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REVISION 0	SECTION 15060 PIPING SUPPORT SYSTEMS	

PART 1. GENERAL

1.01 REFERENCES

- A. The following is a list of standards which may be referenced in this section:
1. American Society for Testing and Materials (ASTM):
 - a. A123/A123M, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
 - b. A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvanealed) by the Hot-Dip Process.
 2. National Building Code of Canada (NBC)
 3. Manufacturers' Standardization Society (MSS):
 - a. SP 58, Pipe Hangers and Supports - Materials, Design and Manufacture.
 - b. SP 69, Pipe Hangers and Supports - Selection and Application.
 - c. SP 89, Pipe Hangers and Supports - Fabrication and Installation Practices.
 4. B31.1, Power Piping.
 5. B31.3, Process Piping.
 6. B31.9, Building Services Piping.
 7. CSA B51-03 boiler, Pressure Vessel, and Pressure Piping Code.

1.02 DEFINITIONS

- A. Design differential temperature: The temperature differential between the piping design temperature and outdoor winter 1 percent design temperature as defined by the governing building code.

1.03 SUBMITTALS

- A. Shop Drawings: Catalog information of piping supports
- B. Details of the piping supports for custom designed items.
- C. Revisions to support systems resulting from changes in related piping system layout or addition of flexible joints.

PART 2. PRODUCTS

2.01 GENERAL

- A. Special support and hanger details are shown for cases where standard catalog supports are inapplicable.

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2.02 MANUFACTURERS

- A. Standard Support Components:
 - 1. Anvil.
 - 2. Cooper B-Line.
 - 3. Or Approved Equal in accordance with B6.

- B. Channel Type Support and Framing Systems:
 - 1. Unistrut.
 - 2. Cooper B-Line.
 - 3. Power-Strut.
 - 4. Or Approved Equal in accordance with B6.

- C. Nonmetallic Support Components:
 - 1. Aickinstrut.
 - 2. Or Approved Equal in accordance with B6.

2.03 MATERIALS

- A. Standard Pipe Supports:
 - 1. Exposed: As tabulated in ANSI/MSS SP 58.

2.04 COMPONENTS

- A. Standard Component Types:
 - 1. Type Definition: Per MSS SP 58.
 - 2. General Service (0 degrees C to 48 degrees C) and Hot Service (50 degrees C to 230 degrees C):

Item	Type (MSS SP 58)	Notes
Horizontal Pipe Attachments (Bare)-General and Hot Service		
Clips	24	
Rings	6, 11	1
Bands	1	
Clamps	3	
Hanging Rollers	41, 43	
Supporting Rolls	44, 46	
Saddles	36, 37, 38	
Horizontal Pipe Attachments (Insulated)-General Service		
Clips	26	
Bands	1	2

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Item	Type (MSS SP 58)	Notes
Hanging Rollers	41, 43	2, 3
Supporting Rolls	44, 46	2, 3
Protective Shields	39, 40	
Saddles	36, 37, 38	2
Horizontal Pipe Attachments (Insulated)-Hot Service		
Bands	1	1, 2
Hanging Rollers	41, 43	2, 3
Protective Shields	39	
Supporting Rolls	44, 46	2, 3
Saddles	36, 37, 38	2
Vertical Pipe Attachments-General and Hot Service		
Riser Clamps	8, 42	
Hanger Rod Fixtures-General and Hot Service		
Turnbuckles	13, 15	
Swing Eyes	16, 17	
Clevises	14	
Building Structural Attachments-General and Hot Service		
Inserts	18	
C-Clamps	19, 23	
Beam Clamps	20, 21, 25, 27, 28, 29, 30	
Welded Attachments	22, 57, 58	
Brackets	33, 34	
Notes: 1. Use for piping 60 mm and smaller. 2. Use rigid insulation insert under hanger. 3. Use insulation shield.		

B. Nonmetallic Pipe Clamps and Hangers:

1. Pipe Sizes: 3 mm through 100 mm.
2. Type: Two-piece, automatic locking, corrosion resistant.
3. Features:
 - a. Clamping segments anchor to base by nylon hinges at base.
 - b. Fastening via centrally located oval mounting holes.
4. Structural Attachments: Furnish required factory fabricated accessories for structural attachments.

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C. Pipe Anchors:

1. Type: Anchor chair with U-bolt or bar strap.
2. Manufacturers and Products:
 - a. Cooper B-Line; Figure B3147A or B3147B.

2.05 FASTENERS

A. Anchor Bolts:

1. Material:
 - a. Type 316 stainless steel, sized by equipment manufacturer, 1/2-inch minimum diameter.

2.06 FABRICATION

A. Shop Assembly: In accordance with MSS SP 89.

B. Shop Finishing:

1. In accordance with MSS SP 85.
2. Coat ungalvanized steel components with rust inhibitive primer as specified in Section 09900, Painting.

2.07 SOURCE QUALITY CONTROL

A. Shop Tests: In accordance with MSS SP 89.

PART 3. EXECUTION

3.01 INSTALLATION

A. General:

1. Install support systems in accordance with MSS SP 69 and MSS SP 89, unless shown otherwise.
2. Support piping connections to equipment by pipe support and not by equipment.
3. Support large or heavy valves, fittings, and appurtenances independently of connected piping.
4. Support no pipe from pipe above it.
5. Support pipe at changes in direction or in elevation, adjacent to flexible joints and couplings, and where shown.
6. Brace hanging pipes against horizontal movement by both longitudinal and lateral sway bracing and to reduce movement after startup.
7. Install lateral supports for seismic loads at all changes in direction.
8. Install pipe anchors where required to withstand expansion thrust loads and to direct and control thermal expansion.
9. Repair mounting surfaces to original condition after attachments are made.

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3.02 FIELD FINISHING

- A. Paint atmospheric exposed surfaces of black and hot-dip galvanized steel components as specified in Section 09900, Painting.

END OF SECTION

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PART 1. GENERAL

1.01 REFERENCES

- A. The following is a list of standards which may be referenced in this section and any supplemental Data Sheets:
1. American National Standards Institute (ANSI):
 - a. B1.20.1, Pipe Threads, General Purpose (Inch).
 - b. B16.1, Cast Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250.
 2. American Society of Mechanical Engineers (ASME):
 - a. BA13.1, Scheme for The Identification of Piping Systems.
 3. American Society for Testing and Materials (ASTM):
 - a. A193/A193M, Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.
 - b. A194/A194M, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service or Both.
 - c. A307, Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.
 - d. A536, Standard Specification for Ductile Iron Castings.
 - e. A563, Standard Specification for Carbon and Alloy Steel Nuts.
 - f. D1784, Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds.
 - g. D1785, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.
 - h. D2464, Standard Specification for Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80.
 - i. D2466, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40.
 - j. D2467, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80.
 - k. D2564, Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems.
 - l. D3261, Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing.
 - m. D3350, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials.
 - n. F714, Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.
 4. CSA (Canadian Standard Association) B51-03, Boiler, Pressure Vessel and Piping code

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1.02 SUBMITTALS

A. Shop Drawings:

1. Manufacturer's standard cut sheets.

1.03 DELIVERY, STORAGE, AND HANDLING

A. In accordance with Section 01600, Material and Equipment, and:

1. Flanges: Securely attach metal, hardboard, or wood protectors over entire gasket surface.
2. Threaded or Socket Welding Ends: Fit with metal, wood, or plastic plugs or caps.
3. Cold Weather Storage: Locate products to prevent coating from freezing to ground.
4. Handling: Use heavy canvas or nylon slings to lift pipe and fittings.
5. Avoid ferrous materials in contact with stainless steel products.

PART 2. PRODUCTS

2.01 PIPING

A. As specified on Piping Schedule located on Drawings.

B. Diameters Shown:

1. Standardized Products: Nominal size.

2.02 JOINTS

A. Mechanical connections of high density polyethylene (HDPE) pipe to aluminum ducting and auxiliary equipment such as flexible connectors, valves, pumps, tanks, and other non-HDPE piping systems shall be through flanged connections consisting of the following:

1. ASTM A240, Type 304 stainless steel backing flange, 863 kPag, ANSI B16.1 standard. Insulating flanges shall be used where shown.
2. Bolts and nuts of sufficient length to show a minimum of three complete threads when the joint is made and tightened to manufacturer's standard. Retorque nuts after 4 hours.
3. Gaskets as specified on Data Sheet.

2.03 GASKET LUBRICANT

A. Lubricant shall be supplied by pipe manufacturer and no substitute or "or-equal" will be allowed.

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2.04 FABRICATION

- A. Mark each pipe length on outside:
 - 1. Size or diameter and class.
 - 2. Manufacturer's identification and pipe serial number.
 - 3. Location number on laying drawing.
 - 4. Date of manufacture.
- B. Flanged pipe shall be fabricated in the shop, not in the field, and delivered to the Site with flanges in place and properly faced. Threaded flanges shall be individually fitted and machine tightened on matching threaded pipe by the manufacturer.

PART 3. EXECUTION

3.01 EXAMINATION

- A. Verify size, material, joint types, elevation, horizontal location, and pipe service of existing pipelines to be connected to new pipelines or new equipment.
- B. Inspect size and location of structure penetrations to verify adequacy of wall pipes, sleeves, and other openings.
- C. Provide the following minimum nondestructive inspection and testing procedures as indicated on the piping schedule:
 - 1. 100 percent visual inspection on all welds

3.02 PREPARATION

- A. Notify Contract Administrator at least 2 weeks prior to field fabrication of pipe or fittings.
- B. Inspect pipe and fittings before installation, clean ends thoroughly, remove foreign matter and dirt from inside, and ensure that no dirt or other foreign matter enters the pipe during assembly.

3.03 INSTALLATION-GENERAL

- A. Join pipe and fittings in accordance with manufacturer's instructions, unless otherwise shown or specified.
- B. Remove foreign objects prior to assembly and installation.
- C. All pipe joints shall be restrained.
- D. Flanged Joints:
 - 1. Install perpendicular to pipe centerline.
 - 2. Bolt Holes: Straddle vertical centerlines, aligned with connecting equipment flanges or as shown.

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3. Use torque-limiting wrenches to ensure uniform bearing and proper bolt tightness.
4. Plastic Flanges: Install annular ring filler gasket at joints of raised-face flange.
5. Raised-Face Flanges: Use flat-face flange when joining with flat-faced ductile or cast iron flange.
6. Verify compatibility of mating flange to adapter flange gasket prior to selecting grooved adapter flanging.
7. Threaded flanged joints must be shop fabricated and delivered to jobsite with flanges in-place and properly faced.
8. Manufacturer:
 - a. Same as pipe manufacturer.

E. Threaded and Coupled Joints:

1. Conform to ANSI B1.20.1.
2. Produce sufficient thread length to ensure full engagement when screwed home in fittings.
3. Countersink pipe ends, ream and clean chips and burrs after threading.
4. Make connections with not more than three threads exposed.
5. Lubricate male threads only with thread lubricant or tape as specified on Piping Data Sheets.

F. High Density Polyethylene Piping:

1. Join pipes, fittings, and flange connections by means of thermal butt-fusion.
2. Butt-fusion shall be performed in accordance with pipe manufacturer's recommendations as to equipment and technique.
3. Special Precautions at Flanges: Polyethylene pipe connected to heavy fittings, manholes, and rigid structures shall be supported in such a manner that no subsequent relative movement between polyethylene pipe at flanged joint and rigid structures is possible.

G. Polyvinyl Chloride (PVC) Piping

1. Solvent socket weld except where connection to threaded valves and equipment may require future disassembly.

3.04 INSTALLATION-EXPOSED PIPING

A. Piping Runs:

1. Parallel to building or column lines and perpendicular to floor, unless shown otherwise.
2. Piping upstream and downstream of flow measuring devices shall provide straight lengths as required for accurate flow measurement.

B. Supports: As specified in 15060, Piping Support Systems.

C. Unions or Flanges: Provide at each piping connection to equipment or instrumentation on equipment side of each block valve to facilitate installation and removal.

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- D. Install piping so that no load or movement in excess of that stipulated by equipment manufacturer will be imposed upon equipment connection; install to allow for contraction and expansion without stressing pipe, joints, or connected equipment.
- E. Piping clearance, unless otherwise shown:
 - 1. Do not route piping in front of or to interfere with access ways, ladders, stairs, platforms, walkways, openings, doors, or windows.
 - 2. Headroom in front of openings, doors, and windows shall not be less than the top of the opening.
 - 3. Do not install piping containing liquids or liquid vapors in transformer vaults or electrical equipment rooms.
 - 4. Do not route piping over, around, in front of, in back of, or below electrical equipment including controls, panels, switches, terminals, boxes, or other similar electrical Work.
- F. Installation of Primary Measuring Elements:
 - 1. Install primary elements and accessories supplied under Division 16, including but not limited to the following:
 - a. Pressure/vacuum indicators, switches and transmitters
 - b. Temperature sensors, indicators, switches and transmitters
 - 2. Install units in locations shown. Attention is directed to suggested mounting details, flow schematics and circuit diagrams on the Electrical Drawings.
 - 3. Provide reducers, weldolets, tapped saddles, shut-off valves, flushing connections, drains, bolts, nuts, washers and gaskets necessary to complete the installation.
 - 4. Provide and install pipe couplings for pressure sensors and pressure switch sensors on piping systems where indicated. Use tapped saddles when connecting to piping systems with wall thickness less than that required for tapping size. Back weld pipe couplings installed on steel or stainless steel pipes.
 - 5. Provide suitable flexible connectors from the pipe couplings to instruments such as pressure switches and pressure gauges to eliminate vibrations and provide a stainless steel lever operated ball valve. Mount pressure switches on separate supports.
 - 6. Provide pipe couplings and install wells for temperature sensors on piping system where indicated.
 - 7. Pipe couplings, tapped saddles, valves, flexible connectors and fittings must be of material similar to that of the piping system and have pressure-temperature ratings equivalent to that of the piping to which they are connected.
 - 8. Couplings, valves, wells, weldolets, tapped saddles, flexible connectors and fittings, etc. must be suitable for installing primary elements supplied under Section - Instrumentation and Control.

3.05 INSTALLATION-BURIED PIPE

- A. Placement:

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1. Keep trench dry until pipe laying and joining are completed.
2. Pipe Base and Pipe Zone: As specified in CW2030 and CW2130.
3. Exercise care when lowering pipe into trench to prevent twisting or damage to pipe.
4. Measure for grade at pipe invert, not at top of pipe.
5. Excavate trench bottom and sides of ample dimensions to permit visual inspection and testing of entire flange, valve, or connection.
6. Prevent foreign material from entering pipe during placement.
7. Close and block open end of last laid pipe section when placement operations are not in progress and at close of day's work.
8. Lay pipe upgrade with bell ends pointing in direction of laying.
9. After joint has been made, check pipe alignment and grade.
10. Place sufficient pipe zone material to secure pipe from movement before next joint is installed.
11. Prevent uplift and floating of pipe prior to backfilling.

B. PVC or HDPE Pipe Placement:

1. Lay pipe snaking from one side of trench to other.
2. Offset: As recommended by manufacturer for maximum temperature variation between time of solvent welding and during operation.
3. Do not lay pipe when temperature is below 5 degrees C, or above 32 degrees C when exposed to direct sunlight.
4. Shield ends to be joined from direct sunlight prior to and during the laying operation.

C. Tolerances:

1. Deflection From Horizontal Line: Maximum 50 mm.
2. Deflection From Vertical Grade: Maximum 6 mm.
3. Joint Deflection: Maximum of 75 percent of manufacturer's recommendation.
4. Pipe Cover: Minimum 1000 mm, unless otherwise shown.

3.06 SLAB, FLOOR, WALL, AND ROOF PENETRATIONS

- A. Application and Installation: As specified in Section 05500, Metal Fabrications.

3.07 VENTS AND DRAINS

- A. Install vents on high points and drains on low points of pipelines only where shown.

3.08 CLEANING

- A. Following assembly and testing, and prior to final acceptance, flush pipelines (except as stated below) with water at 0.8 m/s minimum flushing velocity until foreign matter is removed.
- B. Blow clean of loose debris plant process air, lines with compressed air; do not flush with water.

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- C. If impractical to flush large diameter pipe or blow with compressed air, clean in-place from inside by brushing and sweeping, then flush or blow line at lower velocity.
- D. Remove accumulated debris through drains 50 mm and larger or by removing spools and valves from piping.

3.09 FIELD QUALITY CONTROL

- A. Pressure Leakage Testing: As specified in Section 15955, Piping Leakage Testing.

END OF SECTION

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REVISION 0	SECTION 15200-01 PIPING SCHEDULE	

Service Designation (Note 1)	Service	Material (Note 2)	Spec. No.	Size	Installation (Note 3)	Max. Operating Pressure	Test Pressure and Method (psig, Note 4)	Max. Operating Temp (°C)	Remarks
	Compost Process Air	HDPE	15200-02	All	EXP/BUR	4903 Pa	3, P	85	
	M&R Building Air	HDPE	15200-02	All	EXP	4903 Pa	3, P	65	
	Leachate Drain	HDPE	15200-02	All	BUR	4903 Pa	3, P	85	
	Biofilter Irrigation Water	PVC	15200-03	All	EXP	500 Pa	H	65	
	Leachate Tank Vent	PVC	15200-03	All	EXP/BUR			65	

NOTES:

1. Where piping carried tow or more service designations, the piping material shall conform to the required for the first service listed.

2. Piping Material Legend

- CISP - Cast Iron Soil Pipe
- CLDI - Cement Lined Ductile Iron
- CU - Copper
- HDPE - High Density Polyethylene
- PVC - Polyvinyl Chloride
- SST - Stainless Steel
- STL - Carbon Steel

3. Installation Legend

- EXP - Inside and outside exposed
- SUB - Submerged
- BUR - Buried

4. Testing Method Legend

- H - Hydrostatic Test
- P - Pneumatic Test

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REVISION 0	SECTION 15200-02 HDPE PIPE AND FITTINGS DATA SHEET	

Item	Size	Description																		
General	All	Pipe lengths, fittings, and flanged connections to be joined by thermal butt-fusion shall be of the same type, grade, and class of polyethylene compound and supplied from the same raw material supplier.																		
Pipe		<p>ASTM D3350, high density polyethylene, maximum allowable hoop stress 5,500 kPa at 23 degrees C.</p> <p>Polyethylene resins shall conform to Type PE 3408 or better.</p> <p>Protection shall be provided against ultraviolet light degradation using carbon black, not less than 2 percent well dispersed in the resin.</p> <p>Pipe wall thickness shall reflect the required SDR* and diameter, as shown in Table 8, ASTM F714.</p> <p>Design Stress Rating: ASTM F714, 5,500 kPa hydrostatic.</p> <table> <tr> <td>Pressure Rating (kPa)</td> <td>SDR*</td> </tr> <tr> <td>1380</td> <td>9</td> </tr> <tr> <td>1100</td> <td>11</td> </tr> <tr> <td>890</td> <td>13.5</td> </tr> <tr> <td>687</td> <td>15.5</td> </tr> <tr> <td>687</td> <td>17</td> </tr> <tr> <td>550</td> <td>21</td> </tr> <tr> <td>450</td> <td>26</td> </tr> <tr> <td>350</td> <td>32.5</td> </tr> </table> <p>* SDR: standard dimension ratio = OD/thickness</p>	Pressure Rating (kPa)	SDR*	1380	9	1100	11	890	13.5	687	15.5	687	17	550	21	450	26	350	32.5
Pressure Rating (kPa)	SDR*																			
1380	9																			
1100	11																			
890	13.5																			
687	15.5																			
687	17																			
550	21																			
450	26																			
350	32.5																			
Fittings	150 mm & smaller 200 mm & larger	<p>Molded fittings, butt fusion joined, conforming to ASTM D3261.</p> <p>Same as pipe, butt fusion joined, conforming to ASTM D3350. All fittings shall have same pressure rating as pipe, unless otherwise noted.</p>																		
Flanges	All	Van Stone type, cast ASTM A536 (65/45/12), ductile iron backing ring, IPP Deltaflex convoluted design or equal for bolting to ASME B16.1, Class 125; ASME B16.5 or B16.47, Class 150; and AWWA C207, Class E. Pressure performance of the backing ring equal to SDR rating of the pipe with safety factor of two. Stub ends same grade HDPE and pressure rating as pipe.																		
Bolting		<p>General Conditions: Stainless steel, ASTM A307 Grade B square head bolts and ASTM A563 Grade A heavy hex head nuts.</p> <p>Washers and nuts shall be same material as bolts.</p>																		
Gaskets		Flat ring, 3 mm ethylene propylene rubber (EPR).																		

END OF SECTION

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REVISION 0	SECTION 15200-03 POLYVINYL CHLORIDE (PVC) PIPE AND FITTINGS	

Item	Size	Description
Pipe	All	Schedule 80 PVC: Type I, Grade I or Class 12454-B conforming to ASTM D1784 and ASTM D1785. Threaded Nipples: Schedule 80 PVC.
Fittings	All	Schedule to Match Pipe Above: ASTM D2466 and ASTM D2467 for socket weld type and Schedule 80 ASTM D2464 for threaded type. Fittings shall be manufactured with 2 percent titanium dioxide for ultraviolet protection.
Joints	All	Solvent socket weld except where connection to threaded valves and equipment may require future disassembly.
Flanges	All	One piece, molded hub type PVC flat face flange in accordance with Fittings above, 57 kg ANSI B16.1 drilling
Bolting	All	Flat Face Mating Flange and In Corrosive Areas: ASTM A193/A193M, Type 316 stainless steel Grade B8M hex head bolts and ASTM A194/A194M Grade 8M hex head nuts. With Raised Face Mating Flange: Carbon steel ASTM A307 Grade B square head bolts and ASTM A563 Grade A heavy hex head nuts.
Gaskets	All	Flat Face Mating Flange: Full faced 3 mm thick ethylene propylene (EPR) rubber. Raised Face Mating Flange: Flat ring 3 mm ethylene propylene (EPR) rubber, with filler gasket between OD of raised face and flange OD to protect the flange from bolting moment.
Solvent Cement	All	As recommended by the pipe and fitting manufacturer conforming to ASTM D2564.
Thread Lubricant	All	Teflon Tape.

END OF SECTION

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REVISION 0	SECTION 15410 METAL DUCTWORK AND ACCESSORIES	

PART 1. GENERAL

1.01 REFERENCES

- A. The following is a list of standards which may be referenced in this section:
1. American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Handbook.
 2. ASTM International (ASTM):
 - a. A36/A36M, Standard Specification for Carbon Structural Steel.
 - b. E84, Standard Test Method for Surface Burning Characteristics of Building Materials.
 3. National Air Duct Cleaners Association (NADCA): General Specifications for the Cleaning of Commercial Heating, Ventilation and Air Conditioning Systems.
 4. National Fire Protection Association (NFPA):
 - a. 90A, Standard for the Installation of Air Conditioning and Ventilating Systems.
 - b. 90B Standard for the Installation of Warm Air Heating and Air Conditioning Systems.
 - c. 255, Standard Method of Test of Surface Burning Characteristics of Building Materials.
 5. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA):
 - a. Duct Construction Standards.
 - b. Guidelines for Seismic Restraints of Mechanical Systems.
 - c. Fibrous Glass Duct Construction Standards.
 - d. Fire, Smoke, and Radiation Damper Installation Guide for HVAC Systems.
 - e. HVAC Air Duct Leakage Test Manual.
 6. Underwriters Laboratories Inc. (UL):
 - a. 181, Standard for Safety Factory-Made Air Ducts and Connectors.
 - b. 214, Tests for Flame-Propagation of Fabrics and Films.
 - c. Underwriters Laboratories of Canada (ULC).
 - d. National Fire Code of Canada.
 - e. National Building Code of Canada.

1.02 DEFINITIONS

- A. The following is a list of abbreviations which may be used in this section:
1. L/s: litre per second.
 2. m/s: m per second.
 3. kg/m³: kg per cubic metre.
- B. Sealing Requirements: For the purpose of duct systems sealing requirements specified in

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this Section, the following definitions apply:

1. Seams: Joining of two longitudinally (in direction of airflow) oriented edges of duct surface material occurring between two joints. All other duct surface connections made on perimeter are deemed to be joints.
2. Joints, duct surface connections including:
 - a. Girth joints.
 - b. Branch and subbranch intersections.
 - c. Duct collar tap-ins.
 - d. Fitting subsections.
 - e. Louver and air terminal connections to ducts.
 - f. Access door, and access panel frames and jambs.
 - g. Duct, plenum, and casing abutments to building structures.

1.03 SUBMITTALS

A. Action Submittals:

1. Product Data:
 - a. Rectangular and Rigid Round Ductwork:
 - 1) Schedules of duct systems, materials, joints, sealing, gage and reinforcement.
 - 2) SMACNA Figure Numbers for each shop fabricated item.
 - 3) Reinforcing details and spacing.
 - 4) Seam and joint construction details.
 - 5) Hangers and supports, including methods for building attachment, vibration isolation, and duct attachment.
 - b. Ductwork Accessories:
 - 1) Manufacturer's product data including catalog sheets, diagrams, standard schematic drawings, installation instructions and details, details of materials, construction, dimensions of individual components, and finishes, including the following items:
 - a) Fittings and volume control damper installation (both manual and automatic) details.
 - b) Sealing materials.
 - c) Dampers; include leakage, pressure drop, and maximum back pressure data.
 - d) Duct-mounted access panels and doors.
 - e) Flexible ducts.
 - f) Sheet metal fasteners.

1.04 QUALITY ASSURANCE

A. Industry Standards:

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1. Unless otherwise indicated or specified, sheet metal ductwork shall be constructed and installed in accordance with SMACNA duct construction standard relevant to ductwork system being provided. These standards are herein referenced as the SMACNA Manual, unless otherwise indicated.
 2. Comply with ASHRAE Fundamentals Handbook recommendations, except as otherwise indicated.
- B. Manufacturers: Firms regularly engaged in manufacture of ductwork products of types, materials, and sizes required, whose products have been satisfactorily used in similar service for not less than 5 years.
- C. Suppliers of duct and fitting components shall provide on request the following information:
1. Laboratory performance data for duct, including leakage rate, bursting strength, collapse strength, seam strength, and pressure loss.
 2. Laboratory performance data for fittings, including zero-length dynamic losses.
- D. Installer shall be a firm with at least 3 years' experience of successful installation on ductwork systems similar to that required for this Project.
- E. Changes or alterations to layout or configuration of duct system shall be:
1. Specifically approved in writing by Contract Administrator.
 2. Proposed layout shall provide original design results, without increasing system total pressure.

1.05 EXTRA MATERIALS

- A. Furnish, tag, and box for shipment and storage the following spare parts:

Item	Quantity
Fusible Links	10% of amount installed

- B. Delivery: In accordance with Section 01600, Material and Equipment

1.06 DELIVERY, STORAGE, AND HANDLING

- A. Protect ductwork from dirt, water, and debris. During storage on jobsite, keep ends of ductwork covered to prevent foreign objects and water from entering ductwork.
- B. Deliver sealant materials to Site in original unopened containers labeled with manufacturer, product name and designation, color, expiration period for use, pot life, curing time, and mixing instructions for multi-component materials.
- C. Store and handle sealant materials in compliance with manufacturers' recommendations to prevent deterioration or damage due to moisture, high or low temperatures,

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contaminants, or other causes.

- D. Deliver and store stainless steel sheets with mill-applied adhesive protective paper, maintained through fabrication and installation.

PART 2. PRODUCTS

2.01 GENERAL

- A. Ductwork thinner than 26 gauge will not be allowed.
- B. Ductwork Interior Surfaces:
1. Smooth.
 2. No sheet metal parts, tabs, angles, screws, or other items may project into air ducts, unless otherwise specified.
 3. Seams and joints shall be external.
 4. For ductwork that is required to be reinforced, use only external reinforced.

2.02 SHEET METAL MATERIALS

- A. Construct metal duct systems from materials as indicated in Drawings.
- B. Where no specific ductwork materials are indicated in Specifications or on Drawings, aluminum sheet metal shall be basis of Contract.

2.03 DUCT SEALING MATERIALS

- A. General: The term sealant used here is not limited to materials of adhesive or mastic nature, but also includes tapes and combinations of open weave fabric strips and mastics.
- B. Adhesives, Cements, Sealant, and Installation Accessories: As recommended by duct manufacturer for water-tight and air-tight application.
- C. Solvent-Based Sealants:
1. Ultraviolet light resistant.
 2. Mildew resistant.
 3. Flashpoint: Greater than 21 degrees C, SETA CC.
 4. Manufacturers and Products:
 - a. Hardcast, Inc.; Versagrip 102.
 - b. Rectorseal; AT-33.
 - c. Childers CP-140.
- D. Water-Based Sealants:
1. Listed by manufacturer as nonflammable in wet and dry state.
 2. Manufacturers and Products:
 - a. Foster; Series 32.

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- b. Childers; CP-145A, 146.
- c. Rectorseal; Airlok 181.

2.04 DUCTWORK FASTENERS

- A. General:
 - 1. Rivets, bolts, self drilling or sheet metal screws.
 - 2. Ductwork fasteners shall be same metal as duct being supported, unless otherwise noted.

2.05 DUCTWORK PRESSURE CLASS

- A. Construct duct systems to pressure classifications indicated as follows:
 - 1. Process Ducts: 2000 Pa, positive or negative pressure
 - 2. Exhaust Ducts: 2000 Pa, negative pressure.
- B. Where no specific duct pressure designations are indicated in Specifications or on Drawings, 2000 Pa pressure class shall be basis of Contract.

2.06 RECTANGULAR DUCTWORK

- A. Fabricate rectangular ducts in accordance with SMACNA Rectangular Industrial Duct Construction Standards, unless specified otherwise.
- B. Crossbreaking or Cross Beading: Crossbreak or bead duct sides that are 480 mm and larger and are 20-gauge or less, with more than 1.0 square meter of unbraced panel area, as indicated in SMACNA Manual, unless they are lined or are externally insulated.

2.07 RECTANGULAR DUCTWORK FITTINGS

- A. Fabricate elbows, transitions, offsets, branch connections, and other duct construction in accordance with SMACNA Rectangular Industrial Duct Construction Standards.

2.08 RIGID ROUND DUCTWORK

- A. Construct rigid round ducts in accordance with SMACNA Round Industrial Duct Construction Standards, unless specified otherwise.
- B. Basic Round Diameter: As used in this Article, is diameter of size of round duct that has circumference equal to perimeter of a given size of flat oval duct.
- C. Where space limitations prevent use of round duct or where shown on Drawings, provide ductwork of flat oval construction.
- D. Fabricate round ducts with spiral seam construction, except where diameters exceed 1800 mm. Fabricate ducts having diameters greater than 1800 mm with longitudinal

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butt-welded seams.

- E. Ductwork seams of Snaplock type shall not be used.

2.09 RIGID ROUND DUCTWORK FITTINGS

- A. Construct rigid round ductwork fittings in accordance with SMACNA Round Industrial Duct Construction Standards, unless otherwise specified.
- B. 90-Degree Tees, Laterals, and Conical Tees: Fabricate to conform to SMACNA manual with metal thicknesses specified for longitudinal seam straight duct.
- C. Diverging Flow Fittings: Fabricate with a reduced entrance to branch taps with no excess material projecting from body onto branch tap entrance.
- D. Elbows:
1. Fabricate in stamped (die-formed), pleated, or segmented (gored) construction 1.5 times elbow diameter. Two piece segment elbows are not allowed, except with turning vanes.
 2. Segmented Elbows: Fabricate with welded construction.
 3. Round Elbows 200 mm and Smaller:
 - a. Stamped elbows for 45- and 90-degree elbows and pleated elbows for 30, 45, 60, and 90 degrees configuration.
 - b. Fabricate nonstandard bend angle configurations or nonstandard sized (e.g., 90 and 115 mm) elbows with segmented construction.
 4. Round Elbows 225 mm Through 350 mm:
 - a. Segmented or pleated elbows for 30, 45, 60, and 90 degrees.
 - b. Fabricate nonstandard bend angle configurations or nonstandard sized (e.g., 240 and 265 mm) elbows with segmented construction.

2.10 DUCTWORK HANGERS AND SUPPORTS

- A. General:
1. Attachments, hangers, and supports for ductwork shall be in accordance with SMACNA Manual referenced for type of duct system being installed.
 2. Duct hanging system shall be composed of three elements; upper attachment to building, hanger itself, and lower attachment to duct.
 3. Wire hangers are not acceptable.
 4. Hanger Spacing:
 - a. Ducts Up to 1500 mm in Largest Dimension: 3.0 m, maximum.
 - b. Ducts Over 1525 mm in Largest Dimension: 2.4 m, maximum.
- B. Construction Materials: Supporting devices including, but not limited to, angles used for support and bracing, baseplates, rods, hangers, straps, screws, bolts shall be as follows:
1. Galvanized Steel Ductwork:
 - a. Indoors: Carbon steel, zinc electroplated.

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- b. Outdoors: Carbon steel, hot-dipped galvanized after fabrication.
 - 2. Aluminum Ductwork Indoors and Outdoors: Carbon steel, hot-dipped galvanized after fabrication.
 - 3. Stainless Steel Ductwork Indoor and Outdoors: Stainless steel, same ASTM Grade as ductwork.
- C. Building Attachments:
 - 1. Concrete inserts, powder-actuated fasteners, or structural steel fasteners appropriate for building materials.
 - 2. Do not use powder-actuated concrete fasteners for lightweight aggregate concrete or for slabs less than 100 mm thick.
 - 3. Upper Attachment (Concrete):
 - a. Drive pin fastener and expansion nail anchor may be used for ducts up to 450 mm maximum dimension.
 - b. Threaded stud fastener may be used for ducts up to 900 mm maximum dimension.
 - c. Concrete attachments shall be made of steel.
- D. Duct Fasteners: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials and conforming to requirements of Article Ductwork Fastener.
- E. Trapeze and Riser Supports: Steel shapes conforming to ASTM A36/A36M, hot-dipped galvanized after fabrication.

2.11 DUCTWORK FLEXIBLE CONNECTIONS

- A. General:
 - 1. Factory fabricated metal-edged fabric flexible connectors for commercial or industrial applications.
 - 2. Sheet metal permanently secured to fabric with double fabric fold, double metal crimp.
 - 3. Comply with NFPA 90A and 90B requirements.
 - 4. Airtight and waterproof.
- B. Materials:
 - 1. Flame-retarded or noncombustible fabrics, coatings, and adhesives complying with UL 181, Class 1.
 - 2. Metal Edges: Construct from same material as ductwork, unless otherwise noted.
 - 3. Fabric:
 - a. Comply with UL 214 (except teflon coated).
 - b. Coating: Hypalon.
- C. Construction:
 - 1. Fold and crimp metal edge strips onto fabric as illustrated in SMACNA Manual.
 - 2. Standard Metal Edged Connectors: Strip of fabric 90 mm wide attached to

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two strips of 70 mm wide sheet metal.

D. Manufacturers:

1. Ductmate; PROflex, Commercial.
2. Ventfabrics.
3. Duro-Dyne.

2.12 MANUAL DAMPERS

A. Butterfly Manual Dampers:

1. Fabricate from two gauges heavier than duct in which installed, of same material as ductwork or SS in HDPE duct..
2. Align operating handle with damper blade.
3. Damper Manufacturers:
 - a. Ruskin.
 - b. American Warming and Ventilating.
4. Operator Manufacturers:
 - a. Accessible Ductwork: Mader.

2.13 MISCELLANEOUS ACCESSORIES

A. Miscellaneous:

1. Instrument Test Holes:
 - a. Cast metal, material to suit duct material, including screw cap and gasket and flat mounting gasket.
 - b. Size to allow insertion of pitot tube and other testing instruments.
 - c. Provide in length to suit duct insulation thickness.
2. Flexible Duct Clamps:
 - a. Stainless steel band with cadmium-plated hex screw to tighten band with worm-gear action.
 - b. Provide in sizes from 75 mm to 450 mm to suit duct size.
3. Adhesives: High strength, quick setting, neoprene based, waterproof and resistant to gasoline, and grease.

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PART 3. EXECUTION

3.01 GENERAL INSTALLATION

A. Miscellaneous:

1. Install sheet metal ductwork and flexible ductwork in accordance with SMACNA Manual, NFPA 90A, and NFPA 90B.
2. Install ductwork using manufacturer's recommended adhesives, cement, sealant, and insulation accessories.
3. Align ductwork accurately at connections, within 3.2 mm misalignment tolerance and with internal surfaces smooth.
4. Interface Between Ductwork and Louvers: At locations where ductwork is connected to louver for either intake or exhaust purposes, ductwork shall be installed, sloped, and connected to louver so water entering ductwork system positively drains back to and out of louver.

B. Ductwork Location:

1. Locate ductwork runs vertically and horizontally, unless otherwise indicated.
2. As indicated by diagrams, details, and notations or, if not otherwise indicated, run ductwork in shortest route that does not obstruct usable space or block access for servicing building and equipment.

C. Penetrations:

1. Provide prepared openings for ducts passing through roofs, walls and ceilings.
2. Clearances:
 - a. For uninsulated ducts, allow 25 mm clearance between duct and sleeve, except at grilles, registers, and diffusers.
 - b. For insulated ducts, allow 25 mm clearance between insulation and sleeve, except at grilles, registers, and diffusers.
3. Closure Collars:
 - a. Minimum 102 mm wide on each side of walls or floors where sleeves or prepared openings are installed.
 - b. Fit collars snugly around ducts and insulation.
 - c. Same gauge and material as duct.
 - d. Grind edges of collar smooth to preclude tearing or puncturing insulation covering or vapor barrier.
 - e. Use fasteners with maximum 152 mm centers on collars.

D. Coordination with Other Trades:

1. Coordinate duct installation with installation of accessories, dampers, coil frames, equipment, controls, and other associated work of ductwork system.
2. Ductwork shall be configured, positioned, and installed to permit installation of light fixtures as indicated on Drawings.
3. Coordinate ductwork layout with suspended ceiling, lighting and sprinkler head

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layouts and similar finished Work.

4. Electrical Equipment Spaces: Do not run ductwork through transformer vaults and other electrical equipment spaces and enclosures.

3.02 RECTANGULAR DUCTWORK

- A. Where possible, install ductwork so seams and joints will not be cut for installation of grilles, registers, or ceiling outlets.
- B. If cutting of seams or joints is unavoidable, reinforce cut portion to original strength.

3.03 RECTANGULAR DUCTWORK FITTINGS

- A. Use bell-mouth or conical tee fittings for round duct takeoffs from rectangular mains.
- B. Use 45-degree entry fittings conforming to SMACNA requirements for rectangular takeoffs from rectangular or round mains.
- C. Make offsets with maximum angle of 45 degrees.
- D. Use fabricated fittings for changes in directions, changes in size and shape, and connections.

3.04 RECTANGULAR DUCTWORK TRANSVERSE JOINTS

- A. Install each run with a minimum of joints.
- B. Install couplings tight to duct wall surface with projections into duct at connections kept to a minimum.

3.05 RIGID ROUND DUCTWORK

- A. Except where interrupted by fittings, install round ducts in lengths not less than 3.6 meters.

3.06 RIGID ROUND DUCTWORK JOINTS

- A. Rigid round ductwork joints shall be in accordance with Round Industrial Duct Construction Standards, unless otherwise specified.
- B. Single and Double Wall Supply and Return System Joints:
 1. Less than 900 mm: Slip coupling.
 2. Larger than 900 mm: Flanged connector, Van Stone, or welded companion flange type.
- C. Single and Double Wall Exhaust and Return System Joints:
 1. All Sizes, Spiral Seam Duct: Welded flanged connector.

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2. All Sizes, Longitudinal Seam Duct: Van Stone flange connector.

3.07 DUCTWORK HANGERS AND SUPPORTS

- A. Install ductwork with support systems in accordance with SMACNA Manual, unless otherwise noted.
- B. Support ducts rigidly with suitable ties, braces, hangers, and anchors of type, which will hold ducts true-to-shape and to prevent buckling.
- C. Install additional bracing on ductwork as required, to prevent ballooning or breathing.
- D. Support horizontal ducts within 610 mm of each elbow and within 1220 mm of each branch intersection.
- E. Support vertical ducts at maximum interval of 4880 mm and at each floor.
- F. Upper attachments to structures shall have allowable load not exceeding 1/4 of failure (proof test) load, but are not limited to specific methods indicated.
- G. In new construction, install concrete insert prior to placing concrete.

3.08 FLEXIBLE CONNECTIONS

- A. Flexible Collars and Connections:
 1. Use between fans and ducts.
 2. For round ducts, securely fasten flexible connections by zinc-coated steel clinch-type draw bands.

3.09 DAMPERS

- A. General:
 1. Inspection:
 - a. Inspect areas to receive dampers.
 - b. Notify Contract Administrator of conditions that would adversely affect installation or subsequent utilization of dampers.
 - c. Do not proceed with installation until unsatisfactory conditions are corrected.
 2. Install dampers at locations indicated on Drawings and in accordance with manufacturer's installation instructions.
 3. Install square and level.
 4. Handle damper using sleeve or frame. Do not lift damper using blades or jack-shaft.
 5. Damper blades and hardware shall operate freely without obstruction.
 6. Damper blades and hardware that bind within frame or obstructed by adjacent construction will not be acceptable.
 7. When installed, damper frames shall be gasketed or caulked to eliminate leakage

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- between duct and damper frames.
- 8. Head and sill shall have stops.
- 9. Suitable for installation in mounting arrangement shown.
- 10. Do not compress or stretch damper frame into duct or opening.

B. Manual Dampers:

- 1. Provide balancing dampers for grilles and diffusers [as indicated on Drawings] in branch duct as near main as possible.
- 2. Add or remove balancing dampers as requested by air balancing firm for necessary control of air.

3.10 MISCELLANEOUS ACCESSORIES

A. Inspection Plates and Test Holes:

- 1. Where required in ductwork for balance measurements.
- 2. Test holes shall be, airtight and noncorrosive with screw cap and gasket.
- 3. Extend cap through insulation.

3.11 DUCT SEALING

A. Seal duct seams and joints as follows:

- 1. In accordance with SMACNA requirements As indicated on Drawings.
- B.** If no specific duct sealing requirements are specified, requirements of SMACNA manual shall govern.
- C.** Provide additional duct sealing as required to comply with Article - Ductwork Leakage Testing.
- D.** Seal all audible leak.

3.12 DUCTWORK LEAKAGE TESTING

A. General:

- 1. Tests shall be conducted on completed ductwork systems.
- 2. Testing of partial installations or limited sections of ductwork will not be acceptable.
- 3. All ductwork leakage test procedures and results shall be submitted to Contract Administrator for review.
- 4. Contract Administrator shall retain the right to witness some or all ductwork leakage testing procedures.
- 5. Contractor shall notify Contract Administrator in writing at least 5 working days prior to ductwork testing.

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B. Leakage Criteria:

1. Assemble and install ductwork with maximum leakage limited as indicated in Ductwork Schedule

C. Leakage Testing Method:

1. Contractor shall be responsible for providing all necessary test fans and calibrated measuring devices to accomplish ductwork leakage test and to demonstrate that ductwork systems leakage rate is less than maximum rate specified.
2. Pressure testing shall be accomplished using a pressure blower with a calibrated orifice and manometer.
3. Blower shall maintain SMACNA construction pressure classification during test.
4. Perform testing in accordance with procedures given in SMACNA HVAC Air Duct Leakage Test Manual.

3.13 PROTECTION OF INSTALLED WORK

- A. Open ends of installed ductwork systems shall be covered to prevent dust, foreign objects and water from entering ductwork.
- B. Ductwork systems shall not be used for air conveyance until adequate air filtration devices are installed in air handling equipment, to prevent ingress of construction dust.

3.14 CLEANING

- A. Ductwork shall be cleaned of rust, dust, and debris, both internally and externally, before placing in operation.
- B. Before installing air outlets, use air handler to blow dry air through entire system at maximum attainable velocity. Provide temporary air filters for this operation.
- C. If duct systems are found to contain construction debris at time of construction completion Contractor shall provide complete ductwork system cleaning in accordance with NADCA Standards.

END OF SECTION

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PART 1 GENERAL

1.01 REFERENCES

- A. The following is a list of standards, which may be referenced in this section:
1. Acoustical Society of America (ASA): S2.19, Mechanical Vibration—Balance Quality Requirements of Rigid Rotors—Part 1, Determination of Permissible Residual Unbalance.
 2. Air Movement and Control Association International (AMCA):
 - a. 99, Standards Handbook.
 - b. 201, Fans and Systems.
 - c. 203, Field Performance Measurement of Fan Systems.
 - d. 210, Laboratory Methods of Testing Fans for Aerodynamic Performance Rating.
 - e. 300, Reverberant Room Method for Sound Testing of Fans.
 - f. 301, Methods for Calculating Fan Sound Ratings from Laboratory Test Data.
 3. American Bearing Manufacturers Association (ABMA): 9, Load Ratings and Fatigue Life for Ball Bearings.
 4. ASTM International (ASTM):
 - a. B117, Standard Practice for Operating Salt Spray (Fog) Apparatus.
 - b. D2247, Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity.
 - c. D2794, Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact).
 - d. D3363, Standard Test Method for Film Hardness by Pencil Test.
 5. Occupational Safety and Health Act (OSHA).
 6. Society for Protective Coatings (SSPC):
 - a. SP 3, Power Tool Cleaning.
 - b. SP 5, Joint Surface Preparation Standard White Metal Blast Cleaning.
 - c. SP 6, Joint Surface Preparation Standard Commercial Blast Cleaning.
 - d. SP 10, Joint Surface Preparation Standard Near-White Blast Cleaning.
 7. Underwriters Laboratories Inc. (UL/ULC): 507, Electric Fans.

1.02 DEFINITIONS

- A. The following is a list of abbreviations, which may be used in this Section:
1. AC: Alternating Current.
 2. CISD: Chemical Industry, Severe-Duty.
 3. dB: Decibel.
 4. DWDI: Double Width, Double Inlet.
 5. FRP: Fiberglass Reinforced Plastic.
 6. kW: Kilowatt.
 7. ODP: Open Drip Proof.

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- 8. SWSI: Single Width, Single Inlet.
- 9. TEFC: Totally Enclosed, Fan Cooled.
- 10. UV: Ultraviolet.
- 11. XP: Explosion Proof.

1.03 SUBMITTALS

1.04 ACTION SUBMITTALS:

- 1. Provide for all products specified, as follows:
 - a. Identification as referenced in Contract Documents.
 - b. Manufacturer's name and model number.
 - c. Descriptive specifications, literature and drawings.
 - d. Dimensions and weights.
 - e. Fan sound power level data (reference 10 to power minus 12 Watts) at design operating point.
 - f. Fan Curves:
 - 1) Performance Curves Indicating:
 - a) Relationship of flow rate to static pressure for various fan speeds.
 - b) Brake horsepower curves.
 - c) Acceptable selection range (surge curves, maximum revolutions per minute, etc).
 - d) Static pressure, capacity, horsepower demand and overall efficiency required at the duty point, including drive losses.
 - 2) For variable air volume applications, indicate operating points at 100, 80, 60 and 40 percent of design capacity on fan curves including data to indicate effect of capacity control devices such as inlet vanes on flow, pressure and brake horsepower.
 - g. Capacities and ratings.
 - h. Construction materials.
 - i. Fan type, size, class, drive arrangement, discharge, rotation, and bearings.
 - j. Wheel type, diameter, revolutions per minute, and tip speed.
 - k. Motor data.
 - l. Power and control wiring diagrams, including terminals and numbers.
 - m. Vibration isolation.
 - n. Factory finish system.
 - o. Corrosion protection coating product data.
- 2. Equipment:
 - a. Where submitted equipment results in change to fan inlet or outlet ductwork configuration shown on Drawings, submit system effect factor calculations indicating increased static pressure requirements as described in AMCA 201.
 - b. Where submitted equipment results in change to ductwork and

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equipment configuration shown on Drawings, submit detailed information on structural, mechanical, electrical, or other modifications necessary to adapt arrangement to equipment furnished.

- B. Informational Submittals:
1. Recommended procedures for protection and handling of products prior to installation.
 2. Manufacturer's installation instructions.
 3. Manufacturer's Certificate of Compliance in accordance with Section 01640, Manufacturers' Services, for the following:
 - a. Motors specified to be premium efficient type.
 - b. Fans.
 4. Test reports.
 5. Operation and maintenance data in conformance with Section 01430, Operation and Maintenance Data. Include as-built version of equipment schedules.

1.05 QUALITY ASSURANCE

- A. Performance Ratings: Tested in accordance with AMCA 210.
- B. Sound Ratings: Tested in accordance with AMCA 300.
- C. Fabrication: In accordance with AMCA 99.

1.06 EXTRA MATERIALS

- A. Furnish, tag, and box for shipment and storage the following materials:

<u>Item</u>	<u>Quantity</u>
Vee Belts	One complete set per unit

- B. Delivery: In accordance with Section 01600, Material and Equipment.

PART 2 PRODUCTS

2.01 EQUIPMENT SCHEDULES

- A. Specific equipment requirements are listed in Equipment Schedules. Refer to Supplement 01.

2.02 SPARK RESISTANT CONSTRUCTION

- A. Fans required to be spark resistant shall comply with requirements of AMCA 99-0401.

2.03 NAMEPLATES

- A. All units shall include factory installed permanently attached nameplate displaying unit model and serial number.

2.04 OPERATING LIMITS

- A. Fans designated to meet a specified fan class shall comply with requirements of

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AMCA 99-2408-69.

2.05 ACOUSTICAL LEVELS

- A. Equipment selections shall produce sound power levels in each octave band no greater than shown in Equipment Schedule.

2.06 FAN DRIVES

- A. Furnish multiple drive belts where motor horsepower is 2 hp or larger.
- B. Drive assembly shall be sized for a minimum 140 percent of fan motor horsepower rating.
- C. Sheaves shall be capable of providing 150 percent of motor horsepower.
- D. Fan Shafts: First critical speed of at least 125 percent of fan maximum operating speed.
- E. Belts: Oil and heat resistant, nonstatic type.
- F. Furnish motors for V-belt drives with adjustable rails or bases.
- G. Unless otherwise noted, furnish belt-driven fans with cast iron or flanged steel sheaves.
- H. Motors 20 hp or Smaller:
 - 1. Variable pitch V-belt sheaves allowing at least 20 percent speed variation.
 - 2. Final operating point shall be at approximate sheave midpoint.
- I. Motors Larger than 20 hp: Fixed-pitch sheaves.
- J. Drive Adjustment:
 - 1. When fixed-pitch sheaves are furnished, accomplish system air balancing by either trial of different fixed-pitch sheaves or use of temporary adjustable-pitch sheaves.
 - 2. Provide trial and final sheaves, as well as drive belts, as required.
- K. Weather Cover: Provide factory fabricated drive assembly of same material as fan housing, unless specified otherwise.
- L. Belt and Shaft Guards:
 - 1. Easily removable and to enclose entire drive assembly, meeting federal and provincial OHS requirements.
 - 2. Guard faces of expanded metal having minimum 60 percent free area for ventilation.
 - 3. Bright yellow finish.
- M. Provide speed test openings at shaft locations.

2.07 FINISHES

- A. Carbon Steel Parts: Factory finish as follows, unless indicated otherwise.
 - 1. Parts cleaned and chemically pretreated with a phosphatizing process.

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2. Alkyd enamel primer.
 3. Air-dry enamel topcoat.
- B. Aluminum Parts: Finished smooth and left unpainted, unless stated otherwise.
- C. Stainless Steel Parts: Finished smooth and left unpainted.
- 2.08 COMPOST FAN, CENTRIFUGAL (CF-101 THROUGH CF-104)
- A. General:
1. Factory-assembled utility blower; including housing, fan wheel, drive assembly, motor, and accessories.
 2. Suitable to convey air at temperatures up to 121 degrees C.
 3. .
 4. Bearing AMCA Certified Ratings Seal for sound and air performance.
- B. Housing:
1. Material: Aluminum.
 2. Construction:
 - a. Curved scroll configuration, with continuous seam welding and side angle reinforcement.
 - b. Lifting lugs welded to housing.
 - c. Flanged and drilled outlet to permit duct connection.
 - d. Drain connection located at lowest point of fan housing.
 - e. Inlet: Spun-formed aerodynamic bell mouth.
 3. Base/Pedestal: All-welded heavy gauge Type 316 stainless steel.
- C. Wheel:
1. Centrifugal, one-piece, non-overloading, radial blade type.
 2. Material: Aluminum.
 3. Attached to fan shaft with split taper lock bushing.
- D. Shaft, Bearings, Drive:
1. Shafts:
 - a. Turned, ground and polished steel.
 - b. Ends drilled and countersunk for tachometer readings.
 - c. Keyed for sheave installation.
 2. Bearings:
 - a. Grease lubricated, precision antifriction ball, self-aligning type.
 - b. Mounted in cast iron pillow block housing.
 - c. Selected for average life (ABMA 9 L50) of not less than 200,000 hours operation at maximum cataloged operating speed.
 3. Drives:
 - a. In accordance with Article Fan Drives.
 - b. Factory set to specified fan revolutions per minute.
 - c. Type: Direct.

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d. Arrangement: Counter-Clockwise Bottom Horizontal Discharge.

E. Accessories: Provide as scheduled in Equipment Schedule and as follows:

1. Housing Access Doors: Bolted and gasketed.
2. Flanged Inlet: Heavy gauge construction, factory drilled and flanged.
3. Shaft Seal: Viton construction, located at shaft penetration of housing.
4. Belt Guard: OSHA type, sheet metal construction same material as fan housing, for complete coverage of belts and sheaves.
5. Shaft and Bearing Guard: Sheet metal construction same material as fan housing, for complete coverage of shaft and bearings.
6. Motor and Drive Cover:
 - a. Factory fabricated, OSHA type.
 - b. Sheet metal construction, same material as fan housing.
 - c. Vented, openings sufficient size for proper motor cooling.
7. Unitary Sub-base:
 - a. Structural metal sub-base, same material as fan housing.
 - b. Bolted to bottom of fan base/pedestal.
 - c. Drilled for field installation of vibration isolators.
8. Spark Resistant Construction Classification: AMCA 99-0401 Type B.
9. Corrosion Protection Coating:
 - a. Provide factory-applied corrosion protection coating on these fan components:
 - 1) Wheel (or propeller).
 - 2) Housing.
 - 3) Accessories.
 - 4) Interior surfaces in contact with airstream.
 - b. Coating system shall be baked epoxy phenolic, and shall be in accordance with Article Corrosion Protection Coating.

F. Manufacturers and Products:

1. Cincinnati Fan.
2. Aerovent.
3. Hartzell.
4. Or approved equal in accordance with B6.

2.09 BIOFILTER FAN, CENTRIFUGAL SWSI (BF-110)

A. General:

1. Factory-assembled utility blower; including housing, fan wheel, drive assembly, motor, and accessories.
2. Suitable to convey air at temperatures up to 121 degrees C.
3. Fan Performance: AMCA 99-2408 Class III.
4. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housing:

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1. Material: Epoxy coated steel.
 2. Construction:
 - a. Curved scroll configuration, with continuous seam welding and side angle reinforcement.
 - b. Lifting lugs welded to housing.
 - c. Drain connection located at lowest point of fan housing.
 - d. Inlet/Outlet: Flanged and drilled to permit duct connection as shown on Drawings.
 3. Base/Pedestal: All welded heavy gauge Type 316 stainless steel.
- C. Wheel:
1. Centrifugal, one-piece, non-overloading, blade type as scheduled.
 2. Material: Epoxy coated steel
 3. Attached to fan shaft with split taper lock bushing.
- D. Shaft, Bearings, Drive:
1. Shafts:
 - a. Turned, ground and polished steel.
 - b. Ends drilled and countersunk for tachometer readings.
 - c. Keyed for sheave installation.
 2. Bearings:
 - a. Grease lubricated, precision antifriction ball, self-aligning type.
 - b. Mounted in cast iron pillow block housing.
 - c. Selected for average life (ABMA 9 L50) of not less than 200,000 hours operation at maximum cataloged operating speed.
 3. Drives:
 - a. In accordance with Article Fan Drives.
 - b. Factory set to specified fan revolutions per minute.
 - c. Type: Belt.
 - d. Arrangement: Counter-Clockwise Bottom Horizontal Discharge.
- E. Accessories: Provide as follows and, in addition, as indicated in Equipment Schedule:
1. Housing Access Doors: Bolted and gasketed.
 2. Flanged Inlet: Heavy gauge construction, factory drilled and flanged.
 3. Shaft Seal: Viton construction, located at shaft penetration of housing.
 4. Belt Guard: OSHA type, sheet metal construction same material as fan housing, for complete coverage of belts and sheaves.
 5. Shaft and Bearing Guard: Sheet metal construction same material as fan housing, for complete coverage of shaft and bearings.
 6. Motor and Drive Cover:
 - a. Factory fabricated, OSHA type.
 - b. Sheet metal construction, same material as fan housing.
 - c. Vented, openings sufficient size for proper motor cooling.
 7. Unitary Sub-base:

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- a. Structural metal sub-base, same material as fan housing.
- b. Bolted to bottom of fan base/pedestal.
- c. Drilled for field installation of vibration isolators.
- 8. Spark Resistant Construction Classification: AMCA 99-0401 Type B.
- 9. Corrosion Protection Coating:
 - a. Provide factory-applied corrosion protection coating on these fan components:
 - 1) Wheel (or propeller).
 - 2) Housing.
 - 3) Accessories.
 - 4) Interior surfaces in contact with airstream.
 - b. Coating system shall be baked epoxy phenolic and shall be in accordance with Article Corrosion Protection Coating.

F. Manufacturers:

- 1. New York Blower.
- 2. Aerovent.
- 3. Twin City.
- 4. Or approved equal in accordance with B6.

2.10 CORROSION PROTECTION COATING

A. General:

- 1. Factory-applied corrosion protection coating for application to fan components and accessories, where required by this Section.
- 2. Quality Control:
 - a. Verify dry film thickness before final baking.
 - b. Finished coating system shall be free from voids, checks, cracks and blisters.
- 3. Surface Cleaning: Clean parts to be coated as follows:
 - a. Immerse parts in heated cleaning solution to remove lubricants, machining oils, and residual factory contamination.
 - b. Follow with immersion in potable water bath to neutralize and remove cleaning solution.
 - c. Chemical Pretreatment: Immerse parts in heated chemical solution, iron phosphate for steel, clear/yellow chromate for aluminum.

B. Baked Enamel:

- 1. Material: Alkyd modified urea-melamine single component baking enamel.
- 2. Surface Preparation: Clean surface to SSPC-SP 3.
- 3. Application: Standard air-pressurized spray equipment.
- 4. Curing: Oven baked at a metal temperature not to exceed 149 degrees F.
- 5. Finished Thickness: 25 microns to 50 microns dry film thickness.
- 6. Performance: Coating shall meet or exceed following criteria:
 - a. Impact Resistance: 0.155 kg meter, ASTM D2794 test method.

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- b. Pencil Hardness: 2H, ASTM D3363 test method.
- c. UV Resistance: UV inhibited life of minimum 10 years when exposed to sun.
- d. Service Temperature: Maximum 110 degrees C, continuous.

C. Baked Epoxy Phenolic:

- 1. Material:
 - a. Baking cross-linked epoxy-phenolic.
 - b. For outdoor applications, apply an UV resistant topcoat.
- 2. Surface Preparation: Sandblast surface to SSPC-SP 5.
- 3. Application: Electrostatic or conventional compressed air spray equipment.
- 4. Curing: Oven baked at a metal temperature not to exceed 204 degrees C
- 5. Finished Thickness: 150 microns to 200 microns dry film thickness.
- 6. Performance: Coating shall meet or exceed following criteria:
 - a. Salt Spray Test: Minimum 1,000-hour duration, ASTM B117 test method.
 - b. Humidity Resistance: Minimum 1,000-hour duration, ASTM D2247 test method.
 - c. Impact Resistance: 1.84 kg meter, ASTM D2794 test method.
 - d. Pencil Hardness: 3H, ASTM D3363 test method.
 - e. UV Resistance: UV inhibited life of minimum 10 years when exposed to sun.
- 7. Service Temperature: Maximum 177 degrees C, continuous.

2.11 MOTORS

A. General:

- 1. Fan motors shall comply with provisions of Section 16220, Low Voltage AC Induction Motors.
- 2. Motors for fans specified for use with variable frequency drives shall be inverter duty type.
- 3. Motors shall not operate into service factor in any case.

B. Motor requirements shall be as follows, unless designated otherwise on Equipment Schedule:

- 1. Torque Characteristics: Sufficient to accelerate driven loads satisfactorily.
- 2. Winding Thermal Protection: None.
- 3. Space Heater: No.
- 4. Number of Speeds: VFD.
- 5. Number of Windings: One.
- 6. Motor Efficiency: Energy efficient.
- 7. Shaft Type: Solid, carbon steel.
- 8. Mounting: As required for fan arrangement.
- 9. Service Factor: 1.15.

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2.12 ACCESSORIES

- A. Equipment Identification Plates: Furnish 16-gauge Type 316 stainless steel identification plate securely mounted on each separate equipment component and control panel in a readily visible location. Plate shall bear 3/8-inch high engraved block type black enamel filled equipment identification number and letters indicated in this Specification and as shown on Drawings.
- B. Lifting Lugs: Furnish suitably attached for equipment assemblies and components weighing over 45 kg.

2.13 SOURCE QUALITY CONTROL

- A. General:
 - 1. Fan shall operate at single stable point as indicated by fan curve. Fans having two potential operating points are not acceptable.
 - 2. Fan and motor combination shall be capable of delivering 110 percent of scheduled air quantity and static pressure. Motor shall not operate into motor service factor in any listed case.
 - 3. Consider drive efficiency in motor selection according to manufacturer's published recommendation or according to AMCA 203, Appendix L.
- B. Testing Provisions:
 - 1. Provide tachometer access holes large enough to accept standard tachometer drive shaft.
 - 2. Center punch fan shaft to accommodate tachometer readings.
- C. Balancing:
 - 1. Unless noted otherwise, each fan wheel shall be statically and dynamically balanced to ASA S2.19 Grade G6.3.
 - 2. Fans controlled by variable frequency drives shall be dynamically balanced at speeds 25 percent, 50 percent, 75 percent, and 100 percent of design revolutions per minute.
- D. Vibration Test:
 - 1. Each fan furnished with a 3.7 kW or larger motor shall have factory run vibration test, including vibration signatures taken on each bearing in horizontal, vertical, and axial direction.
 - 2. Vibration reading as measured at scheduled rotational speed shall not exceed the following values when fan is rigidly mounted:
 - a. Belt Drive (except Vane Axial): 0.38 cm per second peak velocity.
 - b. Belt Drive Vane Axial: 0.2 cm per second peak velocity.
 - c. Direct Drive: 0.2 cm per second peak velocity.
 - 3. Written records of run test and vibration test shall be made available upon request.

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PART 3 EXECUTION

3.01 INSTALLATION

- A. Install fans level and plumb.
- B. Scroll Drains: Provide access plug.
- C. Labeling:
 - 1. Label fans in accordance with Article Accessories.
- D. Service Access: Locate units to provide access spaces required for motor, drive, bearing servicing, and fan shaft removal.
- E. Equipment Support and Restraints:
 - 1. Install floor-mounted units on concrete bases designed to withstand, without damage to equipment, the seismic force required by code.
 - 2. Secure vibration controls to concrete bases using anchor bolts cast in concrete base.
- F. Connections
 - 1. Refer to Section 15200, Process Piping.
 - 2. Isolate duct connections to fans.
 - 3. Install ductwork adjacent to fans to allow proper service and maintenance.

3.02 FIELD QUALITY CONTROL

- A. Functional Tests:
 - 1. Verify blocking and bracing used during shipping are removed.
 - 2. Verify fan is secure on mountings and supporting devices, and connections to ducts and electrical components are complete.
 - 3. Verify proper thermal-overload protection is installed in motors, starters, and disconnect switches.
 - 4. Verify that cleaning and adjusting are complete.
 - 5. Disconnect fan drive from motor; verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation.
 - 6. Reconnect fan drive system; align and adjust belts and install belt guards.
 - 7. Verify lubrication for bearings and other moving parts.
- B. Performance Tests:
 - 1. Starting Procedures:
 - a. Energize motor and adjust fan to indicated revolutions per minute.
 - b. Measure and record motor voltage and amperage.
 - 2. Operational Test:
 - a. After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

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- b. Repair or replace malfunctioning units; retest as specified after repairs or replacement is made.
- c. Test and adjust control safeties.
- d. Replace damaged and malfunctioning controls and equipment.

3.03 MANUFACTURER'S SERVICES

- A. Provide manufacturer's representative at Site for installation assistance, inspection and certification of proper installation, equipment testing, startup assistance, and training of City's personnel for specified component, subsystem, equipment, or system.
- B. Manufacturer's Representative: Present at Site or classroom designated by City, for minimum person-days listed below, travel time excluded:
 - 1. 1 person-day per shift for installation assistance and inspection for each type of fan, performance testing, and completion of Manufacturer's Certificate of Proper Installation.
 - 2. Number of shifts: 2.
- C. Refer to Section 01640, Manufacturers' Services, and Section 01810, Equipment Testing and Facility Startup.

3.04 ADJUSTING

- A. Adjust belt tension.
- B. Lubricate bearings.
- C. Balancing:
 - 1. Perform air system testing to verify design flow and pressure is being delivered by all fans.
 - 2. Replace fan and motor sheaves as required to achieve design airflow.
- D. Vibration Testing:
 - 1. Perform field-testing on rotating equipment, to determine actual operating vibration.
 - 2. If manufacturer recommended vibration limits are exceeded, rebalance equipment in-place until design tolerances are met.

3.05 CLEANING

- A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris, and repair damaged finishes.
- B. On completion of installation, internally clean fans according to manufacturers' written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.

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3.06 SUPPLEMENTS

- A. The supplements listed below, following “End of Section,” are a part of this Specification.
 - 1. 15830-01, Fan Schedule - Process.

END OF SECTION

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SYMBOL			CF-101 thru CF-104	BF-110	
SERVICE			ODOROUS COMPOST AIR	ODOROUS COMPOST AIR	
TYPE			UTILITY BLOWER, CENTRIFUGAL SWSI HEAVY-DUTY	UTILITY BLOWER, CENTRIFUGAL SWSI HEAVY-DUTY	
FAN DATA	AIRFLOW	MAX	L/s	2,171	13,875
		@ SP	Pa	2,491	1,993
		MIN	L/s	2,171	13,875
	SPEED	RPM		1,775	1,446
	DRIVE TYPE			VFD, Direct, CWB ALUMINUM	VFD, Belt, CCB Coated Steel
	WHEEL	TYPE			
		MIN. DIA.	mm	737	914
MAXIMUM	kW		10.29	43.03	
SOUND DATA	SOUND POWER LEVEL dB (RE 10 ⁻¹² W) @ MID OCTAVE BAND FREQUENCY (Hz)		63	80	102
			125	85	98
			250	80	103
			500	82	101
			1K	80	96
			2K	77	93
			4K	74	88
			8K	73	81
ELECTRICAL DATA	MOTOR		kW	11.2	44.74 with a max. of 55.93
			RPM	1,750	1,800
			ENCL.	TEFC	TEFC
	VOLT		575	575	
	PH		3	3	
MAXIMUM DIMENSIONS	LENGTH	mm	940	1575	
	WIDTH	mm	864	1700	
	HEIGHT	mm	1220	1473	
	WEIGHT	kg	402	1270	
MANUFACTURER			Cincinnati	Twin City	
MODEL NO.			RBE-17	365 BC-SW	
APPLICABLE REMARKS:			A,C,D	A,B,C,D, E	
ABBREVIATIONS: FC: FORWARD CURVED BI: BACKWARD INCLINED AF: AIR FOIL					
REMARKS:					
A: 100% WHEEL DIAMETER			D: FLANGED INLET/OUTLET		
B: INLET BOX			E: Epoxy Coated		
C: DRAIN, DRAIN PLUG			F:		

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PART 1. GENERAL

1.01 REFERENCES

- A. The following is a list of standards which may be referenced in this section:
1. Air-Conditioning and Refrigeration Institute (ARI): 880, Air Terminals.
 2. ASTM International (ASTM): C636, Standard Practice for Installation of Metal Ceiling Suspension System for Acoustical Tile and Lay-in Panels.
 3. Underwriters' Laboratories of Canada. (ULC): Product Directories.

1.02 DEFINITIONS

- A. NC: Noise Criteria; background sound rating method for indoor sound.
- B. VAV: Variable air volume.

1.03 SUBMITTALS

- A. Action Submittals:
1. Shop Drawings:
 - a. Manufacturer's data and descriptive literature for products specified.
 - b. Furnish the following information for each type of diffuser, register, and grille furnished.
 - 1) Static pressure loss data.

PART 2. PRODUCTS

2.01 EQUIPMENT SCHEDULES

- A. Refer to Drawings.

2.02 RETURN, EXHAUST AND TRANSFER GRILLES AND REGISTERS

- A. Louvered Return, Exhaust and Transfer Grilles and Registers:
1. Construction: As follows:
 - a. Material: Aluminum.
 - b. Finish: Aluminum
 2. Fixed horizontal louvers set at 35 degrees to 45 degrees.
 3. 25 mm minimum flat, rectangular frame.
 4. Manufacturers and Products:
 - a. Krueger; S80/S580H Series.
 - b. Carnes; Type RAAAH.
 - c. Titus; 350 Series.

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PART 3. EXECUTION

3.01 INSTALLATION

- A. Install diffusers, grilles, and registers tight on their respective mounting surfaces, level, plumb, and true with room dimensions.
- B. Provide appropriate frame to adapt to mounting surface.

END OF SECTION

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PART 1. GENERAL

1.01 SUBMITTALS

A. Informational Submittals:

1. Testing Plan: Submit prior to testing and include at least the information that follows.
 - a. Testing dates.
 - b. Piping systems and section(s) to be tested.
 - c. Test type.
 - d. Method of isolation.
 - e. Calculation of maximum allowable leakage for piping section(s) to be tested.
2. Certifications of Calibration: Testing equipment.
3. Certified Test Report.

PART 2. PRODUCTS (NOT USED)

PART 3. EXECUTION

3.01 PREPARATION

- A. Notify Contract Administrator in writing five (5) days in advance of testing. Perform testing in presence of Contract Administrator.
- B. Pressure Piping:
 1. Install temporary thrust blocking or other restraint as necessary to protect adjacent piping or equipment and make taps in piping prior to testing.
 2. Wait five (5) days minimum after concrete thrust blocking is installed to perform pressure tests. If high-early strength cement is used for thrust blocking, wait may be reduced to two (2) days.
 3. Prior to test, remove or suitably isolate appurtenant instruments or devices that could be damaged by pressure testing.
 4. Items that do not require testing include: tank overflows to atmospheric vented drains, tank atmospheric vents.
 5. Test Pressure: As indicated on Piping Schedule.
- C. Test section may be filled with water and allowed to stand under low pressure prior to testing.
- D. Gravity Piping:
 1. Perform testing after service connections, manholes, and backfilling have been completed between stations to be tested.
 2. Determine groundwater level at time of testing by exploratory holes or other

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method acceptable to Contract Administrator.

3.02 HYDROSTATIC TEST FOR PRESSURE PIPING

- A. Fluid: Clean water of such quality to prevent corrosion of materials in piping system.
- B. Exposed Piping:
 - 1. Maximum Filling Velocity: 0.076 meter per second, applied over full area of pipe.
 - 2. Vent piping during filling. Open vents at high points of piping system or loosen flanges, using at least four bolts, or use equipment vents to purge air pockets.
 - 3. Maintain hydrostatic test pressure continuously for 60 minutes, minimum, and for such additional time as necessary to conduct examinations for leakage.
 - 4. Examine joints and connections for leakage.
 - 5. Correct visible leakage and retest as specified.
 - 6. Empty pipe of water prior to final cleaning.
- C. Buried Piping:
 - 1. Test after backfilling has been completed.
 - 2. Expel air from piping system during filling.
 - 3. Apply and maintain specified test pressure with hydraulic force pump. Valve off piping system when test pressure is reached.
 - 4. Maintain hydrostatic test pressure continuously for 2 hours minimum, reopening isolation valve only as necessary to restore test pressure.
 - 5. Determine actual leakage by measuring quantity of water necessary to maintain specified test pressure for duration of test.
 - 6. Maximum Allowable Leakage:

$$L = \frac{SD(P)^{1/2}}{6.894}$$
 where:
 - L = Allowable leakage, in Litre per second.
 - S = Length of pipe tested, in metre.
 - D = Nominal diameter of pipe, in millimeter.
 - P = Test pressure during leakage test, in kPa.
 - 7. Correct leakage greater than allowable, and retest as specified.

3.03 PNEUMATIC TEST FOR PRESSURE PIPING

- A. Do not perform on:
 - 1. PVC or CPVC pipe.
 - 2. Piping larger than 450 mm.
 - 3. Buried and other non-exposed piping.
- B. Fluid: Oil-free, dry air.

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- C. Procedure:
1. Apply preliminary pneumatic test pressure of 172 kPa maximum to piping system prior to final leak testing, to locate visible leaks. Apply soap bubble mixture to joints and connections; examine for leakage.
 2. Correct visible leaks and repeat preliminary test until visible leaks are corrected.
 3. Gradually increase pressure in system to half of specified test pressure. Thereafter, increase pressure in steps of approximately one-tenth of specified test pressure until required test pressure is reached.
 4. Maintain pneumatic test pressure continuously for minimum of 10 minutes and for such additional time as necessary to conduct soap bubble examination for leakage.
 5. Correct visible leakage and retest as specified.
- D. Allowable Leakage: Piping system, exclusive of possible localized instances at pump or valve packing, shall show no visual evidence of leakage.

3.04 HYDROSTATIC TEST FOR GRAVITY PIPING

- A. Testing Equipment Accuracy: Plus or minus 1.9-litre water leakage under specified conditions.
- B. Maximum Allowable Leakage: 0.078 litre per hour per millimeter diameter per 100 feet. Include service connection footage in test section, subjected to minimum head specified.
- C. Gravity Sanitary Piping: Test with 4.6 m of water to include highest horizontal vent in filled piping. Where vertical drain and vent systems exceed 4.6 m in height, test systems in 4.6 m vertical sections as piping is installed.
- D. Exfiltration Test:
1. Hydrostatic Head:
 - a. At least 1.8 meter above maximum estimated groundwater level in section being tested.
 - b. No less than 1.8 meter above inside top of highest section of pipe in test section, including service connections.
 2. Length of Pipe Tested: Limit length such that pressure on invert of lower end of section does not exceed 9.1 m of water column.
- E. Infiltration Test:
1. Groundwater Level: At least 1.8 meter above inside top of highest section of pipe in test section, including service connections.
- F. Piping with groundwater infiltration rate greater than allowable leakage rate for exfiltration will be considered defective even if pipe previously passed a pressure test.
- G. Defective Piping Sections: Replace, and retest as specified.

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3.05 PNEUMATIC TEST FOR GRAVITY PIPING

A. Equipment:

1. Calibrate gauges with standardized test gauge provided by Contract Administrator at start of each testing day. Contract Administrator will witness calibration.
2. Install gauges, air piping manifolds, and valves at ground surface.
3. Provide pressure release device, such as rupture disc or pressure relief valve, to relieve pressure at 41.4 kPa or less.
4. Restrain plugs used to close sewer lines to prevent blowoff.

B. Procedure:

1. Require that no person enter manhole where pipe is under pressure.
2. Slowly introduce air into pipe section until internal air pressure reaches 27.6 kPa greater than average back pressure of groundwater submerging pipe.
3. Allow 2 minutes minimum for air temperature to stabilize.

- C. Allowable Leakage: Test section will be considered defective when time required for pressure to decrease from 24.1 kPa to 17.2 kPa greater than average back pressure of groundwater submerging pipe is less than that computed utilizing values from following table:

TABLE 1*					
A	B	C	D	E	F
Pipe Diameter (mm)	Time per Meter up to Length in Col C (Seconds)	Test Length (m)	Test Time for any Length Between Col C & E (Min:Sec)	Length at Which Time in Col F Applies (m)	Time per Meter for Total Length (Seconds)
100	0.59	193.9	1:54	339.5	0.33
150	1.31	129.2	2:50	226.5	0.75
200	2.33	96.9	3:47	169.8	1.34
250	3.64	77.7	4:43	135.9	2.07
300	5.25	64.5	5:40	111.3	2.98
375	8.20	51.8	7:05	89.1	4.66
450	11.90	43.0	8:30	74.4	6.75
525	16.13	36.9	9:55	63.9	9.21
600	21.05	32.3	11:20	56.1	12.03

EXAMPLE: 375 mm diameter pipe:
For 50 m, T = 8.20 sec (Col B) x 50 m = 410 sec = 6:50
For 75 m, T = 7:05 (Col D)

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TABLE 1*					
A	B	C	D	E	F
Pipe Diameter (mm)	Time per Meter up to Length in Col C (Seconds)	Test Length (m)	Test Time for any Length Between Col C & E (Min:Sec)	Length at Which Time in Col F Applies (m)	Time per Meter for Total Length (Seconds)
For 150 m, T = 4.66 sec (Col F) x 150 m = 699 sec = 11:39					
*Based on 0.015 L/s/m ² with a minimum significant loss of 0.94 L/s and a maximum loss of 1.65 L/s.					

- D. Piping with groundwater infiltration rate greater than allowable leakage rate for exfiltration will be considered defective even if pipe previously passed a pressure test.
- E. Defective Piping Sections: Replace, and retest as specified.

3.06 FIELD QUALITY CONTROL

- A. Test Report Documentation:
 1. Test date.
 2. Description and identification of piping tested.
 3. Test fluid.
 4. Test pressure.
 5. Remarks, including:
 - a. Leaks (type, location).
 - b. Repair/replacement performed to remedy excessive leakage.
 6. Signed by Contractor and Contract Administrator to represent that test has been satisfactorily completed.

END OF SECTION