partial submittals of panelboards are not acceptable and will be rejected.
- D. Manufacturer's Installation Instructions:
  - 1. Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of product.
- E. Test Reports:
  - 1. Indicate field test and inspection procedures and interpret test results and corrective action taken for compliance with specification requirements.
- F. Closeout Submittals:
  - 1. Project Record Documents:
    - a. Record actual locations of panelboards and record actual circuiting arrangements.
  - 2. Operation and Maintenance Data:
    - a. Include manufacturer's recommended operating instructions, maintenance procedures and intervals, and preventive maintenance instructions.
    - b. Include manufacturer's written instructions for testing and adjusting overcurrent protective devices.
    - c. Include time-current curves and selectable ranges for each type of overcurrent protective device.
    - d. Include spare parts data listing, source, and current prices of replacement parts and supplies.



- e. Include manufacturer's Seismic Qualification Certification and Installation Seismic Qualification Certification.

## **1.6 QUALITY ASSURANCE**

- A. Obtain panelboards, overcurrent protective devices, components, and accessories from one source and by single manufacturer.
- B. Regulatory Requirements:
  - 1. Comply with NFPA 70.
  - 2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

## **1.7 DELIVERY, STORAGE, AND HANDLING**

- A. Store in clean, dry space. Maintain factory wrapping or provide additional canvas or plastic cover to protect from dirt, water, construction debris, and traffic.
- B. Comply with NEMA PB 1.1 and manufacturer's written instructions.

## **1.8 WARRANTY**

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr written warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

## **1.9 MAINTENANCE**

- A. Extra Materials:
  - 1. Furnish Owner with two keys per panelboard. Consult with University on keyed lock requirements.

## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Square D
- B. Cutler Hammer
- C. Siemens

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## 2.2 LIGHTING AND APPLIANCE BRANCH CIRCUIT PANELBOARDS

- A. NEMA PB 1, UL 67
- B. Fabrication:
  - 1. Factory assembled.
  - 2. Full length piano hinge doors with latch, lock and key over protective devices. Door-in-door not permitted.
  - 3. Hinge trim shall be provided for access to wireway area of panel.
  - 4. Incoming feeder lugs: copper conductors.
  - 5. Multiple lugs to match number of conductors per phase.
  - 6. Sub-feed (double) lugs, or feed-through lugs where indicated.
  - 7. Filler plates.
  - 8. Wiring terminals for field installed conductors: Pressure wire connectors, except wire-binding screws for No. 10 AWG or smaller conductors.
  - 9. Flat oval head, truss-head screws in tapped holes in rough-in box flanges for door trim installation. Flanges shall be drilled on the job for square and plumb installation
  - 10. Minimum box dimensions: 20" W x 5-3/4" D
- C. Panelboard Buses:
  - 1. Copper
  - 2. Ampere rating as scheduled
  - 3. Ground bus: uninsulated, bonded to panelboard cabinet
  - 4. Insulated neutral bus: 100% of phase bus rating
- D. Molded-Case Circuit Breakers:
  - 1. NEMA AB 1, UL 489
  - 2. Bolt-on type, labeled for 75°C copper and aluminum conductors
  - 3. Quick-make, quick-break, with thermal-magnetic trip.
  - 4. Common internal trip on multi-pole breakers. Handle-ties are not permitted.
  - 5. Ampere rating as scheduled
  - 6. Listed as Type SWD for lighting circuits
  - 7. Listed as Type HACR for air conditioning equipment circuits
  - 8. Bussing, device mounting hardware, and steel knockouts in dead front where "space" is indicated
  - 9. Tandem circuit breakers are not acceptable
  - 10. Locks on trip handles where indicated
  - 11. Ground fault equipment protection (GFEP), rated 30 mA trip, to provide equipment protection for branch circuits feeding electrical heat tracing, where indicated
  - 12. Ground fault circuit interrupter (GFCI), rated at 4-6 mA trip for protection of personnel, where indicated
- E. Cabinet
  - 1. NEMA 250, UL 50
  - 2. NEMA Type 1, Type 4X, stainless steel, kitchen areas
  - 3. Front (trim) flush mounted with door in front with concealed self-adjusting trim clamps, and complete with cylinder-type lock and catch.
  - 4. Same height matching trim, where two cabinets are mounted adjacent to one another in finished areas.

5. All sections of panelboards have the same size, where oversize cabinets are required for one section of multi-section panelboard.
6. Boxes and fronts made of code-gauge galvanized steel.
7. Manufacturer's standard gray enamel finish over prime coat.

### **2.3 SHORT CIRCUIT CURRENT RATING**

- A. Each panelboard with minimum short circuit current rating as indicated on drawings.
- B. Panelboards marked with their maximum short circuit current rating at supply voltage.
- C. Panelboards: Fully rated. Series-rated panelboards are not acceptable.

## **PART 3 EXECUTION**

### **3.1 COORDINATION WITH MANUFACTURER**

- A. Instruct manufacturer about the location of additional wiring gutter space when required (i.e., top, bottom, right, left, or combination).
- B. Instruct manufacturer about the location of main lugs or main circuit breaker (i.e., top or bottom feed based on incoming feeder entrance location).
- C. Instruct manufacturer to provide multiple lugs where conductors in parallel or sub-feed (double) lugs or feed-through lugs are indicated.
- D. Instruct manufacturer on the size of cross-connection cables for panelboards fed via sub-feed (double) lugs or feed-through lugs. Make cable size with ampacity equal to incoming feeder.
- E. Verify that "touch-up" paint kit is available for repainting.
- F. Coordinate painting of cabinets in finished areas with work performed under Division 09 - Finishes.

### **3.2 EXAMINATION**

- A. Verify that space indicated for panelboard mounting meets code-required working clearances and dedicated equipment space.
- B. Notify Architect/Engineer of any discrepancies prior to submittal of product data and shop drawings.

### **3.3 INSTALLATION**

- A. Install panelboards in accordance with NECA 407 and NEMA PB 1.1.

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- B. Install panelboards plumb and rigid without distortion of box, in accordance with manufacturer's written instructions, and in compliance with recognized industry practices.
  - C. Panelboard mounting:
    - 1. Fasten panelboards firmly to walls and structural surfaces, ensuring they are permanently and mechanically anchored.
    - 2. Anchor and fasten panelboards and their supports to building structural elements (wood, concrete, masonry, hollow walls and nonstructural building surfaces) by the methods described in Section 26 0529CR – Hangers and Supports for Electrical Systems.
    - 3. Install two rows of steel slotted channel, with a minimum of 4 attachment points, for each panelboard section.
    - 4. When not located directly on wall, provide support frame of steel slotted channel anchored to floor and ceiling structure.
  - D. Install top breaker handle a maximum of 6'-7" above finished floor or working platform with handle in its highest position.
  - E. Tighten electrical connectors and terminals according to equipment manufacturer's published torque-tightening values. Where manufacturer's torque values are not indicated, use those specified in UL 486A – 486B.
  - F. Install as-built typewritten circuit directory in directory frame (to indicate installed circuit loads) mounted inside each panelboard door. Include description of connected loads, room number, room name, area, or item served for each branch circuit. Indicate motor names and horsepower as applicable. Cover circuit directory with colorless plastic.
  - G. Install engraved plastic nameplates under provisions of Section 26 0553CR – Electrical Systems Identification. Attach nameplate to exterior of each panelboard using small metal screws or rivets. Do not use contact adhesive.
    - 1. Include panelboard name, amperage, voltage, phase, and number of wires.
  - H. Label spare circuits as SPARE. Leave spare breakers in OFF position.
  - I. Room numbers used shall be those used by Owner except as otherwise directed by Architect.
  - J. Install panelboard in dedicated electrical space per NFPA 70 and as shown on drawings. Coordinate with miscellaneous trades for equipment foreign to the electrical installation to be outside of dedicated electrical space.
  - K. Install filler plates in unused spaces.
  - L. Install three 1" spare conduits stubbed into accessible ceiling space or space designated to be ceiling space in the future for all flush-mounted panelboards. Install conduits in accordance with requirements in Section 26 0533CR – Raceway and Boxes for Electrical Systems.

- M. Install three 3/4" spare conduits stubbed into ceiling space above and below for panelboards that serve loads on levels other than that where the panelboard is located. Install conduits in accordance with requirements in Section 26 0533CR – Raceway and Boxes for Electrical Systems.

### **3.4 CONNECTIONS**

- A. Ground panelboards according to Section 26 0526CR – Grounding and Bonding for Electrical Systems.
- B. Connect wiring according to Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables.

### **3.5 FIELD QUALITY CONTROL**

- A. Inspect for physical damage, proper alignment, anchorage, and grounding.
- B. Maintain proper phasing for multi-wire circuits.
- C. Test main circuit breakers in accordance with requirements in Sections 26 0800CR – Commissioning of Electrical Systems.
- D. Interpret test results in writing and submit to Engineer.
- E. Check phase-to-phase and phase-to-ground insulation resistance levels prior to energization of panelboards.
- F. Check panelboards for electrical continuity of circuits and for short-circuits prior to energization.
- G. Submit ammeter readings for all panelboard feeders indicating normal operating load and phase balance.

### **3.6 REPAINTING**

- A. Remove paint splatters or other marks from surface of panelboards.
- B. Touch-up chips, scratches, or marred finishes to match original finish, using manufacturer-supplied paint kit. Leave remaining paint with Owner.

### **3.7 ADJUSTING**

- A. Adjust fronts, covers, hinges, and locks.

### **3.8 CLEANING**

- A. Clean panelboard interiors and exteriors prior to final inspection. Remove paint splatters and other spots, dirt and debris.

**END OF SECTION**



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**SECTION 26 2416.16CR**  
**DISTRIBUTION PANELBOARDS**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables
- B. Section 26 0526CR – Grounding and Bonding for Electrical Systems
- C. Section 26 0529CR – Hangers and Supports for Electrical Systems
- D. Section 26 0553CR – Electrical Systems Identification
- E. Section 26 0800CR – Commissioning of Electrical Systems

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. Section includes circuit breaker type power distribution panelboards as shown on drawings and as scheduled.

**1.4 REFERENCE STANDARDS**

- A. NECA 407 - Recommended Practice for Installing and Maintaining Panelboards
- B. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum)
- C. NEMA AB 1 - Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures
- D. NEMA FU 1 - Low-Voltage Cartridge Fuses
- E. NEMA KS 1 - Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)
- F. NEMA PB 1 - Panelboards
- G. NEMA PB 1.1 - General Instructions for Proper Installation, Operation, and Maintenance of Panelboards Rated 600 Volts or Less
- H. NFPA 70 - National Electrical Code

- I. UL 50 - Cabinets and Boxes
- J. UL 67 - Panelboards
- K. UL 486A – 486B - Wire Connectors
- L. UL 489 - Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures
- M. UL 869A - Reference Standard for Service Equipment

## 1.5 SUBMITTALS

- A. Product Data:
  - 1. Submit catalog data showing specified features of standard products. Eliminate extraneous catalog data.
- B. Shop Drawings:
  - 1. Submit for review prior to manufacture. Include complete description, front view, dimensions, voltage, main bus ampacity, circuit breaker [fusible switch] arrangement and sizes, short circuit current rating, and factory settings of individual protective devices.
  - 2. Submit 1/4" scale electrical room floor plans with panelboard locations.
  - 3. Submit features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
- C. Partial Submittals:
  - 1. Panelboards shall be submitted for review together. Partial submittals of panelboards are not acceptable and will be rejected.
- D. Manufacturer's Installation Instructions:
  - 1. Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of product.
- E. Test Report:
  - 1. Indicate field test and inspection procedures and interpret test results and corrective action taken for compliance with specification requirements.
- F. Closeout Submittals:
  - 1. Project Record Documents:
    - a. Record actual locations of panelboards and record actual circuiting arrangements.
  - 2. Operation and Maintenance Data:
    - a. Include manufacturer's recommended operating instructions, maintenance procedures and intervals, and preventive maintenance instructions.
    - b. Include manufacturer's written instructions for testing and adjusting overcurrent protective devices.
    - c. Include time-current curves and selectable ranges for each type of overcurrent protective device.



- d. Include spare parts data listing, source, and current prices of replacement parts and supplies.

## **1.6 QUALITY ASSURANCE**

- A. Obtain panelboards, overcurrent protective devices, components, and accessories from one source and by a single manufacturer.
- B. Regulatory Requirements:
  - 1. Comply with NFPA 70.
  - 2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

## **1.7 DELIVERY, STORAGE, AND HANDLING**

- A. Store in clean, dry space. Maintain factory wrapping or provide additional canvas or plastic cover to protect from dirt, water, construction debris, and traffic.
- B. Comply with NEMA PB 1.1 and manufacturer's written instructions.

## **1.8 WARRANTY**

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr written warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

## **1.9 MAINTENANCE**

- A. Extra Materials:
  - 1. Furnish Owner with two keys per panelboard. Consult with University on keyed lock requirements.

## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Square D
- B. Cutler Hammer
- C. Siemens PANELBOARDS

### **2.2 POWER DISTRIBUTION**

- A. NEMA PB 1, UL 67.

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- B. Fabrication:
1. Factory assembled
  2. Individualized breaker dead-front cover with door. Full length piano hinge doors with latch, lock and key over protective devices. Door-in-door not permitted.
  3. Incoming feeder lugs: copper conductors
  4. Multiple lugs to match number of conductors per phase
  5. Sub-feed (double) lugs, or feed-through lugs where indicated
  6. Filler plates
  7. Wiring terminals for field installed conductors: Pressure wire connectors, except wire-binding screws for No. 10 AWG or smaller conductors.
- C. Panelboard Buses:
1. Copper
  2. Ampere rating as scheduled
  3. Ground bus: uninsulated, bonded to panelboard cabinet
  4. Insulated neutral bus where applicable: 100% of phase bus rating or larger where indicated on plans.
- D. Molded-Case Circuit Breakers:
1. NEMA AB 1, UL 489
  2. Bolt-on or I-line type, labeled for 75°C copper and aluminum conductors
  3. Quick-make, quick-break, with thermal-magnetic trip and electronic (solid-state microprocessor-based) trip.
  4. Equipped with individually insulated, braced, and protected connectors
  5. Common internal trip on multi-pole breakers. Handle-ties are not permitted.
  6. Ampere rating as scheduled
  7. Front face flush with each other
  8. Large, permanent, individual circuit numbers affixed to each breaker in uniform position
  9. Tripped indication clearly shown by breaker handle taking position between "ON" and "OFF."
  10. Listed as Type HACR for air conditioning equipment circuits
  11. Bussing, device mounting hardware, and steel knockouts in dead front where "space" is indicated
  12. For 225A frame size and below: thermal-magnetic trip
  13. For 250A frame size and above: electronic trip units interchangeable in the field within the frame size and field-adjustable long time pick-up, long time delay, short time pick-up, short time delay, and instantaneous current settings. Each adjustment shall have discrete settings and shall be independent of all other adjustments.
  14. Locks on trip handles where indicated
- E. Cabinet
1. NEMA 250, UL 50
  2. NEMA Type 1, enclosure.
  3. Four-piece front (trim) surface mounted with door over the front, with concealed self-adjusting trim clamps, and complete with cylinder-type lock and catch.
  4. Same height matching trim, where two cabinets are mounted adjacent to one another in finished areas.

5. All sections of panelboards have the same size, where oversize cabinets are required for one section of multi-section panelboard.
6. Boxes and fronts made of code-gauge galvanized steel
7. Manufacturer's standard gray enamel finish over prime coat.

### **2.3 SHORT CIRCUIT CURRENT RATING**

- A. Each panelboard with minimum short circuit current rating as indicated on drawings.
- B. Panelboards marked with their maximum short circuit current rating at supply voltage.
- C. Panelboards: Fully rated. Series-rated panelboards are not acceptable.

## **PART 3 EXECUTION**

### **3.1 COORDINATION WITH MANUFACTURER**

- A. Instruct manufacturer about the location of additional wiring gutter space when required, i.e. top, bottom, right, left, or combination.
- B. Instruct manufacturer about the location of main lugs or main circuit breaker (i.e., top or bottom feed based on incoming feeder entrance location).
- C. Instruct manufacturer to provide multiple lugs where conductors in parallel or sub-feed (double) lugs or feed-through lugs are indicated.
- D. Instruct manufacturer on the size of cross-connection cables for panelboards fed via sub-feed (double) lugs or feed-through lugs. Make cable size with ampacity equal to incoming feeder.
- E. Verify that "touch-up" paint kit is available for repainting.
- F. Coordinate painting of cabinets in finished areas with work performed under Division 09 - Finishes.

### **3.2 EXAMINATION**

- A. Verify that space indicated for panelboard mounting meets code-required working clearances and dedicated equipment space.
- B. Notify Architect/Engineer of any discrepancies prior to submittal of product data and shop drawings.

### **3.3 INSTALLATION**

- A. Install panelboards in accordance with NECA 407 and NEMA PB 1.1.

- B. Install panelboards plumb and rigid without distortion of box, in accordance with manufacturer's written instructions, and in compliance with recognized industry practices.
- C. Panelboard mounting :
  - 1. Fasten panelboards firmly to walls and structural surfaces, ensuring they are permanently and mechanically anchored.
  - 2. Anchor and fasten panelboards and their supports to building structural elements (wood, concrete, masonry, hollow walls and nonstructural building surfaces) by the methods described in Section 26 0529 – Hangers and Supports for Electrical Systems.
  - 3. Install two rows of steel slotted channel, with a minimum of four attachment points, for each panelboard section.
  - 4. When not located directly on wall, provide support frame of steel slotted channel anchored to floor and ceiling structure.
- D. Install top breaker handle a maximum of 6'-7" above finished floor or working platform, with handle in its highest position.
- E. Tighten electrical connectors and terminals according to equipment manufacturer's published torque tightening values. Where manufacturer's torque values are not indicated, use those specified in UL 486A –486B.
- F. Install as-built typewritten circuit directory in directory frame (to indicate installed circuit loads before completing load balancing) affixed to outside cover of each panelboard. Include description of connected loads, room number, room name, area, or item served for each branch circuit. Indicate motor names and horsepower as applicable. Cover circuit directory with colorless plastic.
- G. Install engraved plastic nameplates under provisions of Section 26 0553CR – Electrical Systems Identification. Attach nameplate to exterior of each panelboard using small, corrosion-resistant metal screws or rivets. Do not use contact adhesive.
  - 1. Indicate panelboard name, amperage, voltage, phase, and number of wires.
- H. Label spare circuits as SPARE. Leave spare breakers in OFF position.
- I. Room numbers used shall be those used by Owner except as otherwise directed by Architect.
- J. Install panelboard in dedicated electrical space per NFPA 70 and as shown on drawings. Coordinate with miscellaneous trades for equipment foreign to the electrical installation to be outside of dedicated electrical space.
- K. Install filler plates in unused spaces.

### **3.4 CONNECTIONS**

- A. Ground panelboards according to Section 26 0526CR – Grounding and Bonding for Electrical Systems.

- 
- B. Connect wiring according to Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables.

### **3.5 FIELD QUALITY CONTROL**

- A. Inspect for physical damage, proper alignment, anchorage, and grounding.
- B. Test circuit breakers per requirements in Sections 26 0800CR – Commissioning of Electrical Systems.
- C. Interpret test results in writing and submit to Engineer.
- D. Check phase-to-phase and phase-to-ground insulation resistance levels prior to energizing panelboards.
- E. Check panelboards for electrical continuity of circuits and for short-circuits prior to energizing.
- F. Submit ammeter readings for all panelboard feeders indicating normal operating load and phase balance.

### **3.6 REPAINTING**

- A. Remove paint splatters or other marks from surface of panelboards.
- B. Touch-up chips, scratches, or marred finishes to match original finish, using manufacturer-supplied paint kit. Leave remaining paint to Owner.

### **3.7 ADJUSTING**

- A. Adjust fronts, covers, hinges, and locks.
- B. Circuit Breakers: Set field-adjustable trip settings or change the trip settings, as indicated on drawings.

### **3.8 CLEANING**

- A. Clean panelboard interiors and exteriors prior to final inspection. Remove paint splatters and other spots, dirt and debris.

**END OF SECTION**



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## **SECTION 26 2726CR**

### **WIRING DEVICES**

#### **PART 1 GENERAL**

##### **1.1 RELATED WORK**

- A. Section 26 0526CR - Grounding and Bonding for Electrical Systems
- B. Section 26 0553CR - Electrical Systems Identification

##### **1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### **1.3 DESCRIPTION**

- A. Section includes general-use snap switches, receptacles, and device cover plates.

##### **1.4 REFERENCE STANDARDS**

- A. IEEE C62.41.2 – Characterization of Surges in Low-Voltage (1000V and less) AC Power Circuits
- B. IEEE C62.45 – Surge Testing for Equipment Connected to Low-Voltage (1000V and less) AC Power Circuits
- C. NECA 1 – Good Workmanship in Electrical Contracting
- D. NFPA 70 – National Electrical Code
- E. NEMA WD-1 – General Color Requirements for Wiring Devices
- F. NEMA WD-6 – Wiring Devices - Dimensional Requirements
- G. NEMA 250 – Enclosures for Electrical Equipment (1000 Volts Maximum)
- H. UL 20 – General-Use Snap Switches
- I. UL 498 – Attachment Plugs and Receptacles
- J. UL 943 – Ground-Fault Circuit-Interrupters
- K. UL 1436 – Outlet Circuit Testers and Similar Indicating Devices

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## 1.5 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: List of legends and description of materials and process used for premarking wall plates.
- C. Samples: One for each type of device and wall plate specified, in each color specified.
- D. Manufacturer's Installation Instructions:
  - 1. Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of product.
- E. Test Reports: Indicate field test and inspection procedures and interpret test results and corrective action taken for compliance with specification requirements.
- F. Closeout Submittals:
  - 1. Project Record Documents:
    - a. Record actual locations and ratings of wiring devices.
  - 2. Operation and Maintenance Data:
    - a. Include in manufacturers' packing label warnings and instruction manuals with labeling conditions.
    - b. Include source and current prices of replacement parts and supplies.

## 1.6 QUALITY ASSURANCE

- A. Obtain wiring devices from one source and by single manufacturer.
- B. Regulatory Requirements:
  - 1. Comply with NFPA 70 for components and installation.
  - 2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

## 1.7 DELIVERY, STORAGE, AND HANDLING

- A. Store in clean, dry space. Maintain factory unopened packaging until ready for installation.

## 1.8 WARRANTY

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.



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## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Cooper Wiring Devices; a division of Cooper Industries, Inc.
- B. Hubbell Incorporated; Wiring Device-Kellems
- C. Leviton Manufacturing Company, Inc.
- D. Pass & Seymour/Legrand; Wiring Devices & Accessories

### **2.2 GENERAL-USE SNAP SWITCHES**

- A. Comply with NEMA WD 1 and UL 20.
- B. Switches: Heavy-duty specification grade; back and side wired; flush or surface mounting; Body and Handle: thermoplastic with toggle handle; for connection to copper or copper-clad conductors:
  - 1. Ratings:
    - a. Voltage: 120-277V, AC
    - b. Current: 20 A
  - 2. Single pole
  - 3. Double pole.
  - 4. Three-way.
  - 5. Four-way.
  - 6. Weatherproof: Toggle switch

### **2.3 RECEPTACLES**

- A. Comply with NEMA WD 1, NEMA WD 6 configuration 5-20R, and UL 498.
- B. Receptacles: 125 V, 20A, heavy-duty specification grade; back and side wired; flush or surface mounted; straight blade; 2 pole, 3 wire grounding; thermoplastic body; duplex and single as indicated on drawings.
  - 1. Ground Fault Circuit Interrupter (GFCI):
    - a. Additional compliance with UL 943 Class A.
    - b. Leakage current trip level: 4 to 6 mA.
    - c. Trip time: .025 seconds nominal.
    - d. Non-feed through type
    - e. Reverse line-load function to prevent GFCI from functioning if wired incorrectly.
    - f. Indicator Light: Lighted when device is tripped.
- C. Receptacles: 125 V, 20A, hospital grade; back and side wired; flush or surface mounted; straight blade; 2 pole, 3 wire grounding; thermoplastic body; duplex and single as indicated on drawings.
- D. Isolated Ground (IG):
  - a. Ground strap isolated from mounting strap.
  - b. Ground screw connected directly to ground contacts.

- E. Transient Voltage Surge Suppression (TVSS):
  - a. Additional compliance with UL 1449, with integral TVSS in line to ground, line to neutral, and neutral to ground.
  - b. TVSS Components: Multiple metal-oxide varistors; with a nominal clamp-level rating of 400 volts and minimum single transient pulse energy dissipation of 240 J, according to IEEE C62.41.2 and IEEE C62.45.
  - c. Active TVSS Indication: Visual and audible, with light visible in face of device to indicate device is “active” or “no longer in service.”
- F. Twist-locking:
  - a. NEMA WD 6 configuration L5-20R unless noted otherwise.
- G. Special Purpose Receptacles: Specification grade, rated for voltage, amperage and NEMA configuration as noted on drawings.

## 2.4 DEVICE COVER PLATES

- A. Single and combination types to match corresponding wiring devices:
  - a. Attachment: Metal screws with head color to match plate finish.
  - b. Material for Laboratories, holding rooms, lab equipment rooms, procedure rooms, lab support rooms: Stainless Steel #302.
  - c. Material for Offices, bathrooms, public areas, mechanical rooms, common areas, corridors: Stainless Steel #430.
  - d. Weatherproof Cover Plates: NEMA 250, complying with type 3R weather-resistant, die-cast aluminum with weatherproof while-in-use hinged cover.
  - e. Face plates on emergency power shall have engraved stainless steel cover plate with “Emergency” engraved in red letters.

## 2.5 FINISHES

- A. Color:
  - 1. Switch handles and receptacle bodies: gray , except as follows:
    - a. Switch handles and receptacle bodies connected to Emergency or Standby Power System: Red; labeled “Emergency.” With engraved nameplate on stainless steel cover plate.

## PART 3 EXECUTION

### 3.1 COORDINATION

- A. Coordination with Other Trades:
  - 1. Take steps to insure that devices and their boxes are protected.
  - 2. Keep outlet boxes free of mortar, cement, concrete, dust, paint, and other material that may contaminate the raceway system, conductors, and cables.
  - 3. Install wiring devices after all wall preparation, including painting, is complete.
- B. Special Purpose Receptacles: Coordinate final selections of NEMA configuration (locking, straight, blade, etc.) with configuration of plug on utilization equipment.

- C. Receptacles for Owner-furnished equipment and equipment furnished under other divisions of these specifications: Match plug configurations.

### **3.2 EXAMINATION**

- A. Verify outlet boxes are installed at proper height.
- B. Verify location of wiring devices with architectural interior elevation drawings, prior to rough-in.
- C. Verify outlet boxes are installed at proper height.
- D. Verify wall openings are neatly cut and completely covered by wall plates.
- E. Verify branch circuit wiring installation is completed, tested, and ready for connection to wiring devices.

### **3.3 PREPARATION**

- A. Clean debris from outlet boxes.

### **3.4 INSTALLATION**

- A. Comply with NECA 1, including the mounting heights listed in that standard, unless otherwise scheduled or indicated on drawings. Indicated dimensions are to center of device.
- B. Device Installation:
  - 1. Replace all devices that have been in temporary use during construction or show signs of installation prior to completion of building finishing operations.
  - 2. Keep each wiring device in its package or otherwise protected until it is time to connect conductors.
  - 3. Do not remove surface protection, such as plastic film and smudge covers, until last possible moment.
  - 4. Do not strip insulation from conductors until just before they are spliced or terminated on devices.
  - 5. Strip insulation evenly around the conductor using tools designed for the purpose. Avoid scoring or nicking of solid wire or cutting strands from stranded wire.
  - 6. The length of free conductors at outlets for devices shall meet provisions of NFPA 70, Article 300, without pigtails.
  - 7. Do not place bare stranded conductors directly under device screws. Use crimp on fork terminals for device terminations.
  - 8. When mounting into metal boxes, remove fiber or plastic washers used to hold device mounting screws in yokes, allowing metal-to-metal contact.
  - 9. Connect wiring device grounding terminal to outlet box with bonding jumper and branch circuit equipment grounding conductor. Grounding per requirements in Section 26 0526.
  - 10. Install devices plumb, level with finished surfaces and free from blemishes.
  - 11. Install weatherproof GFCI receptacles:
    - a. Outdoors

- b. As indicated on drawings
- C. Installation Orientations:
  - 1. Install ground pin of vertically mounted receptacles up, and on horizontally mounted receptacles to the left.
  - 2. Install switches with handle operating vertically, with "ON" position up.
  - 3. Unless otherwise indicated or where space problem occurs, mount devices flush, with long dimension vertical.
- D. Device Cover Plates: Do not use oversized or extra-deep plates. Repair wall finishes and remount outlet boxes when standard device plates do not fit flush or do not cover rough wall opening.
- E. Arrangement of Devices: Unless otherwise indicated or where space problem occurs, mount flush, with long dimension vertical and with grounding terminal of receptacles on top. Group adjacent switches under single, multigang wall plates.

### 3.5 IDENTIFICATION

- A. Comply with Section 26 0553CR – Electrical Systems Identification.
  - 1. Switches and Receptacles: Use hot, stamped or engraved machine printing with black-filled lettering on face of cover plate, and durable wire markers or tags inside outlet boxes.
    - a. Receptacles: Label shall indicate receptacle voltage, phase, and amperage for receptacles other than 20A, 120 V, at top of cover plate, and panel and circuit number at bottom of cover plate for all devices.
    - b. Switches: Label shall indicate switch voltage, phase, and amperage at top of cover plate, and panel, circuit number and switch designation at bottom of cover plate.

### 3.6 ADJUSTING

- A. Adjust devices and wall plates to be flush and level.

### 3.7 FIELD QUALITY CONTROL

- A. Inspect each wiring device for defects.
- B. Operate each wall switch with circuit energized and verify proper operation.
- C. Verify each receptacle device is energized.
- D. Perform tests and prepare test reports:
  - a. Test each receptacle device for proper polarity:
  - b. Test every receptacle with a receptacle circuit tester. Tester shall test for open ground, reverse polarity, open hot, open neutral, hot and ground reversed, hot or neutral and hot open. Rewire receptacles with faults and retest.

- 
- E. Test each GFCI receptacle device for proper operation:
    - a. Perform testing using an instrument specifically designed and manufactured for testing ground-fault circuit interrupters. Apply the test to the receptacle. "TEST" button operation will not be acceptable as a substitute for this test. Replace receptacles that do not shutoff power with 5/1000 of an ampere within 1/40th of a second and retest.
  - F. Test Instruments: Use instruments that comply with UL 1436.
  - G. Test Instrument for Convenience Receptacles: Digital wiring analyzer with digital readout or illuminated LED indicators of measurement.
  - H. Tests for Convenience Receptacles:
    - a. Line Voltage: Acceptable range is 105 to 132 V.
    - b. Percent Voltage Drop under 15 A Load: A value of 6 percent or higher is not acceptable.
    - c. Ground Impedance: Values of up to 2 ohms are acceptable.
    - d. GFCI Trip: Test for tripping values specified in UL 1436 and UL 943.
    - e. Using the test plug, verify that the device and its outlet box are securely mounted.
    - f. The tests shall be diagnostic, indicating damaged conductors, high resistance at the circuit breaker, poor connections, inadequate fault current path, defective devices, or similar problems. Correct circuit conditions, remove malfunctioning units and replace with new ones, and retest as specified above.
  - I. Operational Tests: Demonstrate the operation of each switch with the systems fully energized and operating. Each switch shall be demonstrated three times.
  - J. Interpret test results in writing and submit to Engineer.

### **3.8 CLEANING**

- A. Remove excess plaster from interior of outlet boxes.
- B. Clean devices and cover plates after painting is complete. Replace stained or improperly painted devices and cover plates.

**END OF SECTION**



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## SECTION 26 2813CR

### FUSES

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 26 2816CR - Enclosed Switches and Circuit Breakers
- B. Section 26 2913CR - Enclosed Controllers

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and section under Division 01 General Requirements.

##### 1.3 DESCRIPTION

- A. Section includes nonrenewable cartridge fuses, rated 600V and less, for use in low-voltage power distribution system and spare fuse cabinet.

##### 1.4 REFERENCE STANDARDS

- A. NEMA FU 1 - Low Voltage Cartridge Fuses
- B. UL 248-1 - Low Voltage Fuses - Part 1: General Requirements
- C. UL 248-4 - Low-Voltage Fuses - Part 4: Class CC Fuses
- D. UL 248-5 - Low-Voltage Fuses - Part 5: Class G Fuses
- E. UL 248-8 - Low-Voltage Fuses - Part 8: Class J Fuses
- F. UL 248-10 - Low-Voltage Fuses - Part 10: Class L Fuses
- G. UL 248-12 - Low-Voltage Fuses - Part 12: Class R Fuses
- H. UL 248-15 - Low-Voltage Fuses - Part 15: Class T Fuses
- I. UL 512 - Fuseholders

##### 1.5 SUBMITTALS

- A. Product Data:
  - 1. Submit the following for each fuse type and size indicated:
    - a. Manufacturer's technical data on features, performance, electrical characteristics, ratings, and dimensions.
    - b. Time-current curves, coordination charts and tables, and related data.

- c. Let-through current curves for fuses with current-limiting characteristics.
  - d. Fuse size for each elevator disconnect switch.
- B. Closeout Submittals:
- 1. Project Record Documents:
    - a. Record actual class, size, and location of fuses.

## 1.6 QUALITY ASSURANCE

- A. Obtain fuses from one source and by single manufacturer.
- B. Comply with NFPA 70 for components and installation.

## 1.7 MAINTENANCE

- A. Extra Materials:
  - 1. Furnish to the Owner a quantity of spare fuses equal to 10% of the total quantity of each fuse class and size installed, minimum of 3 of each fuse class and size.
  - 2. Furnish 2 fuse pullers for each size fuse.

## PART 2 PRODUCTS

### 2.1 MANUFACTURERS

- A. Bussmann
- B. Ferraz Shawmut

### 2.2 CARTRIDGE FUSES

- A. NEMA FU 1, UL 248-1.
- B. Characteristics: nonrenewable current-limiting cartridge fuse; current rating and class, as specified or indicated, and voltage rating consistent with circuit voltage.
- C. Miscellaneous data:

UL Standard	Class	Volts	Amperage	Interrupting Rating (Amp RMS Sym.)
248-12	RK5	250 or 600	0-600	200,000

### 2.3 FUSEBLOCKS

- A. UL 512



- B. Thermoplastic base with UL flammability 94VO
- C. Clip reinforcing springs – 100A and above
- D. 200,000 A RMS Sym withstand rating
- E. Copper or aluminum connections

#### **2.4 TOUCH SAFE FUSEHOLDERS**

- A. UL 512
- B. Thermoplastic base with UL flammability 94VO
- C. Cover over fuses
- D. Neon indicator lamp: "ON" when fuse opens

#### **2.5 SPARE FUSE CABINET**

- A. Wall-mounted sheet metal cabinet with shelves, suitably sized to store spare fuses and fuse pullers specified with 10% capacity minimum.
- B. Doors shall be hinged, with hasp for Owner's padlock.
- C. Finish shall be gray enamel.
- D. Cabinet shall have nameplate engraved "Spare Fuses" in 1/2" letters on door.

### **PART 3 EXECUTION**

#### **3.1 EXAMINATION**

- A. Examine utilization equipment nameplates and installation instructions. Install fuses of sizes and with characteristics appropriate for each piece of equipment.

#### **3.2 INSTALLATION**

- A. Verify proper fuse locations, sizes, and characteristics.
- B. Install fuses in fusible devices (specified in 26 2816CR – Enclosed Switches and Circuit Breakers, and 26 2913CR – Enclosed Controllers) at job site.
- C. Arrange fuses so manufacturer, class, and size are readable without removing fuse.

- D. Install typewritten labels on inside door of each fused device, indicating fuse replacement information.
- E. Install spare fuse cabinet.

### **3.3 APPLICATION**

- A. Motor Branch Circuits: Class RK5.
- B. Other Branch Circuits: Class RK5.

### **3.4 CLEANING**

- A. Clean fuses and tighten connections prior to energizing of equipment.

**END OF SECTION**

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## **SECTION 26 2816CR**

### **ENCLOSED SWITCHES AND CIRCUIT BREAKERS**

#### **PART 1 GENERAL**

##### **1.1 RELATED WORK**

- A. Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables
- B. Section 26 0526CR – Grounding and Bonding for Electrical Systems
- C. Section 26 0529CR – Hangers and Supports for Electrical Systems
- D. Section 26 0553CR – Electrical Systems Identification
- E. Section 26 0800CR – Commissioning of Electrical Systems
- F. Section 26 2813CR – Fuses

##### **1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### **1.3 DESCRIPTION**

- A. Section includes fusible and non-fusible disconnect switches and circuit breakers in individual enclosures.

##### **1.4 REFERENCE STANDARDS**

- A. ANSI//NECA 1 - Standard Practices for Good Workmanship in Electrical Contracting
- B. NEMA AB 1 - Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breakers Enclosures
- C. NEMA KS 1 - Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)
- D. NFPA 70 - National Electrical Code
- E. UL 98 - Enclosed and Dead Front Switches
- F. UL 486A - 468B - Wire Connectors
- G. UL 489 - Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures

H. UL 869A - Reference Standard for Service Equipment

**1.5 SUBMITTALS**

A. Product Data:

1. Submit catalog cut sheet indicating voltage, amperage, HP ratings, enclosure type, and dimension, fuse clip features, terminal lugs and all accessories including interlock devices, short circuit current ampere rating and factory settings of individual protective devices.

B. Manufacturer's Installation Instructions:

1. Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of product.

C. Test Reports:

1. Indicate field test and inspection procedures and interpret test results and corrective action taken for compliance with specification requirements.

D. Closeout Submittals:

1. Project Record Documents:
  - a. Record actual locations of disconnect switches and ratings of installed fuses.
  - b. Record actual locations and continuous current ratings of enclosed circuit breakers.
2. Operation and Maintenance Data:
  - a. Include manufacturer's recommended operating instructions, maintenance procedures and intervals, and preventive maintenance instructions.
  - b. Include spare parts data listing, source, and current prices of replacement parts and supplies.

**1.6 QUALITY ASSURANCE**

- A. Obtain disconnect switches and enclosed circuit breakers from one source and by single manufacturer.

B. Regulatory Requirements:

1. Comply with NFPA 70 for components and installation.
2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

**1.7 DELIVERY, STORAGE, AND HANDLING**

- A. Store in clean, dry space. Maintain factory wrapping or provide additional canvas or plastic cover to protect from dirt, water, construction debris, and traffic.

- B. Comply with manufacturer's written instructions.

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## 1.8 WARRANTY

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr written warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

## PART 2 PRODUCTS

### 2.1 MANUFACTURERS

- A. Square D
- B. Cutler-Hammer
- C. Siemens

### 2.2 DISCONNECT SWITCHES

- A. NEMA KS 1, UL 98
- B. Load interrupter enclosed knife switch, heavy-duty type.
- C. Fusible or non-fusible type as indicated.
- D. Switch Interiors:
  - 1. Switch blades that are visible in "OFF" position when switch door is open.
  - 2. Plated current carrying parts.
  - 3. Removable arc suppressors to permit easy access to line side lugs.
- E. Switch Mechanism:
  - 1. Quick-make, quick-break, with visible blades and externally operable handle.
  - 2. Lockable only in "OFF" position and accept three industrial type, heavy-duty padlocks.
  - 3. Dual cover interlock to prevent unauthorized opening of switch door when handle is in "ON" position, and to prevent closing of switch mechanism with door open.
  - 4. Defeater mechanism to bypass interlock.
  - 5. Operating handle integral part of enclosure.
  - 6. Handle to physically indicate "ON" and "OFF" position.
- F. Ratings:
  - 1. Ampacity as indicated on drawings.
  - 2. Horsepower rated.
- G. Fusible Switches:
  - 1. Rejection clips for Class R fuses specified.
  - 2. Fuses: Per requirements in Section 26 2813CR – Fuses.

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## 2.3 ENCLOSED CIRCUIT BREAKERS

- A. NEMA AB 1, UL 489.
- B. Enclosed molded-case circuit breakers:
  - 1. Tripped indication clearly shown on breaker handle taking position between “ON” and “OFF”.
  - 2. 225A frame size and below: thermal-magnetic trip.
  - 3. 250A frame size and above: electronic (solid-state microprocessor-based) trip units interchangeable in the field within the frame size and field-adjustable long time pick-up, long time delay, short time pick-up, short time delay, and instantaneous current settings. Each adjustment shall have discrete settings and shall be independent of other adjustments.
  - 4. Locks on trip handles where indicated.
  - 5. Molded-case switch in lieu of thermal-magnetic molded-case circuit breaker, where indicated.
  - 6. Shunt trip, where indicated.
- C. Breaker Mechanism:
  - 1. Quick-make, quick-break.
- D. Ratings:
  - 1. Ampacity as indicated on drawings.
  - 2. Listed as Type HACR for air conditioning equipment circuits.
  - 3. Listed as Type SWD for lighting circuits.

## 2.4 LUGS

- A. Front removable lugs.
- B. Labeled for 75°C copper and aluminum conductors.
- C. Multiple lugs to match number of conductors per phase.
- D. Termination of field installed conductors: Pressure wire connectors, except wire-binding screws for No. 10 AWG or smaller conductors.

## 2.5 ACCESSORIES

- A. Solid neutral assembly, where required.
- B. Equipment ground kit.
- C. Blown fuse indicators on fused disconnect switches.
- D. Factory installed fuse puller on fused disconnect switches.
- E. Two sets of normally open (NO) auxiliary contacts, where disconnect switch is installed at a remote motor served by variable frequency drive (VFD).

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## **2.6 ENCLOSURES**

- A. NEMA KS 1, NEMA AB 1, UL 98, UL 489, as applicable.
- B. NEMA Type 1, Type 3R (outdoor locations) Type 4X, stainless steel, kitchen areas, cooling towers, Type 4, wet and damp indoor locations.
- C. Code-gauge galvanized steel.
- D. Manufacturer's standard gray enamel finish over prime coat.
- E. Surface-mounted. Flush-mounted, where indicated.

## **2.7 SHORT CIRCUIT CURRENT RATING**

- A. Each circuit breaker shall have minimum short circuit current rating equal to the upstream panelboard or switchboard it is being served from.

## **PART 3 EXECUTION**

### **3.1 COORDINATION WITH MANUFACTURER**

- A. Instruct manufacturer about the location of incoming lugs, i.e., top or bottom feed based on incoming feeder entrance location.
- B. Verify that "touch-up" paint kit is available for repainting.

### **3.2 EXAMINATION**

- A. Examine areas and surface to receive disconnect switches and enclosed circuit breakers for compliance with requirements, installation tolerances, and other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.
- B. Verify that space indicated for disconnect switches and enclosed circuit breakers mounting meets code-required working clearances.
- C. Notify Architect/Engineer of any discrepancies prior to submittal of product data and shop drawings.

### **3.3 INSTALLATION**

- A. Install disconnect switches and/or enclosed circuit breakers in accordance with ANSI/NECA 1.
- B. Install disconnect switches and/or enclosed circuit breakers level and plumb, in accordance with manufacturer's written instruction.

- 
- C. Disconnect switches and enclosed circuit breakers mounting :
    - 1. Fasten disconnect switches and enclosed circuit breakers firmly to walls and structural surfaces, ensuring they are permanently and mechanically anchored.
    - 2. Anchor and fasten disconnect switches and enclosed circuit breakers and their supports to building structural elements (wood, concrete, masonry, hollow walls and nonstructural building surfaces) by the methods described in Section 26 0529CR – Hangers and Supports for Electrical Systems.
    - 3. Install two rows of steel slotted channel, with a minimum of four attachment points, for each disconnect switch and enclosed circuit breaker.
    - 4. When not located directly on wall, install support frame of steel slotted channel anchored to floor and ceiling structure.
  - D. Do not support disconnect switches and/or enclosed circuit breakers by raceway.
  - E. Install top disconnect switch and/or enclosed circuit breaker handle a maximum of 6'-6" above finished floor.
  - F. Tighten electrical connectors and terminals according to equipment manufacturer's published torque-tightening values. Where manufacturer's torque values are not indicated, use those specified in UL 486A - 486B.
  - G. Install engraved plastic nameplates under provisions of Section 26 0553CR – Electrical Systems Identification. Attach nameplate to exterior of each switch and/or enclosed circuit breaker using small corrosion-resistant metal screws or rivets. Do not use contact adhesive.
    - 1. Include switch and/or enclosed circuit breaker name, amperage, voltage, phase, and number of wires.
  - H. Install fuses in fusible switches at job site per requirements in Section 26 2813CR – Fuses.

### **3.4 CONNECTIONS**

- A. Ground equipment according to Section 26 0526CR – Grounding and Bonding for Electrical Systems.
- B. Connect wiring according to Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables.

### **3.5 FIELD QUALITY CONTROL**

- A. Inspect for physical damage, proper alignment connections, anchorage, and grounding.
- B. Correct malfunctioning units on-site and retest to demonstrate compliance. Remove and replace with new units and retest.
- C. Test disconnect switches and/or enclosed circuit breakers per requirements in Sections 26 0800CR– Power Distribution Acceptance Tests.



- D. Interpret test results in writing and submit to Engineer.

### **3.6 REPAINTING**

- A. Remove paint splatters and other marks from surface of equipment.
- B. Touch-up chips, scratches, or marred finishes to match original finish, using manufacturer-supplied paint kit. Leave remaining paint with Owner.

### **3.7 ADJUSTING**

- A. Circuit Breakers: Set field-adjustable trip settings or change the trip settings, as indicated on drawings.

### **3.8 CLEANING**

- A. Vacuum dirt and construction debris from interior and exterior of equipment; do not use compressed air to assist in cleaning.

**END OF SECTION**



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**SECTION 26 2913CR**  
**ENCLOSED CONTROLLERS**

**PART 1 GENERAL**

**1.1 RELATED WORK**

- A. Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables
- B. Section 26 0526CR – Grounding and Bonding for Electrical Systems
- C. Section 26 0529CR – Hangers and Supports for Electrical Systems
- D. Section 26 0533CR – Raceway and Boxes for Electrical Systems
- E. Section 26 0553CR – Electrical Systems Identification
- F. Section 26 0800CR – Commissioning of Electrical Systems
- G. Section 26 2813CR – Fuses

**1.2 REFERENCE**

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

**1.3 DESCRIPTION**

- A. Section includes enclosed manual and magnetic motor controllers and enclosed contactors.
- B. Motors shown on the drawings or specified in other Divisions of these specifications shall be provided with motorized equipment and connected under this section. Provide motor controllers and power circuit disconnect devices for all motors, unless shown or specified to be furnished with motorized equipment under other Divisions of these specifications, and/or by others, for installation by this contract.
- C. Variable-frequency controllers furnished by Division 20 for installation by Division 26.
- D. Motor Voltage Information:
  - 1. Voltages available are: 208 and 480 V, 3-phase and 120, 208 and 277V single phase. Circuits are designed for motors with voltage ratings as follows:
    - a. Smaller than 1/2 hp motors: 115 V, single phase.
    - b. 1/2 hp motors and larger: 200 and 460 V, 3-phase.

#### **1.4 REFERENCE STANDARDS**

- A. ANSI/NECA 1 – Standard Practices for Good Workmanship in Electrical Contracting
- B. NEMA AB 1 – Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breakers Enclosures
- C. NEMA 250 – Enclosures for Electrical Equipment (1000 V Maximum)
- D. NEMA ICS 2 – Industrial Control and Systems: Controllers, Contactors and Overload Relays, Rated Not More Than 2000 VAC or 750 VDC
- E. NEMA ICS 4 – Industrial Control and Systems: Terminal Blocks
- F. NEMA ICS 5 – Industrial Control and Systems: Control Circuit and Pilot Devices
- G. NEMA ICS 6 – Industrial Control and Systems: Enclosures
- H. NEMA KS 1 – Enclosed and Miscellaneous Distribution Equipment Switches (600 V Maximum)
- I. NEMA MG 1 – Motors and Generators
- J. NFPA 70 – National Electrical Code
- K. UL 98 – Enclosed and Dead Front Switches
- L. UL 486A-486B – Wire Connectors
- M. UL 489 – Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breakers Enclosures
- N. UL 508 – Industrial Control Equipment

#### **1.5 SUBMITTALS**

- A. Product Data:
  - 1. Motor controllers: Submit catalog cut sheets showing voltage, size, rating and size of switching and overcurrent protective devices, dimensions, and enclosure details.
  - 2. Contactors: Submit catalog cut sheets showing voltage, size, current rating, dimensions, and enclosure details.
  - 3. Factory settings and time-current curves of individual protective devices.
  - 4. Confirm motor sizes and voltages with submittals of other Divisions of specifications, and/or by others, prior to Section submittals.
- B. Manufacturer's Installation Instructions:
  - 1. Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, installation, and/or starting of product.

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- C. Test Reports: Indicate field test and inspection procedures and interpret test results and corrective action taken for compliance with specification requirements.
  - D. Closeout Submittals:
    - 1. Project Record Documents:
      - a. Record actual locations and ratings of enclosed motor controllers and enclosed contactors.
    - 2. Operation and Maintenance Data:
      - a. Include manufacturer's recommended operating instructions, maintenance procedures and intervals, and preventive maintenance instructions.
      - b. Include spare parts data listing, source, and current prices of replacement parts and supplies.

#### **1.6 QUALITY ASSURANCE**

- A. Obtain motor controllers, and contactors from one source and by single manufacturer.
- B. Regulatory Requirements:
  - 1. Comply with NFPA 70 for components and installation.
  - 2. Furnish products listed and classified by Underwriters Laboratories, Inc., as suitable for purpose specified and indicated.

#### **1.7 DELIVERY, STORAGE, AND HANDLING**

- A. Store in clean, dry space. Maintain factory wrapping or provide additional canvas or plastic cover to protect units from dirt, water, construction debris, and traffic.

#### **1.8 WARRANTY**

- A. Refer to Division 01 and Section 26 0000CR – General Electrical Requirements for general warranty requirements.
- B. Manufacturer shall provide standard 1 yr warranty against defects in materials and workmanship for products specified in this Section. Warranty period shall begin on date of substantial completion.

#### **1.9 MAINTENANCE**

- A. Extra Materials: Furnish extra materials described below that match product installed, are packaged with protective covering for storage, and are identified with labels describing contents.
  - 1. Spare pilot lights: Furnish 1 spare lamp for every 5 installed units, but not less than 1 set of 3 of each kind.

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## **PART 2 PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Square D
- B. Cutler-Hammer
- C. Siemens

### **2.2 MANUAL MOTOR CONTROLLERS**

- A. Description: NEMA ICS 2, AC general-purpose, Class A, manually operated, full-voltage controller for small motors, with melting alloy type overload relay, red pilot light, (NO) auxiliary contact, and toggle operator.

### **2.3 FRACTIONAL-HORSEPOWER MANUAL CONTROLLERS**

- A. Description: NEMA ICS 2, AC general-purpose, Class A, manually operated, full-voltage controller for fractional horsepower induction motors, with melting alloy type overload relay, (red) pilot light, and toggle operator.

### **2.4 MOTOR STARTING SWITCHES**

- A. Description: NEMA ICS 2, AC general-purpose Class A manually operated, full-voltage controller for fractional horsepower induction motors, without thermal overload unit, with (red) pilot light, and toggle operator.

### **2.5 FULL-VOLTAGE NON-REVERSING MAGNETIC MOTOR CONTROLLERS**

- A. Description: NEMA ICS 2, AC general-purpose, Class A, magnetic controller for induction motors rated in horsepower, three-phase and single-phase, as scheduled, except where single-phase motors scheduled to be provided with built-in overload elements:
  - 1. Size 1 minimum
  - 2. Control Voltage: 120 V, 60 Hz
  - 3. Overload Relays: NEMA ICS 2, melting alloy, 1 overload relay per phase:
    - a. Melting alloy type:
      - 1) Class 20 inverse-time tripping characteristics.
      - 2) Manual reset.
      - 3) One normally open and one normally closed isolated auxiliary contract.
  - 4. Features:
    - a. Auxiliary Contacts: NEMA ICS 2, 2 each field-convertible contacts in addition to seal-in contact.
    - b. Pushbuttons: (Shrouded type).
    - c. Pilot Lights NEMA ICS 5: push-to-test LED type.
    - d. Hand-Off-Auto (H-O-A) Selector Switches: Rotary type.

- e. Control Power Transformers: 120V secondary, adequate capacity to operate connected pilot, indicating and control devices, plus 100% spare capacity in each motor controller, but not less than 100VA. Fused primary and secondary, and unfused leg of secondary bonded to enclosure.
- f. Terminals: NEMA ICS 4.
- g. Other accessories detailed or required by drawings.

## 2.6 COMBINATION CONTROLLERS

- A. Factory-assembled motor controllers with externally operable disconnect, fusible switch type, in common enclosure; means for locking disconnect handle and means for defeating cover interlock.
  - 1. Fusible Switch: NEMA KS 1 and UL 98; enclosed knife switch, heavy-duty type, external operable handle, clips or pads to accommodate specified fuses:
    - a. Rejection clips for Class R fuses.
    - b. Fuses: Per requirements in Section 262813CR – Fuses.

## 2.7 MOTOR CONTROLLER ACCESSORIES

- A. Factory installed devices in controller enclosure, unless otherwise indicated, as follows:
  - 1. “On-Off” and “Start-Stop” pushbutton stations, pilot lights, selector switches: NEMA ICS 2, heavy duty, oiltight type.
  - 2. 120 V control circuits and pilot light, unless noted otherwise.
  - 3. Red pilot light to indicate motor operation.
  - 4. Green pilot light to indicate motor stopped.
  - 5. Minimum wire size for control circuits: #14 AWG.
  - 6. Stop and Lockout Pushbutton Station: Momentary-break pushbutton station with a factory-applied hasp arranged so a padlock can be used to lock pushbutton in depressed position with control circuit open, where indicated.
  - 7. Control Relays: Auxiliary and adjustable time-delay relays, where indicated:
    - a. Phase-Failure and Undervoltage Relays: Solid-state sensing circuit with isolated output contacts for hardwired connection, with adjustable undervoltage setting.
- B. Control services: As scheduled on motor schedule or indicated.

## 2.8 LUGS

- A. Labeled for 75°C copper and aluminum conductors.
- B. Multiple lugs to match number of conductors per phase.
- C. Termination of field installed conductors: Pressure wire connectors, except wire-binding screws for No. 10 AWG or smaller conductors.
- D. For equipment specified in this section and for equipment furnished under other Divisions of this specification and/or by others.

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## **2.9 MOTOR CONTROLLERS AND CONTACTOR ENCLOSURES**

- A. NEMA 250, NEMA 1CS 6.
- B. NEMA Type 1, Type 3R (outdoor locations) Type 4X, stainless steel, kitchen areas, Type 4, wet and damp indoor locations.
- C. Code-gauge galvanized steel.
- D. Manufacturer's standard gray enamel finish over prime coat.
- E. Surface-mounted.

## **PART 3 EXECUTION**

### **3.1 COORDINATION**

- A. Coordinate motor control wiring with Division 23 of these specifications.
- B. Coordinate motor sizes and voltages with submittals of other Divisions of these specifications and/or by others.
- C. Verify with manufacturer that "touch-up" paint kit is available for repainting.

### **3.2 EXAMINATION**

- A. Examine areas and surface to receive motor controllers and contactors for compliance with requirements, installation tolerances, and other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.
- B. Verify that space indicated for motor controllers and contactors mounting meets code-required working clearances.
- C. Notify Architect/Engineer of any discrepancies prior to submittal of product data.

### **3.3 INSTALLATION**

- A. Install motor controllers and contactors in accordance with ANSI/NECA 1.
- B. Install level and plumb, in accordance with manufacturer's written instruction.
- C. Motor controllers and contactors mounting and seismic restraints:
  - 1. Fasten motor controllers and contractors firmly to walls and structural surfaces, ensuring they are permanently and mechanically anchored.
  - 2. Anchor and fasten motor controllers and contactors and their supports to building structural elements (wood, concrete, masonry, hollow walls and nonstructural building surfaces) by the methods described in Section 26 0529CR – Hangers and Supports for Electrical Systems.



3. Install two rows of steel slotted channel, with minimum of four attachment points, for each motor controller and contactor.
  4. When not located directly on wall, install support frame of steel slotted channel anchored to floor and ceiling structure.
  5. Do not support motor controllers and contactors only by raceway.
- D. Tighten electrical connectors and terminals according to equipment manufacturer's published torque-tightening values. Where manufacturer's torque values are not indicated, use those specified in UL 486A-486B.
- E. Install engraved plastic nameplates under provisions of Section 26 0553CR – Electrical Systems Identification. Attach nameplate to exterior of each motor controller and contactor, using small corrosion resistant metal screws or rivets. Do not use contact adhesive:
1. Indicate motor served, nameplate horsepower, full load amperes, code letter, service factor, voltage/phase rating, and fuse size and type, when applicable.
- F. Connect each motor terminal box to rigid conduit system with maximum 18" of flexible liquid-tight metal conduit. Install conduit per requirements in Section 26 0533CR – Raceway and Boxes for Electrical Systems.
- G. Check for proper rotation and phase relationship of each motor.
- H. Install fuses in fusible switch at job site pre requirements in Section 26 2813CR – Fuses.
- I. Control Wiring Installation:
1. Install wiring between motor control devices according to Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables.
  2. Install motor control wiring in accordance with control wiring diagrams and in raceways where indicated or required by contract drawings.
  3. Bundle, train, and support wiring in enclosures.
  4. Connect hand-off-automatic switch and other automatic-control devices where applicable.
    - a. Connect selector switches to bypass only manual- and automatic-control devices that have no safety functions when switch is in hand position.
    - b. Connect selector switches with motor-control circuit in both hand and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

### **3.4 APPLICATION**

- A. Select features of each motor controller to coordinate with ratings and characteristics of supply circuit and motor; required control sequence; duty cycle of motor, and configuration of pilot device and control circuit affecting controller functions.

### **3.5 CONNECTIONS**

- A. Provide green wire ground through flexible conduit to interconnect motor frame and rigid conduit system.

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- B. Ground and bond motor controller and contactor enclosures according to Section 26 0526CR – Grounding and Bonding for Electrical Systems.
  - C. Connect power and control wiring according to Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables.
  - D. Connect control wiring for operation, control and supervision of motorized equipment as shown on drawings and/or specified in this and other Divisions of these specifications.

### **3.6 FIELD QUALITY CONTROL**

- A. Inspect motor controllers and contactors for physical damage, proper alignment, connections, anchorage, seismic restraints and grounding.
- B. Correct malfunctioning motor controllers and contactors on-site and retest to demonstrate compliance. Remove and replace with new units and retest.
- C. Test continuity of each circuit.
- D. Test motor controllers per requirements in Sections 26 0800CR – Commissioning of Electrical Systems.
- E. Interpret test results in writing and submit to Engineer.

### **3.7 REPAINTING**

- A. Remove paint splatters and other marks from surface of equipment.
- B. Touch-up chips, scratches or marred finishes to match original finish, using manufacturer-supplied paint kit. Leave remaining paint with Owner.

### **3.8 ADJUSTING**

- A. Set field-adjustable circuit breakers trip settings or change the trip settings as indicated on drawings.
- B. Adjust motor circuit protectors.

### **3.9 CLEANING**

- A. Vacuum dirt and construction debris from interior and exterior of equipment; do not use compressed air to assist in cleaning.

**END OF SECTION**

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## SECTION 26 5100CR

### LIGHTING

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 26 0000CR - General Electrical Requirements
- B. Section 26 0526CR - Grounding and Bonding for Electrical Systems
- C. Section 26 0533CR - Raceway and Boxes for Electrical Systems

##### 1.2 REFERENCE

- A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 DESCRIPTION OF WORK

- A. Provide lighting system complete and fully operational per Contract Drawings and Specifications.
- B. Luminaires shall be provided complete with necessary accessories for proper installation.
- C. Catalog numbers shown in luminaire schedule are basic luminaire types. Additional features, accessories and options specified or scheduled shall be included.
- D. Provide lamps for luminaires as recommended by luminaire manufacturer unless otherwise noted.
- E. Specifications and drawings convey the features and functions of luminaires only and do not show every item or detail necessary for the work.
- F. Work includes final aiming and focusing of luminaires under direction of the Architect/Engineer/Lighting Designer.

##### 1.4 REFERENCE STANDARDS

- A. NECA/IESNA 500 - Standard for Installing Indoor Commercial Lighting Systems (ANSI)
- B. NECA/IESNA 501 - Standard for Installing Exterior Lighting Systems (ANSI)
- C. NECD/IESNA 502 - Standard for Installing Industrial Lighting Systems (ANSI)
- D. NEMA LE 4 - Recessed Luminaires, Ceiling Compatibility

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- E. UL 496 – Lampholders
  - F. UL 542 – Fluorescent Lamp Starters
  - G. UL 676 – Underwater Luminaires and Submersible Junction Boxes
  - H. UL 773 - Plug-in Photocontrols for use with area lighting
  - I. UL 924 - Emergency Lighting and Power Equipment
  - J. UL 935 - Fluorescent Lamp Ballasts
  - K. UL 1029 - High Intensity Discharge Lamp Ballast
  - L. UL 1574 – Track Lighting
  - M. UL 1598 – Luminaires
  - N. UL 1838 – Low Voltage Landscape Lighting Systems
  - O. UL 2108 – Low Voltage Lighting Systems
  - P. UL 2388 – Flexible Lighting Products
  - Q. UL 2562 – Pendant Cable
  - R. UL 8750 – LED Light Sources for use in Lighting Products

## **1.5 QUALITY ASSURANCE**

- A. Luminaire and accessory components shall be constructed of materials appropriate for their use.
- B. Luminaires, ballasts, lamps and other components shall meet the requirements of all applicable State and Municipal codes and energy codes.
- C. Provide luminaires listed and labeled by UL or other testing lab acceptable to local jurisdiction for their indicated use and installation conditions.
- D. Contractor shall coordinate installation of lighting systems with all trades.
  - 1. Manufacturers listed in the luminaire schedule shall be assumed capable of supplying listed luminaires. Any such exceptions shall immediately be brought to the attention of Architect and Lighting Consultant.
  - 2. Multiple Name Specification:
    - a. When multiple manufacturers are listed, Electrical Contractor shall choose which of the listed products are to be provided.
    - b. Products of the same type shall be of same manufacturer.

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3. Single Name Specification:
    - a. When only one product is suitable for the application and/or no other known acceptable products exist, only one manufacturer/product is listed in the Luminaire Schedule. For such instances, Electrical Contractor shall provide the listed product with no exceptions.
    - b. Specifier has secured accurate pricing for all single name products prior to bidding and has shared this information with Architect/Owner's Representative. Contractor shall supply contractor net unit pricing for all single name products specified. Unit price shall be for equipment only and not include installation or miscellaneous electrical costs.
  
  - E. Substitution requests:
    1. Will be evaluated prior to Bid.
    2. Shall follow procedures set forth in this Section under paragraph 1.6 and in Section 01 2500 - Substitution Procedures.
    3. Shall be made not less than 14 days prior to bid date.
    4. Shall include the following information:
      - a. Specified and proposed manufacturer's product data sheet, noting options and features.
      - b. Provide dimensioned drawing of luminaire.
      - c. Provide photometric data in form of an electronic IES file on CD or via email, for use in a recognized computer lighting program.
    5. Provide table-top working samples and/or mockup of specified luminaire and proposed alternate.
    6. Samples shall:
      - a. Be fully operable, complete with specified lamp(s) and with functioning with cord and plug.
      - b. Remain available during construction.
    7. Electrical Contractor shall be responsible for all costs incurred by substitution request sample and/or mockup production and review.
    8. Equipment delivery lead time shall not be held as a valid reason for requesting luminaire substitution unless luminaire lead time from specified manufacturer is in excess of 14 weeks. It shall be the sole responsibility of the Electrical Contractor to determine necessary equipment lead times, deliver submittals for review in a timely fashion, and place orders accordingly to ensure timely delivery.
    9. When requesting a substitution, Electrical Contractor shall provide unit and extended pricing for specified luminaire, unit and extended pricing for proposed alternate, and unit and extended delta savings to owner to be realized by accepting proposed alternate. If requested, provide unit pricing for each luminaire type specified to provide a baseline comparison for substitution request.
    10. Electrical Contractor shall guarantee pricing on all luminaire types for which a substitution request has been granted. This price guarantee shall be per unit and shall be maintained through the end of construction, regardless of quantity purchased.

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## 1.6 WARRANTY

- A. Ballasts: Provide manufacturer's warranty for a period of not less than five years. Warranty shall include parts and labor to replace defective ballasts.
- B. Exit Signs Utilizing LED lamp Technology: Provide manufacturer's warranty for a period of not less than five years including parts and labor for full replacement of defective product.
- C. LED Luminaires: Provide Manufacturer's warranty for a period of not less than three years for repair or replacement of defective electrical parts, including light source and power supplies.

## 1.7 SUBMITTALS

- A. After award of Contract, submit complete list of lighting products to be furnished, with manufacturer and catalog designations, including currently quoted lead times for product delivery. Should Electrical Contractor anticipate delivery schedule of any specified product may adversely impact construction schedule, he shall bring it to the attention of the Owner/Architect/Lighting Designer at this time.
- B. In addition to complying with requirements of Section 26 0000CR - General Electrical Requirements, submittals shall include the following:
  - 1. Manufacturer's product data
  - 2. Installation instructions
  - 3. Maintenance data
  - 4. Parts list for each luminaire accessory
  - 5. Photometric Data: photometric data for luminaire, including optical performance as follows:
    - a. Coefficients of utilization
    - b. Luminance table
    - c. Candela distribution data
    - d. Zonal lumens
    - e. Area and roadway luminaires shall include Isocandela Charts and IES Roadway Distribution Classification.
  - 6. Ballast schedule indicating manufacturer, type, and catalog number for each luminaire
  - 7. Ballast cut sheet for each ballast used, referencing luminaire type(s)
  - 8. Lamp schedule indicating manufacturer, type, and catalog number for each luminaire
  - 9. Lamp cut sheet for each lamp used, referencing luminaire type(s)
  - 10. Documentation of lamp and ballast compatibility
  - 11. Product color/finish
    - a. Where specific finish or color is not specified and options exist, submit color or finish samples to Architect/Engineer/Lighting Designer for selection.

- C. Shop Drawings for equipment provided under this Section shall include the following:
1. Detailed drawings of linear and suspended luminaires including dimensions, support spacing, suspension type, power feed type and locations, lamp combinations, ballast locations, luminaire joint locations and end plates.
  2. Detailed drawings for each cove and linear wall system configuration including dimensions, power feed locations, ballast locations, luminaire joint locations, extension plates for end and corner sections and end plates.
  3. For fluorescent strip luminaires mounted in architectural coves, provide dimensioned drawings and sections and include accessory cut sheets as specified.
  4. Detailed drawings for nonstandard/custom luminaires indicating dimensions, weights, method of field assembly, components, features, and accessories. Details shall be scaled at not less than half full size.
  5. Photometric Data: Where indicated on luminaire schedule and Contract Drawings, supply complete photometric data for luminaire, including optical performance rendered by independent testing laboratory developed according to methods of the Illuminating Engineering Society of North America as follows:
    - a. Coefficients of utilization
    - b. Luminance table with data presented numerically, showing maximum luminaire luminance at shielding angles. Readings should be taken both crosswise and lengthwise in case of fluorescent luminaire or luminaire with an asymmetric distribution.
    - c. Candela distribution data, presented graphically and numerically, in 5° increments (5°, 10°, 15°, etc.) Data developed for up and down quadrants normal, parallel, and at 11-1/2°, 45°, 67-1/2° to lamps if light output is asymmetric.
    - d. Zonal lumens stated numerically in 10° increments (5°, 15°, etc.) as above.
    - e. Area and roadway luminaires shall also include isocandela charts and IES roadway distribution classification.
  6. No variation from the general arrangement and details indicated on drawings shall be made on shop drawings unless required by actual conditions. All variations shall be marked on drawings submitted for approval.
- D. Catalogue Cuts lacking sufficient detail will not be accepted.

## 1.8 SAMPLES

- A. Upon return of submittals, and prior to release for manufacturing, Contractor shall furnish one sample of each luminaire for which sample requirement is noted in fixture schedule.
- B. Shipping: Samples shall be complete with specified lamp(s), cord and plug, ready for hanging, energizing, and examining, and shall be shipped, prepaid by Contractor, to Architect/Engineer/Lighting Designer, or as otherwise advised.
- C. Samples will not be returned, nor included in quantities listed for project.
- D. Sample must be actual working unit.

- E. All custom fixtures require a submission of material finish samples, component approval, and a complete operating prototype fixture. Prototype to be submitted prior to commencement of final fixture fabrication and shall include specified lamps. Modifications may be required as a result of the prototype review. These modification and others that do not materially affect the cost of the fixture shall be incorporated at no additional cost to the owner.

## **1.9 LUMINAIRE MOCK-UPS**

- A. Upon return of submittals, and prior to release for manufacturing, Contractor shall provide mock-up as requested on site (or at another agreed upon location) in actual architectural conditions for review by Architect/Engineer/Lighting Designer and Owner.
- B. Provide type and quantity of luminaires as requested by Architect/Engineer/Lighting Designer.
- C. Mock-up shall include working luminaires and fastening devices.

## **PART 2 PRODUCTS**

### **2.1 ACCEPTABLE MANUFACTURERS**

- A. Luminaires:
  - 1. As shown on Luminaire Schedule
- B. Electronic Fluorescent Ballasts:
  - 1. Advance, GE, Osram Sylvania, Robertson, Universal Lighting Technologies or as specified in the Luminaire Schedule.
- C. Electronic Dimming Fluorescent Ballasts:
  - 1. Advance, Lutron, Osram Sylvania or as specified in the Luminaire Schedule.
- D. Emergency Fluorescent Ballasts:
  - 1. Bodine, Iota, Dual-Lite, Exide or as specified in the Luminaire Schedule.
- E. Magnetic HID Ballasts:
  - 1. GE, Valmont Electric, Universal Lighting Technologies, Osram Sylvania or as specified in the Luminaire Schedule.
- F. Electronic HID Ballasts:
  - 1. Vassloh-Schwabe, Advance, Hatch or as specified in the Luminaire Schedule.
- G. Magnetic Low Voltage Transformers:
  - 1. Q-Tran or as specified in the Luminaire Schedule.
- H. Induction Ballasts
  - 1. Philips



- I. Lamps:
  - 1. General Electric, Osram Sylvania, Philips Lighting, Ushio, Venture or as specified in the Luminaire Schedule.
- J. LEDs
  - 1. Lumileds, Cree, Philips, Nichia or as specified in the Luminaire Schedule.

## 2.2 FABRICATION AND MANUFACTURER

- A. Luminaires:
  - 1. Construction
    - a. Luminaires shall bear label indicating circuit voltage. Labels shall not be visible from normal viewing angles.
    - b. Luminaires shall be constructed with joints made by means of welded, brazed, screwed, or bolted construction methods.
    - c. Housings shall be so constructed that all electrical components are accessible and replaceable without removing luminaires from their mountings.
    - d. Surface temperatures of luminaires with ballasts shall not exceed F90°C in 30°C ambient.
    - e. Luminaires recessed in ceilings utilized as air handling plenums shall be certified as suitable for the purpose and shall conform with NEC Article 300-22.
    - f. Miter cuts shall be accurate, joints shall be flush and without burrs.
    - g. Fixtures shall be free of light leaks and designed to provide sufficient ventilation of lamps to provide the photometric performance documented. Ballasts and transformers shall be vented per manufacturer's specifications.
    - h. Provide inscription for exit and stairway signs to conform to applicable codes.
  - 2. Lenses, Reflectors and Diffusers
    - a. All lenses or louvers shall be removable, but held so that normal motion will not cause them to drop out.
    - b. All glass used in incandescent luminaires shall be made from thermal shock resistant borosilicate glass.
    - c. Optical lenses shall be free from spherical and chromatic aberrations.
    - d. Acrylic lenses shall be 100% virgin acrylic material.
    - e. Diffuser materials shall be UV stabilized in applications exposed to sunlight.
    - f. Fluorescent luminaire lenses shall be 0.125" thick, unless otherwise noted.
    - g. Alzak reflectors and louvers shall be low iridescent equivalent to Coil Anodizers. All Alzak parabolic cones shall be guaranteed against discoloration for a minimum of ten years.
    - h. Reflector cones shall not have visible lamp flashing in the cone.
    - i. Fluorescent luminaires installed without glass, acrylic or metal enclosure, shall be equipped with safety type lampholders. Provide wire guard.

3. Optics and Adjustments
  - a. Lamp holders shall be suitable for the indicated lamps and shall be set such that lamps are positioned in optically correct relation to all luminaire components.
  - b. Spread Lens Luminaire: Luminaires with spread lens shall contain lens orientation locking devices to insure that lens orientation is not disturbed during future lamp replacement or cleaning.
  - c. Oval Beam Luminaire: Luminaires with oval shape beam pattern lamps shall contain lamp orientation locking devices to insure that beam orientation is not disturbed during lamp replacement or cleaning.
  - d. Adjustable Angle Luminaire: Luminaires with adjustment beam angle shall contain reliable angle locking devices.
4. Finishes
  - a. Provide luminaires with finish as shown in the luminaire schedule. Verify final finish requirements before releasing luminaires for fabrication.
  - b. Painted luminaires shall be painted after fabrication or "post painted".
  - c. Ferrous parts and supports shall be rust proofed after fabrication.
  - d. For weatherproof or vaportight installations, painted finishes of fixtures and accessories shall be weather resistant enamel using proper primers or galvanized and bonderized epoxy, so that the entire assembly is completely corrosion resistant for the service intended and rated for an outdoor life expectancy of not less than 20 years.
5. Wiring
  - a. Luminaires shall be completely wired at the factory and as required by code.
  - b. Internal wiring shall contain no splices.
  - c. Connections shall be made with insulated "wire nut" type mechanical connectors except that ballast connections shall comply with NEC art. 410.73(G).
  - d. Wire for connections to lamp sockets and lamp auxiliaries shall be minimum #16 ga luminaire wire.
  - e. Luminaires shall be provided with flexible conduit, pigtails, and equipment for external connections.
  - f. Recessed incandescent luminaires shall incorporate integral thermal protection.
  - g. Incandescent luminaires shall be wired with heat resistant wire.
  - h. Recessed HID luminaires with integral ballasts, installed indoors, shall have thermal protection integral with ballast.
  - i. Recessed luminaires installed in inaccessible ceilings shall be UL listed for through wiring with the junction box accessible from the luminaire opening.

- j. Provide wiring for dual-level switching for luminaires as indicated on luminaire schedule and/or where shown on Contract Drawings. Typically first switch designation controls outboard lamps, and second switch designation controls inboard lamp(s), unless noted otherwise.
  - k. Provide wiring for master/slave luminaire configuration as indicated on luminaire schedule and/or where shown on Contract Drawings. For single lamp fixtures, provide a two-lamp ballast for two adjacent fixtures. For three-lamp fixtures, provide one two-lamp ballast for the outboard lamps in each fixture and an additional two-lamp ballast for the center lamp in each of two adjacent fixtures.
  - l. Provide wiring for tandem wired luminaires as indicated on luminaire schedule and/or where shown on Contract Drawings. Supply ballasts and wiring to control all top or inboard lamps together and control all bottom or outboard lamps together.
  - m. Cords shall be fitted with proper strain reliefs and watertight entries where required by application.
6. Support:
- a. Rigid metallic pipe stems shall be utilized for the support of pendant mounted luminaires, unless otherwise noted.
  - b. Stem hangers shall be equipped with aligner box covers or canopies so that stems hang vertically, irrespective of the angle of the surface they are mounted from.
  - c. Wherever a luminaire or its hanger canopy is attached to a surface mounted outlet box, a finishing ring shall conceal the outlet box.
  - d. Yokes, brackets and supplementary supporting members needed to mount luminaires to suitable ceiling members shall be furnished and installed by Contractor. Verify mounting hardware required prior to installation.
7. Framing
- a. Verify type of ceiling construction prior to releasing luminaires for fabrication and delivery.
  - b. Provide mounting appurtenance, flanges, sloped ceiling adaptors where required.
  - c. Provide mounting assembly, clips or other mechanical mounting lugs as required for support of luminaires.
  - d. Light leaks between ceiling trim of recessed luminaires and ceilings are not allowed.
  - e. Luminaire frames shall be manufactured of non ferrous metal or be suitably rust proofed after fabrication.
  - f. Luminaire frames for recessed luminaires shall be furnished by Electrical Contractor and installed by General Contractor.
8. Track-Lighting Systems:
- a. A lighting track system is defined as a manufactured assembly designed to support and energize luminaires that are capable of being readily repositioned on the track. Its length may be altered by the addition or subtraction of sections of track. Lighting track may be either flexible or rigid depending on the specific application.
  - b. Provide lighting track types as specified in the Luminaire Schedule, in lengths as indicated on the lighting plans.

- c. A lighting track system includes current carrying conductors which may convey either line voltages (120V or 277V) or low voltages (12V or 24V). The characteristics of lighting track that conveys line voltages are different than a lighting track system that conveys low voltages and as such are governed by different requirements. Therefore, they are considered individually in these Specifications.
- 1) Line voltage (120V or 277V) Lighting Track systems:
    - a) Provide components, including track, fittings, and luminaires from the same manufacturer as recommended by manufacturer for the intended use. All components shall be UL Listed and comply with the National Electric Code Standards for Lighting Track.
    - b) Maintain continuity of conductors through feeds, splice fittings and boxes. Relative positions of live and neutral conductors must always be maintained along continuous run so that track fittings connect into the track in a consistent manner.
    - c) Support lighting track at intervals recommended by the track manufacturer.
    - d) One or two circuit Lighting Track shall be supplied with separate neutral busbars and have the ability to have each circuit separately dimmed as required when using standard voltage and low voltage fixtures with either magnetic or electronic transformers.
    - e) Lighting Track shall have the ability to be dimmed or switched in selected sections in addition to dimming or switching an entire track configuration or track run.
    - f) One and two circuit 120 volt Lighting Track shall be rated at 120/250 volt, 60 Hz, 2,400 watts maximum each circuit. Neutral busbar(s) shall be oversized and comparable to #10 ga 30 amp wire to reduce the possibility of overheating due to non-linear loads and harmonics.
    - g) One and two circuit 277 volt Lighting Track shall be rated at 277 volt, 50/60 Hz, 5,540 watts maximum each circuit. Neutral busbar(s) shall be oversized and comparable to #10 ga 30 amp wire to reduce the possibility of overheating due to non-linear loads and harmonics.
    - h) A separate grounding busbar shall be integral in all track lengths.
    - i) 277 volt Track fittings shall be identified by a red rotor and a 277 volt label.
  - 2) Low voltage (12V or 24V) Lighting Track systems:
    - a) Provide components, including track conductors, remote mounted transformers, fittings, and luminaires from the same manufacturer as recommended by the manufacturer for the intended use. Components shall be UL Listed as applicable for low voltage use.

- b) Maintain continuity of conductors through feeds, splice fittings and boxes. Relative positions of conductors must always be maintained along continuous run so that track fittings connect into the track in a consistent manner.
  - c) Support lighting track at intervals recommended by the track manufacturer.
  - d) One and two circuit low voltage Lighting Track shall be supplied with three conductors and have the ability to have each circuit separately switched with either magnetic or electronic transformers provided by the track manufacturer. Two circuit low voltage Lighting Track can only be dimmed if both circuits are fed from the same transformer and as a result, separate circuit dimming shall not be attempted or permitted.
  - e) All transformers shall be supplied with both primary and secondary voltage over-current protection devices that shall remain readily accessible for maintenance and testing purposes.
  - f) Lighting Track shall have the ability to be dimmed or switched in selected sections in addition to dimming or switching an entire track configuration or track run. Separate, single circuit transformers are required for each independently controlled circuit with the use of electrically isolated couplers.
  - g) Conductors used in the low voltage Lighting Track shall be, at minimum, the equivalent to #10 ga 30 amp wire or heavier and be capable of carrying a 300 watt load (at 12 volts) up to thirty feet from the transformer feed within range of luminaire voltage tolerance. At 24 volts, the conductors shall be capable of supplying a 600 watt load up to sixty feet from the transformer feed within range of luminaire voltage tolerance.
  - h) If taut strung cable conductors are used as the low voltage Lighting Track system, they shall have a Kevlar core to prevent strain on the outer current carrying conductors.
  - i) Only insulated type taut strung cable conductors shall be used in order to comply with local electrical codes governing installation.
9. Outdoor Lighting Systems:
- a. Provide luminaires, mounting arms, brackets, poles, hand-hole covers, base components, and all other accessories for a complete assembly. Manufacturers shall be responsible for proper fitting of all elements and the structural integrity of the unit.
  - b. Provide poles as shown on luminaire schedule.
    - 1) Poles shall have hand-holes.
    - 2) Fusing for each luminaire head shall be located in hand-hole near base of pole.
    - 3) Pole base anchor bolts shall be galvanized.

- c. Exterior Luminaires:
  - 1) Shall operate at a minimum ambient temperature of 0°F.
  - 2) Shall be fully gasketed, with UL wet location label
  - 3) Shall have approved wire mesh screens for ventilation openings.
  - 4) Anodized aluminum reflectors shall have minimum of 0.02 mm anodizing thickness.
- d. Pole/Luminaire combination shall have EPA rating that will withstand site wind conditions.
- e. All castings and extrusions shall be given minimum one coat of baked-on clear lacquer, unless painted finish is specified.
- f. Aluminum surfaces shall receive a duronodic or polyester powder paint finish.
- g. Cast-in Luminaire housings installed directly in concrete shall be fabricated of hot dip galvanized steel or cast aluminum or composite.
- h. Where cast aluminum housings are used, give two coats of asphaltum paint prior to installation.
- i. Provide 3 mm thick x 51 mm diameter solid neoprene grommets at each point light luminaire surfaces are mounted to concrete structure.

## 2.3 BALLASTS

- A. Ballasts shall be equipped with line fuses.
  - 1. Fuses shall be type and size recommended by luminaire manufacturer.
- B. Ballasts shall be suitable for operating the indicated lamps.
- C. Ballasts for use in cold or freezer rooms, parking structures, loading docks, and outdoors shall be low temperature type.
  - 1. Ballast shall have lowest temperature rating available in standard manufacture for its type.
- D. Ballasts shall be located in luminaire they serve, unless otherwise noted.
- E. Electronic Fluorescent Ballasts:
  - 1. Compact fluorescent lamps, 13 Watts and above, use only electronic programmed rapid start ballasts.
  - 2. Linear fluorescent lamps, T8, T5 and T5HO type, shall use programmed rapid start electronic ballasts.
  - 3. Multi-lamp programmed rapid start ballasts shall be of the series sequence type.
  - 4. Ballasts shall not contain any Polychlorinated Biphenyl (PCB).
  - 5. Ballasts shall:
    - a. Be ETL Certified, CBM Certified, and UL Listed, and meet or exceed NEMA and ANSI Standards.
    - b. Be Class P thermally protected per NEC.
    - c. Be Class A sound rated.
    - d. Operate lamps as scheduled.
    - e. Maintain constant light output over entire operating voltage range.
    - f. Operate lamps at frequency of 40 42 kHz or higher with less than 2% flicker.

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- g. Meet or exceed EMI and RFI limits set by Federal Communications Commission (FCC) rules and regulations, Title 47 CFR part 18.
  - h. Maintain the following performance:
    - 1) Lamp Current Crest Factor  $\leq 1.6$
    - 2) Total Harmonic Distortion  $\leq 20\%$
    - 3) Third Harmonic Distortion  $\leq 10\%$
    - 4) Power factor  $\geq 0.98$
  - i. Be equipped with a cut-off circuit that senses over-voltage condition to lamp for end-of-life protection.
  - j. Have a maximum case temperature test point of  $75^{\circ}\text{C}$ .
  - k. Tolerate operation in ambient temperatures up to  $55^{\circ}\text{C}$ .
  - l. Contain auto restart circuitry in order to restart lamps without resetting power.
  - m. Be of metal can construction to meet all plenum requirements and to eliminate the need for extra grounding wires.
6. Ballast case temperature shall not exceed  $15^{\circ}\text{C}$  temperature rise
- F. Electronic Fluorescent Dimming Ballasts:
- 1. Contractor shall be responsible for compatibility of lamp, electronic dimming ballasts, dimming controls, daylight sensors and occupancy sensors.
  - 2. Contractor shall provide single, two, and three lamp electronic dimming ballasts.
  - 3. Shall meet requirements for electronic fluorescent ballasts.
  - 4. Preheat lamp cathodes before applying arc voltage to ensure rated lamp life is not diminished.
  - 5. Internally limit inrush current to not exceed three amps at 277 volts or seven amps at 120 volts.
  - 6. Have a dimming range from 100% to 10 or 1% for T-5, T-5HO and T-8 linear lamps, 100% to 5% for T4 and T5 bent lamps.
  - 7. Shall be inaudible in a 27 dB ambient throughout dimming range.
  - 8. Lead length from electronic dimming ballast to lamp socket shall not exceed 7 ft for T-8 or 3 ft for T-5 lamps.
  - 9. Maintain:
    - a. Lamp Current Crest Factor  $\leq 1.7$
    - b. Total Harmonic Distortion  $\leq 20\%$
    - c. Power Factor  $\geq 0.98$
    - d. Ballast Factor = .85
- G. Emergency Fluorescent Ballasts:
- 1. Shall operate 1 lamp at 60% output for minimum of 90 minutes.
  - 2. Nickel-cadmium battery Field replaceable
  - 3. Installed inside luminaires.
  - 4. Solid state charging
  - 5. Battery to be recharged within 24 hrs.
  - 6. Remote battery test switch. Automatic testing every 30 days for 30 seconds and once a year for 90 minutes. Provide with flashing indicator light and audible alarm.

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- H. Magnetic High Intensity Discharge (HID) Ballasts:
1. Provide as indicated on Luminaire Schedule, per manufacturer's recommendations and mounting conditions.
  2. Ballasts shall be high power factor premium constant wattage type with a minimum power factor of 90%
  3. Be for 60 Hz operation.
  4. Have thermal protection integral with ballast.
  5. Be fused.
  6. Be rated at lowest possible sound level for type provided.
  7. Meet or exceed NEMA and ANSI Standards.
  8. Metal Halide Ballasts shall be Pulse start type when available for said wattage.
  9. High-Pressure Sodium (HPS) Ballasts shall be equipped with solid-state igniter/starter having an average life in pulsing mode of 10,000 hours at an igniter/starter case temperature of 90°F.
  10. Provide all necessary hardware for remote mounted ballasts.
  11. Contractor shall verify that ballasts are appropriate for use with lamp type, voltage, distance between lamp and ballast, and remote mounting conditions.
- I. Electronic High Intensity Discharge (HID) Ballasts:
1. Provide as indicated on Luminaire Schedule, per manufacturer's recommendations and mounting conditions.
  2. Contractor shall verify that ballasts are appropriate for use with lamp type, voltage, distance between lamp and ballast, and remote mounting conditions.
  3. Provide electronic ballasts for Ceramic Metal Halide lamps with the following features:
    - a. Integrated electronic ballast, igniter and capacitor
    - b. Operating Voltage: Match system voltage, or universal voltage
    - c. Power Factor  $\geq 95\%$
    - d. Total Harmonic Distortion  $\leq 15\%$
    - e. Lamp Current Crest Factor  $\leq 1.3$
    - f. Sound Rating: Class "A"
    - g. Equipped with "Turn Off" safety function to prevent excessive ballast pulsing under conditions of failed lamp, no lamp, or other sustained abnormal conditions
    - h. Not more than  $\pm 0.5$  percent variation in output power with a  $\pm 10\%$  variation in input line voltage
    - i. Comply with FCC Part 18C for non-consumer limits for EMI and RFI. Ballast shall be UL Listed.

## 2.4 INDUCTION GENERATORS

1. Provide as indicated on Luminaire Schedule, per manufacturer's recommendations and mounting conditions.
2. Contractor shall verify that ballasts are appropriate for use with lamp type, voltage, distance between lamp and ballast, and remote mounting conditions.
3. Provide power coupler and generator for QL lamps with the following features:
  - a. Power coupler with antenna, heat conduction rod with mounting flange, and coaxial connecting cable.
  - b. HF generator with an oscillator to provide high-frequency power and maintain a gas discharge in the discharge vessel.
  - c. HF generator shall provide a well-stabilized oscillator power supply
  - d. HF generator shall provide filtering of the mains power.



- e. HF generator shall provide good power factor and low harmonic distortion of the mains power.

## 2.5 TRANSFORMERS

- A. Transformers shall be:
  - 1. Sized to compensate for voltage drop over indicated distances
  - 2. Locally fused
- B. Transformers shall have line voltage switch within reach.
- C. Provide adequate ventilation to meet code and manufacturers requirements.

## 2.6 LED DRIVERS

- A. Contractor shall be responsible for confirming compatibility of LED luminaires and drivers provided, and compatibility of lighting controls and dimming drivers provided.
- B. LED Drivers shall be:
  - 1. Provided in accordance with luminaire manufacturer's recommendations.
  - 2. Sized appropriately for total connected wattage load and to compensate for voltage drop over indicated distances when mounted remotely.
  - 3. Provide with the following characteristics:
    - a. Power Factor >90%
    - b. Total Harmonic Distortion <20%
    - c. Lamp Current Crest Factor < 1.5
    - d. Sound Rating Class A
  - 4. Provide adequate ventilation to meet code and manufacturers requirements.

## 2.7 TANDEM WIRED LUMINAIRE PAIRS

- A. Luminaires may be tandem wired in a master/slave configuration to minimize the use of single lamp ballasts or to minimize circuit connection points.
- B. Tandem wiring shall consist of a UL Listed wiring system fabricated by the luminaire manufacturer to interconnect ballast wiring from the "master" luminaire to the unballasted "slave" luminaire.
- C. Wiring shall be:
  - 1. 12 AWG ga minimum
  - 2. Enclosed in 3/8" diameter flexible metallic conduit.
- D. Tandem wiring shall not be used for luminaires spaced greater than 10 ft apart (on center).
- E. Support conduit with nylon tie wraps or metal clips.

## 2.8 LAMPS

- A. Provide lamps as noted on Luminaire Schedule.

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- B. Provide lamps of same type from same manufacturer.
  - C. Where a specific lamp manufacturer has been indicated in the Luminaire Schedule, lamps shall be supplied from named manufacturer only.
  - D. Linear fluorescent lamps shall be:
    - 1. Rapid start
    - 2. Triphosphor
    - 3. Minimum CRI of 80
    - 4. Color temperature as noted on Luminaire Schedule
  - E. Compact fluorescent lamps shall be:
    - 1. Triphosphor
    - 2. Four pin
    - 3. Minimum CRI of 80
    - 4. Color temperature as noted on Luminaire Schedule
  - F. Metal halide lamps 100 watts or lower, shall be:
    - 1. Ceramic metal halide
    - 2. Minimum CRI of 80
    - 3. Color temperature as noted on Luminaire Schedule
    - 4. Color temperature shall not vary more than 200 Kelvin over rated lamp life.
  - G. Metal Halide lamps 150 watts or higher, shall be:
    - 1. Metal halide lamps
    - 2. Minimum CRI of 70
    - 3. Color temperature as noted on Luminaire Schedule
    - 4. Provide pulse-arc lamps when available.
  - H. Induction lamps shall be:
    - 1. QL Induction lamps.
    - 2. Minimum CRI of 80.
    - 3. Color temperature as noted on Luminaire Schedule.
    - 4. No color shift.
    - 5. Universal operating position.
  - I. Mercury Vapor and Metal Halide Lamps shall have extinguishing mechanisms to terminate operation in event outer globe of lamp is broken, punctured, or missing.
  - J. Incandescent lamps shall be rated for 130-volt operation, except quartz lamps and lamps which are dimmed shall be rated for 120-volt operation.
  - K. Low voltage incandescent lamps, MR16 type, shall have 10,000 hour rated life at 12V and be Ushio Ultraline.
  - L. Provide all other lamp types and special purpose lamps as noted on Luminaire Schedule.

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## PART 3 EXECUTION

### 3.1 INSTALLATION

- A. Marking:
1. Voltage identification: Luminaires designed for voltages other than 110-125 volt circuits shall be clearly marked with rated voltage.
  2. Lamp/ballast coordination: Luminaires equipped with ballast for operation of rapid start lamps shall be plainly marked "Use Rapid Start Lamps Only". Similarly, luminaires equipped with ballasts or other components requiring use of specific types of lamps shall be plainly marked.
  3. Markings must be clear and shall be located to be readily visible to service personnel but invisible from normal viewing angles when lamps are in place.
- B. Installation of Luminaires:
1. Lamps, glassware, reflectors and refractors shall be clean and free of chips, cracks and scratches.
  2. Install decorative luminaires, reflector cones, baffles, aperture plates, lenses, trims, and decorative elements of recessed luminaires after completion of ceiling tile, plastering, painting, and general cleanup is completed. Where luminaire location or construction does not permit sequential installation, all reflectors, lenses, flanges and other visible surfaces shall be carefully protected.
  3. Locations
    - a. Install luminaires at locations and heights as indicated.
    - b. Do not scale electrical drawings for locations of luminaires.
    - c. Architectural reflected ceiling plans show locations of luminaires.
    - d. Where noted on the drawings, the exact location of luminaires shall be confirmed (in the field) with the Architect/Engineer prior to installation.
    - e. Where luminaires are to be concealed, or surface mounted in highly visible public spaces, a small sampling of luminaires shall be installed, adjusted and aimed for Architect/Engineer's review approval, prior to installing remaining luminaire of same type.
    - f. Mount all luminaires so as to maintain full range of motion.
    - g. Install luminaires plumb, square, and level with ceilings and walls.
    - h. Coordinate stem, rod, chain, or aircraft cable hanger lengths with job conditions.
    - i. Industrial type luminaires in unfinished areas, which are near obstructions such as ducts and pipes, shall be:
      - 1) Suspended so that bottom of luminaire is no higher than bottom of obstruction
      - 2) Located at height of lowest luminaire
      - 3) Minimum height: 8'-0"
      - 4) Shall not be located until locations of obstructions are determined.

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4. Support
    - a. Support surface mount luminaires from building structure.
    - b. Metal decking shall not be pierced for luminaire support.
    - c. Provide luminaires and/or luminaire outlet boxes with hangers to support luminaire weight.
    - d. Provide plaster frames for recessed luminaires in plaster ceilings.
    - e. Recessed luminaires shall be supported with 12 ga wire hangers, 2 per luminaire, at diagonally opposite corners.
    - f. Luminaires over 55 lbs shall be supported with 12 gage wire hangers, 4 per luminaire, 2 at 45 degree diagonals, and two perpendicular to structure. Wire hangers and attachment to structure shall be capable of supporting 4 times luminaires weight.
    - g. Surface mount luminaires installed in grid ceilings shall be supported by independent support clips and 12 ga wire.
    - h. Exit signs installed in grid ceilings shall be supported by electrical box hanger and additional 12 ga wire installed from box to structure.
    - i. Support surface mounted luminaires greater than 2 ft in length at a minimum of each additional 2 ft, or as recommended by manufacturer.
    - j. Brace suspended luminaires installed near ducts or other constructions with solid pendants or threaded rods.
    - k. Rigidly align continuous rows of luminaires.
    - l. Luminaire types with remote mounted ballast shall have:
      - 1) Proper support for ballast weight.
      - 2) Mounting distance from remote ballast to luminaire per manufacturer's recommendations.
  5. Mounting and Enclosures
    - a. Install flush mounted luminaires to eliminate light leakage.
    - b. For luminaires mounted adjacent to insulation, provide barrier to prevent insulation from coming in contact with luminaire, unless luminaire is approved for installation in contact with such insulation.
    - c. Provide approved fire rated enclosures around luminaires in fire rated ceilings.
  6. Conduit and Wiring
    - a. Wire for connections to lamp sockets and auxiliaries shall be suitable for temperature, current, and voltage conditions.
    - b. Recessed luminaires shall have final connections made with flexible metal conduit, not in excess of 72", with THHN conductors and green wire ground conductor.
    - c. Conduit shall be hidden from normal view in all possible cases. In public areas where surface mounted conduit must be used, contractor shall install conduit as unobtrusively as possible. Contractor shall obtain field approval by the architect for all exposed conduit runs prior to rough in.
  7. Cast-in Luminaires:
    - a. Where installed in tree grates, furnish burial light lens and louver to tree grate manufacturer for coordination of opening.
    - b. Provide adequate drainage system per manufacturer's recommendations.
- C. Installation of Outdoor Pole Bases
1. General Contractor shall provide bases for luminaires.

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2. Electrical Contractor shall:
    - a. Rough-in conduits
    - b. Furnish information to General Contractor for spacing, base dimensions, heights, orientation of bases, etc.
  3. Where square or rectangular poles or luminaire heads are used, Contractor shall verify orientation with Architect.
- D. Pole Installation:
1. Install luminaires, poles, hardware, etc., for complete system.
  2. Use web fabric slings (not chain or cable) to raise and set poles.
- E. Lamps:
1. Provide new lamps delivered in original manufacturer's cartons.
  2. Fluorescent and metal halide lamps shall be energized continuously for not less than 100 hours for proper seasoning.
- F. Grounding:
1. Ground luminaires and metal poles according to Division 26 Section "Grounding and Bonding for Electrical Systems".
  2. Poles:
    - a. Install 10 ft driven ground rod at each pole.
  3. Nonmetallic Poles:
    - a. Ground metallic components of lighting unit and foundations. Connect luminaires to grounding system with No. 10 AWG conductor.
- G. Spare Parts:
1. Provide 5% spare lamps for each type in Luminaire Schedule
    - a. Spare lamps shall be delivered to Owner in new condition and in original packaging.
    - b. Manufacturer and model number shall match those installed in the project's luminaires.
  2. Provide spare ballasts, 1 for every 100 of each type and rating installed. Furnish at least one of each type.
  3. Provide spare globes and guards, 1 for every 20 of each type and rating installed. Furnish at least one of each type.
  4. Provide spare parabolic louvers and reflector cones, 1 for every 100 of each type. Furnish at least one of each type.
  5. Provide spare plastic diffusers and lenses, 1 for every 100 of each type and rating installed. Furnish at least one of each type.

### **3.2 SUBSTANTIAL COMPLETION**

- A. Quality Control:
1. At Date of Substantial Completion, replace lamps which are not operating properly.
  2. Replace any lamps used as worklights during construction phase.
  3. Protection wrapping on louvered (parabolic) luminaires shall be removed before installation of furniture, but after finish work is complete.
  4. Deliver spare lamps to Owner's representative.

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- B. Tests:
1. Give advance notice of dates and times for field tests.
  2. Provide instruments to make and record test results.
  3. Verify normal operation of each luminaire after luminaires have been installed and circuits have been energized.
  4. Replace or repair malfunctioning luminaires and components, then retest. Repeat procedure until all units operate properly.
  5. Report results of tests.
- C. Adjusting and Cleaning:
1. Clean luminaires of handling marks, dust and dirt.
  2. Cleaning and touch-up work shall be performed in accordance with luminaire manufacturer's recommendations.
  3. Damaged luminaires or components shall be replaced with new.
  4. Keep luminaires clean and protected for remainder of construction period.
  5. Verify orientation of directional luminaires prior to installation.
    - a. This includes wall washers, cove lighting, floodlights, exterior area lights and adjustable accent luminaires. Contractor shall provide electrician's services to aim, adjust, and focus luminaires, as required, at the direction of Architect/Engineer. These electricians shall be available at times designated by the Architect/Engineer and shall be provided at no extra charge to the Owner over base bid. Contractor shall provide equipment for luminaries' focus including ladders and mechanical lifting systems.
  6. Program preset dimming system lighting levels.
  7. Exterior poles, bollards, bases and other exterior luminaires shall be painted to match factory color where finish has been damaged.
  8. No light leaks shall be permitted at the ceiling line from any visible part or joint.
- D. Training
1. Contractor shall provide qualified personnel onsite to provide a minimum of three days of training to Owner's representatives.
  2. This training shall cover:
    - a. Luminaire use and maintenance
    - b. Architectural lighting system use and maintenance
    - c. Group relamping cycles

**END OF SECTION**

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## **SECTION 27 0528.29CR**

### **HANGERS AND SUPPORTS FOR COMMUNICATIONS SYSTEMS**

#### **PART 1 GENERAL**

##### **1.1 SCOPE**

- A. This section includes product and execution requirements for items unique to communications systems and not included in Division 26 sections.
- B. Refer to Section 26 0000.2CR and 26 0529CR - Hangers and Supports for Electrical Systems - Part 1 for requirements for Reference Standards, Submittals, Quality Assurance, Delivery/Storage/Handling, and Guarantee.
- C. All hangars and supports for communication system raceways and boxes are included and shall be provided by Division 26 contractor.

##### **1.2 RELATED WORK**

- A. Related Division 27 Sections include:
  - 1. Section 27 0528.33CR - Raceway and Boxes for Communications Systems
- B. Related sections in other Divisions of Work:
  - 1. Section 26 0529CR - Hangers and Supports for Electrical Systems

##### **1.3 REFERENCES AND STANDARDS**

- A. The Work under this Section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and section under Division 01 General Requirements.

#### **PART 2 PRODUCTS**

##### **2.1 PRODUCTS COMMON WITH ELECTRICAL SYSTEMS**

- A. Refer to Section 26 0529CR - Hangers and Supports for Electrical Systems - Part 3 for:
  - 1. Hanger Rods
  - 2. Beam Clamps
  - 3. Wall Anchors
  - 4. Metal Framing

## **PART 3 EXECUTION**

### **3.1 PRODUCTS COMMON WITH ELECTRICAL SYSTEMS**

- A. Refer to Section 26 0529CR - Hangers and Supports for Electrical Systems - Part 3 for all products identified in Part 1.

**END OF SECTION 27 0528.29CR**



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**SECTION 27 0528.33CR**

**RACEWAY AND BOXES FOR COMMUNICATIONS SYSTEMS**

**PART 1 GENERAL**

**1.1 SCOPE**

- A. This section includes product and execution requirements for items unique to communications and not included in Division 26 sections.
- B. All raceway and boxes for communication system raceways and boxes are included and shall be provided by Division 26 contractor.

**1.2 DESCRIPTION**

- A. Refer to Section 26 0533CR - Raceway and Boxes for Electrical Systems - Part 1 for requirements for Standards, Submittals, Quality Assurance, Delivery/Storage/Handling, and Guarantee for:
  - 1. Outlet Boxes
  - 2. Pull and Junction Boxes
  - 3. Raceways and Wireways (including sleeves, expansion fittings, penetrations and seals)
  - 4. Poke-through Fittings
  - 5. Floor Boxes
  - 6. Cable Supports

**1.3 RELATED WORK**

- A. Related Division 27 Sections include:
  - 1. Section 27 0526CR - Grounding and Bonding for Communications Systems
  - 2. Section 27 0528.29CR - Hangers and Supports for Communications Systems
- B. Related sections in other Divisions of Work:
  - 1. Section 26 0533CR - Raceway and Boxes for Electrical Systems

**1.4 REFERENCES AND STANDARDS**

- A. The Work under this section is subject to requirements of the Contract Documents including the General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

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## **PART 2 PRODUCTS**

### **2.1 PRODUCTS COMMON WITH ELECTRICAL SYSTEMS**

- A. Refer to Section 26 0533CR - Raceway and Boxes for Electrical Systems - Part 2 for Outlet Boxes for Communications, Pull and Junctions Boxes for Communications, Raceways for Communications, and other products identified in Part 1.

### **2.2 COMMUNICATIONS RACEWAYS**

- A. Optical fiber/communications cable raceway (innerduct)
  - 1. UL 2024; flexible type, approved for plenum and general purpose installation as indicated on drawings.
  - 2. Indoor Innerduct: Corrugated.
  - 3. Color:
    - a. General Purpose: Orange.
    - b. Riser: Orange.
    - c. Plenum: Orange.
  - 4. Manufacturers: Carlon; Pyramid; Approved equal.

### **2.3 MULTI-CELL FLEXIBLE RACEWAY**

- A. Manufacturers: MaxCell™.
- B. Innerduct shall be a flexible, multi-celled, textile innerduct system designed for communications.
- C. Innerduct shall meet the following physical requirements:
  - 1. Tensile strength: 2500-lbs or better
  - 2. Melting Point: 480-degrees F or better
  - 3. Resistant to ground chemicals and petroleum products
  - 4. Unaffected by mud, silt or debris after placement of cable.
- D. Innerduct shall be pre-lubricated for lower friction during innerduct and cable installation.
- E. Innerduct Color shall be WHITE.
  - 1. Innerduct shall include a color coded stripe allowing for identification of each bundle.
- F. Each cell shall include a color-coded pull tape.
- G. Product shall be available in a variety of sizes and cell counts. Refer to project Drawings.

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## **PART 3 EXECUTION**

### **3.1 PRODUCTS COMMON WITH ELECTRICAL SYSTEMS**

- A. Refer to Section 26 0533CR - Raceway and Boxes for Electrical Systems - Part 3 for Outlet Boxes for Communications, Pull and Junctions Boxes for Communications, Raceways for Communications, and other products identified in Part 1.

### **3.2 COMMUNICATIONS RACEWAYS**

- A. Optical Fiber Communications Cable Raceway (Innerduct):
  1. Minimum innerduct size: 1", unless otherwise noted on drawings.
  2. Extend innerduct to termination and/or storage enclosure.
  3. Install couplings designed for innerduct size and type where innerduct enters a termination and/or storage enclosure.
  4. Splice innerduct segments using couplings designed for that purpose, where not installed in a continuous length.
  5. Install 200 lb nylon pull cord in empty innerduct. Leave at least 12" of slack at each end of pull wire. Cap innerduct at both ends.
  6. Label innerduct with tags indicating cable type and cables contained therein.
    - a. Label in each maintenance hole, pull box and communications equipment room, where exiting a conduit and at 10 ft intervals in cable tray or where otherwise exposed.

### **3.3 MULTI-CELL FLEXIBLE RACEWAY**

- A. Segment conduits to increase capacity.
  1. Provide quantity and size per project Drawings.
- B. Install per manufacturers recommendations.

**END OF SECTION**



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## SECTION 28 3116CR

### MULTIPLEXED FIRE DETECTION AND ALARM SYSTEMS

#### PART 1 GENERAL

##### 1.1 RELATED WORK

- A. Section 26 0000CR - General Electrical Requirements
- B. Section 26 0519CR - Low-Voltage Electrical Power Conductors and Cables
- C. Section 26 0526CR - Grounding and Bonding for Electrical Systems
- D. Section 26 0533CR - Raceway and Boxes for Electrical Systems
- E. Section 26 0553CR - Electrical Systems Identification
- F. Section 28 3116 – Multiplexed Fire Detection and Alarm Systems

##### 1.2 REFERENCE

- A. Work under this section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

##### 1.3 DESCRIPTION

- A. Clean Room fire alarm devices shall be an extension of the fire alarm system installed on “e3” series plans and risers. “cr-e” series drawings indicate devices particular to the Clean Room, but the system shall be an extension of the entire building fire alarm system.
- B. Refer to specification section 28 3116 for materials, devices, and equipment components of the fire alarm system applicable to the remainder of the building and are applicable to the Clean Room.
- C. The Clean Room is air plenum system. All fire alarm wiring allowed to be installed in free air per specification 28 3116 shall be plenum rated.
- D. All VESDA system materials shall be plenum rated.
- E. The equipment listed below, VESDA system, is particular to the Clean Room and shall be installed in accordance with the plans and specifications.
- F. A VESDA Laser PLUS, very early warning air sampling smoke detector, shall be installed throughout the clean room areas designated on the drawings.

- G. System shall act as initiating device for interface and activation of Multiplexed Fire Alarm Detection System.
- H. Contractor shall engage the services of the manufacturer to design all system components and provide installation documents for contractor for installation.
- I. The system shall consist of highly sensitive LASER based smoke detector using aspirated air sampling and connected to one or more sampling pipes. It shall be provided with a sample pipe inlet(s), internal flow monitoring, smoke detection and a facility for exhaust pipe connection. Reset, disable, test and fault determination functions will be available via the field service access door. System configuration will be provided through AutoLearn Smoke and Flow functions, also available via the field service access door.
- J. The system shall support Pre-Engineered sampling pipe network designs with verified calculations in addition to custom sampling pipe network designs using a computer based design modeling tool.
- K. Provide a Remote Display unit to monitor each detector, and a Programmer to configure settings.
- L. General Scope of work
  - 1. Furnish and install complete air sampling smoke detection system including:
    - a. Highly sensitive LASER-based smoke detector, aspirator, and filter.
    - b. Air sampling pipe network to transport air to the detection system, supported by calculations from a computer-based design modeling tool.
    - c. Intelligent remote displays and/or a high level interface with the building fire alarm system, or a dedicated VESDA System Management (VSM) graphics package.
    - d. Interface either hardwired or via communication protocol with Multiplexed Fire Alarm and Detection System.
    - e. Programming of smoke obscuration and diction set points of Alert, Action, and Fire 1 output relays.

#### 1.4 REFERENCE STANDARDS

- A. IBC - 2006 - International Building Code
- B. IFC - 2006 - International Fire Code
- C. NECA 305 - Standard for Fire Alarm System Job Practices
- D. NFPA 72 - National Fire Alarm Code
- E. NFPA 75 - Standard for Protection of Information Technology
- F. NFPA 101 - Life Safety Code
- G. UL 268 - Smoke Detectors for Fire Protective Signaling Systems

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## 1.5 QUALIFICATIONS

- A. Equipment shall be supplied by company specializing in manufacture and design of highly sensitive aspiration type smoke detection systems with 5 years documented experience
- B. Work shall be performed by licensed contractor authorized and trained by the manufacturer to calculate/design, install, test and maintain the air sampling system and shall be able to produce a certificate stating such on request.
- C. Proof of 5 years documented experience and factory authorization to furnish and install equipment proposed shall be furnished.
- D. Contractor shall be located within 100 miles or less from site of project.

## 1.6 SUBMITTALS

- A. Submit following for approval prior to ordering any equipment:
  - 1. Manufacturer's catalog specification cuts and printed descriptive literature on components being provided.
  - 2. Bill of materials listing part number and quantity of components and devices.
  - 3. Standby battery power calculations.
  - 4. Site drawings showing pipe layouts and airflow calculations (ASPIRE™) and performance criteria.
  - 5. Schematic diagrams, specific to this project only, of all circuits from output relays to terminal strip(s) associated with associated system control panel.
    - a. Diagrams shall show schematic wiring of equipment; and connections to be made to panels or control devices.
    - b. Terminal connections in equipment shall be numbered to correspond to diagrams.
    - c. Wiring diagrams shall be coordinated so that terminal numbering, circuit designation and equipment or device designations are same on both sets of drawings.
  - 6. Copy of the manufacturer's installation, operation and maintenance manuals shall be supplied upon completion of the installation.
  - 7. System commissioning data shall be supplied (in a format recommended by the manufacturer and per the instructions provided by the manufacturer) within 30 days of completion of the installation.

## PART 2 PRODUCTS

### 2.1 MANUFACTURERS

- A. Vision Fire and Security
- B. Fenwal

### 2.2 PERFORMANCE REQUIREMENTS

- A. Shall be UL listed to cover up to 20,000 ft<sup>2</sup>

- B. The detector shall be approved to provide very early smoke detection and provide a minimum of three output levels corresponding to Alert, Action, and Fire 1. The Alert, Action, and Fire 1 thresholds shall be programmable and able to be set at sensitivities ranging from 0.0015 to 6.4% obs/ft.
- C. The detector shall provide fault indication on the unit using configurable fault output relay or via VSN.
- D. The detector shall be self-monitoring for filter contamination.
- E. The system shall allow programming of:
  - 1. Three smoke threshold alarm levels;
  - 2. Separate time delays for each output level;
  - 3. Faults including airflow, detector, power, filter and network as well as an indication of the urgency of the fault;
  - 4. Seven or more configurable relay outputs for remote indication of alarm and fault conditions.

### **2.3 DETECTOR ASSEMBLY**

- A. The detector shall consist of a highly sensitive laser based smoke detector, an aspirator, and a dual-stage filter cartridge.
- B. The Laser Detection Chamber shall be of the mass Light Scattering type and capable of detecting a wide range of smoke particle types of varying size. A particle counting method shall be employed for the purposes of
  - 1. Preventing large particles from affecting the true smoke reading
  - 2. Monitoring contamination of the filter (dust & dirt etc.) to automatically notify when maintenance is required.
  - 3. The Particle counting circuitry shall not be used for the purpose of smoke density measurement.
- C. The detector shall incorporate an ultrasonic flow sensor in the pipe inlet port for airflow monitoring purposes.
- D. The Laser Detection Chamber shall incorporate a separate secondary clean air feed from the filter; providing clean air barriers across critical detector optics to eliminate internal detector contamination.
- E. The detector shall not use adaptive algorithms to adjust the sensitivity from that set during commissioning. A learning tool shall be provided to ensure the best selection of appropriate alarm thresholds during the commissioning process.
- F. It shall be modular, with each detector optionally monitored by a Display featuring LEDs and a sounder. The system shall be configured by a Programmer that is either integral to the system, portable or PC based.
- G. The detector shall also be configured by a PC and allow programming of three or more smoke threshold alarm levels, time delays, faults including airflow, detector, power and filter as well as an indication of the urgency of the fault and three relay outputs for remote indication of alarm and fault.



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- H. The Detector, Filter, Aspirator and Relay Outputs shall be housed in a mounting box and shall be arranged in such a way that air is drawn from the fire risk and a sample passed through the Dual Stage Filter and Detector by the Aspirator.
  - I. The Detector shall be LASER-based type and shall have an obscuration sensitivity range of 0.0015% obs/ft – 6% obs/ft.
  - J. The detector shall have control switches for Reset, Disable, Test and restricted access switches for Alarm Setup and Flow Setup.
  - K. The Detector shall have at least three independent field programmable smoke alarm thresholds across its sensitivity range with adjustable time delays for each threshold between 0-60 seconds.
  - L. The Detector shall also incorporate facilities to transmit the following faults using VESDAnet or relays:
    - 1. Detector
    - 2. Air flow
    - 3. Filter
    - 4. System
    - 5. Zone
    - 6. Network
    - 7. Power
    - 8. Urgent and Minor faults. Minor faults shall be considered as servicing or maintenance signals. Urgent faults indicate the unit may not be able to detect smoke.
  - M. The detector shall have four in-line sample pipe inlets and must contain a flow sensor for each pipe inlet. Both Minor and Urgent flow faults shall be reported.
  - N. The filter must be a two-stage disposable filter cartridge. The first stage shall be capable of filtering particles in excess of 20 microns from the air sample. The second stage shall be ultra- fine, removing more than 99% of contaminant particles of 0.3microns or larger, to provide a clean air barrier around the detector's optics to prevent contamination and increase service life.
  - O. The aspirator shall be a purpose-designed rotary vane air pump. It shall be capable of supporting single or multiple sampling pipe runs as necessary for each zone, with a transport time of less than 60 seconds or as appropriate codes dictate.
  - P. The Assembly shall contain relays for alarm and fault conditions. The relays shall be software programmable to the required functions. The relays shall be rated at 2 AMP at 30 VDC. Remote relays shall be available as an option and either configured to replicate those on the detector or programmed differently.
  - Q. The Assembly shall be surface mounted to a wall. The unit shall be invertible in either option such that controls and displays are readable and not upside down.

- R. The assembly shall have built-in event and smoke logging. It shall store smoke levels, alarm conditions, operator actions and faults. The date and time of each even shall be recorded. Each detector (zone) shall be capable of storing up to 18,000 events and shall not require the presence of a display in order to do so.

## 2.4 DISPLAYS

- A. The detector will be provided with LED indicators only.
- B. Each Detector shall provide the following features at a minimum:
1. Independent high intensity alarm indicators for Pre-Alarm and Fire (Alert indicated by the Pre-Alarm LED flashing) corresponding to the alarm thresholds of the detector.
  2. Fault indicator.
  3. OK indicator.
  4. Isolate indicator.
  5. A single button supporting the following features:
    - a. Reset – (a single push of the button) Unlatches all latched alarm conditions on the assigned VLC zone.
    - b. Isolate – (push and hold) Isolates the individual VLC zone (inhibits Alarm and Fault relays and initiates the Fault relay).

## 2.5 DISPLAY MODULE

- A. A Detector Display module for each detector shall be located within the detector.
- B. Each Display shall provide the following features at a minimum:
1. A 20 segment bargraph display.
  2. Independent high intensity alarm indicators, Alert, Action, and Fire 1 corresponding to the three alarm thresholds of the detector.
  3. Alarm threshold indicators for Alert, Action and Fire 1.
  4. Detector fault and airflow fault indicators.
  5. Faults originating in the particular detector zone (Zone Fault) shall be distinguished from those produced by the overall smoke detection system and from those resulting from network wiring errors (Network Fault). LED indicators shall be provided for each fault category.
  6. Minor and urgent fault LED indicators.
  7. A remotely mounted Display may be optionally equipped with 7 or 12 configurable relays for signaling alarm and fault conditions.
  8. Four buttons supporting the following features:
    - a. Mode/Test - Scrolls through the information on the Display's digital display: Sensitivity (Fire 1 Threshold setting), current smoke level and VLP Zone number. When pressed and held initiates a lamp test on the individual display module.
    - b. Silence - Silences all devices on the system
    - c. Reset - Unlatches all latched alarm conditions on the assigned VLP zone.
    - d. Isolate - Isolates the individual VLP zone (inhibits Alarm and Fault relays and initiates Isolate relay).

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## 2.6 PROGRAMMERS

- A. Programming shall be performed using a Windows® application running on a PC connected through a High Level Interfacing unit (PC-Link HLI)
- B. Provide a remote Programmer module a portable hand-held unit.
- C. Each Programmer shall support the following features at a minimum:
  - 1. Programming of any device on the VESDAnet system.
  - 2. Viewing of the status of any device in the system.
  - 3. Adjustment of the alarm thresholds of a nominated detector.
  - 4. Setting of Day/night, weekend and holiday sensitivity threshold settings.
  - 5. Initiation of AutoLearn™, to automatically configure the detector's alarm threshold settings to suit the current environment.
  - 6. Multi-level password control.
  - 7. Programmable latching or non-latching relay operation.
  - 8. Programmable energized or de-energized relays.
  - 9. Programmable high and low flow settings for airflow supervision.
  - 10. Programmable aspirator speed control.
  - 11. Programmable maintenance intervals.
  - 12. Facilities for referencing with time dilution compensation.
  - 13. Testing of relays assigned to a specific zone to aid commissioning.

## 2.7 DEVICE NETWORKING REQUIREMENTS

- A. The devices in the smoke detection system shall be capable of communicating with each other via twisted pair RS485 cable. The network shall be able to support up to 250 devices (detectors, displays and programmers), of which at least 100 detectors can be supported.
- B. The network shall be capable of being configured in a fault tolerant loop for both short circuit and open circuit. Any communication faults shall be reported unambiguously and shall be clearly attributable to an individual device or wire link in the fault messages.
- C. PC based configuration tools shall be available to configure and manage the network of detectors.

## 2.8 POWER SUPPLY AND BATTERIES

- A. The system shall provide a regulated power supply of nominally 24V DC. The battery charger and battery shall comply with requirements of NFPA 72.
- B. Shall provide 24 hours standby battery backup followed by 30 minutes in an alarm condition.
- C. Shall be UL 1481 Listed to provide fire protection signaling.

- D. Provide Power Supply Fault Indication by use of form C contacts:
  - 1. AC Input
  - 2. Low AC input voltage
  - 3. Loss of battery voltage
  - 4. Short circuit fault

## 2.9 SAMPLING PIPE DESIGN

- A. Sampling Pipe
  - 1. The sampling pipe shall be smooth bore with an internal diameter between  $\frac{3}{4}$  to 1 inch. Normally, pipe with an outside diameter of 1 inch and internal diameter of  $\frac{3}{4}$ " should be used.
  - 2. The pipe material shall be UL 1887 Plenum rated CPVC and otherwise shall suitable for the environment in which it is installed.
  - 3. All joints in the sampling pipe must be air tight and made by using solvent cement, except at entry to the detector.
  - 4. The pipe shall be identified as Aspirating Smoke Detector Pipe along its entire length at regular intervals not exceeding the manufacturers' recommendation or that of NFPA Standard 72, local codes and standards.
  - 5. The far end of each trunk or branch pipe shall be fitted with an end cap and drilled with a hole appropriately sized to achieve the performance as specified and as calculated by the system design.
- B. Sampling Points
  - 1. Sampling holes shall not be separated by more than the maximum distance allowable for conventional point detectors as specified in the local codes and standards. Intervals may vary according to calculations.
  - 2. Each sampling point port shall be identified in accordance with NFPA Standard 72 requirements.
  - 3. Consideration shall be given to the manufacturer's recommendations and standards in relation to the number of sampling points and the distance of the sampling points from the ceiling or roof structure and forced ventilation systems.
  - 4. Sample port size shall be as specified by pre-engineered design requirements or by ASPIRE2 calculations for custom sample pipe networks.

## 2.10 WIRING

- A. Conduit:
  - 1. Refer to Section 26 0533CR Raceway and Boxes for Electrical Systems
  - 2. EMT thin walled, galvanized tubing, ANSI C-80.1.
- B. Conductors:
  - 1. Refer to Section 26 0519CR – Low-Voltage Electrical Power Conductors and Cables. Wiring shall also comply with local, state and national codes and as recommended by manufacturer.
  - 2. Copper, solid or stranded, #14 or larger, with tube THHN insulation, minimum rating of 600 volt.

3. Fire alarm signaling wire shall be in accordance with Article 760 of the National Electric Code, NFPA 70. Number and size of conductors shall be as recommended by the manufacturer, but shall be no less than 18 AWG for initiating device and signaling line circuit, and 14 AWG for notification appliance circuits.
4. All field wiring shall be supervised for open circuits, short circuits, and grounded conditions.
5. The control panel shall be connected to a separate dedicated branch circuit with a separate disconnect switch. This circuit shall be labeled FIRE ALARM CIRCUIT CONTROL.

## 2.11 SYSTEM OPERATION

- A. Detection Alarm Levels
  1. The laser based aspirating detection system shall have three independently programmable alarm thresholds. The three alarm levels shall have factory default configurations as follows:
    - a. Alarm Level 1 (Alert) Activate a visual and audible alarm in the fire risk area.
    - b. Alarm Level 2 (Action) Activate the electrical/electronic equipment shutdown relay and activate visual and audible alarms in the Clean Room Directory Office or other appropriate location.
    - c. Alarm Level 3 (Fire 1) initiates an alarm condition in the Fire Alarm Control Panel to activate all warning systems.
- B. Initial Detection Alarm Settings
  1. Initial settings for the alarm levels shall be determined by the requirements of the fire zone. However, the setting for Fire 1 (Alarm Level 3) shall always appear as 100% on the bar graph scale. Default settings of the unit shall be:
    - a. Alarm Level 1 (Alert) 0.025% Obs/ft
    - b. Alarm Level 2 (Action) 0.044% Obs/ft
    - c. Alarm Level 3 (Fire 1) 0.062% Obs/ft
  2. Initial (factory default) Alarm Delay Thresholds shall be:
    - a. Alarm Level 1 (Alert) 10 seconds
    - b. Alarm Level 2 (Action) 10 seconds
    - c. Alarm Level 3 (Fire 1) 10 seconds
    - d. Fault Alarm 5 seconds
  3. Fault Alarms
    - a. The Detector Fault relay shall be connected to the appropriate alarm zone on the Fire Alarm Control Panel in such a way that a Detector Fault would register a fault condition on the FACP. The Minor Fault and Isolate relays shall also be connected to the appropriate control system. Fault relays shall be energized in the Normal condition, so that upon complete loss of detector power, the FACP will annunciate a detector fault condition.
- C. Final Detection Alarm Settings
  1. Allow the detectors to run for a minimum of two weeks under normal operating conditions to determine baseline obscuration levels. Reprogram default settings of the unit as needed to minimize false alarms.

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## 2.12 CLEAN ROOM SMOKE DETECTION

- A. Provide following sequence of operation through control panel.
  - 1. Alarm Level 1 (Alert):
    - a. Activate a visual and audible alert at the VESDA Detector panel and/or Display Module.
    - b. Send Trouble signal to Building Management System.
  - 2. Alarm Level 2 (Action):
    - a. Activate a visual and audible alert at the VESDA Detector panel and/or Display Module.
    - b. Send Supervisory signal to Building Fire Alarm system.
  - 3. Alarm Level 3 (Fire 1)
    - a. Activate a visual and audible alert at the VESDA Detector panel and/or Display Module
    - b. Send Alarm signal to Building Fire Alarm system.

## PART 3 EXECUTION

### 3.1 GENERAL

- A. The contractor shall install the system in accordance with the Manufacturer's System Design Manual.
- B. Contractor shall provide 120V emergency power from emergency/life safety power panel EL2A. Provide dedicated circuits for all VESDA system components.

### 3.2 CAPILLARY SENSING NETWORK

- A. Where false ceilings are installed, the sampling pipe shall be installed above the ceiling, and capillary-sampling points shall be installed on the ceiling and connected by means of a capillary tube.
- B. The typical internal diameter of the capillary tube shall be  $\frac{3}{8}$ " , the maximum length of the capillary tube shall be 26 ft unless the manufacturer in consultation with the engineer have specified otherwise.
- C. The capillary tube shall terminate at a ceiling sampling point specifically designed and approved by the manufacturer. The performance characteristics of the sampling points shall be taken into account during the system design.

### 3.3 AIR SAMPLING PIPE NETWORK CALCULATIONS

- A. Air Sampling Pipe Network Calculations shall either be Pre-engineered pipe work setups as provided in the VESDA Laser Product Manual or for specific performance requirements that fall outside the pre-engineered designs, a sampling pipe aspiration-modeling program such as ASPIRE2 shall be used to provide air sampling pipe network calculations. Pipe calculations shall be supplied with the proposed pipe layout design to indicate the following performance criteria.

- B. Transport Time
  - 1. The manufacturer's recommended transport time (i.e. the time taken by smoke sampled to reach the detector) for the least favorable sampling point is less than 120 seconds.
  - 2. Local codes and standards may also apply. For example:
    - a. NFPA 72 120 Seconds
    - b. NFPA 76 60 Seconds
  - 3. The maximum transport time shall not exceed local code requirements.

### 3.4 COMMISSIONING TESTS

- A. The contractor shall allow for the manufacturer's representative to attend commissioning of the entire installation in the presence of the owner and/or its representative.
- B. The Contractor shall provide all necessary instrumentation, equipment, materials and labor.
- C. The Contractor shall record all tests and system calibrations and a copy of these results shall be retained on site in the System Log Book.

### 3.5 SYSTEM CHECKS

- A. Visually check all pipes to ensure that all joints, fittings, bends, sampling points, etc., comply with the Specification.
- B. Check the system to ensure the following features are operational and programmed in accordance with the specification.
  - 1. Alarm threshold levels,
  - 2. Pipes in use,
  - 3. Detector address,
  - 4. Display address
  - 5. Time and date,
  - 6. Time delays,
  - 7. Air flow fault thresholds,
  - 8. External button operable (Reset / Disable),
  - 9. Referencing
  - 10. Units set to U.S./S.I.,
- C. Check to ensure that all ancillary warning devices operate as specified.
- D. Check interconnection with Fire Alarm Control Panel to ensure correct operation.

### 3.6 TESTS

- A. Introduce smoke into the detector assembly to provide a basic Go / No-Go functional test.
- B. Verify that transport time from farthest sampling port does not exceed the local code requirements. Refer to NFPA 72 (and NFPA 76 if applicable) for transport time requirements.

- C. Activate the appropriate Fire Alarm zones and advise all concerned that the system is fully operational. Fill out the log book and commissioning report accordingly.
- D. Upon completion of successful test, Contractor shall:
  - 1. Certify system to Owner in writing
  - 2. Complete NFPA 1-7.2.1 record of completion form
  - 3. Provide as-builts and O&M manuals.

### **3.7 MANUFACTURER'S SERVICES**

- A. Supervision of installation shall be provided by trained service technician from manufacturer of fire alarm equipment.
- B. Technician shall be US certified and have had minimum of 2 years of service experience in fire alarm industry.
- C. Technician's name shall appear on equipment submittals and letter of certification from fire alarm manufacturer shall be sent to project engineer.
- D. Manufacturer's service technician shall be responsible for following items:
  - 1. Pre-installation visit to job site to review equipment submittals and verify method by which system shall be wired.
  - 2. Make periodic job site visits to verify installation and wiring of system.
  - 3. Upon completion of wiring, final connections shall be made under supervision of technician.
  - 4. At time of final checkout, technician shall give operational instructions to Owner and/or his representative.
  - 5. Job site visits shall be dated and documented in writing and signed by electrical contractor.
  - 6. Discrepancy shall be noted on document and copy kept in system job folder, which shall be available to project engineer any time during project.

### **3.8 WARRANTY**

- A. Contractor shall warrant completed fire alarm system wiring and equipment to be free from inherent mechanical and electrical defects for a period of 2 years from the date of substantial completion of project.
- B. Contractor shall post warranty period along with company's name and telephone number inside fire alarm panel.
- C. Warranty service for equipment shall be provided by system supplier's factory trained representative.
- D. Warranty shall include parts, labor and necessary travel.
- E. Occupied facility shall not be without UL and NFPA approved and fully operational fire alarm system for period longer than 2 hours. Emergency response shall be provided within 2 hours of notification, to contractor, of failure of system to perform operationally per UL and NFPA standards.



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- F. Non-emergency service calls shall be responded to within 24 hours of notification to contractor.
  - G. Repairs and/or replacement shall be completed within 72 hours of time of notification. Other than emergency, actual repairs and /or replacement shall be provided during normal working hours, Monday through Friday, excluding holidays.
  - H. If repair and/or replacement cannot be made within prescribed time, other means and methods of protection shall be provided to insure safety of building occupants during which time system is not in compliance with standards. This may involve up to and include hiring Owner approved qualified personnel to stand fire watch, at contractor's expense.

### **3.9 TRAINING**

- A. Contractor shall provide minimum of 4 hours system operation training for Owner, Architect/Engineer, and fire department personnel.
- B. Training session shall be at a time to be stipulated by the Owner.
- C. Training shall be completed prior to final inspection.

### **3.10 MAINTENANCE CONTRACT**

- A. Equipment manufacturer shall make available to Owner, maintenance contract proposal to provide minimum of 2 inspections and tests per year in compliance with NFPA-72 Codes.

### **3.11 SPECIAL CONSIDERATIONS**

- A. Contractor shall notify Owner's security officer 24 hours in advance of any zones inoperative for a period of time exceeding 2 hours.
- B. Existing fire alarm systems must be returned to full operation at end of each working day, or notification to campus security of what zones are inoperative on a daily basis in writing, hand delivered.

**END OF SECTION**

