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END OF SECTION

MECHANICAL GENERAL REQUIREMENTS 20 01 01

1 GENERAL

1.1 General Contract Documents

- .1 Comply with General Conditions of the Contract, Supplementary Conditions of the Contract, and Division 01 - General Requirements.
- .2 Where content in this Specification section duplicates requirements in various Division 01 Specification sections, this section and the applicable Division 01 sections are to be read together and the most stringent requirements apply.

1.2 Work Included

- .1 Work to be done under Divisions 20, 21, 22, 23 and 25 to include furnishing of labour, materials and equipment required for installation, testing and putting into proper operation complete mechanical systems as shown, as specified, as intended, and as otherwise required. Complete systems to be left ready for continuous and efficient satisfactory operation.
- .2 Read drawings and specifications together as a whole and in conjunction with other such documents included under the Construction Contract.

1.3 Document Organization

- .1 Applicable Divisions for Mechanical Work:
 - .1 Division 20 - Common Work for Mechanical
 - .2 Division 22 - Plumbing and Drainage
 - .3 Division 23 - Heating, Ventilation and Air Conditioning (HVAC)
 - .4 Division 25 - Building Automation System
- .2 For clarity, any reference in the Contract Documents to Division 20 includes Divisions 21, 22, 23 and 25.
- .3 The Specifications for these Divisions are arranged in sections for convenience. It is not intended to recognize, set or define limits to any subcontract or to restrict Contractor in letting subcontracts.
- .4 Contractor is responsible for completion of work whether or not portions are sublet.

1.4 Division 20, as it applies to Divisions 22, 23 and 25

- .1 Division 20 contains common work requirements that are applicable as necessary to the Work of Divisions 21 to 25 and apply as if written in full within those Divisions.

1.5 Language

- .1 The specification is written as a series of instructions addressed to the Contractor, and by implication to subcontractors and to suppliers. For clarity and brevity, use is made of numbered lists and bulleted lists. Where a list follows a semi-colon (;) the punctuation is for clarity. Where a list follows a colon (:) the punctuation is to be read as a short-hand form of the verb "to be" or "to have" as context requires.
- .2 It is not intended to debate with the Contractor the reasons for these instructions, and words associated with justification for an instruction or restatement of anticipated performance have been omitted to avoid possible ambiguities.

1.6 Definitions and Abbreviations

- .1 Specification section 20 01 13 *Definitions and Abbreviations – Mechanical* contains general definitions and abbreviations that apply to one or more specification sections of this Division of the Work. Other specification sections of the mechanical Divisions of the Work may also include additional specific definitions and/or abbreviations that apply to that specification section.
- .2 The following general terms apply to Divisions 20 to 25 of the Work:
 - .1 The words "indicated", "shown", "noted", "listed" or similar words or phrases used in this Specification, mean that material or item referred to is "indicated", "shown", "listed" or "noted" on Drawings or in Specification.
 - .2 Wherever the word "listed" is used in conjunction with a product and a product certification standard (including but not limited to CSA, ULC, CGSB, BNQ, UL), it shall be understood to mean that the product is "listed" by an accredited 3rd party testing laboratory as being certified to the referenced product standard.
 - .3 Wherever the words "approved", or similar words or phrases are used in the Specification they shall be understood, unless the context otherwise provides, to mean that material or item referred to shall be "approved by" the Owner.
 - .4 Wherever the words "satisfactory", "as directed", "submit", "permitted", "reviewed", or similar words or phrases are used in the Specification they shall be understood, unless the context otherwise provides, to mean that material or item referred to shall be "satisfactory to", "as directed by", "submitted to", "permitted by", or "reviewed by" the Consultant.
 - .5 Instructions using any form of the word:
 - (a) "install" means to place in position and activate for service or use,
 - (b) "supply" means to procure and deliver materials to the place of the Work, or to make available labour or services for the stated purpose,
 - (c) "provide" means to supply material, labour and services to install the referenced item.
 - .6 The term "building code" means the edition of the applicable building code at the time of obtaining a building permit.
 - .7 Wherever manufacturers or manufacturer's products are identified in lists under the phrase "Standard of Acceptance", these are manufacturers and/or products which meet the project standards in regard to performance, quality of material and workmanship.

1.7 Examination

- .1 Examine any existing buildings, local conditions, building site, the specifications and drawings, and report any condition, defect or interference that would prevent execution of the work.
- .2 No allowance will be made for any expense incurred through failure to make these examinations of the site and the documents prior to Tender or on account of any conditions on site or any growth or item existing there which was visible or known to exist at time of Tender.
- .3 Before commencing work under this Division, examine the work of other Divisions of the Work and report any defect or interference.

1.8 Design Services

- .1 Provide specialty design services for elements of the Work where specified in other sections of Division 20. Drawings and specifications prepared by such specialty design service providers shall be sealed by a professional engineer licensed in the jurisdiction of the Work.

1.9 Product Substitutions

- .1 Comply with Specification section 01 25 00 *Substitution Procedures* for requests for substitution of products.

2 SHIPPING, HANDLING AND STORAGE

2.1 Shipping

- .1 Provide adequate protection of equipment during shipping and handling so as to provide equipment at the Work site in ex-works condition when handled by commercial carrier systems.
- .2 Provide, as necessary, removable bracing of the internal components in each item of equipment so that the equipment can be moved on its side or back, without sustaining damage.
- .3 Where removeable internal bracing has been provided, the equipment to be provided with warning labels to call for the removal of the shipping bracing prior to energization.
- .4 Any component that is packaged or shipped separately is to be individually crated and tagged with unit number and the equipment number of the assembly to which it belongs.
- .5 Provide each "shipping section" with a permanently-attached, readily-visible identification tag bearing the equipment number of the assembly of which it is a part.

2.2 Storage

- .1 Store equipment and materials at the worksite to protect them from any damage until placed into its final location. Maintain similar protection of installed equipment and materials to protect against damage until they are turned over to the Owner. Make good any damage to equipment or materials up to the time of ready for takeover.
- .2 Store equipment in accordance with the manufacturer's instructions and not less than:
 - .1 stored in a dry, clean location,
 - .2 cover with polyethylene plastic sheeting,
 - .3 include a desiccant material under the protective sheeting to absorb moisture, or provide heated ventilated air
- .3 Provide adequate ventilation and temporary heating to prevent condensation of moisture within the equipment.

2.3 Provisions for Handling and Field Erection

- .1 For equipment that will require hoisting on site, provide removable side panels, lifting angles or lifting plates to accommodate the use of slings or crane hooks, for each shipping section.
- .2 For floor mounted equipment, provide on each shipping section removable steel channel base plates to permit use of pipe rollers or dollies without damaging the equipment.

3 OWNER'S SPECIAL REQUIREMENTS FOR EXISTING SITES

- .1 The following special requirements are in addition to the requirements of Division 01 of the Work.
- .2 Provide a written list of names for employees and sub-trades entering the building, advising which areas they need access to at least 48 hours prior to expected time of arrival. This lead time is required to prearrange security passes.
- .3 Security passes must be visibly worn at all times by all employees.
- .4 Trades people to strictly adhere to owner's building security procedures otherwise entrance into the building will be denied.

- .5 Trades people are to enter the entrance identified by the Owner.
- .6 Park vehicles in designated areas. Do not block driveways.
- .7 Use only the freight elevator to transport tools and material. Freight elevator door must be shut immediately after exiting the cab.
- .8 Do not disable or activate any electrical or mechanical system without prior approval by the Owner's Project Manager. Also, prior to disabling or activation of any electrical or mechanical system, obtain approval from Building Operations and Building Security.
- .9 Submit prior notification to Building Security Staff before any construction activity commences which will result in heat, smoke, dust or fumes, such as welding, saw cutting, soldering, spray painting, which might affect sensitive fire detection and protection equipment.
- .10 Provide at least 48 hours prior notification to Building Operations for any fire system isolation requests.
- .11 Schedule work and meet with sub-trades daily on site, to show trades people the work areas and work to be done.
- .12 Trades-people are to supply and use their own tools. No tools, ladders or equipment, etc. will be loaned by the Owner.
- .13 Provide environmental cleaning of the job site daily during construction and upon completion. This includes both under raised floor and above ceilings. Do not store materials or garbage on the loading dock.
- .14 Provide special care, attention and protection when transporting equipment and materials to prevent accidental damage to fire protection equipment, finishes, furnishings and fixtures.
- .15 "No Smoking" – this is a smoke-free building. Violators will be asked to leave and may be denied reentry. Smoking is not allowed on the roof.
- .16 [][A security escort will be required for any work being done in secured areas, e.g. raised floor, computer room and mechanical/electrical rooms.]
- .17 If Building Operations deems that work on a particular system requires security escort, allow 48 hours to make appropriate arrangements.
- .18 For any open flame work, provide fire extinguishers and security fire watch.
- .19 Obtain the approval of the Building Manager for the storage of materials on site.
- .20 Perform a daily cleanup prior to leaving the site.
- .21 Secure oxygen and acetylene cylinders at all times and capped nightly.
- .22 Restore operating and redundant systems to their normal condition at the end of each work day unless otherwise approved by the Owner
- .23 At the conclusion of each work day, the Contractor's superintendent/supervisor is to advise the Building Manager on the day's activities and plans for the next day's work.

4 PROGRESS PAYMENT PROCEDURE

4.1 Schedule of Values

- .1 Comply with Specification section 01 29 00 *Payment Procedures*.

5 CONSTRUCTION CHANGES

5.1 General

- .1 Comply with Specification section 01 26 00 *Contract Modifications*.

6 SUBMITTALS

6.1 Shop Drawings and Product Data Sheets

- .1 Submit shop drawings, manufacturers product data and samples in accordance with the requirements of Specification sections of Division 01, this Part, and as further required in other Specification sections of Division 20.
- .2 Submit shop drawings in the same unit of measure as are used on the drawings. Both metric and U.S. customary units may be included.
- .3 Submit shop drawings by email to: shopdrawings@hhangus.com, except where a project document management web-service is used.
- .4 Include a H.H. Angus shop drawing cover sheet form prepared for this project for each shop drawing submittal (refer to part "Attachments" for an example of this form) , or include the same information on the general or trade contractor's submittal cover sheet;
 - .1 Information required on each submission:
 - (a) Client/Architect name,
 - (b) Project Name,
 - (c) H.H. Angus project number,
 - (d) Date,
 - (e) Contractor name,
 - (f) Contractor reference No.,
 - (g) Manufacturer name,
 - (h) Product type,
 - (i) Specification section number,
 - (j) Contractor trade category: architectural, structural, conveying equipment, user equipment, mechanical, electrical, telecommunications, civil or other.
 - (k) If a re-submission, the Consultant's previous submittal reference number.
- .5 Submit shop drawings in PDF format except as follows;
 - .1 if the Consultant agrees to a shop drawing to be submitted in hardcopy format, submit in 8.5 x 11 or 11 x 17 size, black and white originals of graphic quality suitable for photocopying and digital scanning. Allow one additional week for processing of shop drawings submitted in hardcopy format.
- .6 Manufacturer's letter sized product data sheets for standard items are acceptable in place of shop drawings provided that physical characteristics are identified and are related to specification references.
- .7 Submit with manufacturers data sheets, typed schedules listing manufacturer's and supplier's name and catalogue model number.
- .8 For plumbing fixtures and other permeant fixtures, submit fixture sheets with catalogue numbers. Identify and arrange fixture sheets in the same sequence and using the same identification number as shown in specification fixture lists.
- .9 Shop drawings and/or product data sheets to show;
 - (a) dimensioned outlines of equipment and construction details,
 - (b) equipment weights and center of gravity,
 - (c) performance ratings,
 - (d) dimensioned details showing service connection points,

- (e) elevations illustrating locations of visible equipment such as gauges, pilot lights, breakers and their trip settings, windows, meters, and access doors,
 - (f) description of operation,
 - (g) single line diagrams,
 - (h) general routing of bus ducts and connecting services,
 - (i) mounting and fixing arrangements,
 - (j) operating and maintenance clearances,
 - (k) access door swing spaces, and
 - (l) where products are required to be certified to a published standard, the mark of the testing organization who certified the product and the standard reference number to which it is certified.
- .10 Shop drawings and product data to be accompanied by;
- (a) detailed drawings of bases, supports and anchor bolts,
 - (b) sound power data, where applicable, and
 - (c) performance curve for each piece of equipment marked with point of operation.
- .11 Shop drawing and data sheet submission is taken as certification that the products are;
- .1 from the manufacturer's current production, and
 - .2 in compliance with applicable codes, standards, and regulations.
- .12 For standard catalogued (non-custom) products, do not submit drawings showing internal construction details, component assemblies or interior piping and wiring diagrams. Such information may be necessary to understand correct functioning of equipment and are to be submitted with operating and maintenance data.
- .13 Check and stamp each shop drawing as being correct before submission. Shop drawings without such stamps will be rejected and returned.
- .14 Keep one copy of each reviewed shop drawing and product data sheet on site and have them available for reference purposes.
- .15 Where equipment is delivered without reviewed shop drawings, equipment will be condemned and is to be removed from site and replaced with new equipment after shop drawings have been submitted and reviewed.

6.2 Coordination, Fabrication, or Installation Drawings

- .1 Contractor coordination, fabrication, installation and/or sleeving drawings are to be provided in accordance with specification Section 20 01 03 *Mechanical Coordination and Installation Design Services*.
- .2 Contractor's coordination, fabrication, installation, and/or sleeving drawings will not be reviewed as shop drawings. If submitted as a shop drawing, a transmittal only will be returned identifying the submitted drawings have not been reviewed as a shop drawing.
- .3 Maintain a copy on site of such drawings for reference by the Consultant.
- .4 The Consultant reserves the right to request selected Contractor's coordination, fabrication, or installation drawings for review.

6.3 Effect of Consultants Review of Submittals

- .1 Consultant's review of shop drawings is performed on a sampling basis only, to confirm to Consultant's satisfaction that the Contractor understands the Work to be performed and is interpreting the design documents correctly, and such reviews are performed for the benefit of the Owner.

- .2 For greater certainty, the review of shop drawings by Consultant does not constitute a quality control function for the benefit of Contractor, nor does such a review relieve Contractor of their responsibility for complying with the Contract documents.

7 APPLICABLE CODES, STANDARDS AND REGULATIONS; PERMITS

7.1 Codes, Standards and Regulations

- .1 Where a published product standard or installation code is adopted by statute or regulation by an applicable AHJ, the applicable edition of the standard or code is the one that has been adopted
 - .1 at the time of obtaining a permit for the applicable portion of the Work, or
 - .2 in the absence of a requirement for a permit, the start date of construction.
- .2 Where a published product standard or installation code is not adopted by statute or regulation, then the most current edition of that standard or code at the start date of construction applies.
- .3 Install mechanical and electrical systems in accordance with the applicable requirements adopted by the AHJ in the jurisdiction of the Work.
- .4 Where requirements of the Specifications exceed those of applicable codes, standards, and regulations the requirements of the Specifications is to govern.
- .5 In the event of a conflict between codes, bulletins, regulations, or standards, or where work shown is in conflict with these documents, obtain interpretation before proceeding. Failure to clarify any ambiguity will result in an interpretation requiring application of the most demanding requirements.

7.2 Confined Spaces

- .1 Unless otherwise prescribed by the Constructor's / Owner's workplace safety program, treat spaces not designed and constructed for continuous human occupancy as confined spaces in accordance with applicable health and safety legislation, including but not limited to:
 - .1 horizontal and vertical service spaces, shafts, and tunnels,
 - .2 inside of equipment which permits entry of the head and/or whole body, and
 - .3 ceiling spaces which are identified as containing a hazardous substance.

7.3 Permits, Tests and Certificates

- .1 Arrange and pay for permits, tests, and Certificates of Inspection required by the AHJ applicable to the element of the Work.
- .2 Submit applications requiring Owner's signature before commencing work.
- .3 Obtain and submit applicable AHJ Inspection certificates or reports including but not limited to:
 - (a) Electrical inspection,
 - (b) Plumbing and drainage inspection,
 - (c) HVAC inspection,
 - (d) Pressure Vessel Inspection.
 - (e) Piping and Boiler Inspection.
 - (f) Fuel safety Inspection.
- .2 Renew certificates or reports so as to remain in force through the warranty period.
- .4 Co-ordinate and perform testing required by an AHJ in accordance with the Part on Testing in this Section.

8 COMMON PRODUCT REQUIREMENTS

8.1 Standard of Material and Equipment

- .1 Provide materials and equipment in accordance the requirements of Specification section of Division 01 and as follows.
- .2 Materials and equipment:
 - .1 new and of uniform pattern throughout work,
 - .2 of Canadian manufacture where obtainable,
 - .3 standard products of approved manufacture,
 - .4 labeled or listed (certified) to applicable standards in accordance with Specification sections of the Work and as required by authorities having jurisdiction,
 - .5 registered in accordance with the requirements of the applicable provincial pressure vessels regulation and registered in accordance with CSA B51 for Canadian Registration Numbers, as applicable,
 - .6 in compliance with Standards and Regulations including but not limited to;
 - (a) chemical and physical properties of materials,
 - (b) design,
 - (c) performance characteristics, and
 - (d) methods of construction and installation.
 - .7 identical units of equipment to be by the same manufacturer. ,
 - .8 identical component parts of same manufacturer in similar units of equipment, but various component parts of each unit need not be from one manufacturer.
- .3 Materials and equipment are described to establish standards of construction and workmanship. Where manufacturers and/or products are listed under "Standard of Acceptance", select manufacturers and or products from these lists. Use of manufacturers or products other than as listed are subject to specification requirements concerning requests for substitution.
- .4 Include items of material and equipment not specifically noted on Drawings or mentioned in Specifications but which are required to make a complete and operating system.
- .5 Confirm capacity or ratings of equipment being provided, when based on ratings of equipment being provided under other trade Sections, before such items are purchased.
- .6 Factory fabricated control panels and component assemblies are to be listed for electrical safety requirements.
- .7 Select materials and equipment in accordance with manufacturer's recommendations and these Specifications, and install same in accordance with manufacturer's instructions and these Specifications.
- .8 Materials and equipment not satisfying these selection criteria will be condemned. Remove condemned materials from job site and provide properly selected and approved materials.

8.2 Manufacturers Nameplates

- .1 Provide manufactured equipment with metal nameplate with raised or recessed lettering, mounted on each piece of equipment. On insulated equipment, mechanically fasten plates on metal stand-off bracket arranged to clear insulation.
- .2 Manufacturer's nameplate to indicate equipment size, capacity, model designation, manufacturer's name, serial number, voltage, cycle, phase and power rating of motors, and approval listings.

- .3 Certified products are to clearly show the mark of the certification agency when in the final installed state.

8.3 Factory Applied Painting

- .1 Protect factory finished equipment during construction, and clean at completion of work.
- .2 Touch-up factory painted prime and/or final coats damaged during construction, with colour matching paint recommended by the equipment manufacturer.
- .3 Use heat resistant paint where conditions require.

8.4 Factory Applied Prime Painting

- .1 Factory-prime paint other equipment fabricated from iron or steel, including equipment supports and hangers, access platforms, access doors, registers, grilles, diffusers, dampers, metal radiation enclosures and fire hose cabinets where separate product specifications do not require a factory applied final coat.

8.5 Field Painting

- .1 After equipment has been installed and piping and insulation is completed, clean rust and oil from exposed iron and steel work provided under this Division, whether or not it has been factory prime painted.
- .2 In "occupied" areas of building touch up any damage to prime coat resulting from shipping or installation and leave ready for final decorative painting under Finishes, Division 9.
- .3 In "un-occupied" areas of the building such as mechanical equipment rooms, boiler rooms, fan rooms, crawl spaces, pipe tunnels and penthouses, provide corrosion coatings and floor sealers in accordance with specification section 20 05 02 *Painting for Mechanical Services*.
- .4 In addition, apply prime and/or final paint coats to equipment and materials where specifically detailed in other Sections of these Divisions.

8.6 Provision for Future

- .1 Where space is indicated as reserved for future equipment or for future extension to building, leave such space clear and install piping, raceways and equipment so that connections can be made to future apparatus or building.
- .2 Identify provisions and service terminations for future on Record Drawings.

8.7 Maintenance of Bearings

- .1 Turn-over rotating equipment at least once a month from delivery to site until start-up.
- .2 Run-in sleeve type bearings in accordance with manufacturer's written recommendation. After "run-in", drain, flush out and refill with new charge of oil or grease.
- .3 Protect bearings, shafts and sheaves against damage, corrosion and dust accumulation during building construction.

8.8 Pre-purchased Equipment; Damage and Ownership

- .1 At time of receipt of pre-purchased or pre-tendered equipment at the job site by the installing mechanical contractor, provide the services of the manufacturer/distributor/supplier's technical representative to:
 - .1 inspect the equipment prior to unloading,

- .2 witness the unloading and advise the contractor on the appropriate method for handling the equipment in order to avoid damage during the unloading, moving and setting in place phase of the equipment, and
- .3 report any damage to the Consultant.
- .2 In the event the equipment has been found to be damaged before unloading, it is to be returned immediately to the factory for repairs and/or replacement by the manufacturer/supplier.
- .3 In the event of damage occurring at any time during unloading and until the equipment is accepted by the Owner, the installing contractor is responsible for repairs and/or replacement of the damaged equipment to the satisfaction of the Owner.

9 OFFICE AND STORAGE; TOOLS

9.1 Office and Storage

- .1 Provide temporary office, washroom and lunchroom facilities, workshop, and tools and material storage space in accordance with Specification section 01 52 00 *Construction Facilities*.

9.2 Tools, Temporary Equipment and Materials

- .1 Provide tools, equipment, scaffolding, extension cords, lamps and miscellaneous consumable materials, required to carry out the Work.

10 COORDINATION; INSTALLATION DRAWINGS

10.1 Coordination

- .1 Consultant drawings are diagrammatic and illustrate the general location of equipment, and intended routing of ductwork, piping, etc. and do not show every structural detail. In congested areas drawings at greater scale may be provided to improve interpretation of the Work. Where equipment or systems are shown as "double line", they are done so either to improve understanding of the Work, or simply as a result of the use of a CAD drawing tool, and in either case such drawings are not represented as fabrication or installation drawings.
- .2 Lay out and coordinate Work to avoid conflict with work under other Divisions.
- .3 Make good damage to Owner's property or to other trade's work caused by inaccurate layout or careless performance of work of this Division.
- .4 When equipment provided under other Sections connects with material or equipment supplied under this Section, confirm capacity and ratings of equipment being provided.
- .5 Take information involving accurate measurements from dimensioned Architectural Drawings or at building.
- .6 Install services and equipment which are to be concealed, close to building structure so that furring is kept to minimum dimensions.
- .7 Location of pipes, ductwork, raceways and equipment may be altered without extra cost provided instruction is given or approval is obtained, in advance of installation of items involved. Changes will be authorized by site instructions and are to be shown on Record Drawings.
- .8 Location of floor drains, hub drains, combination drains, plumbing fixtures, convectors, unit heaters, diffuser, registers grilles and other similar items may be altered without extra cost provided instruction is given prior to roughing in. No claim will be paid for extra labour and materials for relocating items up to 3 m (10 ft) from original location nor will credits be anticipated where relocation up to 3 m (10 ft) reduces material and labour.

- .9 Include incidental material and equipment not specifically noted on Drawings or mentioned in Specifications but which is needed to complete the work as an operating installation.

10.2 Field, Fabrication, and Installation Drawings

- .1 Prepare field, fabrication, and/or installation drawings to show location of equipment and relative position of services, and to demonstrate coordination with the work of other trades;
 - .1 drawing scale: minimum 1:50 (1/4"=1'-0")
 - .2 use information from manufacturer's shop drawings for each trade and figured dimensions from latest Architectural and Structural Drawings,
 - .3 layout equipment and services to provide access for repair and maintenance,
- .2 Circulate drawings to other trades involved in each area, and conduct coordination meetings with those trades.

11 ANCHORS AND INSERTS

- .1 Supply anchor bolts and locating templates for installation in advance of concrete pouring.

12 CUTTING, PATCHING AND REMEDIAL WORK

12.1 General

- .1 Assume responsibility for prompt installation of work in advance of concrete pouring, masonry, roofing, finishing trades and similar work. Should any cutting or repairing of either unfinished or finished work be required because such installation was not done, employ the particular trade whose work is involved to do such cutting and patching and pay for any resulting costs.
- .2 Neatly cut or drill holes required in existing building elements to accommodate building services including ductwork, piping, cable, raceways, bus duct or cable tray.
- .3 Arrange and pay for all cutting and patching as required for the Work. Before cutting, drilling, or sleeving structural load bearing elements, obtain the Consultant's approval of location and methods in writing. Employ original installer or expert in the finishing of material required to perform cutting or patching for weather-exposed, moisture-resistant elements or sight-exposed surfaces.

12.2 Structure Scanning and Cutting

- .1 Layout cutting of structural elements, such as floors slabs, walls, columns or beams and obtain approval before starting work. Conduct an initial electromagnetic scan of reinforcing rods and electrical conduit, and review with structural engineering Consultant.

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- .2 the use of radiographic imaging methods is subject to approval by the Owner on a case by case basis.
- .2 Based on the preceding results, provide two-dimensional ground penetrating radar scans to locate concrete reinforcement, conduits and other embedment's. Scanners to be operated by personnel trained by the measurement device manufacturer.

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- ° Hilti PS1000 X-SCAN

- .3 Relocate core drilling location if steel or conduit is found in the proposed location and repeat procedure. Reroute any circuits damaged by core drilling.

- .4 Scan for all shots and anchors in floors, walls, and ceilings.

13 PROTECTION OF PERSONNEL, WORK, AND PROPERTY

13.1 Personnel Protection

- .1 Without limiting the Contractor's responsibilities regarding occupational health and safety requirements at the construction site, provide specific personnel protection as follows:
 - .1 protect exposed live equipment during construction for personnel safety,
 - .2 shield and mark live parts "LIVE 120 VOLTS", or with appropriate voltage,
 - .3 arrange for installation of temporary doors for rooms containing electrical distribution equipment. Keep these doors locked except when under direct supervision of electrician,
 - .4 do not leave conduit, wires, cables, tools, equipment or materials in such a way that they constitute a hazard,
 - .5 provide toe guards around openings in the roof or floor to prevent materials or debris from dropping down to a lower level,
 - .6 remove loose equipment and tools from overhead areas before leaving each day,
 - .7 cut off bolts at floor level to eliminate a possible tripping hazard.

13.2 Protection During Construction

- .1 Provide protection required to enable existing building and equipment to remain in continuous and normal operation.
- .2 Take the necessary precautions to protect equipment, existing building and service from damage during the Work. Accept responsibility for any damage and make good without cost to the Owner.
- .3 Protect existing surfaces and items so that they are not damaged in any way whatsoever by the work of all trades. Take precautions as necessary to prevent damage to walls, floors, ceilings, windows, doors, door frames, moldings, finishes, piping, ductwork, light fixtures, etc. Provide protection, hoarding, tarpaulins, dust sleeves etc., as required. Any damage caused because of lack of adequate protection to be made good at no cost to the Owner.
- .4 Take care when working above or around equipment that must remain in service.
- .5 Take care to eliminate dust in equipment areas.
- .6 Protect switchgear fronts from accidental breaker trips when working around or above them. Provide an extended shield constructed of 12 mm (½") fire retardant plywood a minimum of 450 mm (18") from board front to allow access to board.

13.3 Core Drilling

- .1 Wherever core drilling is required, provide temporary dust proof screens.
- .2 In areas where core drilling through a slab in an operating facility is necessary, clearly mark out the areas to be drilled on the underside of slab. Owner's representative to be notified at least 1 week prior to core drilling operation. Provide tarping of equipment supervised by the Owner.

- .3 During core drilling operations, station at least one person directly below the area of drilling with a large plastic container pressed to underside of slab to capture and hold core and water upon completion of operations.
- .4 Continuously use a wet/dry commercial quality vacuum at location of drilling operation to remove all excess water from the area.

13.4 Temporary Dust Proof Screens

- .1 Provide temporary dust proof screens in accordance with Specification section 01 56 00 *Temporary Barriers and Enclosures*

13.5 Protection of Floors During Equipment Installation

- .1 Provide protection of floor finishes during installation or removal of equipment, and at any other time when moving or installing heavy equipment.
- .2 Install 19mm (¾") plywood over 6 mil plastic over finished floor areas when moving heavy equipment that could damage floor finish, or when installing equipment or line materials overhead.
- .3 Repaint or re-tile any floors or walls damaged or scratched during construction.

13.6 Housekeeping

- .1 Maintain a high level of cleanliness.
- .2 Remove scrap and refuse from the work area daily.
- .3 Whenever possible, clean up immediately following completion of work.
- .4 Deposit oily and waste solvent rags in approved containers to minimize the fire hazard.
- .5 Sweep and damp mop daily.

14 WORK IN EXISTING BUILDING

14.1 General

- .1 Comply with Specification section 01 14 00 *Work Restrictions* for restrictions on working in existing occupied buildings and as follows.
- .2 During the tender period, the Contractor shall perform a site inspection of the place of work and surroundings including the accessible ceiling spaces and other areas where access could be considered reasonable. Make a thorough investigation of as-built conditions to determine scope of renovation or demolition work required prior to submitting tender.
- .3 The Work includes changes to existing building and changes at junction of old and new construction. Route pipes, ducts, conduits and other services to avoid interference with existing installation.
- .4 Perform core drilling any day between 7 pm and 7 am. Coordinate with Owner for specific times.
- .5 Relocate existing pipes, ducts, conduits, bus ducts and any other equipment or services required for proper installation of new work, including as required for temporary removal and re-installation to suit new installation work.
- .6 Remove existing plumbing fixtures, lighting fixtures, piping, ductwork, wiring, and equipment to suit new construction. Cut back and cap drain, vent and water outlets, conduits and electrical outlets, not being used.

- .7 Unless noted otherwise removed materials and equipment become the property of the Contractor and are to be taken from the site and disposed of appropriately.
- .8 On completion of relocations, confirm relocated equipment are in proper working order.
- .9 Where Owner wishes to take over renovated areas ahead of project completion date and these areas are to be fed from new distribution systems, make temporary connections to existing services in these areas. Reconnect to permanent services, at later date, when new distribution systems are available.

14.2 Continuity of Services

- .1 Keep existing buildings in operation with minimum length of shutdown periods.
- .2 Make connections to existing systems at approved times.
- .3 Obtain written approval recording times when connections can be made.
- .4 Arrange work so that physical access to existing buildings is not unduly interrupted.
- .5 Be responsible for and make good any damages caused to existing systems when making connections.
- .6 Provide premium time labour to tie-in to services at night or on weekends.
- .7 For piping systems, make connections to existing piping by draining down the existing piping system. Use of hot-tapping or freezing of piping is only permitted where approved by the Owner and a specification section for such work has been included in the project specifications.
- .8 Provide temporary services to drain down existing piping systems which convey liquids or steam condensate, including provision of temporary hoses, etc., and provide services to perform the drain down of these systems, except where the Owner elects to perform such drain-downs.
- .9 For piping systems conveying liquids, after completion of new work to existing piping systems, refill the existing and new piping systems including provision of cleaning of new piping and addition of chemical treatments, as applicable, in accordance with the requirements of other sections of Division 20. Include for addition of replenishing chemical treatment for existing piping systems in accordance with the Owner's existing chemical treatment program, or in the absence of such, in accordance with the chemical water treatment requirements specified in other Sections of Division 20.

15 MOVING AND SETTING IN PLACE OF OWNER-SUPPLIED PRODUCTS

15.1 General

- .1 The requirements of this Part applies to;
 - .1 Division 20 equipment that has been directly purchased by the Owner, and
 - .2 other Owner-supplied products or equipment (i.e. process equipment) that has building services requirements.
- .2 Comply with the requirements of Specification section of [01 11 00 *Summary of Work*] and as specified herein.

15.2 Owner-Supplied Products (Supplied by Owner Equipment – “SBO”)

- .1 Items marked SBO on drawings are to be;
 - .1 purchased by the Owner,
 - .2 received, checked, and stored by the Contractor, and
 - .3 subsequently unpacked, uncrated, assembled and located in its final location by the Contractor, and installed in accordance with the manufacturer instructions,
 - .4 participate in the start-up and testing of the equipment and placing into service.

- .2 Provide mechanical and electrical services to SBO equipment in accordance with the SBO equipment manufacturer's instructions and as otherwise shown.

15.3 Existing Owners Equipment to be Relocated (E.R. or Ex. Rel.)

- .1 Applies to owners existing equipment which has mechanical and electrical services, and marked on the drawings as E.R. Ex.Rel. or otherwise so identified.
- .2 Items so marked on drawings are to be moved from their present location and reinstalled by the Contractor.
- .3 Disconnect and reconnect mechanical and electrical services to accommodate this equipment relocation.

16 TEMPORARY HEATING

- .1 Temporary heating required while building is under construction will be provided under Division 01.
- .2 Permanent heating system may be used for temporary heating, when this equipment is installed in its permanent location and the building is closed-in and Contractor under Division 1 provides staff for operation and maintenance whenever permanent heating system is being used for temporary heating.
- .3 Hot water boilers may not be used unless heating units, radiation, pumps and piping are complete, the piping system has been pressure tested, cleaned, and final chemical water treatment is in operation.
- .4 Permanent heating equipment used for temporary heating to be thoroughly cleaned and put in first class operating condition and appearance at completion of the Work, as approved by the Owner.

17 FINAL CLEANING AND ADJUSTMENTS

17.1 Final Cleaning

- .1 Conduct final cleaning in accordance with Division 01 74 00 requirements and as specified herein.
- .2 Perform final cleaning after construction activities that create dust have been completed.
- .3 Thoroughly clean exterior surface of exposed piping, and vacuum external surfaces of exposed ducts and interior surfaces of air handling units. Clean strainers in piping systems and install clean filters in air handling systems immediately prior to handover of the building to the Owner.
- .4 HEPA vacuum the top and interiors of motor controllers, VFDs, control panels, and control cabinets followed by a thorough HEPA vacuuming of the service room floors. Thoroughly wash floors with wet mop and clean water. Control access to the room after cleaning. Provide temporary filter media on air supply ducts to these rooms to prevent re-contamination from other areas of construction.
- .5 Remove tools and waste materials on completion of work and leave work in clean and perfect condition.

17.2 Final Adjustments

- .1 Calibrate components and controls and check function and sequencing of systems under operating conditions.
- .2 Supply lubricating oils and greases for proper operation of equipment and systems until work has been accepted.

18 RECORD DRAWINGS

18.1 Record Drawings

- .1 Maintain record drawings in accordance with Section 01 78 00 during the course of the Work and as follows.

- .2 A set of design drawings in AutoCad, Revit, or PDF format (as determined by the Consultant) will be provided by the Consultant. Record changes in actual installation as the Work progresses by the following method:
 - .1 make sets of white prints for each phase of Work and mark-up the print drawings, or
 - .2 revise the AutoCad or Revit file directly, and identify all changes made.
- .3 Mark-up these record drawings to provide dimensioned locations of drains, pipes, ductwork, conduit, manholes, foundations and similar buried items within the building, with respect to building column centres. Mark level with respect to an elevation which will be provided.
- .4 Retain on-site the survey information from excavation and backfill of site services, and after approval, transfer this information to the record documents.
- .5 Retain these drawings and make available to Consultant for periodic review.
- .6 At 50%, 75% and 90% project completion, scan marked-up drawings to PDF format and submit copy to the Consultant, or to the project on-line document management service if one is used.

18.2 As-Built Drawings

- .1 Prior to testing, balancing and adjusting, transfer site record drawing information to a copy of the computer aided drafting/design program ("CAD") files, in the same software format used for the Consultants design drawings, to record final as-built condition.
- .2 Obtain a current set of CAD files from the Consultant. The Consultant's CAD files may not reflect all or any construction changes.
- .3 Drawings are to remain set to and follow Consultants CAD Standards - do not alter drawing scales, reference files, colours, layers or text styles,
- .4 Where items have been deleted, moved, renumbered or otherwise changed from contract drawings, revise the CAD files to record these changes. "Bubble" these revisions, and place these annotations on a separate and easily identified drawing layer.
- .5 Show on mechanical as-built drawings final location of piping, ductwork, switches, starters, Motor Control Centres, thermostats, and equipment.
- .6 Show on site services as-built drawings survey information provided by an accredited land surveying service.
- .7 Identify each drawing in lower right hand corner in letters at least 12 mm (½ in) high with a note as follows:

<p style="text-align: center;">AS-BUILT DRAWINGS. This drawing has been revised to show systems as installed (Signature of Contractor) (Date).</p>
--

- .8 The site services drawings are to include the signature and stamp of the accredited surveyor adjacent to the note.
- .9 Submit one (1) set of white prints of the draft as-built CAD files for Consultant's review.
- .10 Once "AS BUILT DRAWINGS" white prints are reviewed, transfer Consultant's comments to the CAD files. Return CAD files modified to "As Built" condition to Consultants electronically by removable mass storage device or by electronic file transfer as designed by the Consultant.
- .11 Submit three (3) sets of white prints and one (1) electronic copy of CAD files with Operating and Maintenance Manuals to the Owner.

19 OPERATING AND MAINTENANCE INSTRUCTIONS

19.1 Operating and Maintenance Manuals

- .1 Provide operating and maintenance manuals in accordance with Section [01 78 00 *Closeout Submittals*] and as follows.
- .2 Provide operation and maintenance data bound in vinyl covered, hard back, three-ring covers, nominally 50 mm (2 in) thick, suitable for paper size of 210 mm x 300 mm (8½ in x 11 in);
 - .1 organize material in volumes, generally grouped by Trade section;
 - (a) Table of Contents,
 - (b) General Information,
 - (c) Sub-contractors (list),
 - (d) Site services,
 - (e) Fire Protection,
 - (f) Plumbing,
 - (g) Heating and Cooling Plant and Distribution,
 - (h) Air Handling Equipment and Distribution,
 - (i) Building automation, Controls and Instrumentation,
 - (j) Testing Reports,
 - (k) As-Built Drawings,
 - (l) Warranties.
 - .2 Title sheet in each volume to be labeled "Operating and Maintenance Manual" and to bear;
 - (a) Project Name,
 - (b) Project Number,
 - (c) Date,
 - (d) Trade Section,
 - (e) List of Contents.
 - .3 Provide three hard-copies to Owner.
- .3 In addition, provide PDF files for each document, produced from original direct-to-digital file creations;
 - .1 organize documents into separate PDF files for each Trade Section identified above, and apply PDF Bookmarks to create a Table of Contents for each file.
- .4 Operating data to include;
 - .1 control schematics for each system,
 - .2 description of each system and associated control elements,
 - .3 control operating sequences at various load conditions, reset schedules and anticipated seasonal variances,
 - .4 operating instructions for each system and each component,
 - .5 description of actions to be taken in event of equipment failure,
 - .6 valve schedules and flow diagrams,
 - .7 service piping identification charts.
- .5 Maintenance data to include;

- .1 manufacturer's literature covering servicing, maintenance, operating and trouble-shooting instructions for each item of equipment,
 - .2 fault locating guide,
 - .3 manufacturer's parts list,
 - .4 reviewed shop drawings,
 - .5 equipment manufacturer's performance sheets,
 - .6 equipment performance verification test results,
 - .7 voltage and ampere rating for each item of electrical equipment,
 - .8 spare parts list and an itemized cost,
 - .9 name and telephone numbers of service organization and technical staff that will provide warranty service on the various items of equipment.
- .6 Approval procedure;
- .1 submit one set of first draft of Operating and Maintenance Manuals for approval at least one month prior to planned substantial performance date,
 - .2 make corrections and resubmit for a final review,
 - .3 review contents of Operating and Maintenance Manuals with Owner's operating staff or representative to ensure thorough understanding of each item of equipment and its operation.
 - .4 hand-over two (2) hard-copies and one (1) PDF copy on removable storage device of the Operating and Maintenance Manuals to the Owner's operating staff and obtain written confirmation of delivery. Provide a copy of the delivery record to the Consultant.

19.2 Operating and Maintenance Training

- .1 Provide operating and maintenance training in accordance with Section 01 79 00 *Demonstration and Training* and as follows.
- .2 Provide training to Owners operations staff to thoroughly explain operation and maintenance of each system, incorporating specialized instruction by manufacturers as described under other Sections in these Divisions. Include classroom instruction and hands-on instruction, delivered by competent instructors.
- .3 Develop the proposed training plan, and submit an outline of the training program for review, adjustment and approval by the Owner.
- .4 Structure each session to start with the classroom instruction for the overall system, followed by hands-on instruction for each equipment, utilizing the services of the manufacturers' representative as required.
- .5 Organize and schedule each training session to deliver the required instruction in an efficient and effective manner on a schedule agreed upon with the Owner. Allow for two (2) training sessions for each training topic, separated by approximately one week each. Develop the proposed training plan and obtain approval from the Owner before commencing training.
- .6 All training to be scheduled and provided between the hours of 7 am to 5 pm, Monday to Friday. Where training is required to be performed outside of these hours due to availability of Owners operations personnel, if the trainers are paid for overtime outside of these hours, the overtime portion only is eligible to be paid by the Owner as an extra cost.
- .7 Complete the training as close to Substantial Performance as possible, so that the operations staff are prepared to operate the systems after Substantial Performance is certified.
- .8 Organize each training sessions as follows:

- .1 Plumbing – Division 22
- .2 HVAC – Division 23
- .3 Building Management System – Division 25
- .9 Keep records of date and duration of each instruction period together with names of persons attending. Submit signed records at completion of instruction.
- .10 For each training session, include the following topics;
 - .1 general purpose of system (design intent),
 - .2 use of O&M manuals,
 - .3 review of control drawings and schematics,
 - .4 start-up, normal operation, shutdown, unoccupied operation, seasonal changeover, manual operation, control set-up and programming troubleshooting, and alarms,
 - .5 interaction with other systems,
 - .6 adjustments and optimizing methods for energy conservation,
 - .7 health and safety issues,
 - .8 special maintenance and replacement sources,
 - .9 occupancy interaction issues, and
 - .10 system response to different operating conditions.
- .11 Develop and provide training material, including printed documents and electronic presentation aids (e.g. MS PowerPoint) for each session. Submit three (3) copies of materials in both hardcopy and PDF format, in accordance with article on Operating and Maintenance Manuals.
- .12 Sessions may be video recorded by the Owner as an aid to ongoing training of Owners staff.

20 CARE, OPERATION AND START-UP

- .1 Provide all labour and materials as necessary to perform start-up and testing of equipment and systems.
- .2 Arrange and pay for services of manufacturer's factory service technician to supervise start-up of the installation, check, adjust, balance and calibrate components and equipment as specified in the specification sections of Division 20.
- .3 Provide these services for such period, and for as many visits as necessary to put equipment in operation, and ensure that operating personnel are conversant with every aspect of the operation, care and maintenance thereof.
- .4 Arrange and pay for services of applicable manufacturer's factory service engineer or certified independent testing organization to supervise initial start-up of specialized portions of installation and to check, adjust, balance and calibrate components including related wiring and controls. Provide these services for such periods, and for as many visits as may be necessary to put applicable portion of the installation in complete working order. Provide a certificate indicating that the equipment is free and clear of deficiencies.

21 TESTING

21.1 General

- .1 The following describes the general requirements for testing of mechanical systems; refer to additional testing requirements in applicable sections of Division 20 of the Work.

- .2 Conduct tests during progress of Work and at its completion to verify equipment and systems meet the contract documents. Submit details of test methods in writing and obtain approval before commencing work.
- .3 Supply test equipment, apparatus, gauges, meters and data recorders, together with skilled personnel to perform tests and log results.
- .4 Submit written notice 24 hours in advance of each test series, setting out the time, place and nature of the tests, to the Inspection Authority and personnel witnessing tests.
- .5 The Owner reserves the right to witness any test; any such witnessing activity shall not be construed as acceptance of the system or equipment by the Owner.
- .6 Conduct tests before application of external insulation and before any portion of pipes, ducts or equipment is concealed.
- .7 Do not subject expansion joints, flexible pipe connections, meters, control valves, convertors, and fixtures, to test pressures greater than the stated working pressure of equipment. Isolate or remove equipment or devices during tests when prescribed test pressure is greater than working pressure of any piece of equipment or device.
- .8 Should section of pipe, duct, or electrical cable fail under test, replace faulty piping, duct, or cable with new fittings, pipe, duct or cable and then retest. Do not repair threaded pipe joints by caulking nor welded joints by peening. Repeat tests until results are satisfactory.
- .9 Where it is necessary to test portions of piping, ductwork or electrical cable system before system is complete, overlap successive tests so that no joint or section of duct or pipe is missed in testing.
- .10 Upon completion of work and testing of same, submit logs to demonstrate that tests have been carried out satisfactorily. Repeat any tests if requested.

21.2 Testing - Potable Water Piping

- .1 Except where otherwise specified in other sections of Division 22, test potable water systems with water or air as required by the plumbing code in effect at the location of the Work.
- .2 For water service pipes 100 mm (4") and larger, disinfect the pipe with chlorine ("hyper-chlorinate") from the street valve to the first shut-off valve inside the building. At completion of disinfection, take water samples just before the utility meter and pay for the samples to be tested by an accredited testing laboratory. Test the water samples for contaminants and to measure the residual chlorine concentration and provide test certificate confirming water contaminates are below the threshold values proscribed by applicable legislation.
- .3 Where stainless steel piping is used in the domestic water system, between the entry point in the building and the utility water meter, after taking the water sample for laboratory testing, immediately drain down the incoming service piping up to the utility meter and then flush with clean city water until a site test of the drain water shows a residual chlorin level not greater than the incoming city water supply.
- .4 Where stainless steel piping is used in potable water piping inside the building (i.e. downstream of the utility meter), do not allow any hyper-chlorinated water used for disinfection of piping to come into contact with the stainless steel piping.

21.3 Testing - Other Piping

- .1 Except where otherwise specified in other sections of Divisions 21, 22 or 23, hydraulically pressure test other water piping systems at 1½ times system design pressure (relief valve setting) or 1000 kPa (150 psi), whichever is greater, for 10 minutes then reduce the test pressure and hold for 24 hours. Pressure must remain essentially constant throughout test period without pumping. Make allowance for correction of pressure readings for variations in ambient temperature between start and finish of test.
 - .1 Alternatively, hold the pressure at the design pressure and testing all joints with a soap test.

- .2 Test natural gas system in accordance with CSA B149.1 *Natural Gas and Propane Piping Code*.
- .3 Test fuel oil systems in accordance with CSA B139 *Installation Code for Oil Burning Equipment*.
- .4 Test drainage, waste and vent piping for tightness and grade as required by the plumbing code in effect at the location of the Work.
- .5 Test special service piping as detailed in other sections of Divisions 21, 22 and 23.

21.4 Testing - Ventilation

- .1 Pressure test ductwork in accordance with section 23 31 13 *Ductwork*, or other applicable sections of Division 23.

21.5 Testing - Electrical

- .1 Make tests of equipment and wiring. Test wiring systems in accordance with section 20 05 12 *Wiring Requirements for Mechanical*.
- .2 Replace defective equipment and wiring with new material.

22 COMMISSIONING

- .1 Participate in commissioning of equipment and systems in accordance with Section 20 08 15 *Mechanical Commissioning*.
- .2 Equipment supplied on this project will be subject to detailed factory inspection and/or on-site testing and commissioning prior to being placed in service. The electrical contractor, their major system and equipment suppliers, and the Independent Testing Agent (ITA) will be required to participate in special commissioning meetings to review progress and status of the commissioning program.
- .3 Include in Bid amount for licensed electricians to participate in the commissioning program, to undertake temporary power connections, operation of equipment, opening and closing of panel boards and switchboards, testing of power and control wiring, and assisting the ITA and the equipment suppliers' field personnel in the startup and testing of the equipment.
- .4 The contractor and equipment suppliers to include in the Bid amount the costs to accommodate and undertake factory and site testing.

23 TEMPORARY AND TRIAL USAGE

- .1 Temporary and trial usage by Owner of any mechanical or electrical device, machinery, apparatus, equipment or any other work or materials before final completion and written acceptance is not to be construed as evidence of acceptance by Owner.
- .2 Owner to have privilege of such temporary and trial usage, as soon as that said work is claimed to be completed and in accordance with Contract Documents, for such reasonable length of time as is sufficient for making complete and thorough test of same.
- .3 No claims will be considered for damage to or failure of any parts of such work so used which may be discovered during temporary and trial usage, whether caused by weakness or inaccuracy of structural parts or by defective materials or workmanship of any kind whatsoever.
- .4 Defects in workmanship and materials identified during temporary and trial usage are to be rectified under warranty.

24 SPECIAL TOOLS AND SPARE PARTS

24.1 Spare Parts

- .1 Prior to application for Substantial Performance, furnish spare parts as follows;
 - .1 one set of mechanical seals for one pump of each model size,

- .2 one pump casing joint gasket for each model size,
 - .3 one head gasket for each shell-and-tube heat exchanger with removable heads,
 - .4 one glass for each gauge glass,
 - .5 one set of V-belts for each drive of the same model size,
 - .6 one set of filter cartridges for each filter or filter bank installed.
- .2 Maintain an inventory record and delivery receipt record of spare parts delivered to the Owner, and include them in the Operating and Maintenance manuals.

25 CONSULTANT REVIEWS

25.1 General

- .1 Consultant's attendance at site including but not limited to site meetings, demonstrations, site reviews and any resulting reports are for the sole benefit of the Owner and as required by the local authority have jurisdiction. It is the Contractor's responsibility to ensure that the Work is complete and constructed in accordance with the design documents.

25.2 Site Reviews

- .1 General reviews and progress reviews do not record deficiencies during the course of the Work until such time as a portion or all of the work is declared complete. In some instances, before the work is completed, readily noticeable deficiencies may be recorded by the Consultant where the deficient item is indicative of issues such as poor workmanship, incorrect materials or installation methods, or may be difficult to correct at a later date. Any such reported items, or lack thereof, shall not be relied on in any way as part of the Contractor's quality assurance program nor relieve the Contractor in the performance of the Work, specifically in identification and rectification of deficiencies or incomplete Work.
- .2 Deficiency reviews conducted by the Consultant are performed on a sampling basis, and any deficiency item is to be interpreted as being indicative of similar locations elsewhere in the Work, unless otherwise shown.

25.3 Milestone Reviews

- .1 Specific milestone reviews may be conducted at key stages by the Consultant, including;
- .1 before backfilling of buried drainage,
 - .2 before closing of shafts,
 - .3 before closing of ceilings,
 - .4 before closing of walls,
 - .5 equipment demonstration,
 - .6 Substantial Performance deficiency review,
 - .7 Total Performance deficiency review.
- .2 Coordinate with the Consultant the type and quantity of milestone reviews required by the Consultant and incorporate these requirements in the construction schedule.
- .3 Notify the Consultant in writing seven (7) calendar days in advance of work to be concealed to arrange a site review prior to the Work being concealed where required by the Consultant. Any noted deficiencies are to be corrected before being concealed. Failure to provide notification can result in the Work being exposed for review at the Contractor's cost.

25.4 Partial Occupancy Reviews

- .1 Where the Work is planned to include occupancy by the Owner of a part of the Work but not the entire Work ("partial occupancy"), the procedures specified for Substantial Performance Review will apply to the portion of the Work being considered for partial occupancy.

25.5 Substantial Performance Review

- .1 At the time of applying for project Substantial Performance, submit to Consultant a comprehensive list of items to be completed or corrected.

25.6 Final Review

- .1 At project completion submit written request for final review of mechanical and electrical systems. Refer to section 20 08 19 *Project Close-Out*.
- .2 Include with the request a written certification that:
 - .1 reported deficiencies have been completed,
 - .2 systems have been balanced and tested and are ready for operation,
 - .3 completed maintenance and operating data have been submitted and approved,
 - .4 equipment/line material tags are in place and equipment identification is completed,
 - .5 cleaning is finished in every respect,
 - .6 all mechanical equipment surfaces have been touched up with matching paint, or re-finished as required,
 - .7 spare parts and replacement parts specified have been provided and receipt acknowledged,
 - .8 As-built and Record drawings are completed and approved,
 - .9 Owner's operating personnel have been instructed in operation and maintenance of systems,
 - .10 fire protection verification is 100% completed and Verification Certificates have been submitted and accepted.

26 CONTRACTOR INSPECTIONS

26.1 General

- .1 The Division 20 contractor shall assign one person responsible for ensuring that Work from all mechanical trades is complete prior to;
 - .1 closing in wall, ceilings or burying of services,
 - .2 partial-occupancy reviews, and
 - .3 substantial performance reviews.
- .2 In conjunction with the Contractor's Mechanical and Electrical sub-contractors, the Contractor shall walk the site and thoroughly inspect that the work is complete, in good workmanship and installed according to the contract documents and derived documents therefrom. The Contractor shall then submit a report attesting to the completed state of the Work (the "Statement of Completion" report, as detailed later in this part).
- .3 In the case of Contractor inspections for partial-occupancy or substantial performance, submit the Statement of Completion report at least 24 hours prior to the scheduled review by the Consultant.

26.2 Contractor Inspections for Partial Occupancy and Substantial Performance

- .1 In preparation for the Consultants general review for partial-occupancy and/or substantial performance of the Work, the Contractor shall perform a comprehensive inspection of the Work to ensure that their

contractual obligations are met before requesting a Consultant's review of the Work. In performing this inspection, the Contractor shall create a Statement of Completion report which is to include;

- .1 date and time of the Contractor's inspection, signed by the person who conducted the inspection,
- .2 names of the mechanical contractor's personnel who participated in the inspection,
- .3 confirmation that previously noted deficiencies have been completed,
- .4 confirmation that the work is 100% complete, tested, balanced and free of deficiencies, or include a list of outstanding deficiencies and incomplete Work with;
 - (a) a reason why the Work has not been completed (i.e. another trade has to complete their work)
 - (b) a plan of action to complete the Work, and
 - (c) a commitment date for completion of the Work including rectification of all deficiencies.
- .2 The format of the Statement of Completion shall be approved by the Consultant.
- .3 The Consultant shall review and sign-off the Statement of Completion Report and return a copy to the Contractor. The Contractor shall retain on-site a log of all signed off Statement of Completion reports.
- .4 If a required Statement of Completion report is not received, the Consultant reserves the right to withhold conducting a review for partial-occupancy or substantial performance.
- .5 After receipt of the Contractor's Statement of Completion report, if upon entering an area of the work covered by the Statement of Completion report the Consultant determines, in its sole opinion, that the applicable Work is not ready for review, the Consultant may elect to cancel the review of the Work or the affected portion of the Work, and shall assume no responsibility for any damages or losses as a result of cancellation of the review. The Contractor shall remedy the incomplete work and request another review with 72 hours prior written notice, and shall resubmit the revised Statement of Completion at least 24 hours prior to the new review.

27 CORRECTION AFTER COMPLETION

- .1 At completion, submit a written warranty undertaking to remedy defects in work for a period of one year from date of substantial performance of the Work. This warranty is not to supplant other warranties of longer period called for on certain equipment or materials.
- .2 Warranties are to encompass replacement of defective parts, materials or equipment, and to include incidental fluids, gaskets, lubricants, supplies, and labour for removal and reinstallation of the corrected Work.
- .3 Submit similar warranties for one year from date of acceptance for any part of work accepted by Owner, before completion of the whole Work.

28 ATTACHMENTS

28.1 Schedule of Values Form

- .1 Attached sample of the Schedule of Values form layout.

28.2 Shop Drawing Submittal Form

- .1 Attached sample of shop drawings submittal form.

SCHEDULE OF VALUES

Project Name: <<name of project>>
Owner Name: <<owner name>>
Contractor Name: <<name of trade contractor: mechanical, electrical, etc>>
Division(s) of the Work: <<i.e. 20, 21, 22...>>
For the billing period ending: dd-mmm-yyy

This sheet is an example of a required schedule of values to be developed by the Contractor, to be submitted with each progress payment request.
Specific level of detail for each work element to be approved by the Consultant.

Item	Base Contract Element	Contract Value		Complete to Date		Previously Billed		This Billing		Balance to Complete	
		\$	%	\$	%	\$	%	\$	%	\$	%
1.1	<<work element>>	1,000,000.00	65.9%	400,000.00	40.0%	225,000.00	22.5%	175,000.00	17.5%	600,000.00	60.0%
1.2	<<work element>>	250,000.00	16.5%	30,000.00	12.0%	5,000.00	2.0%	25,000.00	10.0%	220,000.00	88.0%
1.3	<<work element>>	125,000.00	8.2%	50,000.00	40.0%	22,000.00	17.6%	28,000.00	22.4%	75,000.00	60.0%
X X	Itemized Price No. 1	25,000.00	1.6%	0.00	0.0%	0.00	0.0%	0.00	0.0%	25,000.00	100.0%
X X	Separate Price No. 1	12,500.00	0.8%	5,000.00	40.0%	0.00	0.0%	5,000.00	40.0%	7,500.00	60.0%
CCA.1	Cash Allowance Disbursements Summary	75,000.00	4.9%	34,000.00	0.0%	8,000.00	0.0%	26,000.00	0.0%	41,000.00	0.0%
X X	Coordination drawings	15,000.00	1.0%								
X X	As-built documents and operating manuals	15,000.00	1.0%								
	Original Contract Values	1,517,500.00	100.0%	519,000.00	34.2%	260,000.00	17.1%	259,000.00	17.1%	968,500.00	63.8%
CO.1	Approved Changes Summary	13,400.00		5,200.00	38.8%	2,000.00	14.9%	3,200.00	23.9%	8,200.00	61.2%
	Total Current Contract Values	1,530,900.00		524,200.00	34.2%	262,000.00	17.1%	262,200.00	17.1%	976,700.00	63.8%

Reference	Cash Allowance Disbursement	CA Value		Complete to Date		Previously Billed		This Billing		Balance to Complete	
		\$	%	\$	%	\$	%	\$	%	\$	%
CAA_1	<<description of cash allowance>>	20,000.00		20,000.00	100.0%	8,000.00	40.0%	12,000.00	60.0%	0.00	0.0%
CAA_2	<<description of cash allowance>>	55,000.00		14,000.00	25.5%	-	0.0%	14,000.00	25.5%	41,000.00	74.5%
	Total	75,000.00		34,000.00	45.3%	8,000.00	10.7%	26,000.00	34.7%	41,000.00	54.7%

Reference	Approved Changes	Change Value		Complete to Date		Previously Billed		This Billing		Balance to Complete	
		\$	%	\$	%	\$	%	\$	%	\$	%
CO_01	<<description of change of work>>	5,800.00		-	0.0%	-	0.0%	0.00	0.0%	5,800.00	100.0%
CD-01	<<description of change of work>>	7,600.00		5,200.00	68.4%	2,000.00	26.3%	3,200.00	42.1%	2,400.00	31.6%
	Total	13,400.00		5,200.00	38.8%	2,000.00	14.9%	3,200.00	23.9%	8,200.00	61.2%

Reference	Unquoted/Unapproved Changes	Status	Quotation	
			\$	%
CCN-01	<<description of change of work>>	Waiting for approval	12,000.00	
CCN-02	<<description of change of work>>	Unquoted		
	Total		12,000.00	



Toronto Montreal Vancouver Dallas Chicago

SHOP DRAWING SUBMITTAL

***Include this cover page with each shop drawing submission.
Submissions without this form will be returned without review.
Submit one submittal form per shop drawing; do not group under one submittal sheet***

Client/Architect: Click or tap here to enter text.

Project Name: Click or tap here to enter text.

HHA Project No: Click or tap here to enter text.

Contractor to complete the following for each submission.

Date: _____

Contractor Name: _____ Ref. No: _____

Manufacturer Name: _____

Product Type/Description: _____

Specification section number: _____

Contractor Trade Category:

- | | | | |
|--|-------------------------------------|--|---|
| <input type="checkbox"/> Architectural | <input type="checkbox"/> Structural | <input type="checkbox"/> Conveying Equipment | <input type="checkbox"/> User Equipment |
| <input type="checkbox"/> Mechanical | <input type="checkbox"/> Electrical | <input type="checkbox"/> Telecommunications | <input type="checkbox"/> Civil |
| <input type="checkbox"/> Other | | | |

If this is a resubmission, check here: ☐

Previous submission HHA reference no.: _____

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END OF SECTION

QUALIFICATIONS AND AUTHORITIES - ONTARIO

20 01 02

1 GENERAL

1.1 Scope

- .1 This specification section:
 - .1 describes the qualification requirements for tradesmen in the province of Ontario;
 - .2 defines the applicable authorities having jurisdiction related to construction in Ontario; and
 - .3 describes the responsibilities of the contractor and/or Owner for registration and inspection of systems and application for construction or installation permits.

1.2 Definitions

- .1 **TSSA:** Technical Standards and Safety Authority
- .2 **ESA:** Electrical Safety Authority

2 QUALIFICATIONS

2.1 Trades Qualification and Apprenticeship

- .1 Tradesmen to hold a a certificate of qualification or be an apprentice in accordance with the *Building Opportunities in the Skilled Trade Act, 2021, S.O. 2021, c. 28*, including but not limited to the following prescribed trades in accordance with the *Prescribed Trades and Related Matters* regulation O.Reg. 876/21:
 - .1 Construction Millwright,
 - .2 Electrician – construction and maintenance,
 - .3 Fuel and electrical systems technician,
 - .4 Heat and frost insulator,
 - .5 Information technology – hardware technician,
 - .6 Information technology – network technician,
 - .7 Network cabling specialist,
 - .8 Instrumentation and control technician,
 - .9 Plumber,
 - .10 Refrigeration and air-conditioning systems mechanic,
 - .11 Sheet metal worker,
 - .12 Sprinkler and fire protection installer,
 - .13 Steamfitter,

2.2 Work-Specific Qualification Licenses

- .1 Fabricators and installers of pressure piping and equipment which are subject to O.Reg. 220/01 *Boilers and Pressure Vessels* regulation shall hold the required license for performing such work, unless otherwise exempt by the regulation.
- .2 Contractors performing work on liquid or gaseous fuel piping systems and related equipment shall hold certificates of authorization made under O.Reg. 215/01 *Fuel Industry Certificates* to perform work within the scope of the following regulations;;

- .1 Gaseous Fuels, O.Reg. 212/01
- .2 Propane Storage and Handling, O.Reg. 211/01
- .3 Fuel Oil, O.Reg. 213/01
- .4 Compressed Natural Gas, O.Reg. 214/01

3 AUTHOURITIES

3.1 Authorities having Jurisdiction

- .1 When referenced in specification sections in Division 20 to 25, the authority-having-jurisdiction ("AHJ") over regulated portions of the work are identified in the following table.

Work Element	Authority	AHJ Abbreviation
Fire Protection	Municipal Building Department or Fire Department	None
Plumbing	Municipal Building Department	None
HVAC	Municipal Building Department	None
Flammable and Combustible Liquids	Fire Department	None
Liquid fuels (for vehicle refueling)	Technical Standards and Safety Authority	TSSA
Heating Oil and Diesel Fuel	Technical Standards and Safety Authority	TSSA
Propane	Technical Standards and Safety Authority	TSSA
Pressure Piping	Technical Standards and Safety Authority	TSSA
Refrigeration	Technical Standards and Safety Authority	TSSA
Licensed Plant Operators	Technical Standards and Safety Authority	TSSA
Electrical	Electrical Safety Authority	ESA

4 PERMITS, REGISTRATION AND INSPECTION

4.1 Building Code Permits

- .1 Submit and pay for building permits, and arrange and coordinate for inspections as required under the Ontario Building Code.

4.2 Other Work Permits, Registration and Inspection

- .1 Arrange, provide documentation, and pay for permits, registration, and inspection of the following work elements:
 - .1 Boilers, pressure vessel and pressure piping,
 - .2 Buried liquid fuel tanks and underground piping,
 - .3 Electrical work performed under Division 20 to 25, and

- .4 Where described elsewhere in Division 20 to 25.
- .2 Arrange, provide documentation, and pay for variance approvals and field inspections where specified elsewhere in Division 20 to 25.

END OF SECTION

BASIC MATERIALS AND METHODS

20 05 01

1 GENERAL

1.1 Scope

- .1 Articles that are of a general nature, and applicable to each Section of Division 20 to 25.

2 ACCESSIBILITY FOR BUILDING CONTROL DEVICES

- .1 Mount control devices, intended to be adjusted or to otherwise be operated by the occupant for the operation of building services or safety devices, as follows:
 - .1 room environmental controls, including thermostats/adjustable room temperature sensors: at 1200 (47 in) above the finished floor,
 - .2 all other controls: between 900 and 1100 mm (36 in. and 43 in.) above the finished floor.
 - .3 be positioned to have a clear space in front of and centered on the control device, of 810 x 375 mm (32 x 15 in).
 - .4 be operable using a closed fist and with a force not exceeding 22.2 N (5 lbf).
- .2 The above requirements do not apply to control devices that are solely located and used by the building operations staff.

3 DIELECTRIC FITTINGS

- .1 Dielectric unions – NPS 2 and under:
 - .1 body and union nut material selected to suit connecting piping materials, including carbon steel/copper, carbon steel/stainless steel, and copper/stainless steel,
 - .2 flat-face union design,
 - .3 tail-piece with NFPT ends with thermobaked epoxy coating, and Teflon shoulder gasket,
 - .4 head-piece with integral O-ring, with threaded or sweat pipe ends.
 - .5 union nut,
 - .6 pressure rating: Class 3000.
 - .7 dielectric coating resistance rating: minimum 500 V/mil thickness.

Standard of Acceptance

- ° Hart Industrial Unions - fig. D-3136 series

- .2 Dielectric insulating flanges - NPS 2-1/2 to NPS 4;
 - .1 For connecting copper to carbon steel piping.
 - .2 Ductile iron flanges, Class 125 to ANSI B16.42.
 - .3 Copper tailpiece for soldered joint,
 - .4 NFPT thread to AMSE B1.20.1 x copper solder joint,
 - .5 BUNA-N gasket,
 - .6 lead free materials to NSF 61+G.
 - .7 maximum design pressure: 1200 kPa (175 psi)
 - .8 maximum operating temperature: 82°C (180°F)

Standard of Acceptance

- Watts No. LF3100
- .3 Dielectric insulated flange – single face with copper tube tailpiece – NPS 2-1/2 to NPS 4;
 - .1 For connecting copper to carbon steel piping.
 - .2 Van Stone style carbon steel flange with copper tailpiece with flared flaired end,
 - .3 carbon steel flange, Class 150 to ANSI B16.5, with powder coated finish.
 - .4 copper tailpiece with rolled flange face-end, and EPDM insulating gasket isolating the copper tube from the steel flange.

Standard of Acceptance

- CTS Flange Canada - fig. CTS Copper Flange Adaptor
- .4 Dielectric Insulating gaskets for flanges NPS 6 and over:
 - .1 for use with ASME Class 150 and 300 dimensional flanges.
 - .2 suitable for connecting dissimilar piping materials, including carbon steel/copper, carbon steel/stainless steel, and copper/stainless steel,
 - .3 compatible with pressure and temperature service,
 - .4 BUNA-N or EPDM gasket seals compatible with potable water
 - .5 flange bolts run in insulating sleeves with insulating washers under nuts.

Standard of Acceptance

- Advance Products and Systems
- .5 Provide dielectric isolation between pipes of dissimilar metals with suitable insulating dielectric unions, insulating flanges, or insulating gaskets between flanges;
 - .1 place dielectric isolation between steel piping and bronze or brass valves.
 - .2 do not use bronze or brass valves as dielectric fittings.
-

4 V-BELT DRIVES

4.1 Products

- .1 Provide V-belt drive for each motor driven device which is not directly connected to the motor. Keep overhung loads on prime mover shafts within manufacturer's design guidelines.
- .2 Sheaves for motors 7.5 kW (10 hp) and less, with not more than two belts:
 - .1 cast iron or steel secured to shafts with removable keys.
 - .2 adjustable pitch on motor, fixed pitch on driven device, giving plus or minus 10% speed range,
 - .3 selected to meet specified operating condition at mid position in pitch adjustment.
- .3 Sheaves for motors greater than 7.5 kW (10 hp) or drives with three or more belts:
 - .1 cast iron or steel with split tapered bushing and keyway.
 - .2 fixed pitch.

- .4 Belts:
 - .1 matched sets of 'B' section, selected for service factor of 2.0 times installed motor horsepower.
 - .2 capable of carrying load with one belt broken.
- .5 Motor slide rails:
 - .1 adjustment plates for centre line alignment
 - .2 belt tension adjusting screws.

4.2 Installation

- .1 Tension belts to manufacturer's recommendations before start-up and after first 100 hr of operation using calibrated belt tensioning gauge.
- .2 Provide replacement pulleys and belts during start-up and balancing to suit field operating conditions.

5 DRIVE AND COUPLING GUARDS

5.1 Products

- .1 Provide guards to protect belt drives, flywheels, rotating couplings on equipment and fan inlet and outlets.
- .2 Guards:
 - .1 removable for servicing,
 - .2 arranged to permit lubrication with guards in place.
- .3 Guards for belt drives:
 - .1 expanded metal screen welded to steel bar stock or angle frame,
 - .2 minimum 1.2 mm (18 ga) thick galvanized sheet metal tops and bottoms,
 - .3 40 mm (1½") diameter holes at both shaft centres for insertion of tachometer.
- .4 Flexible coupling and flywheel guards:
 - .1 Removable "U" shaped, minimum 1.6 mm (16 ga) thick galvanized mild steel or expanded metal mesh on substantial welded angle iron or round barstock frame.
- .5 Guards on unprotected fan inlets and outlets:
 - .1 Minimum 20 mm (¾ in) galvanized wire mesh or expanded metal screen with net free area of guard not less than 80% of fan opening.

5.2 Installation

- .1 Belt guards to accommodate movement of motors for belt tension adjustment.
- .2 Where equipment is installed on resiliently mounted base frame or pad, attach belt guard to this base
- .3 Belt guards and fan inlet guards may be omitted where fan and motor is installed in plenum less than 1.4 m (4 ft) high and disconnect for fan motor is mounted adjacent to and outside access door to plenum.
- .4 Fan inlet guards may be omitted where fan is fitted with inlet guide vanes.

6 SLEEVES

6.1 General

- .1 Sleeve pipes, ducts and conduits passing through masonry walls, concrete floors, and fire rated gypsum board ceilings and partitions.
- .2 Maintain fire rating integrity where pipes and ducts pass through fire rated walls, floors and partitions.

6.2 Floor and Wall Sleeves

- .1 Sleeves in fire separations:
 - .1 sized to suit fire stopping methods employed for bare pipes, conduits, insulated pipes, and bare and insulated ducts without fire dampers, and
 - .2 sized to suit conditions of approval given in manufacturers installation instructions for fire and smoke dampers.
- .2 Sleeves in other construction:
 - .1 sized to clear insulated pipes and ducts by 13 mm (½ in) all round, and
 - .2 sized to clear conduits, bare pipes, and bare ducts by 6 mm (¼ in) all round.
- .3 Sleeves for pipes, conduits and ducts smaller than 0.4 m² (4 sq ft) through solid walls and floors:
 - .1 Schedule 40 steel pipe or 1 mm (20 ga) (minimum) sheet metal, lapped and spot welded.
 - .2 Sleeves for pipes, conduits and ducts smaller than 0.4 m² (4 sq ft) through gypsum board partitions:
 - (a) 1 mm (20 ga) minimum sheet metal, lapped and spot welded with 20 mm (¾ in) lip flange at one end.
- .4 Sleeves for ducts 0.4 m² (4 sq ft) and larger through walls and floors:
 - .1 1.6 mm (16 ga) minimum sheet metal, lapped and spot welded with 20 mm (¾ in) lip flange at one end.
- .5 Manufactured floor sleeves with integral fire stopping:
 - .1 floor sleeve with integrated firestopping, for insulated and non-insulated metal pipes, and plastic pipes,
 - .2 for installation in concrete floors and metal deck/concrete floors,
 - .3 adaptors for support or pipe riser clamps,
 - .4 listed to CAN/ULC-S115.

Standard of Acceptance

- ° Hilti - fig. CP 680 series

6.3 Waterproof Sleeves - Indoors

- .1 Applications:
 - .1 where pipes and ducts pass through floors in areas subject to water, in mechanical rooms, in kitchens, in washing areas and in slabs over electric and telephone rooms.
- .2 Waterproof sleeves for pipes and conduits:
 - .1 Schedule 40 pipe, with 75 mm (3 in) wide annular water bar continuously welded at midpoint, hot dip galvanized to ASTM A123 after fabrication.
- .3 Waterproof sleeves for ducts less than 0.4 m² (4 sq ft):

- .1 1 mm (20 ga) galvanized steel, with 40 mm (1½ in) flange at midpoint.
- .4 Waterproof sleeves for ducts 0.4 m² (4 sq ft) and larger and openings with multiple ducts:
 - .1 1.6 mm (16 ga) galvanized steel, with 40 mm (1½ in) flange at midpoint, or,
 - .2 form opening with wood (removed after concrete is set) and trim opening with welded steel angle frame 75 mm (3 in) high, bolted to slab and caulked, or,
 - .3 trim opening with 75 mm x 75 mm (3 in x 3 in) continuous concrete curb doweled to slab.
- .5 Modifications for existing construction:
 - .1 annular fins and flanges attached to sleeve at point equivalent to surrounding floor level or curb.

6.4 Foundation Wall Sleeves

- .1 For installation in poured concrete foundation walls.
- .2 Manufactured foundation wall sleeves:
 - .1 PVC wall sleeve with 50 mm (2 in) wide water bar,
 - .2 sized to suit pipe OD and pipe link-seal.

Standard of Acceptance

- ° Metraflex

- .3 Fabricated wall sleeve:
 - .1 schedule 10 carbon steel pipe with 50 mm (2 in) wide water bar welded to mid-point of sleeve, hot dipped galvanized to ASTM A123 *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*, after fabrication,
 - .2 sized to suit pipe OD and pipe link-seal.

6.5 Roof Sleeves for Pipe and Conduit

- .1 Manufacturer roof sleeves:
 - .1 one-piece spun aluminium sleeve, minimum 1.6 mm (0.064 in) wall thickness, with integral continuous welded flashing,
 - .2 insulated with polyurethane insulation for hot and cold piping,
 - .3 with 135° gooseneck for flexible electrical conduit, with minimum clearance from gooseneck outlet to flashing flange of:
 - (a) minimum 300 mm (12 in) for installation on conventional roofs,
 - (b) minimum 450 mm (18 in) for installation on inverted roofs.
 - .4 with vented flashing insert and flashing cap for hot piping,
 - .5 with ventilation perforations at top of sleeve and a flashing cap for natural gas piping,
 - .6 stainless steel fasteners,
 - .7 EPDM base seal between conduit or pipe and bottom of sleeve,
 - .8 EPDM top seal, with triple pressure seal, either integral to the sleeve or as a two-piece sleeve and flashing cap,
 - .9 sleeve height: 300 mm (12 in),
 - .10 suitable for hot and cold piping, with or without pipe insulation, and rigid and flexible electrical conduit.

Standard of Acceptance

- Thaler – fig. MEF series

Application	Thaler Model
Hot piping	MEF-3A
Cold piping	MEF-3A
Natural gas piping	MEF-9
Rigid electrical conduit	MEF-1
Flexible electrical conduit	MEF-2A

6.6 Installation

- .1 Place and secure sleeves in concrete form work.
- .2 Supply sleeves to be set in concrete and masonry walls with installation detail drawings.
- .3 Regular sleeves;
 - .1 terminate flush with surfaces of concrete and masonry walls.
- .4 Waterproof sleeves in new construction;
 - .1 extend 75 mm (3 in) above finished floor.
 - .2 with flange embedded within concrete floor.
- .5 Sleeves in existing concrete and masonry walls and floors;
 - .1 installed in neatly cut or drilled holes in existing construction,
 - .2 cutting and drilling of structural elements, such as floors, slabs, walls, columns, or beams to be carried out in accordance with procedure set out in Article "Cutting and Patching" below.
 - .3 terminate sleeves flush with surfaces of concrete and masonry walls,
 - .4 extend waterproof sleeves 75 mm (3 in) above finished floor with flange, countersunk, and bolted down flush into floor surface,
 - .5 fill opening between sleeve and wall or floor with 2 hour fire rated fire-stopping sealant with water barrier.
- .6 Roof sleeves for pipe and conduit:
 - .1 install manufactured roof flashing sleeves in accordance with manufacturer instructions, specifically in accordance with requirements applicable to the type of roofing membrane requirements,
 - .2 where limestone ballast is used, apply asphalt or similar protective coating onto flashing sleeve to a height of 50 mm (2 in) above ballast layer,
- .7 Fill future-use sleeves with weak concrete, gypsum plaster or similar material.
- .8 Coat exposed exterior surfaces of un-galvanized ferrous sleeves with heavy application of zinc rich paint
- .9 At fire separations and smoke separations, pack and seal void between sleeve and pipe, duct without fire damper, conduit, or insulation in accordance with Article "Fire Stopping and Smoke Seals" in this Section.

- .10 At other locations, pack void between sleeve and pipe, conduit, duct or insulation for full depth of sleeve, with mineral wool and seal with silicone-free caulking compound.
- .11 Install fire dampers in accordance with conditions of approval given in manufacturer's instructions.

7 LINK SEALS

7.1 General

- .1 Fit each pipe passing through floor slab in contact with ground or basement walls below grade with link seal between sleeve and bare pipe.
- .2 Submit manufacturer's literature and schedule showing location, service, inside diameter of wall opening, sleeve length and pipe outside diameter.
- .3 Link seal:
 - .1 Manufactured from modular synthetic rubber links with stainless steel hardware.
 - .2 Loosely assembled with bolts to form continuous rubber belt around pipe, with pressure plate under each bolt head and nut.
 - .3 Constructed to provide electrical insulation between pipe and sleeve.

Standard of Acceptance

- Power Plant Supply – fig. Thunderline Linkseal
- Advance Products & Systems – fig. Innerlynx
- Metraflex - fig. MetraSeal

7.2 Installation

- .1 Determine inside diameter of each wall opening or sleeve before ordering seal.
- .2 Position seal in sleeve around pipe and tighten bolts to expand rubber links until watertight seal is obtained.

8 FIRE STOPPING AND SMOKE SEALS

8.1 General

- .1 Provide fire stopping and smoke seals where ducts, pipes or conduits penetrate fire separations.
- .2 Fire stop materials to be impervious to water when installed in a horizontal separation, including waterproof service sleeves.
- .3 Firestop material manufacturer or their designated service representative to provide the following services:
 - .1 selection of listed fire stopping assemblies for each applicable service penetration and fire separation assembly/rating,
 - .2 provide training of contractor's staff for proper installation of fire stopping assembly; create and maintain a log of those personnel who obtain training,
 - .3 inspect the completed installation of all penetrations and submit a written report to the Consultant, including photo record of randomly selected instances of each fire stopping method. Where deficiencies are discovered, note the deficiencies in the report and provide remedial instructions to the contractor to correct the deficiency. After deficiencies are corrected, re-inspect the deficiencies to conform their correction, update and resubmit the report to the Consultant.
- .4 Submit a complete fire stopping and smoke seal shop drawing schedule to the Consultant for review. Include details, cut sheets, system description and location for each proposed fire stopping and smoke sealing application.

8.2 Products

- .1 Materials to form ULC listed or cUL listed/classified assemblies.

Standard of Acceptance

- Hilti Firestop Systems
- 3M
- Nelson Firestop Products
- Eastern Wire + Conduit (Royal Quickstop)

- .2 Other manufacturers having products with explicitly similar characteristics, listings or classifications and approvals are acceptable.

8.3 Installation

- .1 Install firestopping and smoke seals in accordance with the manufacturer's recommendations and in accordance with its listing.
- .2 Firestopping and smoke seals to be installed only by personnel trained by the manufacturer on the installation of such systems.
- .3 Seal space between penetrating service and sleeve or opening in in fire rated floors and walls with a firestop and smoke sealing system.
- .4 Select thickness and arrangement of back-up materials to suit size of service, length of sleeve and anticipated movement.
- .5 At time of application of materials, surfaces to be clean, dry and free from dust, oil, grease, loose or flaking paint and foreign materials.
- .6 Select firestopping system to allow insulation and vapour barrier to pass un-broken through assembly.
- .7 Do not apply fire stopping materials to fire or smoke dampers.

9 WALL AND FLOOR PLATES

9.1 General

- .1 Provide finishing plates fitted to ducts, pipes, and electrical services provided under Division 20 of the Work which pass through walls, floors and ceilings in finished areas.

9.2 Products

- .1 Escutcheons for small diameter piping and small diameter electrical conduit:
- .1 manufactured chrome plated two-piece split type with hinge and set-screw.
- .2 Finishing plates for ducts, larger pipes, larger electrical conduits and electrical cables:
- .1 finishing plate (ring) fabricated from minimum 0.9 mm (20 ga) thick T304 stainless steel with No. 4 brushed finish, with minimum 25 mm (1 in) high collar ring,
- .2 mounting holes drilled at not less than three (3) symmetrically location positions around the ring to allow mechanical fastening,
- .3 plate diameter to be sufficiently sized to overlap the wall, floor or ceiling opening by not less than 25 mm (1 in) all around the opening.

9.3 Installation

- .1 Escutcheons;

- .1 secure escutcheons to pipe and electrical conduit with mechanical fastener.
- .2 Finishing plates:
 - .1 set finishing plates flat against the finished surfaces, and secure to the surface with stainless steel pan-head mechanical fasteners. Provide insert anchor plugs in the finished surface as necessary to secure the fasteners.

10 PIPE SUPPORTS, EQUIPMENT SUPPORTS, AND TRENCH COVERS

10.1 General

- .1 Design and fabricate supplementary supporting steel for piping, ductwork and equipment supports, and trench and pit covers, from steel plate and sections. For clarity, the contractor under these Division 20 to 25 of the Work is responsible for design, fabrication and installation of such materials.
- .2 Concrete housekeeping bases for mechanical and electrical equipment which are in direct contact with floor slab, are to be provided by this Division 20.
- .3 Concrete for equipment supported on vibration isolated inertia bases is to be provided by this Division 20.
- .4 Work to be done by firms specializing in these fields.
- .5 Submit shop drawings for steel and concrete work, prepared by Professional Engineers licensed in the jurisdiction of the Work

10.2 Applicable Codes and Standards

- .1 Legislation:
 - .1 Ontario Building Code,
 - .2 R.R.O. 1990, Reg. 851 Industrial Establishments
- .2 Installation codes and standards:
 - .1 CAN/CSA-S16.1 Limit States Design of Steel Structures.
 - .2 CSA W59 Welded Steel Construction (Metal Arc Welding).
- .3 Product standards:
 - .1 ASTM A36 Standard Specification for Carbon Structural Steel
 - .2 ASTM A53/A53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless.
 - .3 ASTM A123 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
 - .4 ASTM A 307 Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength.
 - .5 CAN/CSA G40.20/G40.21 General Requirements for Rolled or Welded Structural Quality Steel.

10.3 Supplementary Supports and Support Brackets

- .1 Provide supplement supports and brackets for the support of equipment, piping and ductwork.
- .2 Fabricate supports from structural grade steel with anchor bolts and fastenings, so that horizontal supporting beam deflections do not exceed 1/360 for the span, and not exceed an absolute deflection of 5 mm (0.20 in), with a safety factor of 1:4 to the ultimate strength of the material

- .3 Design the supports in consultation with the building structural Consultant, to transfer live loads and dead loads to the building structural elements,
- .4 Construct the supports as frames bracketed from walls, and/or supported from building structure above, and/or floor below.

10.4 Slide Pads for Equipment Support

- .1 General:
 - .1 slide pads for equipment supports for equipment subject to thermal expansion,
 - .2 designed for continuous-weld and/or tack-welding of backing plate to the equipment support,
 - .3 assembled in pairs per load point.

Standard of Acceptance

- Piping Technologies & Products Inc.
- .2 Composite 25% glass-filled PTFE bearing plate bonded to carbon steel backing plate:
 - .1 PTFE thickness: 0.1 mm (3/32 in.)
 - .2 backing plate: 3 mm (1/8 in.) thick carbon steel plate,
 - .3 compressive strength: 19.3 MPa (2800 psi)
 - .4 temperature rating: -45 to +260°C (-50 to +500°F)
 - .5 coefficient of friction: 0.15
- .3 Graphite bearing plate bonded to carbon steel backing plate:
 - .1 graphite thickness: 13mm & 6mm (1/2 in & 1/4 in.)
 - .2 backing plate: 6 mm (1/4 in.) thick carbon steel plate,
 - .3 compressive strength: 19.3 MPa (2800 psi)
 - .4 temperature rating: -45 to +537°C (-50 to +1000°F)
 - .5 coefficient of friction: 0.15.

10.5 Trench Covers, and Pit Covers

- .1 Fabricated with:
 - .1 75 mm x 75 mm x 9.5 mm (3 in x 3 in x 3/8 in) welded angle frame with anchor bars,
 - .2 25 mm x 9.5 mm (1 in x 3/8 in) trim bar to fit concrete pit, and with matching checker-plate cover,
 - .3 hot dip galvanized after fabrication

10.6 Installation - General

- .1 Locate supporting steel to permit removal of parts for service or repair, and to allow clear access to valves, fittings, and equipment,
- .2 Set equipment on supporting frames and brackets and install hangers, anchor bolts, vibration mountings and snubbers.
- .3 Set equipment base plates on housekeeping pads on minimum 13 mm (1/2 in) epoxy grout and fill hollow portion of base with concrete.
- .4 Install anchor bolts, vibration mountings and snubbers between equipment and housekeeping pad, or inertia pad and housekeeping pad.
- .5 Provide anchorage, dowels, anchor clips, bar anchors, expansion bolts and shields, and toggles.

- .6 Make field connections with bolts to CAN/CSA-S16.1, or by welding.
- .7 Supply items for casting into concrete or building into masonry to appropriate trades together with setting templates.
- .8 Touch-up field welds, bolts and burnt or scratched surfaces after completion of erection with primer.
- .9 Where trench covers are cut in field or damaged, touch up with zinc rich paint.

11 HOUSEKEEPING PADS AND CURBS

11.1 Materials

- .1 Concrete: 20 MPa (3000 psi),

11.2 Concrete Housekeeping Pads

- .1 Construct housekeeping pads using plywood form-work and site-poured concrete, and run pads continuously beneath the equipment.
- .2 Structurally-connect the housekeeping pads to the concrete floor slab with dowels, consisting of not less than 13 mm (½ in) diameter steel rods. For existing concrete floors, floors are to be drilled and dowels secured in the holes with chemically-hardening adhesive.
- .3 Provide anchorage, dowels, anchor clips, bar anchors, expansion bolts and shields, and toggles.
- .4 [[Refer to Specification section 20 05 49 *Seismic Restraint for Mechanical Systems* for additional requirements for housekeeping pads where equipment is to be seismically restrained.]
- .5 Finish exposed surfaces to make them flat, level, and smooth.
- .6 Chamfer corners 25 mm (1 in).
- .7 Housekeeping pad plan dimensions:
 - .1 extending 75 mm (3 in) larger all around than the base of apparatus for non-seismic applications,
 - .2 minimum 200 mm (8 in) larger all around than equipment-base anchor attachment points for seismically restrained equipment.
- .8 Pad height to conform to the following table;

Equipment Type	Floor Type	Vibration Isolation	Thickness of Housekeeping Pad mm (in)
Stationary, not motorized	All	All	100 (4)
Fans	All	Yes	150 (6)
Motorized, up to 7.5kW (10 HP)	All	Yes or No	150 (6)
Motorized, 11 to 19kW (15 to 25 HP)	Slab on Grade	No	250 (10)
	Slab on Grade	Yes	150 (6)
	Suspended Slab	Yes	150 (6)
Motorized, 22kW (30 HP) and over	Slab on Grade	No	300 (12)
	Slab on Grade	Yes	150 (6)
	Suspended Slab	Yes	150 (6)

11.3 Concrete Housekeeping Curbs

- .1 Concrete housekeeping curbs constructed to the same requirements as for housekeeping pads except as follows.
- .2 Dimensions for containment curbs: 150 mm wide x 150 mm high (6 in. x 6 in.), unless otherwise shown.
- .3 Concrete curbs used in lieu of housekeeping pads when shown on drawings;
 - .1 curb height for AHUs: minimum 150 mm (6 in.) unless higher dimensions are shown.
 - .2 curb width for AHUs requiring seismic restraint:
 - (a) extending a minimum of 200 mm (8 in.) from the outside edge of the AHU base frame channel, and
 - (b) extending 100 mm (4 in.) from the inside face of the AHU base frame channel.
 - .3 curb width where no seismic restraint is required for AHUs:
 - (a) extending a minimum of 75 mm (3 in) greater than, and on each side of, the AHU base frame channel flange width.
- .4 Void space between underside of AHU and structural floor filled with 64 kg/m³ (4 lb/ft³) mineral-wool rigid board insulation.

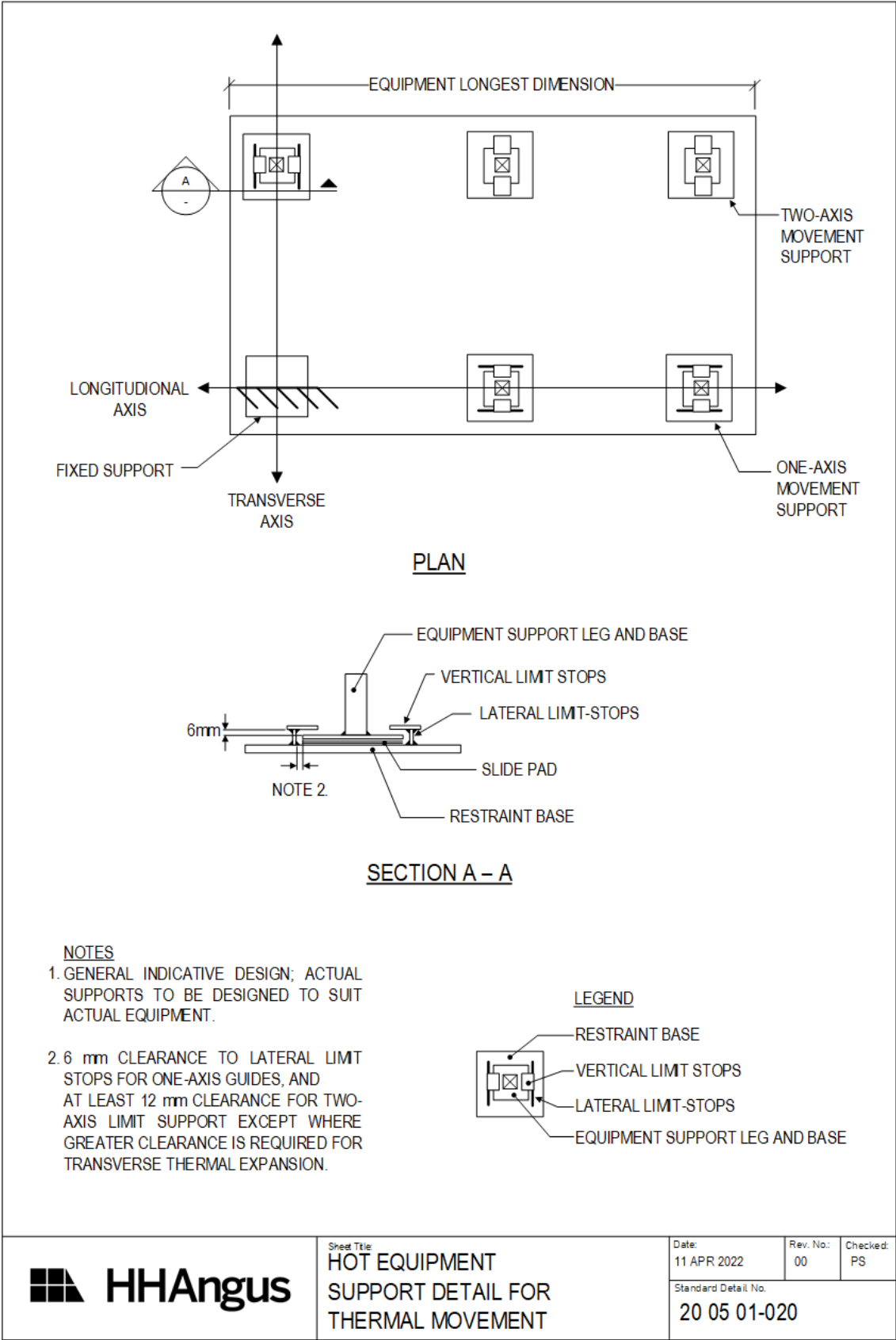
12 INSTALLATION OF EQUIPMENT SUBJECT TO THERMAL EXPANSION

- .1 The following specific installation requirements apply to hot equipment which is not supported on spring vibration isolators, including but not limited to:
 - .1 boilers, hot water heaters,
 - .2 heat exchangers,
 - .3 expansion tanks,
 - .4 deaerators and condensate tanks,
 - .5 diesel exhaust SCR emission control units.
- .2 Fasten equipment to building structure to accommodate thermal expansion in accordance with manufacturer's instructions. In the absence of such instructions, fasten equipment support legs as follows unless otherwise shown;
 - .1 rigidly mechanically-fasten one fixed support point which is closest to the inlet exhaust piping connections,
 - .2 for supports located on the same transverse or longitudinal axis as the fixed support point, provide slide guides with lateral limit-stops (lateral to the direction of thermal movement) with a lateral clearance gap not exceeding:
 - (a) 6 mm (1/4 in.) lateral movement for outdoor equipment and/or equipment subject to seismic restraint,
 - (b) 12 mm (1/2 in.) total movement otherwise.
 - .3 for other support points, provide guides with two-axis horizontal limit-stops to allow free movement under thermal conditions,
 - .4 when installed outdoors, or where subject to seismic restraint, or both, provide vertical movement limit stops to limit free movement due to wind loading or seismic forces to not more than 6 mm (1/4 in.).

- .3 Provide support slide pads beneath each support leg other than the fixed support;
 - .1 use PTFE slide pads for equipment with an operating temperature less than 260°C (500°F),
 - .2 use graphite slide pads for equipment with an operating temperature greater than 260°C (500°F).

12.2 Standard Details

- .1 The following standard details are appended to the end of this Specification section.
 - .1 20 05 01-020 Hot Equipment Support Detail for Thermal Movement



END OF SECTION

COMMON ELECTRICAL REQUIREMENTS FOR MECHANICAL SERVICES

20 05 12

1 GENERAL

1.1 Scope

- .1 Provide wiring, conduit, fittings, supports, disconnect switches, service lights, and related devices and equipment for mechanical trades work, at voltages of 600V and less and to the extent specified herein.
- .2 Pre-installation survey of SCCR values for equipment supplied under Divisions 20 to 25 which requires power wiring supply, to verify nameplate SCCR is equal to or greater than the minimum specified SCCR values.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 29 Hangers and Supports
 - .2 20 05 49 Seismic Restraint.
 - .3 20 05 14.13 Motor Controllers
 - .4 20 05 14.16 Variable- Frequency Drives
 - .5 25 55 13 Building Automation Smoke Damper Control Panels

1.3 Definitions and Abbreviations

- .1 The following definitions apply to this section and referenced sections:
 - .1 **Control panels** – an electrical device that controls or monitors mechanical equipment, or that interfaces with instrumentation devices.
 - .2 **Control wiring** - wiring for the purpose of communication or control of equipment and instrumentation.
 - .3 **Electrical safety code** - the edition with amendments of CSA C22.1 as adopted by applicable legislation at the location of the Work.
 - .4 **Mechanical breaker panel (MBP)** means a 120/208 V mechanical power panel with overcurrent protection circuit breakers provided as part of an MCC.
 - .5 **Mechanical service panel (MSP)** - panelboard with branch circuit overcurrent protection devices provided by Division 26, and dedicated to supply power for equipment provided by mechanical trades work.
 - .6 **Mechanical trades work** - equipment and systems provided under Divisions 20 to 25.
 - .7 **Motor controllers** - constant speed motor controllers of the manual, magnetic or solid-state type in accordance with specification section 20 05 14.13.
 - .8 **Motor Control Center** – has the meaning as specified in section 20 05 14.13.
 - .9 **Packaged equipment** - equipment containing some or all of: motor(s), controls and/or other electrically powered equipment, such as but not limited to: electric heating equipment, water treatment equipment, packaged HVAC equipment, electric boiler, electric domestic water heaters, etc.)
 - .10 **Power Panel (PP)**: 208 up to 600 V, 3 phase, panelboard with branch circuit overcurrent protection devices provided by Division 26, which serves general building loads and may also serve equipment provided by mechanical trades work.

- .11 **Power wiring** means wiring that provides electrical power to equipment including to control panels, including BAS panels, that are not integral to the controlled equipment.
- .12 **Receptacle panel (RP)** - a 120/208 V panelboard with branch circuit breakers, provided by Division 26.
- .13 **SCCR**: the RMS symmetrical short-circuit current rating of the equipment or motor controller, measured at the input to the motor or controlled equipment (short-circuit withstand rating has the same meaning).
- .14 **VFD**: variable frequency drives in accordance with specification section 20 05 14.16.
- .15 **Wiring** means conductors, cable, conduit, fittings, supports and accessories.
- .2 With respect to these definitions, for equipment provided by Division 26 the actual terminology used in the Division 26 drawings and specification may differ but the intent remains the same.
- .3 For clarity, any reference herein to Division 20 means Divisions 20 to 25 inclusive.

1.4 Applicable Codes and Standards

- .1 Legislation:
 - .1 Electrical safety legislation in the jurisdiction of the Work.
 - .2 For clarity, on Federal Government projects, comply with the provincial or territorial legislation at the place of the Work which adopts the applicable edition of CSA 22.1 with any amendments
- .2 Installation standards and codes:
 - .1 CSA C22.1 Canadian Electrical Code Part 1, as amended and adopted by the AHJ for electrical safety in the province or territory at the place of the Work.
- .3 Product standards:
 - .1 CSA C22.2 No. 4 Enclosed and Dead-Front Switches
 - .2 CSA C22.2 No. 38 Thermoset-Insulated Wires and Cables
 - .3 CSA C22.2 No. 39 Fuseholder Assemblies
 - .4 CSA C22.2 No.94.1 Enclosures for Electrical Equipment, Non-Environmental Considerations
 - .5 CSA C22.2 No. 106 HRC – Miscellaneous Fuses
 - .6 CSA C22.2 No. 124 Mineral Insulated Cable
 - .7 CSA C22.2 No. 131 Type TECK 90 Cable
 - .8 CSA C22.2 No. 208 Fire Alarm and Signal Cable
 - .9 CSA C22.2 No. 230 Tray Cable
 - .10 CSA C22.2 No. 239 Control and Instrumentation Cables

1.5 Quality Control

- .1 Electrical wiring for mechanical trades work to be performed by a specialist electrical contractor firm with an established reputation in the field of wiring of mechanical equipment and controls.

1.6 Short Circuit Current Ratings (SCCR) and Markings

- .1 Except where another Specification section requires a SCCR of a different value, equipment provided under Division 20 to 25 which is supplied electrical power in accordance with CSA C22.1 shall have a short circuit capacity rating (SCCR) of not less than 25kAIC RMS symmetrical.

- .2 The SCCR value is to be marked on all equipment provide with power wiring in accordance with CSA C22.1. Where the SCCR nameplate rating references an instruction manual, provide a separate label that states the SCCR value.

1.7 Permits, Fees and Inspections

- .1 Arrange and pay for electrical permits and any required inspections for electrical work for mechanical equipment and systems.
- .2 Submit to the electrical safety authority the required number of drawings and specifications for examination and approval prior to commencement of work.
- .3 Notify Consultant of changes required by the electrical safety authority prior to making changes.
- .4 On completion of the Work, furnish certificates of acceptance (or similar report) from the electrical safety authority to the Consultant.

1.8 Standard Details

- .1 Device legend with list of abbreviations and schematic wiring diagrams are included at the end of this section that delineate the scope of work between Division 20 and Division 26 and as further specified herein.
- .2 This material is to be used in the interpretation of specification requirements for power wiring and control wiring of Division 20 to 25 equipment.

1.9 Submittals

- .1 Submit manufacturer catalogue cut-sheets for the following materials;
 - .1 VFD Inverter Duty cable,
 - .2 service lights.

1.10 Storage of Materials

- .1 Store wire and cable in a clean, dry, well-ventilated area.
- .2 Protect white insulated wire from exposure to NOx gas (e.g.: exhaust from propane fueled equipment) by wrapping with shrink wrap, by locating away from sources of NOx and by maintaining adequate ventilation to minimize NOx levels.
- .3 Where white insulated wire has discoloured:
 - .1 do not install,
 - .2 dispose of the wire,
 - .3 remove and replace wire that has been installed.

2 PRODUCTS

2.1 Motor Feeder and Control Wiring ("Building Wires")

- .1 Application:
 - .1 motor and equipment power feeders controlled by constant speed motor controllers;
 - (a) do not use for motors controlled by variable frequency drives,
 - .2 control wiring including control valves and damper actuators, panel control wiring, motor controller interlock wiring, BAS control wiring, and switch-type instrumentation,
 - .3 convenience power outlets and service lights.
- .2 Conductors:

- .1 solid copper for No. 12 and 14 AWG,
- .2 stranded conductors for 10 AWG and larger.
- .3 Minimum wire size:
 - .1 No. 12 AWG for equipment power,
 - .2 No. 14 AWG, for control wiring at 120 VAC or lower.
- .4 Insulation:
 - .1 chemically cross-linked thermosetting polyethylene (XLPE) material, RW90 or RWU90,
 - .2 1000 V insulation for 600 V systems,
 - .3 600 V insulation for 100 VAC to 480 VAC systems.
 - .4 300 V insulation for systems less than 100 VAC, and for systems 24 VDC and less.
- .5 Colour coded conductors:
 - .1 colour impregnated into insulation at time of manufacture,
 - .2 phase conductors No. 8 AWG and larger with black insulation, may be colour coded with adhesive colour coding tape.
- .6 Listed to CSA C22.2 No. 38.
 - Standard of Acceptance*
 - Aetna Insulated Wire
 - General Cable
 - Nexans Canada Inc.
 - Prysmian Cables & Systems Ltd.
 - Southwire

2.2 VFD Inverter Duty Cable

- .1 Application:
 - .1 for motor power feeders between a VFD and its driven motor,
 - .2 specifically manufactured to reduce high frequency noise and grounding of common mode currents.
- .2 Cable:
 - .1 symmetrical conductor, low-capacitance design with three ground wires and shield,
 - .2 conductors: braided copper wire with RW90 XLPE insulation.
 - .3 voltage rating: 1000 VAC, with resistance to voltage spikes of not less than 2 kV.
 - .4 bonding conductors: three (3) bare copper conductors,
 - .5 shielding:
 - (a) designed for EMC/RFI reduction and as a low-impedance path for high-frequency common mode currents,
 - (b) 100% coverage by two-layers of copper-wrap tape shield, or
 - (c) shielding provided by continuous corrugated and welded aluminium armoured sheath.
 - .6 sheath:
 - (a) method 1: continuous corrugated and welded aluminum armour sheath (armour and shield),

- (b) method 2: interlocked aluminium sheath for armour, separate copper wrap shields as specified above,
- (c) method 3: no armour sheath required when cable has the specified copper tape shielding and is installed in conduit,
- .7 outer jacket: TPE or PVC liquid-tight with FT4 and AG14 rating, and UV resistant.
- .8 listed to CSA C22.2 No. 38, and CSA C22.2 No. 230.

Standard of Acceptance

- NEXANS - fig. DriveRx (armoured)
- ShawCor - fig. CSA Armoured AIA VFD (armoured)
- ShawCor - fig. CSA Unarmored Tray VFD (unarmoured)
- Belden - fig. Symmetrical 2kV (unarmoured)
- Belden - fig. Symmetrical 2kV (armoured)

.3 Cable shield termination fittings:

- .1 High-frequency/low impedance shield termination kit to provide 360° connection to the cable shield, with flexible tinned copper braid bonding strap with attached lug, and constant force spring collar.

Standard of Acceptance

- Southwire – fig. 85451

- .2 High-frequency/low impedance cable gland, with integral 360° copper alloy shield contact spring.

Standard of Acceptance

- Southwire - fig. 85452

2.3 VFD Common Mode Voltage Bonding Cable

- .1 High frequency bonding strap between motor frame and VFD.
- .2 Flat-braided tinned-copper, low-impedance, factory-cut mounting hole at motor end, crimped ring terminal for termination at VFD.
- .3 Custom length to suit installation.

Standard of Acceptance

- AEGIS - fig. HF Ground Strap]

2.4 Extra-Low Voltage Power Wiring – 24 VAC, 24 VDC

- .1 Application: power wiring to 24 VAC or 24 VDC electrically commutated motors.
- .2 Type: ACIC,
- .3 Cable:
 - .1 insulated solid or stranded copper conductors,
 - .2 insulation: XLPE, colour coded or numbered wires,
 - .3 minimum wire size: 16 AWG,
 - .4 voltage rating: 600 V.
- .4 Armour:
 - .1 aluminium interlocked armour.

- .5 Jacket:
 - .1 FT4 flame retardant,
 - .2 FT6 when installed in raised floors, or in ceiling spaces that are used as return air plenums.
- .6 Listed to CSA C22.2 N0. 239,
 - Standard of Acceptance*
 - General Cable (Carol)
 - Belden
 - Nexans Canada Inc.

2.5 Instrumentation Cabling

- .1 Application: instrumentation and control wire suitable for analogue 4-20 mA and 0-10 VDC signaling.
- .2 Cable:
 - .1 insulated solid-copper twisted-multipair conductors, shielded cables with individually shielded pairs, 100% coverage overall shield, drain wires and overall rated jacket,
 - .2 insulation: XLPE, colour coded or numbered wires,
 - .3 minimum wire size: as specified by equipment manufacturer or controls vendor, but not less than 18 AWG,
- .3 Armour:
 - .1 corrugated steel, or
 - .2 none required if installed in conduit or approved wireway.
- .4 Jacket:
 - .1 FT4 flame retardant,
 - .2 FT6 when installed in open style cable trays in ceiling spaces that are used as return air plenums.
- .5 Listed to CSA C22.2 No. 239,
 - Standard of Acceptance*
 - General Cable (Carol)
 - Belden
 - Nexans Canada Inc.

2.6 Fire Rated Mineral Insulated Cable

- .1 Application – power feeders:
 - .1 conductors: solid annealed copper,
 - (a) 2 conductors, minimum 14 AWG for power wiring for Division 20 to 25 control equipment including dampers and terminal units,
 - (b) 2 or 3 conductor as applicable, size as shown but not less than 12 AWG for power wiring to Division 20 to 25 mechanical equipment (other than control equipment)
 - .2 insulation: compacted magnesium oxide (“MI”)
 - .3 sheath: seamless annealed copper.
 - .4 voltage rating: 600 V
 - .5 terminations: as supplied by the cable manufacturer.

- .6 fire rating: listed for 2 hour fire-resistance rating with hose stream test to ULC-S139 cables labelled accordingly.
- .7 ship cables with ends sealed.
- .8 listed to CSA C22.2 No. 124 and ULC-S139.

Standard of Acceptance

- Pentair/Pyrotenax System 1850

.2 Application - communication wiring:

- .1 conductors: solid annealed copper, single twisted pair 18 AWG.
- .2 insulation: compacted magnesium oxide ("MI")
- .3 shield: seamless annealed copper.
- .4 secondary insulation: compacted magnesium oxide ("MI").
- .5 sheath: seamless annealed copper.
- .6 voltage rating: 300 V.
- .7 terminations: as supplied by the cable manufacturer.
- .8 listed for fire alarm cabling CSA FAS 105.
- .9 fire rating: 2 hour fire-resistance rating with hose stream test to ULC-S139.
- .10 ship cables with ends sealed.
- .11 listed to CSA C22.2 No. 208 and ULC-S139.
- .12
 - Pentair/Pyrotenax System 1850 Twisted Pair

2.7 Fire Rated Ceramifriable Silicone Rubber Insulated Cable

- .1 Application: controls and communications wiring.
 - .1 No of conductors:
 - (a) single twisted pair for control and BAS MSTP communication,
 - (b) 4x shielded twisted-pair for Ethernet communications.
 - .2 conductors: annealed copper, 18 AWG, with flame retardant tape cover,
 - .3 insulation: thermoset ceramifriable silicon rubber, colour coded red/black,
 - .4 drain wire: 20 AWG copper,
 - .5 shield: copper/polyester tape,
 - .6 jacket: low smoke, zero halogen polyolefin, red colour,
 - .7 voltage rating: 72 V maximum,
 - .8 fire rating: 2 hour fire-resistance rating with hose stream test to ULC-S139,
 - .9 listed to CSA C22.2 No. 208 and ULC-S139.

Standard of Acceptance

- Vitalink (Marmon, Comtran) FAS 105

2.8 Conduits and Fittings

- .1 Conduits:

- .1 rigid hot dipped galvanized steel threaded conduit,
- .2 electrical metallic tubing (EMT), hot dipped galvanized with couplings,
- .3 PVC coated hot dipped galvanized rigid steel conduit: with 40 mil PVC exterior coating, 2 mil urethane interior and thread coating,
- .4 flexible metal conduit and liquid-tight flexible metal conduit.
- .2 Conduit fastenings:
 - .1 single hole steel straps to secure surface conduits 50 mm (2") and smaller,
 - .2 two hole steel straps for conduits larger than 50 mm (2"),
 - .3 beam clamps to secure conduits to exposed steel work,
 - .4 channel type supports for two or more conduits,
 - .5 Ø6 mm threaded rods to support suspended channels.
- .3 Conduit fittings:
 - .1 manufactured for use with conduit specified including coatings,
 - .2 factory "ells" where 90° bends are required for 25 mm (1in.) and larger conduits,
 - .3 insulated throat steel set screw or raintight insulated throat steel compression connectors and couplings for EMT,
 - .4 threaded or compression type raintight/concrete tight insulated throat zinc plated steel connectors and couplings for rigid steel conduit,
 - .5 raintight insulated throat steel connectors at all surface equipment enclosures and other electrical equipment in sprinklered areas for all conduit terminations.

2.9 Outlet Boxes

- .1 Construction:
 - .1 hot dipped galvanized steel single and multi-gang flush device boxes for flush installation,
- .2 Size:
 - .1 76 mm x 50 mm x 38 mm (3" x 2" x 1½") or as indicated,
 - .2 102 mm (4") square outlet boxes when more than one conduit enters one side with extension and plaster rings as required.

2.10 Disconnect Switches

- .1 Construction:
 - .1 listed to CSA C22.2 No. 4,
 - .2 enclosure type:
 - (a) painted metal with hinged door,
 - (b) indoors: type 1, 3R, 4 or 12, unless otherwise specifically shown,
 - (c) outdoors: type 3R.
 - .3 fuseholder assemblies listed to CSA C22.2 No. 39,
 - .4 include fuses unless shown as unfused,
 - .5 fuseholders suitable for Class J fuses, sized to suit the fuse sizes without the use of adaptors,
 - .6 horsepower rated,

- .7 one, two or three pole as required for single phase or polyphase circuits,
- .8 two pole with solid neutral or three pole with solid neutral for three wire and four wire circuits with neutral,
- .9 six pole for two speed motor applications,
- .10 provision for padlocking in the Off switch position,
- .11 mechanically interlocked door to prevent opening when handle is in the ON position,
- .12 heavy duty, quick-make, quick-break action,
- .13 ON-OFF switch position indication on switch enclosure cover.
- .2 Fuses:
 - .1 HRCI-J time delay up to 600A,
 - .2 HRCI-L for ratings above 600A,
 - .3 minimum interrupting capacity: 200 kAIC
 - .4 product of one manufacturer,
 - .5 ampere rating as indicated, where not indicated, the maximum rating permitted by the electrical code.
- .3 Special requirements for disconnect switch located upstream of harmonic filters:
 - .1 double break contacts per pole, to isolate fuses on both the line and load side,
 - .2 14 AWG power taps on both line and load sides for control power transformers.
- .4 Special requirements for disconnect switch located between a VFD and the controlled equipment:
 - .1 auxiliary switch position status switch;
 - (a) rating: 10 A at 120 VAC,
 - (b) switch contacts open when disconnect switch is Not-Closed.
- .5 Ratings:
 - .1 IEC 90 rotary switch for motors up to 18.6 kW (25 HP),
 - .2 NEMA flange mount switch-handle for all ratings.

Standard of Acceptance

- Square "D"/Schneider Electric Company (Canada) Ltd.
- Eaton
- Siemens Canada Ltd.
- Klockner Moeller/Eaton

2.11 Equipment Service Lights

- .1 Protected globe light fixture ("Marine light"):
 - .1 die-cast aluminium housing and cage, frosted glass lens, stainless steel hardware, suitable for wall and ceiling mounting,
 - .2 enclosure rating: NEMA 4X or IP 65, vapourtight,
 - .3 listed and fixture marked for use in wet locations,
 - .4 bulb: LED with electronic driver, minimum life of 50,000 hours at L70 lumen level,
 - .5 optics: 3500 to 4000 K light, nominally 1400 lumens,
 - .6 operating temperature: -20 to +40°C (-4 to +104°F),

- .7 operating humidity: up to 100% relative humidity at operating temperatures between 0 and +40°C (32 to 104°F),
- .8 power: 120 VAC.

Standard of Acceptance

- Cooper - fig. LVL20UG

.2 Area light fixture ("Area light"):

- .1 reinforced-polyester fiberglass housing, stainless steel hardware, with lens gasket, suitable for wall and ceiling surface-mounting,
- .2 fixture length: 600 mm (24 in),
- .3 lens: low profile, high impact 50% DR acrylic lens, for wide distribution,
- .4 enclosure rating: NEMA 4X or IP 65, vapourtight,
- .5 listed and fixture marked for use in wet locations,
- .6 bulb: LED with electronic driver, minimum life of 60,000 hours at L80 lumen level,
- .7 optics: 3500 to 4000 K light, nominally 3000 lumens,
- .8 operating temperature: -20 to +40°C (-4 to +104°F),
- .9 operating humidity: up to 100% relative humidity at operating temperatures between 0 and +40°C (32 to 104°F),
- .10 power: 120 VAC.

Standard of Acceptance

- Cooper - fig. 2VT3
- Lithonia - fig. FEM LED

2.12 Switches

- .1 Toggle switch, with neon pilot light – light is On when switch is Off.
- .2 Rating: 20 A at 120 Vac.
- .3 Switch cover: weatherproof with silicone rubber gasket, and clear bubble over toggle.

Standard of Acceptance

- Hubbell - HBL1795

2.13 Receptacles

- .1 Class A GFCI type, 15 A at 120 VAC indoors, and 20 A T-slot for outdoors.
- .2 Receptacle outlet hood:
 - .1 in-use weatherproof, for both indoor and outdoor locations,
 - .2 die cast aluminum base and cover with gasket,
 - .3 vertical mount.
 - .4 self-closing lift cover.
 - .5 CSA 3R rated.

Standard of Acceptance

- Bryant Electric – WPB26EH

2.14 Rooftop Maintenance Receptacle Pedestals

- .1 Manufactured roof-mounted maintenance receptacle pedestal;
 - .1 formed galvanized steel with powder coat finish, or stainless steel square tube,
 - .2 roof deck mounting flange, for bolting from the top of flange to roof, or fastened using a two part deck flange assembly,
 - .3 minimum height above roof: as required for receptacle to be located at not less than 750 mm (30 in.) above the roof flange,
 - .4 receptacle: Class A GFCI type, 120 V, 20 A T-slot, with in-use weatherproof receptacle cover,
 - .5 factory-wired or field wired. For factory wiring, minimum no. 12 AWG RW90 conductors in liquid-tight flexible metallic conduit.
 - .6 CSA Type 3R rated.

Standard of Acceptance

- Valid Manufacturing fig. Rooftop Pedestal
- MAPA fig. MPX series]

2.15 Conduit and Equipment Supports

- .1 General:
 - .1 supports for conduit may conform to Specification section 20 05 29 except/and as specified herein.
 - .2 Materials: carbon steel supports, hot dipped galvanized after fabrication.
 - .3 manufacturer standard products suitable for support load rating of conduit and conductors:

Standard of Acceptance

- Burndy Canada Ltd.
- Canstrut
- Electrovert Ltd.
- E. Myatt & Co. Ltd
- Steel City Electric Ltd.
- Pilgrim Technical Products Ltd.

- .2 Upper attachment – concrete inserts
 - .1 galvanized wedge inserts to MSS SP-58 type 18.
 - .2 maximum tension load rating: 4.4 kN (1000 lbs),

Standard of Acceptance

- Anvil - fig. 281
- Unistrut - fig. P-3245

- .3 Upper attachment – existing concrete:
 - .1 conform to Specification section 20 05 29.
- .4 Upper attachment – steel beams:
 - .1 carbon steel beam clamp (top flange), hook rod with locking jaw, fasteners and lockwashers, to MSS SP-58, type 25,

Standard of Acceptance

- Anvil - fig. 227
- Myatt - fig. 504, 505

.5 Upper attachment - steel joists:

- .1 for installation of support rod in the interstice space of double-ell steel joists and open-web steel joints for support on the lower chord,
- .2 carbon steel washer plate with double locking nuts on top-side of washer,
- .3 second steel washer plate on underside of joist with nut where supported equipment is subject to vibration.

Standard of Acceptance

- Anvil - fig. 60
- Myatt - fig. 545

.6 Hanger rods:

- .1 continuous threaded rod, carbon steel, USS national course thread,
- .2 minimum rod size: Ø6 mm (1/4 in. dia.),
- .3 tension load ratings to MSS SP-58,

Standard of Acceptance

- Anvil - fig. 146
- Myatt - fig. 434

.7 Horizontal Pipe Support – Swivel Ring Hanger

- .1 swivel ring hangers, carbon steel ring strap, zinc plated, adjustable knurled swivel nut, to MSS SP-58 Type 10,
- .2 nominal conduit size: 12mmC to 100 mmC.

Standard of Acceptance

- Anvil - fig. 69, CT-69
- Myatt - fig. 41, 42, 43
- Unistrut

.8 Support channels:

- .1 U shape, minimum size 41 mm x 41 mm x 2.5 mm (1-1/2" x 1-1/2" x 1/10") thick, surface mounted, suspended or set in poured concrete walls and ceilings.
- .2 channel size selected for total supported loads,
- .3 conduit attachments: one-piece or two piece conduit clamps suitable for suspended loads and bottom supported conduit loads.

.9 J Hooks:

- .1 galvanized steel open-style J hooks with rolled edges for fastening direct to building structure or hanger rods.

.10 Rooftop conduit supports:

- .1 conform to specification section 20 05 29.

2.16 Wire Markers

- .1 Printed, self-laminating vinyl wire and cable labels and sleeve-labels.

Standard of Acceptance

- Brady BMP21 Plus series

3 EXECUTION

3.1 Pre-Installation Survey for Short Circuit Current Ratings

- .1 Prior to installation of power wiring to mechanical equipment provided under Division 20 to 25, conduct a survey of such mechanical equipment's' SCCR values. Verify that the equipment nameplate SCCR rating is equal to or greater than:
 - .1 the general value specified in this section, or
 - .2 the specific value specified in the relevant Specification section for the equipment.
- .2 Where the nameplate SCCR is less than the specified minimum SCCR required value, provide a fused disconnect switch as specified herein ahead of the equipment, even if the equipment already has an integral disconnect switch. The cost for the provision of such disconnect switches shall be borne by the trade contractor supplying the mechanical equipment, at no cost to the Owner.
- .3 For clarity, this survey also applies to existing mechanical equipment where the Work includes replacement of the power wiring supplying the equipment.

3.2 General Installation Requirements

- .1 Install electrical wiring work under this specification section in accordance with the applicable electrical safety code and regulations applicable at the location of the Work.
- .2 In other than service rooms, run conduit and cable concealed within walls or above ceilings.
 - .1 for open-cell concrete block walls, install conduit during wall construction with openings for outlet boxes,
 - .2 for solid concrete walls, rough-in conduit and outlet boxes supported from structural reinforcing bars prior to pouring of concrete,
 - .3 where walls or ceiling structures are exposed, such as steel or finished concrete, arrange conduit neatly on the supporting surface, avoid the use of elbows to the greatest extent possible, and locate conduit as close as possible to the building structure.
- .3 In service rooms, run conduit and cables exposed.

3.3 Conduit Support and Hanger Installation

- .1 As an alternative to the materials specified herein, specification section 20 05 29 may also be used for support of conduits.
- .2 Support conduit from building structure in accordance with specification section 20 05 29.
- .3 Support conduit directly from or on structural building elements. Do not support conduit directly from other services.
- .4 Provide all miscellaneous materials including nuts, washers, and backing plates to make a complete support installation.
- .5 Where wall brackets are used, select brackets and size mounting bolts and backing plates to suit the supported load, allowing for a safety factor by not loading the bracket more than 80% of its published load rating.

- .6 In steel framed construction, support conduit from structural members. Where structural members are not suitably located for upper hanger attachment locations, and where inserts of adequate capacity cannot be installed in concrete slabs, provide supplementary steel framing members;
 - .1 fabricate supplementary steel from standard HSS sections, single EL section, double C “strongback” sections, or pipe rolls,
 - .2 size supporting steel to limit span deflection to 1/250 (0.4%) between support points,
- .7 Support horizontal conduit at intervals not exceeding 3 m (6 ft).
- .8 Support vertical conduit at intervals not exceeding 3 m (6 ft).
- .9 Where trapeze hangers are used, secure conduit to trapeze with U-bolts or conduit clamps.
- .10 Mechanically fasten supplementary steel to structural steel.

3.4 Armoured Cable Support

- .1 Support armoured cable VFD cables on 300 mm (12 in.) centres on channel supports and secured with conduit clamps. Do not use nylon or wire lashing or perforated strap to support or secure cables.
- .2 Support instrumentation armoured cables horizontally in cable trays or with J-hooks on 300 mm (12 in.) centres.
- .3 Support instrumentation armoured cables vertically by securing to building structure or secondary framing with perforated straps with 3 mm (1/8 in.) thick EPDM protective strip between the strap and cable.

3.5 Plenum-Rated Control and Instrumentation Cables Support

- .1 Support plenum-rated instrumentation and control cables in cable trays or with J-hooks on 300 mm (12 in.) centres. Support vertical cable drops to controls instrumentation, controlled devices or related equipment by use of vinyl tie-wraps fastened to building structure, supplementary steel, or equipment hanger rods. Do not support cables on piping or ductwork.

3.6 Installation of Power and Control Wiring – General Requirements

- .1 Wiring methods and standards to conform with those specified in Electrical Division 26 for the area of building in which installation is to be made, except as otherwise specified in this section.
- .2 Except where fire rated cables or VFD Inverter duty cables are required, use building wire for:
 - .1 power wiring for motors and packaged equipment,
 - .2 power wiring to control panels, heat tracing and other non-motorized packaged equipment, and
 - .3 non-analog control wiring at 120 VAC or less, and 24 VDC or less.
- .3 Provided polyphase motor and equipment power conductors with the following colour coding:
 - .1 Phase A – Red,
 - .2 Phase B – Black,
 - .3 Phase C – Blue ,
 - .4 Neutral - White,
 - .5 Ground - Green,
 - .6 Control - Orange.
- .7 Where colour coded tape is utilized, apply at least 50 mm (2") at terminations, junction boxes and pull boxes. Do not paint conductors.

- .4 Provide single-phase motor and control wiring conductors with the following colour coding:
 - .1 Line – Red,
 - .2 Neutral – White,
 - .3 Ground – Green.
- .5 Install all wiring in conduit or approved raceway.
- .6 Use conduit type as follows:
 - .1 EMT: use thin wall conduit up to and including 32 mm (1 ¼ in) size for wiring in ceilings, furred spaces, in hollow walls and partitions and where not exposed to mechanical injury, and as otherwise shown.
 - .2 Rigid : use rigid galvanized steel conduit for wiring in poured concrete, where exposed, and for conduit 40 mm (1½ in) size and larger.
 - .3 Liquid-tight flexible: use only for the last 1000 mm (3 ft) of motor feeder at connection to motor, and for instrumentation wiring to equipment subject to vibration.
 - .4 select conduit size to be of sufficient size to allow easy removal of conductors at any time. Conduit sizes, where shown, are minimum and shall not be reduced.
- .7 Provide separate conduit for power wiring for each motor or starter. Except for motor temperature transducer wiring, do not install control wiring in the same conduit as power wiring.
 - .1 exception: motor temperature transducer wiring between motor and associated motor controller may be run in the same conduit as the associated motor feeder provided the conduit is sized for the additional wire pair.

3.7 Installation of Power Wiring for VFDs and Associated Motors

- .1 Use VFD inverter duty cables for motor feeders between VFDs and associated motor.
- .2 Run VFD inverter duty cables in rigid conduit or EMT between the VFD and the motor, with liquid-tight flexible conduit used at the motor connection;
 - .1 use only site-formed bent elbows for changes of direction; do not use ells,
 - .2 make an elbow radius so that the bend radius of the cable is not less than the minimum bending radius specified by the cable manufacturer,
 - .3 do not combine wiring from any other source or purpose within VFD feeder conduit.
- .3 VFD inverter duty cables may be run in free- air (without conduit) where all the following conditions are met;
 - .1 the VFD cable is of the armoured type,
 - .2 the armoured cable is located in the same room as the VFD and the motor,
 - .3 the armoured cable length does not exceed a total length of 10 m (33 ft);
 - (a) for longer cables, the 10 m (33 ft) free-air length is to be located at the motor end,
 - .4 where the cable passes through the wall of air handling units,
 - (a) provide a 100 mm (4 in) long section of rigid conduit (sleeve) through the wall,
 - (b) the sleeve is provided with escutcheons to seal the wall opening,
 - (c) the ends of the conduit are reamed and cleaned of burrs and sharp edges, and
 - (d) the cable/sleeve is sealed with a non-hardening mastic (i.e. firestop compound) at one end.
- .4 Terminate the shield on VFD inverter duty cables as follows:

- .1 terminate at both ends of the cable at the motor enclosure box ground screw and at the VFD cabinet entrance potential bond screw,
- .2 connect the shield to the ground screw of any intervening devices between the VFD and the motor where the cable is interrupted, including disconnect switches, output load-filters,
- .3 connect the ends of the shield with a low-impedance 360° contact termination kit, either by use of a special-purpose gland or by a special-purpose bonding strap.
- .5 Terminate the three ground conductors at each end. A pigtail may be used for final termination to the motor ground lug or the VFD ground lug provided the pig-tail size is not less than the size of the individual cable ground wire.
- .6 Where the VFD cable must be interrupted at an equipment disconnect switch or otherwise spliced, terminate the ends of the shield using low-impedance termination kits at the common ground lug in the disconnect switch or junction box. Bond the six (6) ground conductors with a common pigtail to a ground lug.

3.8 Harmonic Filter Control Power

- .1 Provide 120 VAC control power supply to operate contactors in the passive harmonic filters, of either:
 - .1 dedicated 120 VAC circuit with 15 A circuit breaker,
 - .2 VFD auxiliary 120 VAC power supply (if available), or
 - .3 control transformer power supply consisting of:
 - (a) primary side connection downstream of the harmonic filter disconnect switch,
 - (b) control transformer with primary voltage at VFD power supply voltage and 120 VAC secondary,
 - (c) fuse protection on primary and secondary side of transformer.
- .2 The control transformer may be located in the service disconnect switch upstream of the harmonic filter, inside the VFD enclosure (when permitted by VFD manufacturer), or in a custom electrical enclosure.
- .3 Provide control power wiring to the VFD and between the VFD and the passive harmonic filter. Provide an interposing dual-voltage relay (12 VAC/VDC coil, 120 VAC rated contacts) to operate the harmonic filter contactor.
- .4 Provide a CSA C22.2 No. 94.1 Type 1 or 3 electrical enclosure to house the transformer (if used) and dual-voltage relay and associated fuse protection and wiring, unless these materials can be included in the disconnect switch and/or the VFD enclosure.
- .5 Program the VFD to open the harmonic filter contactor (to disconnect the filter capacitors) when the VFD output is below 70% of motor rated speed.

3.9 Installation of Instrumentation, Communications and Control Cabling

- .1 Install wiring in conduit.
- .2 Neatly train circuit wiring in cabinets, panels, pullboxes and junction boxes and hold with nylon cable ties.
- .3 Run instrumentation, communication and control cabling point to point and terminate on terminal strips. Do not splice communication or control cabling. Where long runs make a continuous point to point installation impractical, make splices on labelled terminal blocks in an accessible labelled terminal cabinet, installed at 1200 mm (48") above floor, and indicate cabinet location, terminal and wire numbers on the As-built drawings.
- .4 Terminate control cables in equipment with suitable connectors.

- .5 Clearly identify cables/conductors at both ends, with permanent wire markers, indicating device/panel identification and terminal numbers on the device/panel (refer to standard detail 20 15 12-021 at the end of this specification section):
 - .1 Use applicable reference name or ID tag for the device or control panel.
 - .2 Print the labels such that the applicable panel/device identification is closest to the end of the cable.
 - .3 Where individual wires are run in conduit, collect wires associated to the same control panel/device and apply a label to the group of wires inside each control panel/device. Where there is insufficient space inside a device (such as a transmitter), the label may be applied to the conduit at the point of connection to the device.
 - .4 Where there are multiple conductors, individually identify each wire by its termination reference on the panel or device to which it connects.
 - .5 Where there are only two wires and it is readily understood where each wire is to be terminated (i.e. white neutral, green ground), individually marking of the wires is not required.

3.10 Installation of Fire Rated Cable

- .1 Provide fire rated cables for power and control wiring for fans, dampers, terminal units, control devices such as limit switches, etc., and other applicable equipment in the following systems:
 - .1 fans and dampers for smoke control systems, including areas of refuge,
 - .2 fans and dampers for smoke venting systems (as an aid to firefighting),
 - .3 smoke dampers, motorized fire dampers and combination smoke dampers that are required to function as part of a smoke control system (see specification section 25 55 13 for applicable dampers),
- .2 Exceptions: fire rated cables are not required under the following conditions;
 - .1 between an MCC, MPP or other power distribution panel, and the motor controller, VFD or damper actuator, if both the power source panel and the controller/VFD or actuator are in the same room or space,
 - .2 between a motor controller or VFD, and the motor served if both the controller/VFD and the motor are in the same room or space,
 - .3 between a motor controller or VFD, and a damper associated with the controlled motor, if the motor controller/VFD and the damper are located in the same room or space,
 - .4 between a BAS controller and the controlled equipment if both are located in the same room or space,
- .3 Select the type of fire rated cable for power and control wiring as follows:

Application	Mineral Insulated	Ceramifiable Insulation
Motor feeders	Yes	N/A
Dampers	Yes	Yes
BAS MSTP wiring	Yes	Yes
BAS Ethernet wiring	N/A	Yes

- .4 Handle cables with care to avoid cable kinks; it is recommended that cable be uncoiled from supply reel by rolling. Do not install kinked cables.

- .5 Install fire rated cables in accordance with ULC S139 and with the manufacturer's written instructions.
- .6 Install ceramifiable fire rated cable in conduit. Use conduit, fittings and supports in strict conformance with the cable manufacturer's installation instructions and product certification listing. Use of any other type of conduit, fasteners and support systems are not permitted.
- .7 Install cables on hangers or on channels secured to walls, beams or floor slabs, using clamps supplied by or recommended by the manufacturer.
- .8 Support cables with clamps, straps, clips of:
 - .1 copper,
 - .2 stainless steel,
 - .3 steel material,
- .9 Secure cables so that they cannot contact any dissimilar metals other than the approved supporting materials.
- .10 In damp or wet areas, wrap cables with electrical tape where the cable contacts the supporting materials unless the supporting materials are copper or stainless steel.
- .11 Support fire rated cables directly from fire rated structure in accordance with its listing requirements, at spacings as required by the manufacturer installation requirements.
- .12 Bend cables using a suitable hickey with a bending radius of not less than six times the cable diameter, unless the cable manufacturer instructions specify smaller turning radius.
- .13 Terminate cables using glands and seals as supplied by the cable manufacturer. Install gland and seal assemblies using tools specifically designed for the purpose.
- .14 Upon completion of cable terminations and prior to energization, test the insulation resistance of each cable with an insulation tester. Where measured values are not acceptable to the Consultant, rework or replace the cable until satisfactory results are obtained.
- .15 Provide the services of the cable manufacturer field service representative to inspect the cable installation and termination methods and provide a written report documenting that the cables have been installed in accordance with the requirements of the ULC standard and the ULC listing and in accordance with the manufacturer's recommendations. Submit the report to the Consultant.]

3.11 Grounding

- .1 Ground electrical equipment and wiring in accordance with the applicable electrical safety code and regulations applicable at the location of the Work except where greater requirements are specified herein.
- .2 Provide insulated green bonding conductor in each power and control conduit sized per Table 16 of the Electrical Safety Code. Minimum bonding conductor size #12AWG copper.
- .3 Install grounding conductors, outside electrical rooms and electrical closets, in conduit.
- .4 Make connections to neutral and equipment with brass, copper or bronze bolts, star-washers, and connectors.
- .5 Except for VFD Inverter Duty cables, ground all motors with separate green insulated copper ground conductor installed in power feeder conduit, wired from ground terminal in the motor controller to a ground lug bolted directly to the motor frame, located inside the motor terminal box. Size the ground conductor per Table 16 of the electrical safety code except that the smallest conductor size to be #12 AWG.
- .6 Ground VFD inverter duty cables using all three integral ground conductors, from the ground terminal in the VFD enclosure to the ground lug bolted directly to motor frame inside the motor terminal box.
- .7 For VFDs, bond both ends of the VFD inverter duty cable as previously specified herein.

3.12 Disconnect Switches

- .1 Provide a disconnect switch for each piece of mechanical equipment provided under Division 20 to 25 which requires a power supply. This requirement is to be met by the following methods as applicable to each piece of equipment:
 - .1 as an integral factory-installed component of the equipment, or
 - .2 as a field-installed switch where;
 - (a) the equipment does not have an integral disconnect switch, or
 - (b) the equipment includes a factory installed disconnect switch but the equipment as a whole does not have a SCCR rating which meets or exceeds the required minimum SCCR rating specified herein or as specified in the applicable equipment Specification section.
- .2 For clarity, provide a disconnect switch upstream of harmonic filters provided for VFDs.
- .3 Locate the disconnect switches as follows;
 - .1 within 9 m (29 ft) and in the line-of-site of motors serving non-refrigeration motorized equipment, and within 9 m (29 ft) of the motor controller or VFD controlling the equipment,
 - .2 within 3 m (9.5 ft) and in the line-of-site of equipment containing refrigeration compressors and related motorized equipment that forms part of a refrigerant circuit,
 - .3 at cooling towers and other outdoor equipment where the motor controller is located indoors, and
 - .4 within 1 m (3 ft) of non-motorized equipment,
 - .5 within 1 m (3 ft) of harmonic filters for VFDs.
- .4 Disconnect switch types for motorized equipment:
 - .1 fused type for motor controllers and VFD's, including harmonic filters.
 - .2 fused type for motorized packaged equipment,
 - .3 unfused for non-motorized equipment,
 - .4 unfused type at the controlled equipment for:
 - (a) cooling towers and other outdoor equipment where the motor controller is located indoors, or
 - (b) where the motor controller is in excess of the distance specified above or is not in line of site of the controlled equipment.
- .5 Disconnect switches on load side of VFD:
 - .1 where a disconnect switch is required between a VFD and the driven motor due to excess distance or lack of line-of-site requirements, provide an unfused disconnect switch with integral disconnect status position switch, as close as possible to the motor,
 - .2 wire the status switch back to the VFD input for drive output protection.
- .6 Disconnect switches for non-motorized equipment:
 - .1 provide unfused disconnect switch for non-motorized mechanical equipment.
- .7 Where the nameplate SCCR value of a mechanical equipment is less than the specified minimum SCCR value required, provide a fused disconnect switch to isolate the mechanical equipment, even if the equipment has an integral disconnect switch.
- .8 Where fuse protection is specified, install fuses of the correct overcurrent rating as specified by the mechanical equipment installation instructions.
- .9 Where fuse protection is specified, provide a set of six spare fuses of each size used in the disconnect switches. Turn spare fuses over to the Owner and submit a copy of the receipt signed by the Owner.

- .10 Provide power wiring between the field-installed disconnect switch and the associated equipment, with the conductors of the same wire gauge as the branch circuit conductors.

3.13 Outlet Boxes

- .1 Size boxes in accordance with CSA C22.1. Use 102 mm (4") square or larger outlet boxes as required for special devices.
- .2 Gang boxes where wiring devices are grouped. Use combination boxes with barriers where outlets for more than one system are grouped.
- .3 Provide blank cover plates for boxes without wiring devices.

3.14 Service Lights, Switches and Receptacle

3.15 Rooftop Maintenance Receptacles

- .1 Outdoor maintenance receptacles for rooftop equipment provided under Division 26.
- .2 Provide maintenance receptacles on roofs where mechanical trades work equipment is installed;
 - .1 locate an outlet within 7.5 m (24 ft) of each piece of rooftop HVAC equipment, except standalone fans that use a remote motor controller,
 - .2 one outlet may serve multiple equipment provided the distance limitation is met,
 - .3 all outlets may be connected to the same circuit,
 - .4 install each outlet at least 750 mm (20 in.) above the finished roof,
- .3 Support receptacles as follows;
 - .1 on a building wall,
 - .2 on the exterior side of the mechanical trade's equipment provided it does not impede maintenance access to the equipment and the equipment manufacturers written instructions permit its installation,
 - .3 as part of a manufacturer maintenance receptacle pedestal unit.
- .4 Where a manufactured maintenance receptacle pedestal is used;
 - .1 fasten the pedestal to the roof in accordance with the manufacturer instructions, including provision of any miscellaneous under-deck framing steel required,
 - .2 for field installed wiring, run No. 12 AWG building wire in liquid-tight flexible metallic conduit inside of the maintenance receptacle pedestal,
- .5 Where receptacles are mounted on building walls or mechanical trades equipment,
 - .1 provide 120 V, 20 A duplex receptacle, CSA configuration 5-20R, with an in-use weatherproof outlet cover,
 - .2 provide a weatherproof roof sleeve for conduit penetrations through the roof, located not more than 500 mm (20 in.) from the receptacle.
 - .3 use liquid-tight flexible metallic conduit between the roof penetration and the receptacle.
- .6 Arrange and pay for roofing work required, including roof openings, waterproof membrane modification and repair, roof-flashing and counter-flashing. Retain the services of the original roofing contractor to perform this work where a roof warranty is still in effect.
- .7 Where conduit is to be run on the roof to connect multiple maintenance receptacles,
 - .1 run wiring in PVC coated galvanized rigid conduit,

- .2 support conduit on a galvanized steel framing system supported on the roof, with horizontal conduit located at least 600 mm (24 in.) above the roof,
- .3 liquid-tight flexible metallic conduit may be used at final connection ends, but is limited to a length of 500 mm (20 in.).]

3.16 Seismic Restraint

- .1 Provide seismic restraints for electrical conduit in accordance with specification section 20 05 49.

3.17 Coordination and Division of Responsibility – Division 20 and Division 26

- .1 Schedule A at the end of this Specification section specifies the division of responsibility between Division 20 and Division 26 for provision of electrical work for mechanical equipment, including termination of conductors.
- .2 For clarity;
 - .1 the Division 20 electrical Work may be performed by the Division 26 contractor, but the work is managed and paid for by the Division 20 contractor.
 - .2 related work performed under Division 26 is listed in Schedule A for reference.
- .3 Coordinate power requirements for mechanical trades equipment with the contractor under Division 26 of the work, including;
 - .1 provide a list of all planned and ordered mechanical trades equipment with motor horsepower ratings and electrical power requirements, prior to the Division 26 contractor procuring their power distribution equipment,
 - .2 periodically update this power requirements list as mechanical trades equipment is ordered, and review with the Division 26 contractor to allow them to revise breaker ratings in a timely manner,
- .4 Where the branch circuit breaker rating requirements change as a result of the actual ordered mechanical trades equipment, coordinate and pay for any breaker and feeder changes required whether the affected work is in Division 20 or Division 26 scope of work.

3.18 Wiring Diagrams

- .1 The following wiring diagrams are included at the end of this section:
 - .1 20 05 12 - 001 Mechanical – Electrical Coordination (Sheet 1 of 3)
 - .2 20 05 12 - 002 Mechanical – Electrical Coordination (Sheet 2 of 3)
 - .3 20 05 12 - 003 Mechanical – Electrical Coordination (Sheet 3 of 3)
 - .4 20 05 12 - 005 Rooftop Custom A.H.U. – Maintenance Receptacles
 - .5 20 05 12 - 006 Rooftop HVAC Equipment – Maintenance Receptacles

Schedule A – Coordination of Division 20 and 26 Scope of Work			
Reference	Work Element	Div. 20	Div. 26
All	Motor Control Centers, motor controller racks, motor controllers, VFDs, Mechanical Breaker Panels (MBP), and disconnect switches	●	
Mechanical Equipment at voltage > 600 VAC	Power wiring from Division 26 switchgear to: <ul style="list-style-type: none"> - motor controller, - between motor controller and the mechanical equipment (where motor controller is free-standing separate from the mechanical equipment) - field-installed disconnect switches, and wiring between the disconnect switch and the mechanical equipment 		●
	Field-installed disconnect switches.		●
General Mechanical Equipment fed from Dedicated Power Panels for Mechanical Equipment (Note 1)	Mechanical Service Panels (MSP), including branch overcurrent protection devices.		●
	Power wiring from MSPs and/or MCCs to: <ul style="list-style-type: none"> - motors, including between motors and motor controllers, VFDs and/or disconnect switches as applicable, - packaged equipment, including disconnect switches as applicable, - equipment not requiring motor controllers or disconnect switches (control panels, heat tracing, etc.) 	●	
	Power wiring from RP and/or MBP to: <ul style="list-style-type: none"> - motors, including between motors and motor controllers, - packaged equipment, including disconnect switches as applicable, - equipment not requiring motor controllers or disconnect switches (control panels, heat tracing, etc.) 	●	
General Mechanical Equipment fed from Non-dedicated Power Panels (Note 2)	Non-dedicated Power Panels (PP) and receptacle panels (RP), including branch overcurrent protection devices.		●
	Distribution splitters		●
	Power wiring from PPs and/or distribution splitters to: <ul style="list-style-type: none"> - motor controller, - disconnect switch ahead of VFD, - disconnect switch for package equipment, - packaged equipment (with integral disconnect switch) - equipment not requiring motor controllers or disconnect switches (control panels, heat tracing, etc.) 		●
	Power wiring from RP to: <ul style="list-style-type: none"> - motor controller or disconnect switch, - disconnect switch for package equipment, - packaged equipment (with integral disconnect switch), - equipment not requiring motor controllers or disconnect switches (control panels, heat tracing, etc.) 		●
























Schedule A – Coordination of Division 20 and 26 Scope of Work			
Reference	Work Element	Div. 20	Div. 26
	Power wiring from: <ul style="list-style-type: none"> - disconnect switch to a VFD, - motor controller or VFD to the motor, - disconnect switch to packaged equipment 	●	
BAS Controls and OEM Controls	In service rooms: provision of 120/208 VAC mechanical service panels (MSP) complete with 15 A breakers in service rooms for use by Division 20 to 25.		●
	In service rooms: where MCC's are used, dedicated 120 VAC mechanical breaker panels (BP) complete with 15 A breakers for use by Division 20 to 25.	●	
	Power wiring for controls in service rooms: wiring from MSP or BP to the BAS and OEM control equipment.	●	
	Other than service rooms: Dedicated 120V 15A normal and emergency branch circuit breakers as indicated on the receptacle panel schedules.		●
	Power wiring for controls other than in service rooms: wiring from dedicated circuits in receptacle panels to control equipment.	●	
	120 V, single phase power supply with a junction box at specific control devices as shown.		●
	Breaker tamper-protection locks.	●	
	Instrumentation and actuator power and control wiring, for both BAS controls and OEM controls.	●	
	Control wiring to interlock motor controllers and to connect safety and operating controls.	●	
Equipment Service Lights	120 VAC, 15A power circuits for equipment service lights, terminated in the equipment service light.		●
	120 VAC, 15A power circuits for equipment convenience receptacles, terminated in the receptacle.		●
	Power wiring from adjacent junction boxes to light switches/service convenience receptacles and fixtures	●	
	Equipment service lights, switches and convenience receptacles.	●	
Fire and Smoke Dampers	Power wiring to damper interlock control panels for smoke dampers, motorized fire dampers, and combination smoke/fire dampers.		●
	Wiring between damper interlock control panels (for smoke dampers, motorized fire dampers, and combination smoke/fire dampers), to their associated dampers.	●	

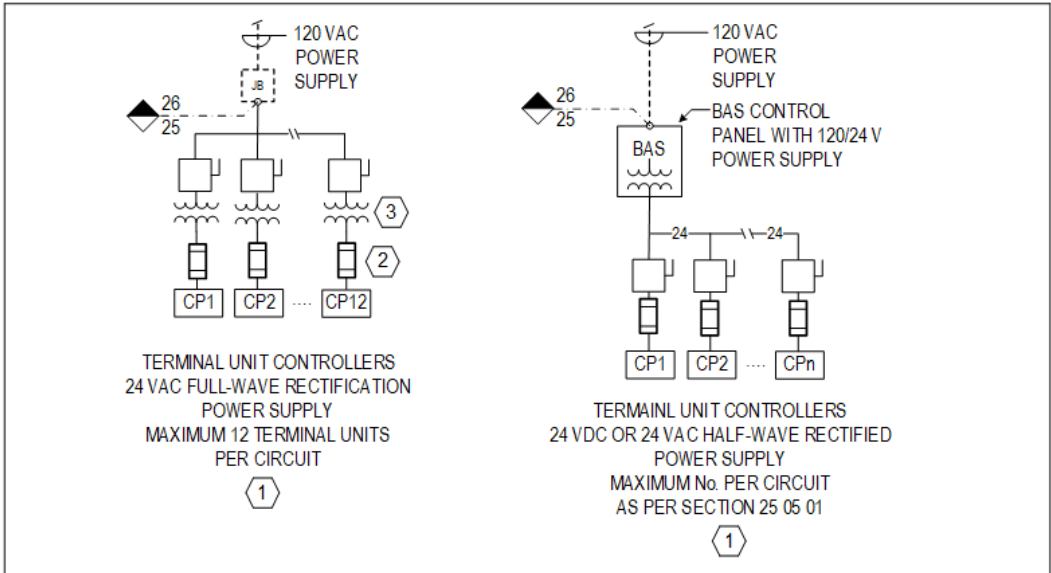
Schedule A – Coordination of Division 20 and 26 Scope of Work			
Reference	Work Element	Div. 20	Div. 26
Life Safety Interface	[Fire Alarm System ("FAS") control and monitoring modules located at BAS control interface panel.][Fire Alarm System ("FAS") control and monitoring modules located at/near fan starter or damper actuator, and wiring between control module and damper motor and fan starter.]		●
	FAS control and monitoring modules located at/near sprinkler and standpipe supervised valves and flow switches including wiring between each module and the respective valve/flow switch.		●
	Wiring between FAS control and monitoring modules, and smoke control and smoke venting fans and dampers.		●
	Termination of FAS control and monitoring wiring in BAS panels	●	
Rooftop Maintenance Receptacles	Rooftop maintenance receptacle pedestals.	●	
	Power wiring from breaker panel (BP) to and terminating in the rooftop maintenance receptacles.		●

Notes:

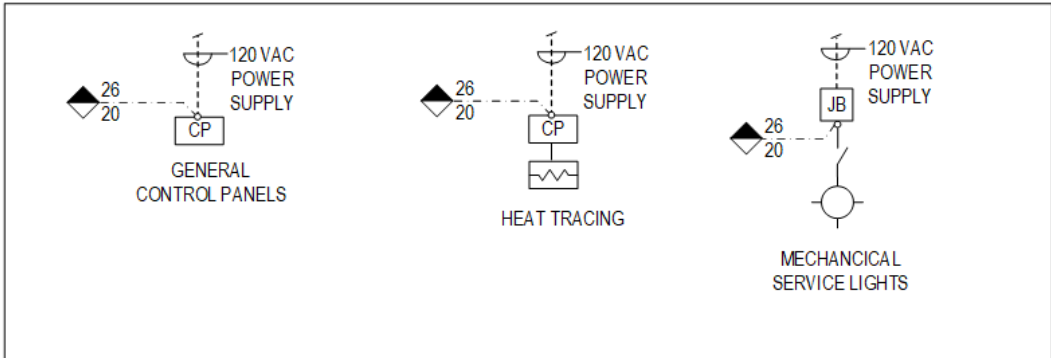
[1] MPP and MBP will be located in mechanical services rooms.

[2] PP and RP are not dedicated for mechanical equipment and may be located in any type of service room or space.

LEGEND			
	CONSTANT SPEED MOTOR CONTROLLER		SCOPE OF WORK: DIVISION "A" / DIVISION "B" BOUNDARY
	VARIABLE FREQUENCY DRIVE		
	UNFUSED SERVICE DISCONNECT SWITCH		WIRING AND/OR EQUIPMENT BY DIVISIONS 20-25
	FUSED SERVICE DISCONNECT SWITCH		WIRING AND/OR EQUIPMENT BY DIVISION 26
	TRANSFORMER		
	120 VAC/ XX VDC POWER SUPPLY, CLASS AS SHOWN		
	120/208 VAC MECHANICAL BREAKER PANEL		
	MECHANICAL SERVICE PANEL (DIV 26)		
	POWER PANEL (DIV 26)		
	JUNCTION BOX		
	MOTOR		
	ELECTRIC HEAT TRACING		
	PACKAGED EQUIPEMENT WITH MOTORS AND INTEGRAL MOTOR CONTROLLERS		
	CONTROL PANELS, TERMINAL UNIT CONTROLLERS, AND OTHER NON- MOTORIZED EQUIPMENT		
	FUSE		
	LIGHT SWITCH (FOR SERVICE LIGHTS) - FLOOR PLAN		
	POWER SWITCH (SINGLE-LINE)		
	SERVICE LIGHT		
	ALARM BEACON		
<p><u>General Notes</u></p> <p>1. This drawing indicates general coordination of mechanical and electrical work. Refer to plan and riser drawings and specifications for project specific requirements, which take precedence over this drawing.</p>			
	Sheet Title MECHANICAL – ELECTRICAL COORDINATION BLOCK DIAGRAM (SHEET 1 OF 3)	Date 21 JUNE 2023	Rev. No.: 03
		Checked PS	Standard Detail No. 20 05 12 - 001



TERMINAL UNITS



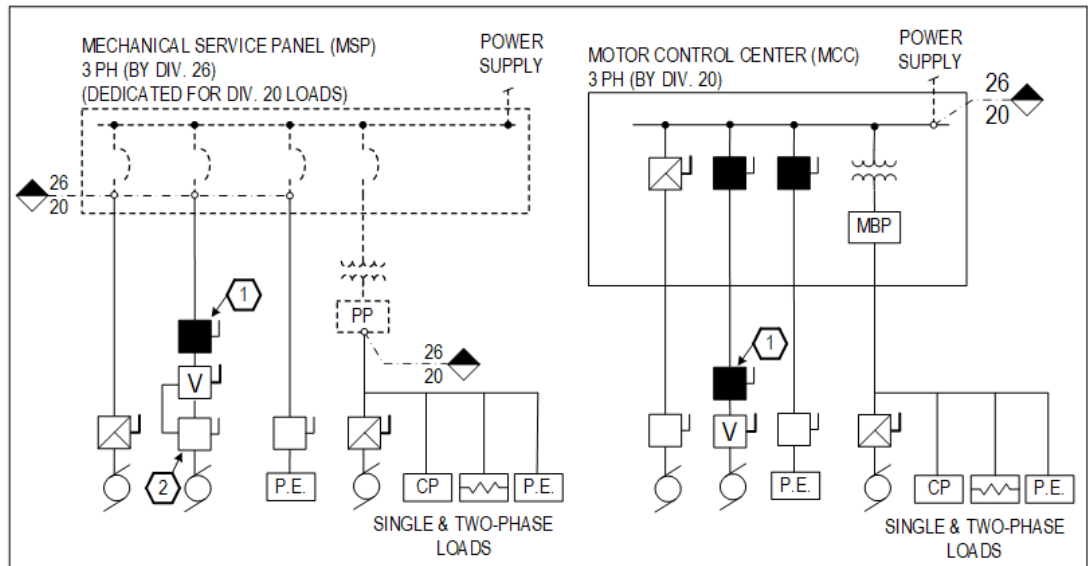
MISCELLANEOUS EQUIPMENT

- DRAWING NOTES**
(NOTES AND NUMBERING BELOW PERTAINS TO THIS DRAWING ONLY)
1. REFET TO SPECIFICATION SECTION 25 05 01 FOR APPLICABLE WIRING METHODS.
 2. PROVIDE FUSE PROTECTION IF TRANSFORMER DOES NOT HAVE INTEGRAL CIRCUIT BREAKER.
 3. PROVIDE DEDICATED TRANSFORMER FOR FULL-WAVE RECTIFIED 24 VAC CONTROL DEVICES.

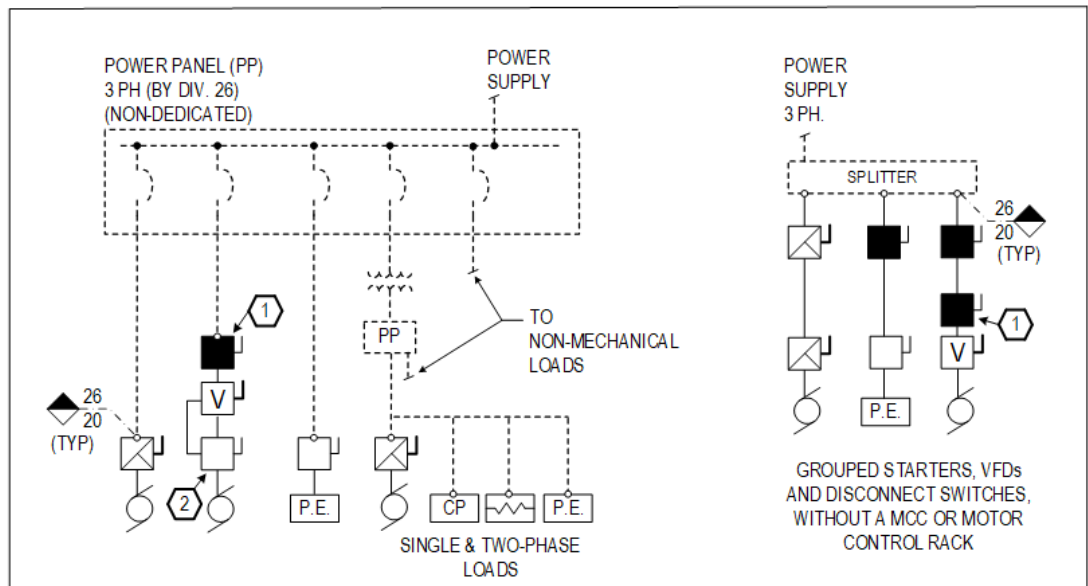


Sheet Title:
MECHANICAL – ELECTRICAL
COORDINATION BLOCK DIAGRAM
(SHEET 2 OF 3)

Date: 21 JUNE 2023	Rev. No.: 03	Checked: PS
Standard Detail No. 20 05 12-002		



DEDICATED POWER DISTRIBUTION EQUIPMENT



NON-DEDICATED POWER DISTRIBUTED EQUIPMENT

DRAWING NOTES
(NOTES AND NUMBERING BELOW PERTAINS TO THIS DRAWING ONLY)

1. SEPARATE FUSED DISCONNECT WHEN REQUIRED TO MEET SPECIFIED SCCR VALUES. (TYP).
2. SEPARATE UNFUSED DISCONNECT WHERE V.F.D. IS REMOTE FROM THE MOTOR. PROVIDE DISCONNECT SWITCH POSITION INDICATOR WITH INTERLOCK WIRING TO THE V.F.D. (TYP).

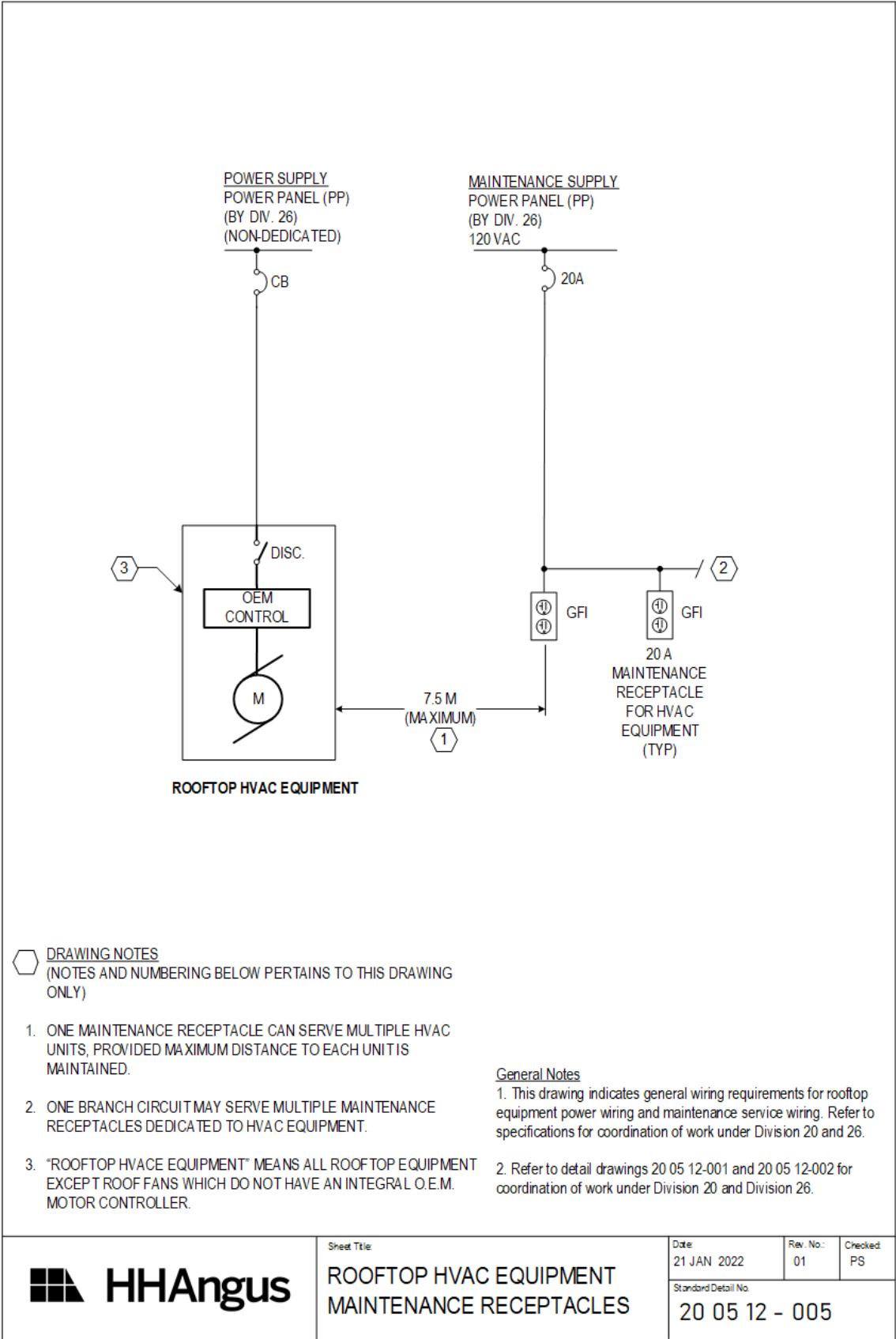
General Notes

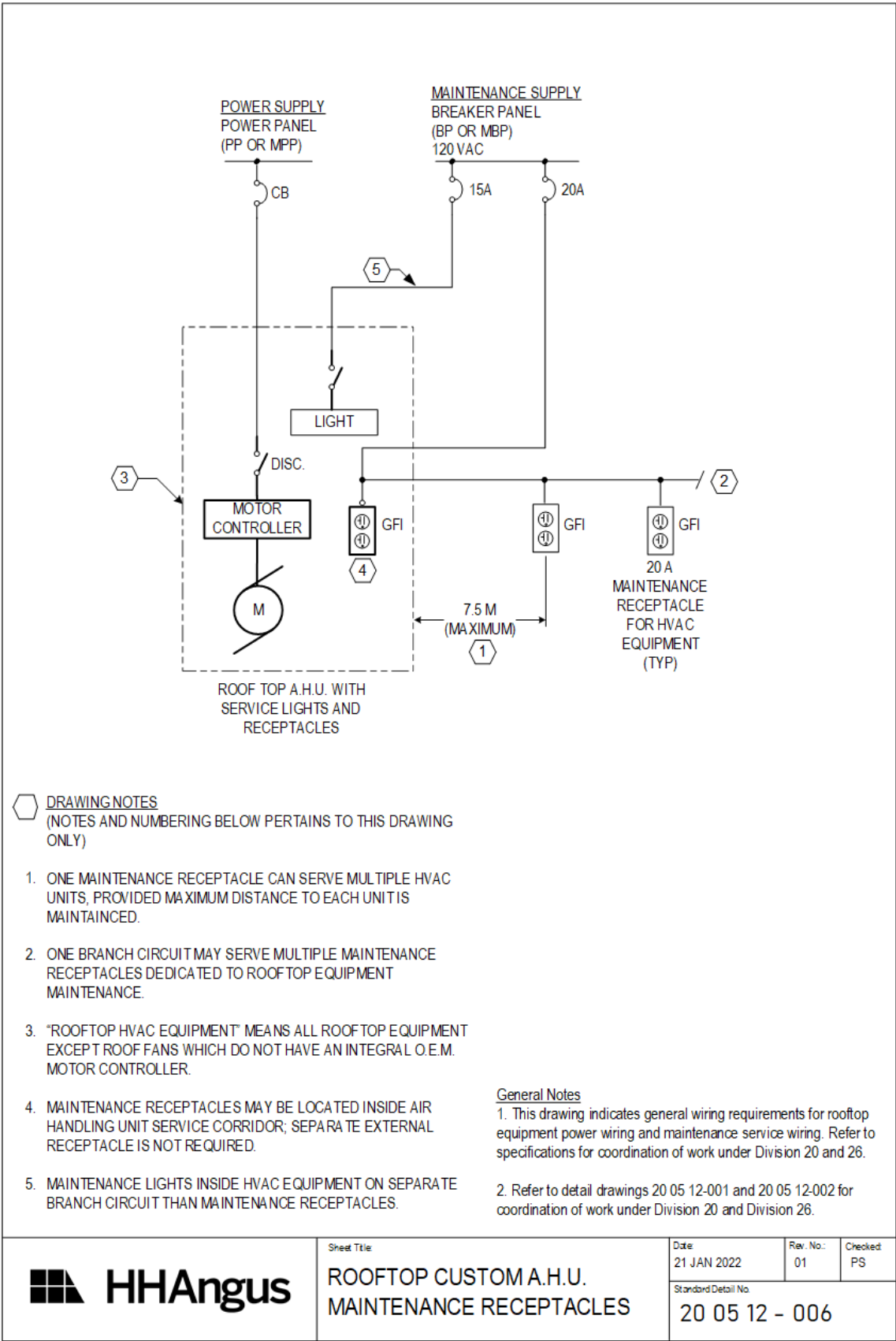
1. This drawing indicates general coordination of mechanical and electrical work. Refer to plan and riser drawings and specifications for project specific requirements, which take precedence over this drawing.
2. Dedicated power distribution equipment is only located in mechanical service rooms.

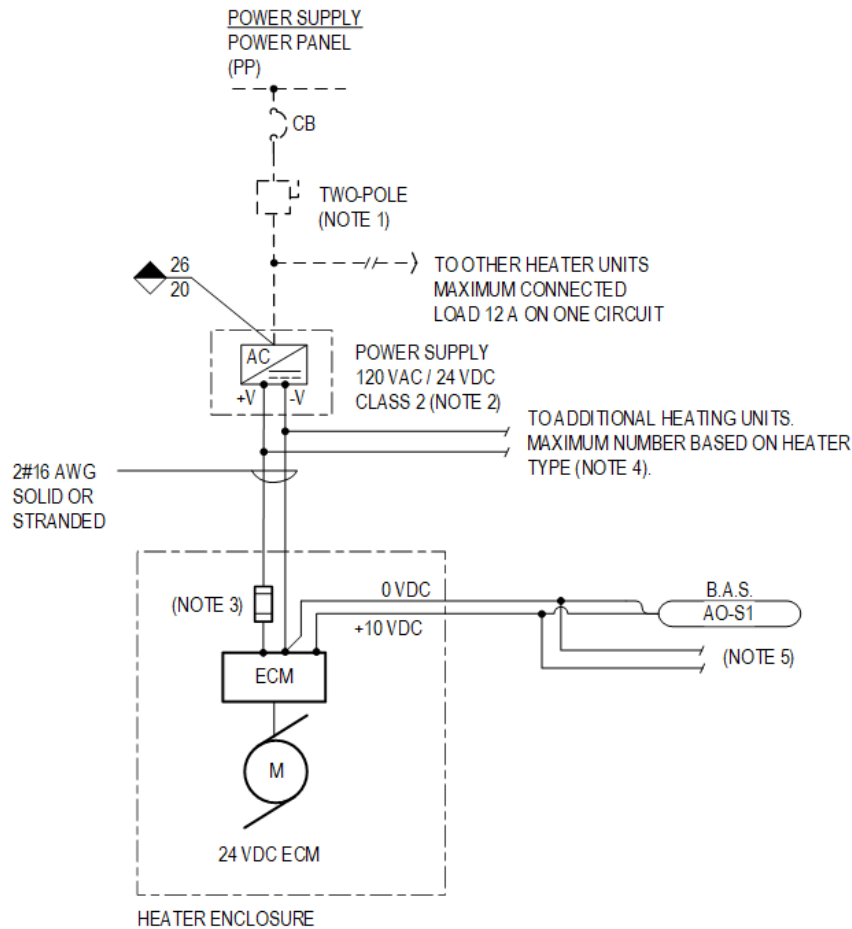


Sheet Title
**MECHANICAL – ELECTRICAL
COORDINATION BLOCK DIAGRAM
(SHEET 3 OF 3)**

Date: 21 JUNE 2023	Rev. No.: 04	Checked: PS
Standard Detail No. 20 05 12 – 003		







REFERENCE NOTES

1. DISCONNECT BOTH LINE AND NEUTRAL
2. POWER SUPPLY MOUNTED IN TYPE 1 ELECTRICAL ENCLOSURE AND MOUNTED WITHIN 10 M(30 FT) OF FIRST HEATER SERVED AS SHOWN..
3. PROVIDE FUSE OF AMPERE RATING AS SPECIFIED BY HEATING EQUIPMENT MANUFACTURER
4. REFER TO PLAN DRAWINGS FOR NUMBER OF INDIVIDUAL HEATER UNITS SERVED BY THE SAME 24 VDC POWER SUPPLY.
5. THE SAME B.A.S. OUTPUT MAY CONTROL MULTIPLE HEATER UNITS IN THE SAME ZONE.

GENERAL NOTES

1. THIS DRAWING INDICATES GENERAL WIRING REQUIREMENTS FOR 24 VDC FAN-COIL HEATING UNITS. REFER TO EQUIPMENT MANUFACTURER INSTALLATION INSTRUCTIONS FOR SPECIFIC WIRING REQUIREMENTS.
2. REFER TO DETAIL DRAWINGS 20 05 12-001 AND 20 05 12-002 FOR GENERAL COORDINATION OF WORK UNDER DIVISIONS 20 AND 26.



Sheet Title

FORCED-AIR CONVECTORS
24 VDC & CONTROL WIRING

Date
08 DEC 2022

Rev. No.:
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Checked:
PS

Standard Detail No.

20 05 12 - 007

END OF SECTION

COMMON MOTOR REQUIREMENTS FOR MECHANICAL EQUIPMENT 20 05 13

1 GENERAL

1.1 Scope

- .1 Provide single phase and three-phase low-voltage AC induction motors from fractional horsepower to 200 horsepower, and brushless DC ECM motors.
- .2 This specification section applies to general purpose motors and inverter duty motors, except where otherwise specified by other specification sections of Divisions 20 to 25.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 14.13 Motor Controllers
 - .2 20 05 14.16 Variable- Frequency Drives

1.3 Definitions

- .1 The following definitions apply to this section and referenced sections:
 - .1 **ECM:** electrically commutated motor (AC supply, brushless DC motor).
 - .2 **ODP:** open drip proof (motor enclosure).
 - .3 **Soft-start motor controller:** a solid-state electronic motor controller that regulates output current and voltage during motor starting.
 - .4 **FEFC:** totally enclosed non-ventilated (motor enclosure without motor driven cooling fan).
 - .5 **TEFC:** totally enclosed fan cooled (motor enclosure with motor driven cooling fan).

1.4 Applicable Codes and Standards

- .1 Legislation:
 - .1 [O.Reg. 509/18 Energy and Water Efficiency – Appliances and Products
 - .2 U.S. DOE 10 CFR 431 Code of Federal Regulations Part 431 (to the extent adopted in O.Reg. 509/18)]
- .2 Product standards:
 - .1 CSA C22.2 No. 100 Motors and Generators
 - .2 CSA C390-10 Test Methods, Marking Requirements, and Energy Efficiency Levels for Three-phase Induction Motors
 - .3 CSA C747-09 Energy Efficiency Test Method for Small Motors
 - .4 IEEE 85-1973 Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery
 - .5 IEEE 112-2004 Standard Test Procedure for Polyphase Induction Motors and Generators
 - .6 IEEE 114-2010 Standard Test Procedure for Single-Phase Induction Motors
 - .7 NEMA MG1-2016 Motors and Generators

1.5 Submittals

- .1 Submit manufacturer data sheets with the following information for motors 50 HP and smaller:
 - .1 motor model/catalogue numbers,
 - .2 motor full load ratings: current, speed, voltage, horsepower, efficiency, and KVAR.
- .2 Submit manufacturer data sheets with the following information for motors greater than 50 HP:
 - .1 associated driven equipment identification tag,
 - .2 motor model/catalogue numbers,
 - .3 motor full load ratings: current, speed, voltage, horsepower, efficiency, and KVAR,
 - .4 bearing data,
 - .5 acceleration time at maximum inertia,
 - .6 guaranteed efficiency and power factor at full load, 75% load, 50% load, and 25% load,
 - .7 dBA scale sound power levels.
- .3 For inverter duty motors 5 HP and larger, submit manufacturer data sheets or similar documentation for the following information:
 - .1 confirmation of compliance to NEMA MG-1 for inverter duty,
 - .2 protection method for grounding of stray motor currents,
 - .3 motor frequency operating range (minimum to maximum),
 - .4 insulation winding class,
 - .5 details of motor bearing construction.

1.6 Shipping and Storage

- .1 Ship motors from factory;
 - .1 packed in impact-absorbing material, or fastened to hardwood skid or pallet for fork truck handling. Do not use Styrofoam or similar plastic-based materials,
 - .2 protected against dirt and moisture during transit and outdoor storage,
 - .3 clearly identified with permanent ink marking on packing,
- .2 Protect motors attached to equipment against dirt and moisture during transit and outdoor storage.

1.7 Operating and Maintenance Manuals

- .1 Include in the operating and maintenance manuals the following data for all motors supplied to the project:
 - .1 shop drawing data as specified herein,
 - .2 motor weight,
 - .3 sliding base dimensioned drawings,
 - .4 internal winding connection diagram,
 - .5 speed torque performance data for across line start, from stand-still to synchronous speed,
 - .6 installation and maintenance instructions.

2 PRODUCTS

2.1 Motors - General Requirements

- .1 Listed to CSA C22.2 No.100.
- .2 Listed to CSA C390 for NEMA MG-1 Premium efficiency ratings (three phase, 1 – 200 HP)
- .3 Motors selected and marked with a power rating that is the greater of:
 - .1 not less than the input brake horsepower of driven equipment at both the specified operating condition and at maximum run-out conditions at design driven equipment operating speed, without operation in the motor service factor, and
 - .2 not less than the minimum horsepower rating as shown.
- .4 Common motor characteristics:
 - .1 frequency: [60][50] Hz.
 - .2 voltage:
 - (a) 115 and 220 volt, for single phase motors as shown,
 - (b) [575 and 208][460 or 208] volt, for three phase motors, as shown.
 - .3 nominal rated-load speed: 1750 RPM unless otherwise shown,
 - .4 minimum ambient operating temperature at nameplate power rating: 40°C (104°F),
 - .5 vibration velocity: not to exceed 2.0 mm/s (0.08 inches/second) measured at bearing housing,
 - .6 motor generated noise, 10 HP and larger: not to exceed 85 dBA, measured at 3 m (10 ft) in accordance with IEEE 85.
- .5 Permanently lubricated ball bearing rotor supports.
- .6 Motor enclosure:
 - .1 cast iron, aluminum, or rolled steel construction,
 - .2 drain openings,
 - .3 shouldered lifting eye bolts (three phase TEFC motors),
 - .4 bi-directional, spark-proof, abrasion and corrosive resistant cooling fan keyed to shaft (three phase TEFC motors),
 - .5 compression type grounding lug or double ended cap screw of silicon bronze, mounted in conduit box by drilling and tapping into motor frame.
- .7 Motor nameplate:
 - .1 stainless steel plate mounted on enclosure with stainless steel fastening pins,
 - .2 information as described in NEMA MG-1 including motor efficiency rating,
 - .3 motor bearing part numbers and motor wiring diagram instructions,
- .8 Protective coating, TEFC motors:
 - .1 primer and 4 to 5 mils epoxy overcoat on external surfaces, and corrosion resistant coating of epoxy paint on internal surfaces, shaft, rotor, stator iron, and end bells,
 - .2 shaft extension protected with rust preventive strippable coating capable of being peeled off or unwrapped.
- .9 Motor termination junction boxes and motor leads:
 - .1 cast iron or sheet steel diagonally split, tapped for conduit, and attached to motor frame with cadmium plated hex head cap screws,

- .2 arranged for conduit entry from either side or bottom,
- .3 gaskets between box and motor frame and between halves of box, with cover secured with cadmium plated hex head cap screws,
- .4 motor leads in conduit box;
 - (a) identified in accordance with ANSI C6.1,
 - (b) with the same insulation class as windings,
 - (c) sized in accordance with EASA recommended minimum ampacity values,
- .5 motor leads between motor frame and termination box to pass through tight fitting neoprene rubber seals.

2.2 Motor Efficiency

- .1 Motor efficiency test method:
 - .1 CSA C747 or IEEE 114 for single phase ECM and AC motors,
 - .2 CSA C747 or IEEE 112 for polyphaser motors up to 3 HP, and.
 - .3 CSA C390 or IEEE 112 for three-phase motors 1 to 200 HP.
- .2 Motor efficiency ratings:
 - .1 Minimum motor efficiency to be not less than the greater of the following:
 - (a) applicable legislation for energy efficiency,
 - (b) NEMA Premium® for three-phase integral horsepower motors, and
 - (c) as specified in the Schedules appended at the end of this specification section.
- .3 These motor efficiency ratings do not apply to electric motor-driven fire pumps.

2.3 Single Phase Motors

- .1 Single phase motor rating less than 375 W (1/2 hp):
- .2 Types:
 - .1 PSC motor:
 - (a) permanent split capacitor type for AC power supply,
 - (b) suitable for variable speed applications.
- .3 ECM motor:
 - .1 brushless DC electrically commutated motor with integral microprocessor based inverter and controller, for AC power supply,
 - .2 factory programmed or field programmable for specific application,
 - .3 capable of accepting an external 0-20 mA or 0-10 V signal for remote variable speed operation including fan On/Off control.
- .4 Winding insulation: Class B.
- .5 Suitable for mounting in the horizontal or vertical orientation.
- .6 Continuous duty rating with 1.35 service factor.
- .7 ODP or TEFC enclosure, resilient mounts.
- .8 Built-in overload protection.
- .9 Motor over-temperature protection as specified herein.

2.4 Three Phase Motors, Fractional Horsepower

- .1 Motors of 375 W (½ HP) and 560 W (¾ HP).
- .2 For use with magnetic motor controllers.
- .3 Three phase squirrel cage induction type, NEMA T frame, general purpose type, to NEMA MG-1.
- .4 NEMA B design.
- .5 Winding insulation: Class F, with a rated motor winding temperature rise of not more than 90°C above an ambient temperature of 40°C at full motor load,
- .6 Continuous duty rating with minimum 1.15 service factor.
- .7 ODP or TENV enclosure.
- .8 Motor over-temperature protection as specified herein.

2.5 Three Phase Motors, Integral Horsepower

- .1 Motors 745 W (1 hp) to 150 kW (200 hp).
- .2 For use with constant speed magnetic motor controllers.
- .3 Three phase squirrel cage induction type, NEMA T frame, general purpose type.
- .4 NEMA design:
 - .1 Type B for centrifugal fans and pumps,
 - .2 Type C for positive displacement pumps and compressors.
- .5 Winding insulation: Class F, with a rated motor winding temperature rise of not more than 90°C above an ambient temperature of 40°C at full motor load,
- .6 Continuous duty rating with minimum 1.15 service factor.
- .7 TEFC enclosure.
- .8 Suitable for horizontal, vertical or belt-driven mounting.
- .9 Motor over-temperature protection as specified herein.
- .10 Motor winding leads:
 - .1 three (3) leads for single speed operation,
 - .2 six (6) leads for two-speed operation (five lead two-speed motors are not acceptable).

2.6 Three Phase Motors – Inverter Duty

- .1 Application: motors 745 W (1 hp) to 150 kW (200 hp) operating on power supply controlled by a variable frequency drive (inverter) motor controllers and soft-start constant speed motor controllers.
- .2 General requirements:
 - .1 three phase squirrel cage induction type, NEMA T frame, general purpose type, suitable for pulse width modulated wave form,
 - .2 winding insulation: Class F insulation, with a rated motor winding temperature rise of not more than 90°C above an ambient temperature of 40°C at full motor load (i.e. Class B temperature rise),
 - .3 continuous duty rating and rated for 200% of full load starting torque,
 - .4 service factor: 1.15 on Sine Wave and 1.0 on pulse-width modulated power supply,
 - .5 TEFC enclosure,
 - .6 suitable for horizontal, vertical or belt-driven mounting,

- .7 motor over-temperature protection as specified herein,
- .8 motor winding leads: three (3) leads,
- .9 motor over-temperature protection as specified herein except where the protection function is provided by the variable frequency drive.
- .3 Special requirements:
 - .1 motors rated for inverter duty in accordance with NEMA MG-1 Part 31,
 - (a) stator winding insulation ratings:
 - i) peak voltage and partial discharge-free voltages:

Rated Voltage V RMS	Withstand Voltage Zero-to-Peak (Line-to-Line) V	Partial Discharge-Free Zero-to-Peak (Line-to-Line) V
208, 3 phase	645	513
575, 3 phase	1782	1281

- ii) for operation on a VFD with a carrier frequency of between 2 and 12 kHz.
 - iii) with a VFD switching voltage rise time of 0.1 μ s and higher.
- .2 speed range: minimum 10:1 (6 to 60 Hz) for variable torque applications,
- .3 provided with stray rotor current grounding system consisting of;
 - (a) 3 HP and smaller: electrically conductive bearing grease for motors,
 - (b) all HP ratings: rotor shaft grounding system at the drive-end bearing, either integral to the bearing construction or externally mounted to the motor frame.

Standard of Acceptance

- ° AEGIS - fig. SGR series
- .4 for motors 100 HP and larger, provide insulated bearings on the non-drive end.
- .5 motor to be compatible with type of soft-start motor controller or variable frequency drive supplied under other specification sections, and that the starter/motor system will be capable of providing rated torque over a frequency range from 15 to 60 hz while operating within motor temperature rise specification,
- .6 motor to be capable of operating between 60 Hz and 90 Hz with torque reducing at drive frequency above 60 Hz,
- .7 ball bearing rotor supports suitable for continuous low speed operation at minimum motor speed.
- .8 drive end face drilled and tapped (4 places) for mounting of auxiliary devices.
- .4 Motor stator winding:
 - .1 made up with copper magnet wire coated with moisture resistant triple-build Class F insulation, non-hygroscopic varnish, phase paper insulation, and with thermal rating of not less than 150°C for 30,000 hours life when tested in accordance with IEEE No. 57,
 - .2 insulation resistance greater than 100 megohms when measured at 25°C with 1000-volt direct current mega-ohm bridge,
 - .3 slot-wound installation, held in stator slots that have had sharp edges and burs removed prior to winding insertion,

- .4 connection leads mechanically secured and silver soldered,
- .5 designed for operation in either direction of rotation.
- .5 Motor bearings:
 - .1 anti-friction single shield, vacuum-degassed steel ball bearings,
 - .2 lubricated bearings; extended pipe zerk fitting, and ½-lb relief fitting for external lubrication while machine is in operation, bearing seal, lubricated at factory after assembly,
 - .3 bearing shield on motor winding side of bearing,
 - .4 rated fatigue life of L'-10 (B-10) 150,000 hours for direct coupled applications and 50,000 hours for belted applications,
 - .5 belt drive-set rating based on radial loads and pulley sizes from NEMA MG1-14.43.
- .6 Motor junction box sized and provided with at least two (2) conduit connection points, one for motor feeder cable and one for motor thermal sensor control wiring.

2.7 Motor Over-Temperature Protection

- .1 Motor thermal protection for single phase motors mounted in air ducts, plenum chambers or in air stream inside air handling equipment:
 - .1 motor winding thermostats, normally closed contact, phenolic snap-acting disc thermal switch, temperature calibrated,
 - .2 automatic reset type.

Standard of Acceptance

- Texas Instruments - Klixon Phenolic Motor Protectors

- .2 Motor thermal protection for three phase motors less than 37 kW (50 HP) that are mounted in air ducts, plenum chambers or in air stream inside air handling equipment:
 - .1 Winding sensors;
 - (a) three (3) Positive Temperature Coefficient (PTC) temperature sensors, one in each motor winding, wired in series, and compatible with Texas Instruments - Klixon model 42AA100E control unit,
 - (b) control unit provided under section 20 05 14.13 or 20 05 14.16.
- .3 Motor thermal protection for three phase motors 37 kW (50 HP) and larger:
 - .1 Winding sensors;
 - (a) three (3) Positive Temperature Coefficient (PTC) temperature sensors, one in each motor winding, wired in series, and compatible with Siemens model 3RN10 12 control unit,
 - (b) control unit provided under section 20 05 14.13 or 20 05 14.16.

2.8 Field Applied Rotor Grounding System for Operation with Variable Frequency Drives

- .1 Shaft-grounding ring system with contact brushes providing 360 degree coverage of drive shaft, to provide grounding of rotor to motor frame.

Standard of Acceptance

- AEGIS - fig. SGR series

2.9 Sliding Base for Motors with V-belt Drives

- .1 Construction:
 - .1 fabricated from steel as a single unit with double supported slide and two adjusting bolts,
 - .2 finished with coating as specified above for motor exterior.

3 EXECUTION

3.1 Application

- .1 Refer to other specification sections for motor style requirements for single phase motors and fractional horsepower polyphase phase motors (ODP, TENV or TEFC).
- .2 Where motors are provided with internal thermistors for motor overtemperature protection, run thermistor control wiring:
 - .1 in the same conduit as the motor power conductors for constant speed motor controllers,
 - .2 in a separate conduit from the motor power conductors for variable frequency drive motor controllers.

3.2 Field Applied Rotor Grounding System

- .1 Install shaft-grounding system on motors operating on variable speed drives and not provided with OEM rotor grounding systems.

3.3 Maintenance During Construction

- .1 Rotate motors by hand at one month intervals while at the project site.

3.4 Schedules

- .1 The following schedules of motor minimum electrical efficiency ratings apply:
 - .1 Schedule A – Single Phase Electric Motor Efficiency, 0.25 to 0.5 HP,
 - .2 Schedule B – Two-phase Electric Motor Efficiency 0.25 to 3 HP, and Three-phase Electric motor Efficiency 0.25 to 0.75 HP,
 - .3 Schedule C – Three Phase Electric Motor Efficiency, 1 to 200 HP.

Schedule A - Single Phase Electric Motor Efficiency, 0.25 to 0.5 HP

Motor HP (kW)	Single Phase, Permanent-Split Capacitor 0.25 to 0.5 HP Nominal Full-Load Efficiency (%) [Note 1]		
	Open Motors		
	6 Pole 1200 RPM	4 Pole 1800 RPM	2 Pole 3600 RPM
0.25 (0.18)	62.2	68.5	66.6
0.33 (0.25)	66.6	72.4	70.5
0.5 (0.37)	76.2	76.2	72.4

Notes:

[1] From U.S. DOE 10 CFR Part 431, SubPart X, §431.446(a)

Schedule B – Polyphase Electric Motor Efficiency, 0.25 to 3 HP

Motor HP (kW)	Polyphase Induction Motors 0.25 to 3 HP Nominal Full-Load Efficiency (%) [Note 2]			Remarks
	Open Motors			
	6 Pole	4 Pole	2 Pole	
0.25 (0.18)	67.5	69.5	65.6	2 Phase & 3 Phase
0.33 (0.25)	71.4	73.4	69.5	2 Phase & 3 Phase
0.5 (0.37)	75.3	78.2	73.4	2 Phase & 3 Phase
0.75 (0.55)	81.7	81.1	76.8	2 Phase & 3 Phase
1 (0.75)	82.5	83.5	77.0	2 Phase only
1.5 (1.1)	83.8	86.5	84.0	2 Phase only
2 (1.5)	---	86.5	85.5	2 Phase only
3(2.2)	---	86.9	85.5	2 Phase only

Notes:

[2] From U.S. DOE 10 CFR Part 431, SubPart X, §431.446(a)

Schedule C – Three-Phase Electric Motor Efficiency, NEMA Premium, 1 to 200 HP

Motor HP (kW)	Three-Phase Induction Motors 1 to 200 HP Nominal Full-Load NEMA Premium Efficiency (%) [Note 3]							
	2 Pole 3600 RPM		4 Pole 1800 RPM		6 Pole 1200 RPM		8 Pole 900 RPM	
	Encl.	Open	Encl.	Open	Encl.	Open	Encl.	Open
1 (0.75)	77.0	77.0	85.5	85.5	82.5	82.5	75.5	75.5
1.5 (1.1)	84.0	84.0	86.5	86.5	87.5	86.5	78.5	77.0
2 (1.5)	85.5	85.5	86.5	86.5	88.5	87.5	84.0	86.5
3 (2.2)	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5
5 (3.7)	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5
7.5 (5.5)	89.5	88.5	91.7	91.0	91.0	90.2	86.5	89.5
10 (7.5)	90.2	89.5	91.7	91.7	91.0	91.7	89.5	90.2
15 (11)	91.0	90.2	92.4	93.0	91.7	91.7	89.5	90.2
20 (15)	91.0	91.0	93.0	93.0	91.7	92.4	90.2	91.0
25 (18.5)	91.7	91.7	93.6	93.6	93.0	93.0	90.2	91.0
30 (22)	91.7	91.7	93.6	94.1	93.0	93.6	91.7	91.7
40 (30)	92.4	92.4	94.1	94.1	94.1	94.1	91.7	91.7
50 (37)	93.0	93.0	94.5	94.5	94.1	94.1	92.4	92.4
60 (45)	93.6	93.6	95.0	95.0	94.5	94.5	92.4	93.0
75 (55)	93.6	93.6	95.4	95.0	94.5	94.5	93.6	94.1
100 (75)	94.1	93.6	95.4	95.4	95.0	95.0	93.6	94.1
125 (90)	95.0	94.1	95.4	95.4	95.0	95.0	94.1	94.1
150 (110)	95.0	94.1	95.8	95.8	95.8	95.4	94.1	94.1
200 (150)	95.4	95.0	96.2	95.8	95.8	95.4	94.5	94.1

Notes:

[3] From U.S. DOE 10 CFR Part 431, SubPart B, §431.25(h), Table 5, and NEMA MG-1 Table 12-12.

END OF SECTION

VARIABLE FREQUENCY DRIVE MOTOR CONTROLLERS

20 05 14.16

1 GENERAL

1.1 Scope

- .1 Provide variable frequency drive ("VFD") motor controllers, harmonic filtration equipment, and load-side power conditioning equipment, for electric motor-driven equipment provided under mechanical trades work.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections;
 - .1 20 05 12 Wiring Requirements for Mechanical Services
 - .2 20 05 49 Seismic Restraint

1.3 Definitions and Abbreviations

- .1 The following definitions apply to this section.
 - .1 **Harmonic filter**: an electronic device which reduces the current harmonic distortion created by the VFD.
 - .2 **SCCR**: the RMS symmetrical short-circuit current rating of the VFD, measured at the load-side terminals of the VFD (short-circuit withstand rating has the same meaning).
 - .3 **THID**: current total harmonic distortion.
- .2 For other definitions, conform to definitions in specification section 20 05 12.

1.4 Applicable Codes and Standards

- .1 Product standards:
 - .1 CSA C22.2 No. 5 Molded-case Circuit Breakers, Molded-case switches and Circuit-breaker Enclosures
 - .2 CSA C22.2 No. 14 Industrial Control Equipment
 - .3 CSA C22.2 No. 39 Fuseholder Assemblies
 - .4 CSA C22.2 No. 94.2 Enclosures for Electrical Equipment, Environmental Considerations
 - .5 CSA C22.2 No. 106 HRC – Miscellaneous Fuses
 - .6 CSA C22.2 No. 274 Adjustable Speed Drives
 - .7 ICC ES ACC-156 Acceptance Criteria for Seismic Certification by Shake-Table Testing of Nonstructural Components
 - .8 IEC 61800-3 Adjustable Speed Electrical Power Drive Systems – Part 3: EMC Requirements and Specific Test Methods

1.5 Seismic Qualification

- .1 Seismically qualify (certify) specified herein to remain operational after being subjected to the design seismic forces assuming a building height factor (NBCC) $A_x = 3.0$ with equipment rigidly mounted, by the shaker table method in accordance with Specification section 20 05 49.

1.6 Submittals

- .1 Submit shop drawing material in accordance with the requirements of Division 01.

- .2 Submit shop drawings for VFD motor controller and include the following minimum information:
 - .1 outline dimensions, conduit entry locations and weight,
 - .2 power efficiency rating,
 - .3 input THID,
 - .4 device SCCR value that will be marked on each drive unit,
 - .5 protection method used to meet the required short-circuit current rating,
 - .6 the interrupting rating of the required integral or external overcurrent protection device,
 - .7 included AC line reactor capacity to suit the available short-circuit (fault) current (ASCC),
 - .8 control and power wiring diagrams,
 - .9 complete technical product description including a list of options provided,
 - .10 termination diagrams for electrical contacts, relays, thermostats, timers and components in control circuits shown.
- .3 Include SCCR data for each size of VFD supplied to the project, including:
 - .1 VFD model reference and HP rating,
 - .2 site-specific available short-circuit current value (ASCC) as specified herein,
 - .3 disconnecting means by type,
 - .4 overcurrent protection device by type,
 - .5 overcurrent protection rating, SCCR kA RMS symmetrical (at the input side of the drive),
 - .6 AC line reactor, size to suit the site-specific ASCC.
- .4 Where an external disconnecting means with overcurrent protection equipment is being supplied (due to the VFD not being available with such integral devices), submit shop drawings of the overcurrent protection equipment with confirmation from the VFD manufacturer that it meets their protection requirements.
- .5 Submit shop drawings for harmonic filters and include:
 - .1 certified factory test results for harmonic mitigation performance and energy efficiency under actual VFD drive loading, including product serial numbers.

1.7 Product Support

- .1 Manufacturer to have factory trained application engineering and service personnel locally available at the installation locations and/or available through a toll free 24/365 technical support line.

1.8 Warranty

- .1 Provide an extended warranty covering parts, labour, travel time and expenses, for VFDs for a period of not less than twenty-four (24) months from the date when the equipment is handed over to the Owner.

2 PRODUCTS

2.1 General – Short Circuit Current Rating

- .1 Short circuit protection rating (SCCR) for VFD motor controllers:
 - .1 packaged VFD minimum SCCR value: 25kAIC RMS symmetrical .
 - .2 SCCR rating may be met by;
 - (a) design and testing of VFD package and provided with internal overcurrent protection device,
 - or

- (b) field-installed external overcurrent protection device field-installed on the line side of drive.
- .3 SCCR value to be marked on the VFD nameplate. Where the SCCR nameplate rating references an instruction manual, provide a separate label on the VFD that states the SCCR value.
- .4 Where the VFD requires field-installed external overcurrent protection to meet the required SCCR rating, the drive manufacturer is responsible to provide information to the installation contractor for the required circuit breaker or fuse type and rating that they require to be included in the external protection device.

2.2 Variable Frequency Drives (VFD) – General Requirements

- .1 Type:
 - .1 electronic pulse-width-modulating type for speed control of NEMA Design B inverter-duty induction motors, using constant voltage/frequency control,
 - .2 designed for control of HVAC fans and pumps, with internal PID control loops,
 - .3 six-pulse drive:
 - (a) input stage AC-DC rectifier: diode or IGBT power switches,
 - (b) DC bus link capacitors,
 - (c) output stage DC-AC inverter: IGBT power switches.
 - .4 motor-horsepower rated,
 - .5 designed for installation on high-resistance grounded systems or un-grounded systems,
 - .6 listed to CSA C22.2 No. 274 and conform to CSA C22.2 No. 14.
- .2 VFDs to include the following equipment either as an integral part of the drive, or as a separate field-installed device:
 - .1 main power disconnecting means with overcurrent protection to meet the SCCR rating,
 - .2 input harmonic filtration where specified based on motor HP rating,
 - .3 output load voltage spike suppression and reflected wave reduction devices where specified based on motor feeder length,
- .3 Principle operating features:
 - .1 operating speed range: minimum 10:1, except where specified in other specification sections for mechanical trades work.
 - .2 ability to automatically restart after an over-current, over-voltage, under-voltage, or loss of input signal protective trip.
- .4 Operating voltage:
 - .1 +10%, -10% of nominal supply voltage range to drive,
 - .2 input frequency: 60 Hz,
 - .3 protection circuitry to lock-in drive or bypass over this voltage tolerance.
- .5 Output voltage frequency range: 0 – 320 Hz.
- .6 Output switching frequency:
 - .1 2 kHz to 12 kHz, adjustable/selectable,
 - .2 automatic switching frequency de-rating in case of overheating.
- .7 VFD efficiency:
 - .1 output current not less than 97% of input current at 100% full load.
- .8 Power factor:

- .1 not less than 0.98 lagging in operating range from 75% to 100% full load.
- .9 Drive overload rating:
 - .1 110% of normal duty current rating for 1 minute every 10 minutes,
 - .2 130% of normal duty current for 2 seconds.
- .10 Environmental operating conditions without derating:
 - .1 temperature: -10 to +50°C (14 to 122°F) continuous,
 - .2 altitude: 0 - 1000 m (0 - 3300 ft) above sea level,
 - .3 humidity: 5 to 95% relative humidity non-condensing.
- .11 Seismic rating:
 - .1 designed to withstand the seismic loads in accordance with specification section 20 05 49,
 - .2 product-type seismically rated for structural and functional integrity based upon shake table test to ICC ES ACC-156.
- .12 Supply VFDs from one manufacturer.

Standard of Acceptance

- ABB - fig. ACH580
- Danfoss - fig. VLT
- Eaton - fig. H-Max
- Benshaw - fig. H2
- Siemens - fig. BT300
- Yaskawa - fig. H600
- Schneider Electric - fig. Altivar 212W, 61W

2.3 VFD - Enclosure and Electrical Protection

- .1 Electrical enclosure:
 - .1 enclosures to be of the following types in accordance CSA C22.2 No. 94.1/UL50:
 - (a) indoor installations: Type [1 or 12] [3, 3R, 4 or 12]
 - (b) outdoor installation: Type 3, 3R or 4.
 - .2 alternative enclosure for indoor installation in sprinklered buildings:
 - (a) Type 1, 2 or 12 enclosure with gasketed door,
 - (b) top of the unit provided with a sprinkler-shield to protect against entry of water from a fire-protection sprinkler head,
 - (c) ventilation openings provided with a sprinkler-shield or louvres to prevent entry of water from a fire-protection sprinkler head, with a water entry angle of 20 degrees and larger measured down from the horizontal, and
 - (d) top-entry conduit or cable entries are fitted with rain-tight glands.
- .2 Cooling fans:
 - .1 designed to maintain operating function of VFD at maximum environmental temperature and humidity conditions,
 - .2 designed for easy replacement, and without requiring dismounting the VFD or removal of circuit boards,
 - .3 operate under temperature control.
- .3 Service disconnect switch:

- .1 disconnect switch with overcurrent protection device,
- .2 interlocked to disconnect all input power to the VFD, and lockable in the open position,
- .3 door mounted or enclosure-flange mounted operating handle,
- .4 Overcurrent protection device:
 - .1 motor circuit protectors (breaker): magnetic-only instantaneous trip, adjustable setting, to CSA C22.2 No. 5, with minimum interrupting capacity not less than the required SCCR value or provided with supplemental fuses to achieve the SCCR rating,
- .5 Equipment and motor protection:
 - .1 under- and over-voltage protection, phase loss protection and phase unbalance protection,
 - .2 current limiting device adjustable from 70% to 100% of rated motor current,
 - .3 suitable for operation on a high-resistance grounding system of not less than 5 A ground fault current,
 - .4 motor and motor cable short-circuit protection for line-to-line and line-to-ground faults,
 - .5 instantaneous electronic overcurrent-protection,
 - .6 motor overtemperature protection (calculated, or measured where otherwise specified),
 - .7 motor overload protection,
 - .8 phase-loss detection (both line and load side),
 - .9 underload supervision (belt loss detection),
 - .10 overload supervision,
 - .11 loss of control signal input reference,
 - .12 motor stall protection.
- .6 AC Mains surge protection device:
 - .1 transient surge protection consisting of 4 MOVs (phase-to-phase and phase-to-ground), or
 - .2 transient voltage surge suppressor/surge protection device (TVCSS/SPD).
- .7 Panel heater:
 - .1 internal panel heater for Type 3R enclosures, with integral circulating fan,
 - .2 heater capacity: as required to maintain panel interior temperature at manufacturer minimum temperature requirements, with an outdoor ambient temperature of [-10°C (+14°F)] [-25°C (-13°F)] [[-30°C (-22°F)] when in service.
 - .3 integral heater and fan controller, with temperature sensor,
 - (a) operates at same voltage as VFD,

2.4 VFD - Control Inputs/Outputs

- .1 Internal 24 VDC power supply for process transducer inputs.
- .2 Analog inputs;
 - .1 two (2) configurable inputs for current or voltage signals, 0-10 V or 0-20 mA;
 - (a) frequency/speed setpoint value command,
 - (b) actual feedback input.
- .3 Analog output:
 - .1 two (2) configurable outputs for 0-20mA and/or 0-10VDC;
 - (a) current actual value,

(b) voltage actual value

.4 Digital inputs:

- .1 six (6) inputs, 12 to 24 VDC, 10 to 24 VAC,
- .2 Stop/Start command,
- .3 constant frequency/speed selection bypass command,
- .4 start permissive interlock,
- .5 3 other programmable inputs.

.5 Digital outputs:

- .1 four (4) programmable Form-C relay outputs, 250 VAC/30 VDC, 2A RMS continuous;
 - (a) auxiliary output control (e.g., damper or valve command),
 - (b) motor run status,
 - (c) drive fault status,
 - (d) passive harmonic filter capacitor contactor control.

2.5 VFD - Programming and Functions

.1 General:

- .1 built-in time clock in the VFD keypad with battery backup of 10 years minimum life span,
- .2 time clock date-and-time stamp for faults and records operating parameters at the time of fault. On battery failure, the VFD automatically reverts to hours of operation since initial power up,
- .3 time clock programmable to control start/stop functions, constant speeds, PID parameter sets and output Form-C relays,
- .4 self-tuning function to automatically match VFD to the motor impedance,
- .5 motor flux optimization circuit to automatically reduce applied motor voltage to the motor to optimize energy consumption and reduce audible motor noise;
 - (a) selectable software for optimization of motor noise, energy consumption, and motor speed control.
- .6 programmable number of restart attempts, trial time, and time between attempts.
- .7 utilize pre-programmed application macros specifically designed to facilitate start-up,
- .8 application macros provide one command to reprogram all parameters and customer interfaces for a particular application to reduce programming time, and
- .9 two (2) user macros to allow the end-user to create and save custom settings.
- .10 password protection against parameter changes.

.2 General control functions:

- .1 three (3) programmable critical frequency lockout ranges to prevent VFD from operating the load continuously at an unstable speed, fully adjustable, from 0 to full speed.
- .2 two (2) PID Set point controllers allowing pressure or flow signals to be connected directly to the VFD;
 - (a) microprocessor for the closed-loop control,
 - (b) 250 ma of 24 VDC auxiliary power and be capable of loop powering a transmitter supplied by others,
 - (c) PID set-point adjustment from the VFD keypad, or via the communications bus,

- (d) two (2) independent parameter sets for the PID controller and the capability to switch between the parameter sets via a discrete input, serial communications or from the keypad.
- .3 the independent second PID loop able to utilize the second analog input and modulate one of the analog outputs to maintain the set point of an independent process (i.e., valves, dampers, etc.),
- .4 all set points, process variables, etc. to be accessible from the serial communication network,
- .5 programmable "Sleep" and "Wake up" functions to allow the drive to be started and stopped from the level of a process feedback signal,
- .6 "bumpless transfer" of speed reference and output when switching between "Hand" and "Auto" modes – speed changes by controlled ramp rate,
- .7 programmable loss-of-load (broken belt / broken coupling) with programmable time delay for motor start-up, via the serial communications bus,
- .8 programmable underload and overload curve functions to allow user defined indications of broken belt or mechanical failure / jam condition causing motor overload,
- .9 loss of input reference (4-20mA or 2-10V): User option of either (1) stopping and displaying a fault, (2) running at a programmable preset speed, (3) hold the VFD speed based on the last good reference received, or (4) cause a warning to be issued as selected by the user, with alarm output via the serial communication bus,
- .3 Programmable time-delay functions:
 - .1 VFD start delay and a keypad indication that this time delay is active,
 - .2 four (4) separate, independent timer functions that have both weekday and weekend settings,
 - .3 output relay provides a contact closure to signal a valve/terminal boxes to open prior to the motor starting,
 - .4 field programmable from 0 - 120 seconds,
 - .5 start-delay active regardless of the start command source (keypad command, input contact closure, time-clock control, or serial communications), and when switching from drive to bypass (where bypass is specified).
- .4 Speed control functions:
 - .1 minimum five (5) programmable preset speeds,
 - .2 two (2) independently adjustable acceleration and deceleration ramps with 1 - 1800 seconds adjustable time ramps.
 - .3 minimum speed setting adjustable from 0 to 70%,
 - .4 maximum speed setting adjustable from 50 to 150%,
- .5 Upset condition recovery functions:
 - .1 flying start into a rotating load, to match output drive frequency to motor frequency before taking load,
 - .2 control-board kinetic energization protection: control deceleration of motor to use motor-load inertia to keep drive controller energized as long as possible during loss of mains AC failure,
 - .3 carrier frequency control circuit to reduce the carrier frequency based on actual VFD temperature that allows higher carrier frequency settings without derating the VFD.
- .6 Passive harmonic filter low-load function:
 - .1 digital output relay opens capacitor-bank contactor in passive harmonic filters when motor control speed is $\leq 70\%$ of rated motor speed, and when the VFD is Off.
 - .2 adjustable control setpoint.
- .7 Fireman's override control function (constant frequency/speed selection bypass command):

- .1 on receipt of a contact closure from the Fire Alarm System or Building Automation System, the VFD operates in one of two selectable modes:
 - (a) operate at a programmed predetermined fixed speed ranging from -500Hz (reverse) to 500Hz (forward), or
 - (b) operate in a specific fireman's override PID algorithm that automatically adjusts motor speed based on override set point and feedback; setpoint adjusted over the serial communications bus.
- .2 operating mode overrides all other inputs (analog/digital, serial communication, and all keypad commands), except safety run interlocks, and force the motor to run in one of the two modes.
- .3 "Override Mode" displayed on the keypad.
- .4 upon removal of the override signal, the VFD resumes normal operation, without the need to cycle the normal discrete input run command.

2.6 VFD - Operator Interface

- .1 Digital display panel:
 - .1 removable back-lit LCD display operator interface unit, with navigation keys and minimum of two (2) soft keys to operation and programming,
 - .2 Bluetooth or WiFi accessibility, with free down-loadable app which replicates control panel functions on a mobile device or tablet,
 - .3 Hand-Off-Auto section and manual speed control without having to navigate to a parameter,
 - .4 Fault reset and Help keys,
 - .5 Digital display with keypad, including quick-access for "Hand-Off-Auto" selection, fault reset, and "Help" functions,
- .2 Loss-of-load alarm,
- .3 Display unit:
 - .1 LCD display, text or graphic display,
 - .2 user selectable language: English or French.
 - .3 complete descriptive words for programming and fault diagnostics,
 - .4 faults displayed in complete descriptive words.
- .4 "Help" button access to on-line assistance for programming and troubleshooting, including a minimum of 14 programming assistants:
 - .1 start-up
 - .2 parameter
 - .3 PID
 - .4 reference
 - .5 I/O
 - .6 serial communications
 - .7 option module
 - .8 panel display
 - .9 low noise set-up
 - .10 maintenance
 - .11 troubleshooting

- .12 drive optimizer
- .5 Operating values displayed in engineering units, including the following:
 - .1 output frequency,
 - .2 motor speed (RPM, %, or Engineering units),
 - .3 motor current,
 - .4 motor torque,
 - .5 motor power (kW),
 - .6 DC bus voltage,
 - .7 output voltage.

2.7 VFD - Building Automation System ("BAS") Integration

- .1 Two communication ports: EIA-485 and RJ45,
- .2 BAS network interface: BACnet MS/TP, Modbus RTU [[and BACnet/IP]
- .3 BACnet device protocols certified by BTL listing to ASHRAE Standard 135 BACnet as an Application Specific Controller,
- .4 If additional hardware is required to obtain the BACnet interface, the VFD manufacturer to provide one BACnet gateway per drive; multiple VFDs sharing one gateway is not acceptable.
- .5 BAS digital communication functions include:
 - .1 write command:
 - (a) run-stop control,
 - (b) speed set adjustment,
 - (c) proportional/integral/derivative PID control adjustments,
 - (d) current limit,
 - (e) accel/decel time adjustments,
 - (f) remote VFD fault reset,
 - (g) lock and unlock the keypad.
 - .2 read command:
 - (a) monitor current values including process variable feedback, output speed / frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), and drive temperature.
 - (b) monitor the VFD relay output status, discrete input status, and all analog input and analog output values.
 - (c) Monitor all diagnostic warning and fault information,
- .6 BAS may force digital and analog outputs via the serial interface; this control is independent of any VFD function except the local Emergency Shut-Down function.

2.8 VFD - Input RFI Filters

- .1 VFD integral RFI/EMC filter, Category C2 to IEC/EN 61800-3.

2.9 VFD – Internal Harmonic Filters

- .1 VFD internal harmonic filters:
 - .1 dual (positive and negative) DC bus chokes equivalent to 5% impedance,
 - .2 and 3% impedance AC line reactor where required as specified in Part 3 – EXECUTION.

2.10 Line Reactor Harmonic Filter

- .1 3% impedance AC line reactor, copper windings on iron core, for installation inside of VFD enclosure or as a separate device.
- .2 Enclosure: to CSA C22.2 No. 94.1/94.2, Type 1 or 3R (for filters not forming part of the VFD).
- .3 Refer to article in Part 3 – EXECUTION for when this harmonic filter type is required based on motor HP rating.

Standard of Acceptance

- MTE - fig. RL Line Reactors

2.11 Passive Harmonic Filters

- .1 General:
 - .1 passive inductor/resistor/capacitor network to treat low frequency harmonics generated by 6-pulse VFD drives, for treatment of at least the 5th, 7th, 11th and 13th harmonic.
 - .2 input voltage: same as associated VFD, 60 Hz, 3 ph., 3 W.
 - .3 listed to CSA C22.2 No. 14 and/or CSA C22.2 No. 107.1, but need not be classified as a motor controller,
 - .4 may be provided as an integral part of the VFD unit where offered by the VFD manufacturer.

Standard of Acceptance

- Mirius - fig. Lineator AUHF
- MTE - fig. Matrix AP
- TCI LLC - fig. HGP
- VFD manufacturer product

- .2 Performance:
 - .1 limit THID to less than 8% total harmonic distortion between 30% and 100% full load. Filter must be capable of operating in voltage distortion up to 8% without derating,
 - .2 have no resonance between harmonic filter with system impedances or attract harmonic currents from other harmonic sources,
 - .3 power factor: 0.98 lagging to 0.95 leading in operating range from 30% to 100% full load,
 - .4 maximum voltage injection at no load: < 3% of nominal line voltage.
 - .5 maximum capacitive reactive power KVAR generated: 20% of kVA rating,
 - .6 full load efficiency: not less than 99% at full load.
 - .7 short circuit capacity rating: 100 kAIC symmetrical.
- .3 Construction:
 - .1 enclosure: to CSA C22.2 No. 94.1/94.2, Type 3R (for filters not forming part of the VFD),
 - .2 copper conductors,
 - .3 wiring insulation class: 220°C (428 F),
 - .4 temperature rise: 130°C (266 F).
 - .5 contactor-control for capacitors:
 - (a) contactors wired in series to the filter capacitors, to disconnect the capacitors and resistors under motor low or no- load conditions based on control signal from the associated VFD,

- (b) contactor coil control power: 120 VAC based on VFD control output relay rating,
- .6 anti-vibration pad mounts between the reactor or transformer core and the enclosure.
- .4 Refer to article in Part 3 – EXECUTION for when this harmonic filter type is required based on motor HP rating.

2.12 Active Harmonic Filter

- .1 General:
 - .1 active inductor/capacitor network to inject non-fundamental counter-current to cancel out current harmonics, synchronizes the current and voltage waveform,
 - .2 designed to control harmonics from one or more VFDs when installed at the common power distribution point,
 - .3 input voltage: same as associated VFD, 60 Hz, 3 ph., 3 W.
 - .4 listed to CSA C22.2 No. 14 and/or CSA C22.2 No. 107.1, but need not be classified as a motor controller.

Standard of Acceptance

- ° TCI LLC - fig. HGA

- .2 Performance:
 - .1 limit THID to less than 5% total harmonic distortion between 30% and 100% full load, for the 2nd through 50th order harmonic current.
 - .2 voltage distortion: filter injected THDV not to exceed 5% at the line side of the filter.
 - .3 responds time:
 - (a) at steady state - not greater than 1 line cycle.
 - (b) at load change – not greater than 3 line cycles.
 - .4 having no resonance between harmonic filter with system impedances or attract harmonic currents from other harmonic sources,
 - .5 power factor: improve reactive current to be between 0.90 and 0.99 lagging over the load operation range,
 - .6 maximum capacitive reactive power KVAR generated: 20% of kVA rating,
 - .7 full load efficiency: not less than 99% at full load.
 - .8 short circuit capacity rating: 100 kAIC symmetrical.
- .3 Construction:
 - .1 enclosure: to CSA C22.2 No. 94.1/94.2, Type 3R (for filters not forming part of the VFD),
 - .2 two current transformers for two-phases of the load side of the filter for control of the equipment,
 - (a) current rating: no less the full load current of the conductor being measured,
 - (b) rated for 400 Hz.
 - .3 copper conductors,
 - .4 wiring insulation class: 220°C (428 F),
 - .5 temperature rise: 130°C (266 F).
 - .6 digital LCD operator interface, door mounted, for programming and monitoring of the filter,
 - (a) three operating modes: harmonic correction, power factor correction, and combination harmonic and power factor correction,
 - (b) Modbus RTU communications over RS-485 network interface,

- (c) store and display trend log historical data for line voltage, line current, filter current, current THD, filter bus voltage, and filter heatsink temperature.
- .7 anti-vibration pad mounts between the reactor or transformer core and the enclosure.
- .4 Refer to article in Part 3 – EXECUTION for when this harmonic filter type is required based on motor HP rating.

2.13 Load-Side Load Reactor

- .1 3% impedance AC load reactor, copper windings on iron core, for installation inside of VFD enclosure or as a separate device.
- .2 Enclosure: to CSA C22.2 No. 94.1/94.2, Type 3R (for filters not forming part of the VFD),
- .3 Refer to article in Part 3 – EXECUTION for when this load-side filter type is required.

Standard of Acceptance

- ° MTE - fig. RL Line Reactors

2.14 Load-Side dV/dT Filter for Motor Protection

- .1 General:
 - .1 Low pass RLC circuit filter device to:
 - (a) limit voltage spikes due to drive output and reflected wave voltage,
 - (b) reduce the rate of change of current / increase voltage rise time,
 - (c) reduce common mode current.
 - .2 operating environment: 4 to 40°C (40 to 104°F), 5 to 95% RH non-condensing,
 - .3 input voltage: same as associated VFD, with an output fundamental frequency of 60 Hz,
 - .4 listed to CSA C22.2 No. 14 and/or CSA C22.2 No. 107.1, but need not be classified as a motor controller.

Standard of Acceptance

- ° MTE - fig. dV E-Series
- ° TCI LLC - fig. V1K

- .2 Performance:
 - .1 matched to VFD carrier frequency range between 2 to 4 kHz,
 - .2 limit peak voltage at motor to not exceed 150% of VFD DC bus voltage for motor feeder lengths of up to 300 m (1000 ft),
 - .3 reduce common mode current by not less than 30%,
 - .4 overload rating:
 - (a) 200% rated current for 10 seconds per hour
 - (b) 150% rated current for 1 minute per hour
 - .5 full load efficiency: not less than 98% at full load.
- .3 Construction:
 - .1 enclosure: to CSA C22.2 No. 94.1/94.2, Type 3R, with ventilation openings,
 - .2 RLC circuit construction:
 - (a) three-phase iron core, air-gapped inductors, copper wire wound with insulation temperature rise of not less than 115°C, impregnated with 100% solids epoxy resin,

- (b) metallized polypropylene film capacitors, wye-connected with ungrounded neutral, rated at not less than 700 VAC,
- (c) wire-wound cement resistors.
- .3 wire insulation rating: 1000 V class
- .4 wire insulation class: minimum Class H 180°C (356°F).
- .4 Refer to article in Part 3 – EXECUTION for when this load-side filter type is required.

2.15 Load-Side Sine Wave Filter for Motor Protection

- .1 General:
 - .1 For operation with VFD's with pulse-width modulation, operated in scalar (constant V/Hz) mode only.
 - .2 Low pass RLC sinewave filter device:
 - (a) tuned to shunt frequencies at and above the target carrier frequency,
 - (b) eliminate voltage spikes due to drive output and reflected wave voltage,
 - (c) reduce rate of change of current / increase the voltage switching rise time,
 - (d) produce an output voltage sinewave to the motor.
 - .3 operating environment: 4 to 40°C (40 to 104°F), 5 to 95% RH non-condensing,
 - .4 input voltage: same as associated VFD, with an output fundamental frequency of 60 Hz,
 - .5 listed to CSA C22.2 No. 14 and/or CSA C22.2 No. 107.1, but need not be classified as a motor controller.

Standard of Acceptance

- MTE - fig. dV E-Series
- TCI LLC - fig. MSD Motor Shield

- .2 Performance:
 - .1 matched to VFD carrier frequency range between 2 to 16 kHz,
 - .2 produce a sinusoidal voltage signal with not more than 5% THVD,
 - .3 filter output voltage @ 600 VAC system voltages: not to exceed 1020 V,
 - .4 output dV/dt waveform: at least 6 V/μs @ 600 VAC system power,
 - .5 voltage drop at filter output terminals: not to exceed 5% of rated voltage,
 - .6 overload rating:
 - (a) 200% rated current for 3 minutes per hour
 - .7 full load efficiency: not less than 98% at full load.
- .3 Construction:
 - .1 enclosure: to CSA C22.2 No. 94.1/94.2, Type 3R, with ventilation openings,
 - .2 tuned RLC circuit construction:
 - (a) three-phase iron core, air-gapped inductors, copper wire wound with insulation temperature rise of not less than 135°C (275°F), impregnated with 100% solids epoxy resin,
 - (b) metallized polypropylene film capacitors, bio-degradable impregnate, wye-connected with ungrounded neutral, rated at not less than 700 VAC, with pressure-sensitive circuit interrupters to disconnect the three phases simultaneously,
 - (c) wire-wound cement resistors.

- .3 wire insulation rating: 1000 V class
- .4 wire insulation class: Class H 180°C (356°F) or better.

Standard of Acceptance

- Mirius - fig. Inversine
- MTE - fig. SineWave Guardian
- TCI - fig. MSD

- .4 Refer to article in Part 3 – EXECUTION for when this load-side filter type is required.

2.16 Field-Installed Disconnect Switches

- .1 Field-installed disconnect switches to conform to Specification section 20 05 12, except/and as specified herein.
- .2 Disconnects with overcurrent protection device:
 - .1 include fuses or circuit breakers which have a short-circuit interrupting capacity equal to or greater than the SCCR specified for VFDs.
 - .2 select fuse or circuit breaker type and rating in accordance with VFD manufacturer installation instructions for the purpose of achieving the required SCCR value.

3 EXECUTION

3.1 General

- .1 Provide each controlled motor with a dedicated VFD, unless otherwise shown to group motors on a common VFD on a special case basis.

3.2 VFD Installation

- .1 Except where the VFD is provided with a Type 12 enclosure, provide temporary dust protection around installed VFDs until the drives are energized.
- .2 Install variable speed drives in accordance with manufacturer's requirements. Provide field wiring in accordance with Specification section 23 05 12.
- .3 [[Where the VFD has an RFI/EMC filter, disconnect the filter as required by the VFD manufacturer when the drive is installed on high-resistance ground systems or ungrounded systems.]
- .4 Install VFD as closed as possible to controlled equipment unless otherwise shown. Position the motor controller so that:
 - .1 the door front is readily visible and accessible from the workspace,
 - .2 for wall-hung motor controllers, install with the top of the motor controls located between 1700 and 1800 mm above the local work surface and all adjacent motor controllers aligned to the same height,
 - .3 there is a minimum clear space of 1000 mm (40 in.) in front of the motor controller.
- .5 Mount motor controllers to building walls or structure, on Unistrut or similar rails;
 - .1 do not weld miscellaneous support steel to building structure,
 - .2 secure VFDs with seismic-rated fasteners where seismic restraint is required in accordance with specification section 20 05 49.
- .6 Where there is no adjacent or insufficient wall space or building structure upon which to mount the motor controller, provide a floor-mounted fabricated support assembly to mount the motor controller. Design the support assembly to:

- .1 support the dead-weight of the motor controller,
- .2 withstand a 220 N (50 lbf) horizontal force from any direction applied to the VFD enclosure, with a maximum deflection of 3 mm (1/8 in).
- .3 resist seismic movement where seismic restraint is required in accordance with specification section 20 05 49.
- .7 Provide control wiring between the VFD and associated harmonic filter to disable the filter when the drive is at low-speed or is Off.

3.3 Grouped Drive Enclosures Installation

- .1 Install grouped drive enclosure units on housekeeping pads, and mechanically secure to the pad. Use seismic-rated fasteners where seismic restraint is required in accordance with specification section 20 05 49.]

3.4 Motor Feeder Installation

- .1 Provide inverter-duty motor feeder cable in accordance with Specification section 20 05 12, between VFD and the controlled motor, including connections to specified load-side filters.

3.5 Disconnect Switch Installation

- .1 Provide disconnect switches with overcurrent protection for:
 - .1 VFDs not provided with integral disconnect switches,
 - .2 VFDs with integral bypass motor controllers, and
 - .3 VFDs which have an internal SCCR rating that is less than the minimum SCCR value specified herein.
- .2 Locate the disconnect switch immediately upstream of the VFD;
 - .1 install the disconnect switch within 9 m (29 ft) and in line-of-site of the VFD and the motor served by the VFD,
 - .2 where a VFD has an associated harmonic filter installed immediately adjacent to the VFD, the disconnect switch may be mounted ahead of the harmonic filter.
- .3 Where a disconnect switch is required between the drive and the motor, provide an un-fused disconnect switch that has an auxiliary contact switch to indicate when the disconnect switch is not closed.

3.6 Harmonic Filters Installation

- .1 Provide harmonic filters for VFDs based on drive HP rating in accordance with the following table 1, to not exceed the maximum current total harmonic distortion when measured at the line side of the filter/drive assembly.

Table 1: Harmonic Filter Requirements					
Individual Motor Rating HP	Harmonic Filter Method				Maximum THID Rating
	Dual DC Choke 5%	AC Line Reactor 3%	Passive Filter	Active Filter	
≤ 5	Included	---	---	---	45%
>5 and ≤ 40	Included	Yes	---	---	35%
>40 and ≤ 100	Included	---	Yes	---	8%
>100	Included	---	---	Yes	5%

- .2 Install harmonic filters in accordance with the manufacturer's instructions.
- .3 Where a 3% impedance AC line reactor is required, if it is not provided integral to the VFD, provide a field-installed reactor in its own electrical enclosure as specified herein, located immediately ahead of the VFD.
- .4 For passive harmonic filters;
 - .1 provide interlock control wiring between the VFD and the harmonic filter to control the contactor isolating the filter capacitor bank. Control interlock to consist of:
 - (a) 600 V/120 VAC control transformer with fuse protection on primary and secondary legs,
 - (b) interposing double-voltage relays at VFD output, for 24 VAC coil and 120 VAC contacts,
 - (c) interlock wiring: minimum 14AWG-15mmC,
 - (d) wiring logic arranged to open contactor when VFD is off or at part load.
 - .2 set the filter contactor-control trip setting in the VFD to open the contactors when the load drops below a value that causes the drive/filter combination to create a leading power factor, and when the drive is Off. Default value = 70% of maximum rated motor speed.

3.7 [[Active Harmonic Filter Installation for Multiple-Drives

- .1 Where shown provide an active harmonic filter(s) connected to the power distribution panel supplying a group of VFDs, sized for the total connected load to the distribution panel.]

3.8 Load-Side Filters Installation

- .1 Provide load-side motor protection filters based on motor feeder developed length from the VFD to the motor in accordance with the following table(s) 2:
 - .1 Table 2A: for new inverter duty motors provided with new VFD inverter duty feeder cable.
 - .2 Table 2B: for existing motors of any type provided with new VFD inverter duty feeder cables.
 - .3 Table 2C: for existing motors of any type provided with standard motor feeder conductors.

Table 2A: New Inverter-Duty Motors and VFD Inverter-Duty Feeder Cable	
Motor Feeder Length	Output Load-Filter
0 to ≤18 m (0 to 60 ft)	None required
>18 m and ≤ 30 m (>60 ft and ≤ 100 ft)	3% Line Reactor
>30 m and ≤ 50 m (>100 ft and ≤ 160 ft)	dV/dT filter
>50 m (>160 ft)	Sine wave filter

Table 2B: Existing Motor with VFD Inverter-Duty Feeder Cable	
Motor Feeder Length	Output Load Power Conditioner
0 to ≤12 m (0 to 40 ft)	None required
>12 m and ≤ 20 m (>40 ft and ≤ 65 ft)	3% Line Reactor
>20 m and ≤ 46 m (>65 ft and ≤ 150 ft)	dV/dT filter
>46 m (>150 ft)	Sine wave filter

Table 2C: Existing Motor with Standard Motor Feeder Conductors	
Motor Feeder Length	Output Load Power Conditioner
0 to ≤ 6 m (0 to 20 ft)	None required
>6 m and ≤ 12 m (>20 ft and ≤ 40 ft)	3% Line Reactor
>12 m and ≤ 43 m (>40 ft and ≤ 140 ft)	dV/dT filter
>43 m (>140 ft)	Sine wave filter

- .2 Install the load-side filter in accordance with manufacturer's instructions, and as close as possible to the load-side connect of the VFD;
 - .1 load-side filters may be installed above, to the side, or beneath the associated VFD.

3.9 Control Wiring for Remote Disconnect Switch at Motor

- .1 Where a separate disconnect is installed between the drive and the controlled motor, provide interlock control wiring between disconnect switch auxiliary-contact switch and the VFD, to prevent drive from operating if the motor disconnect switch is open.

3.10 Cleaning

- .1 Vacuum clean the inside of VFD panels to remove construction dirt and debris before energizing the VFD.
- .2 Do not start-up VFDs until the local area has been brought to final clean, floors are sealed, and any drywall in the same space is sanded and painted.

3.11 Temporary Use of VFDs During Construction

- .1 Except where a VFD is provided with a Type 12 enclosure, VFDs are not specified for operation in a construction dust-laden environment. Except for VFDs in Type 12 enclosures, do not operate VFDs for the purpose of temporary construction heat or ventilation prior to final construction cleaning of the space in which the drives are located.
- .2 If such heating equipment is to be used prior to final construction clean, provide temporary dust protection enclosures around the VFDs and provide ventilation to the temporary enclosure with a source of filtered supply air.

3.12 Start-Up and Testing

- .1 Provide the services of a certified factory authorized representative for the start-up of each drive, including any configuration and programming required. Complete and submit a VFD manufacturer's start-up inspection and test form for each drive.
- .2 Set the carrier frequency to 4 kHz as the default value. Where noise is found to be objectionable, increase carrier frequency to the lowest possible value until noise level is acceptable or cannot be discerned from the background noise.
 - .1 where a load-side dV/dT filter is installed, do not use a carrier frequency greater than 4 kHz.
- .3 Commission harmonic mitigation devices on-site. Test the performance of these devices at 0%, 30% and 100% motor load;
 - .1 for the purpose of this test "100% motor load" means the motor current draw when the equipment driven by the motor is operating at its full design load,
 - .2 measure voltage, current, power factor, harmonic distortion (by frequency) and total harmonic distortion at the line-side terminals to the drive/harmonic mitigation device assembly,

- .3 obtain measurements with a recording type Fluke 41 or equivalent harmonics analyzer for individual and total harmonic currents and voltages,
 - .4 [[where multiple instances of the same drive, harmonic mitigation device and motor HP rating occur, testing may be limited to not less than three examples of the same equipment line-up,]
 - .5 submit written test records to Consultant for review, and include the test records in the operation and maintenance manuals.
- 4 Commission load-side motor protection filters onsite. Test the performance of these devices at 30% and 100% motor load;
- .1 for the purpose of this test "100% motor load" means the motor current draw when the equipment driven by the motor is operating at its full design load,
 - .2 measure peak-overshoot and peak-normal voltage at VFD load terminals, at load-filter output terminals, and at motor terminals,
 - .3 voltage rise time at the same locations,
 - .4 obtain measurements with a recording type voltage meter capable of recording and graphically displaying peak voltage and voltage rise-time,
 - .5 [[where multiple instances of the same drive, load-side filter device and motor HP rating occur, testing may be limited to not less than three examples of the same equipment line-up,]
 - .6 submit written test records to Consultant for review, and include the test records in the operation and maintenance manuals.

3.13 Setting Skip-Speed for Driven Equipment Natural Frequency

- .1 Conduct a vibration field test on the following driven equipment to determine its first natural frequency:
 - .1 all cooling towers,
 - .2 each style of pump and HP rating,
- .2 Based on the vibration field tests, program the VFD skip-speed function to prevent operation of the motor at the speed corresponding to the driven-equipment's first natural frequency;
 - .1 set the skip speed range setpoint to be equal to $\pm 5\%$ of measured equipment first natural frequency, unless a wider or narrower range is determined by field testing.
- .3 Provide a machine printed, self-adhesive label and place below the drive nameplate, identifying the skip-speed frequency programmed in the drive.

This drive has been programmed to skip over the following speed range: Hz to Hz
--

3.14 Demonstration and Training

- .1 Provide the services of a factory trained manufacturer's representative to provide training to Owner's operations staff. Include in training;
 - .1 installation instructions,
 - .2 programming of VFD,
 - .3 operation of VFD,
 - .4 at-site servicing of VFD,
 - .5 replacement of VFD keypad controller,
 - .6 manual and automatic operation of bypass, if applicable,

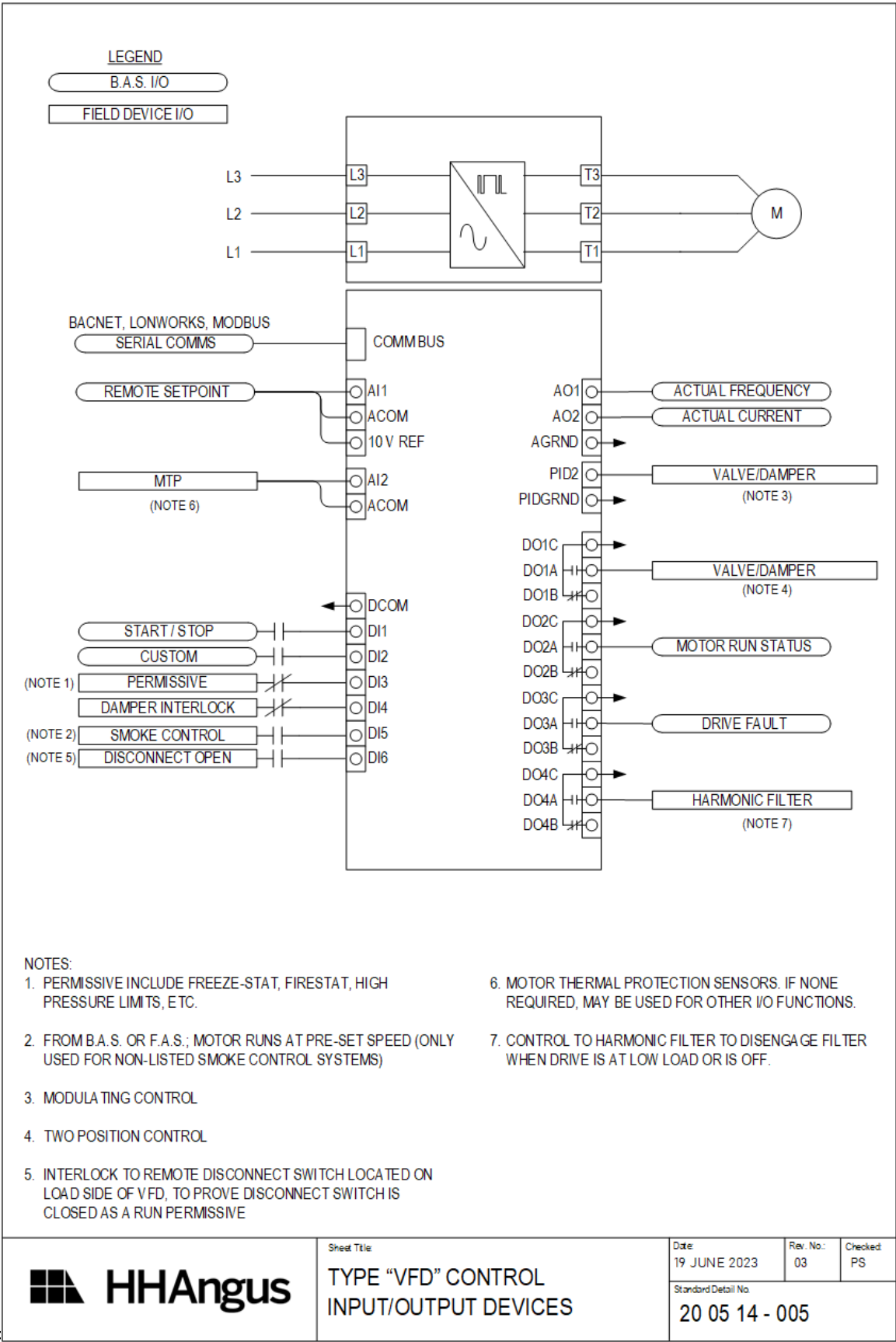
- .7 serial communications,
- .8 fireman's smoke control override,
- .9 method of isolating VFD and bypass (if provided) for servicing the equipment,
- .10 purpose and function of harmonic filters,
- .11 purpose and function of load-side motor protection filters.

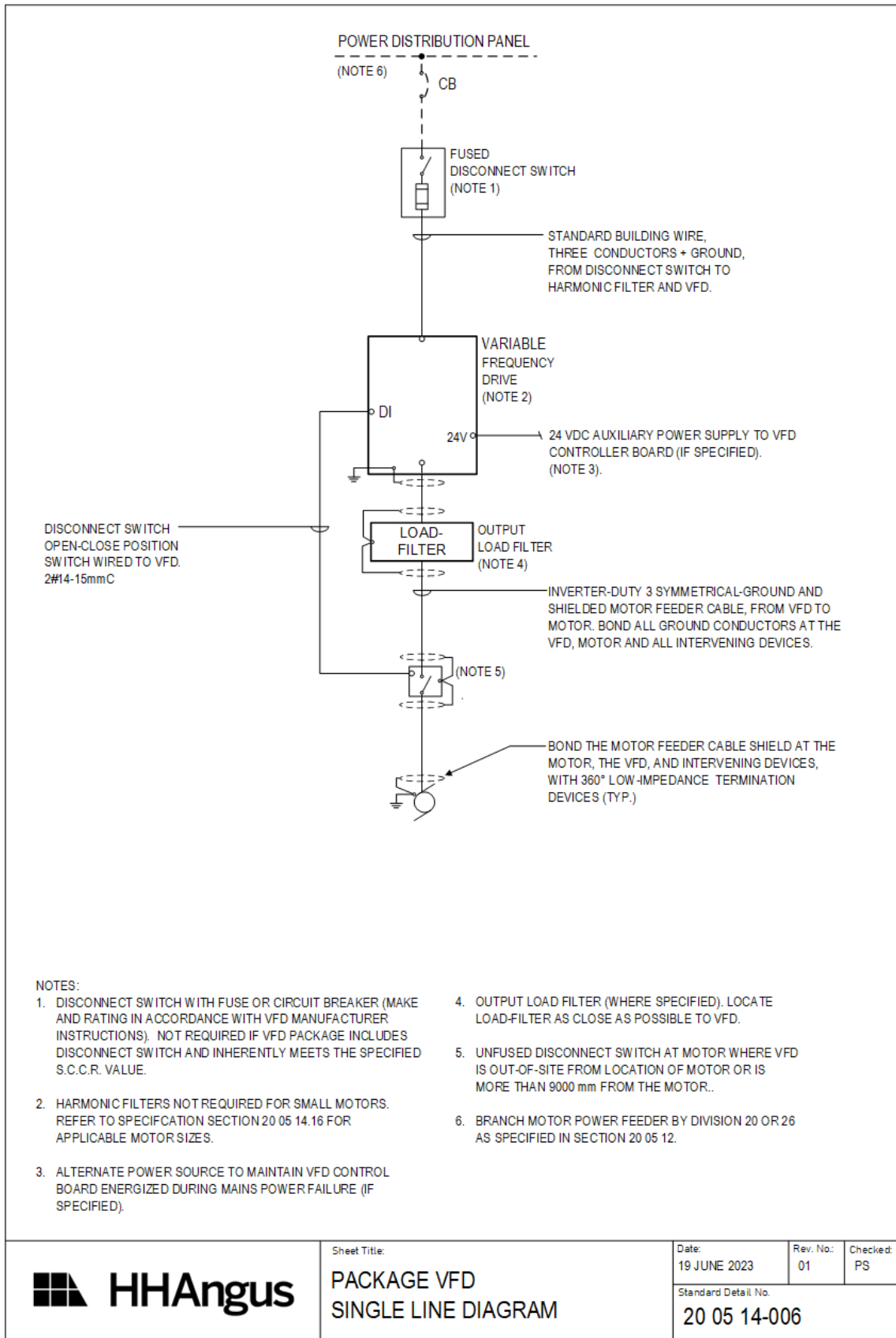
3.15 Hand-Over

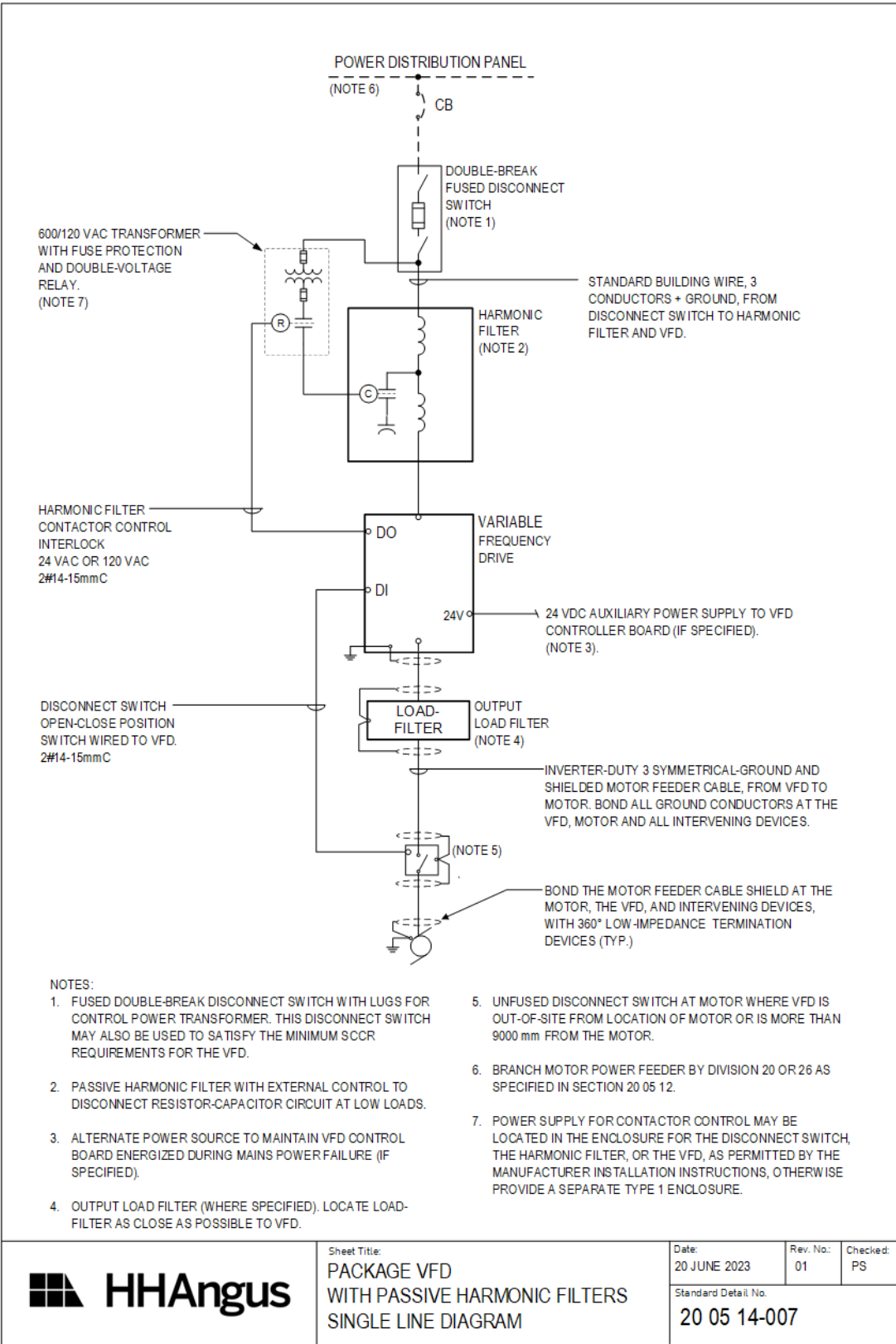
- .1 Provide to the Owner the service and maintenance manuals, wiring and interconnection diagrams and the start-up reports.

3.16 Wiring Diagrams

- .1 The included VFD motor controller wiring diagrams are to be read in conjunction with equipment specifications, control sequences, and motor/starter schedules for implementation of control sequences and identification of components required in each in each motor controller.
- .2 The following standard details provide indicative wiring requirements for VFD motor controllers.
 - .1 20 05 14-005 Type "VFD" – Control Input/Output Devices
 - .2 20 05 14-006 Packaged VFD - Single Line Drawing
 - .3 20 05 14-007 Packaged VFD with Passive Harmonic Filter - Single Line Drawing







END OF SECTION

COMMON HANGER AND SUPPORT REQUIREMENTS FOR PIPING

20 05 29

1 GENERAL

1.1 Scope

- .1 Provide hangers and supports for piping, including insulation protection devices.
- .2 The requirements of this specification section apply to all piping systems, except where required otherwise by specific piping specification sections including:
 - .1 20 05 16 Rooftop Supports for Building Services and Equipment
 - .2 20 05 16 Flex Connections, Expansion Joints, Anchors and Guides
 - .3 21 05 01 Common Work Results for Fire Suppression
 - .4 22 60 13.53 Laboratory Gas Piping General Requirements
 - .5 22 60 13.70 Medical Gas Piping
 - .6 23 11 13 Facility Fuel Oil Piping and Accessories
 - .7 23 11 23.13 Facility Natural Gas Piping and Accessories
 - .8 Applicable sections of Division 22 sections for plumbing and drainage piping,
- .3 Provide engineering services associated with the design, analysis, and selection of custom piping supports, including pipe riser supports.

1.2 Related Work

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 06 Rooftop Supports for Building Services and Equipment
 - .2 20 05 16 Flex Connections, Expansion Joints, Anchors and Guides
 - .3 20 05 48 Vibration Isolation
 - .4 20 05 49 Seismic Restraints for Mechanical Services
 - .5 20 07 19 Piping Insulation

1.3 Definitions and Abbreviations

- .1 The following definitions apply to this section:
 - .1 **Ambient piping:** piping with a fluid temperature greater than 16°C (61°F) and up to and including 40°C (104°F).
 - .2 **Cold piping:** piping with a fluid temperature greater than 4°C (39°C) and up to and including 16°C (61°F).
 - .3 **Dual temperature piping:** piping which operates non-simultaneously as both cold piping and hot piping depending on the season.
 - .4 **Hot piping:** piping with a fluid temperature greater than 60°C (140°F).
 - .5 **Low temperature piping:** piping with a fluid temperature greater than 40°C (104°F) and up to and including 60°C (140°F)

1.4 Applicable Codes and Standards

- .1 Product and installation codes and standards:

- .1 ANSI/MSS SP-58 Pipe Hangers and Supports – Materials, Design, Manufacture, Selection, Application, and Installation
- .2 CAN/UL 203 Standard for Pipe Hanger Equipment for Fire Protection Service
- .2 Refer to each applicable piping specification section for supplemental requirements for pipe supports.

1.5 Analysis, Design, and Inspection Services

- .1 Where custom fabricated pipe and equipment supports are proposed to be used, provide the services of a professional engineer, licensed in the province or territory of the Work and who specializes in the design of piping and equipment supports (the "Specialty Engineer"), for the design of piping and equipment support systems and to provide inspection services of the completed installation.
- .2 Provide services of a Specialty Engineer for the design and selection of constant-load and variable-load hanger supports. Where a manufacturer of such equipment provides this design service, this is deemed to meet this requirement.
- .3 Specialty Engineer design services to include;
 - .1 provide the design of the piping support system, including anchors, guides, expansion joints, and shall include seismic restraints where applicable,
 - .2 analysis of dead loads, thermal expansion loads, wind load, static seismic loads (where applicable) and capacity of materials utilized for connections to equipment and structure.
 - .3 provide design drawings showing locations of supports, restraints and details of construction and attachment of supports and restraints,
 - .4 seismic design to conform to Specification section 20 05 49 where applicable.
- .4 Specialty Engineer inspection services to include:
 - .1 at periods during installation and at completion of the installation of the piping supports and anchor devices, the Specialty Engineer shall inspect the installation, identify and report deficiencies (if any) which are observed, and re-inspect the installation after deficiencies have been corrected,
 - .2 Specialty Engineer to submit periodic inspection reports and a final inspection report after all work is completed and deficiencies have been corrected, confirming the installation conforms to the design requirements. Prepare and submit any required declarations or similar document to this effect where required by local legislation. Include in the final report site photographs of the complete installation prior to covering with insulation, with specific photos at pipe anchors, guides, and expansion joints.
- .5 Provide shop drawings of custom supports, which shall be sealed by the Specialty Engineer.
- .6 Provide signed declarations for commitment for general review and final review letters of conformity as required by applicable legislation at the place of the Work.

1.6 Design Criteria

- .1 The support spacing and hanger rod size specified herein is based on supporting a single pipe directly from the structure in accordance with MSS SP-58. If multiple pipes are supported from trapeze hangers (or similar), or from common hanger rods supporting a tier of multiple piping, then;
 - .1 the total load on the support rods or similar elements shall not exceed published tension load rating data in accordance with Table 2 of MSS SP-58.
 - .2 design of custom trapeze hangers shall meet the design criteria as specified in Part 2 of this section.
- .2 Provide complete custom engineered design services in accordance with the requirements of MSS SP-58 for support of vertical piping for the following portions of the Work:

- .1 vertical piping located in vertical services spaces (shafts) where any of the following criteria apply;
 - (a) piping is NPS 8 and larger,
 - (b) the vertical pipe length exceeds 25 m (82 ft),
 - (c) pipe expansion joints are shown, or
 - (d) vibration isolated supports, variable spring supports or constant load supports are shown.
- .2 where horizontal piping is supported on;
 - (a) trapeze hangers or supported on/suspended from horizontal structural elements, or
 - (b) pipe racks.
- .3 Where the mechanical system are required to have seismic restraints, this section is to be read in conjunction with the requirements of Specification section 20 05 49.

1.7 Submittals

- .1 Submit manufacturer product data sheets for hanger components, and include:
 - .1 load ratings,
 - .2 typical composite detail drawings for complete hanger assembly, including upper attachment, hanger rods, hanger rod swivels, pipe attachments, shields and saddles, and load ratings, for each pipe condition and size.
- .2 Submit support details for glass, fibre-reinforced plastic, and other plastic piping systems which are coordinated with the piping material manufacturer installation instructions.
- .3 Where variable spring supports or constant load supports are shown, provide completely engineered design and fabrication drawings, including any supplementary steel requirements, and loads transferred to the building structure.
- .4 Submit engineered design drawings for fabricated trapeze hangers and completely engineered support systems, including
 - .1 construction detail drawings for each loading condition,
 - .2 span deflection calculations,
 - .3 building attachment load calculations and type.
 - .4 shop drawings to be sealed by a professional engineer licensed in the project location jurisdiction.
- .5 Where custom designed supports are proposed, shop drawings are to be sealed by a professional engineer licensed in the place of the Work.

1.8 Quality Control

- .1 Where custom engineered supports are used, provide the services of a specialist professional engineer licensed in the location of the Work, to design the support systems and to conduct an inspection of the completed installation that it is in general conformance with the sealed shop drawing requirements, and submit an inspection report to the Owner and the Consultant.

2 PRODUCTS

2.1 General

- .1 Fabricate pipe hangers, supports, sway braces and associated components from stock or production parts, manufactured and fabricated in conformance with MSS SP-58, and the requirements of the piping code specified for each piping system.
- .2 Pipe hangers and supports for fire protection systems to be listed to CAN/UL 203, except where such listing requirement is excluded under applicable NFPA standards.

- .3 Select elements of pipe support systems to provide adequate factors of safety under loads applied by gravity, by temperature induced expansion and contraction, by internal pressure in mechanically jointed plain end pipe, and by fluid flow pressure thrust.
- .4 Where specified products define the applicable pipe size NPS range (notwithstanding that the product may be available for larger pipe sizes), the maximum specified pipe size is limited to not exceed the load rating of the specified product under maximum allowable pipe spans as defined in MSS SP-58 for insulated pipe filled with water.
- .5 Product finishes (unless otherwise specified for each product):
 - .1 outdoors: hot dipped galvanized,
 - .2 in mechanical service rooms, pipe tunnels and pipe trenches: hot-dipped galvanized,
 - .3 other indoor locations: plain finish, zinc plated, or painted finish.
 - (a) exception: do not use any zinc coated or electro-plated products in data center rooms.
- .6 Select pipe support products from manufacturers standard product line.

Standard of Acceptance

- Anvil
- Unistrut
- Taylor
- Acrow Richmond
- Portable Pipe Hangers
- Hilti
- nVent Caddy
- Pipe Shields
- Buckaroos

2.2 Upper Attachments – Inserts for New Concrete

- .1 General:
 - .1 upper hanger attachment for casting into new cast-in-place concrete decks, for piping or equipment supports,
 - .2 for attachment to formwork prior to concrete pour,
 - .3 designed to receive USS coarse thread hanger rods.
 - .4 in the following tables, pipe size limit is based on insulated pipe filled with water at the maximum allowable span in accordance with Schedules A1(a), A2(a), and A3 at the end of this section. Larger pipe sizes may apply where reduced spans are used in accordance with the alternate rod size and support span limits in accordance with Schedules A1(b) and A2(b) as the end of this section.
- .2 Fixed rod position:
 - .1 fixed position type,
 - .2 listed to CAN/UL 203 for fire protection piping, for pipe NPS ¾ through NPS 8,
 - .3 materials: malleable iron, or zinc-plated carbon-steel with plastic form, with nailing feature,
 - .4 minimum load rating in tension based on connected rod size:

Rod Nominal Size	Tension Load kN (lbf)	Single Pipe Size Limit NPS
Ø3/8	3.25 (730)	2
Ø1/2	5.0 (1130)	3
Ø5/8	5.6 (1260)	4
Ø3/4	11.1 (2500)	8

Standard of Acceptance

- ° Anvil - fig. 152
- ° Hilti - fig. KCM

.3 Fixed rod position – high capacity:

- .1 fixed position type,
- .2 stainless steel insert body, with two (2) fibreglass and concrete barrier disc for attachment to concrete rebar,
- .3 minimum load rating in tension based on connected rod size:

Rod Nominal Size	Tension Load kN (lbf)	Single Pipe Size Limit NPS
Ø3/4	14.4 (2500)	8
Ø7/8	19.9 (4480)	12
Ø1	26.2 (5900)	18
Ø1-1/4	42.2 (9500)	20
Ø1-1/2	61.4 (13,800)	30

Standard of Acceptance

- ° Anvil - fig. 286

.4 Single-direction adjustable rod position:

- .1 listed to CAN/UL 203 for fire protection piping, for pipe NPS ¾ through NPS 8.
- .2 galvanized wedge inserts to MSS SP-58 type 18, with single-direction adjustment of rod position,
- .3 minimum load rating in tension based on connected rod size:

Rod Nominal Size	Tension Load kN (lbf)	Single Pipe Size Limit NPS
Ø3/8	3.25 (730)	2
Ø1/2	5.0 (1130)	3
Ø5/8	5.6 (1200)	4
Ø3/4	11.1 (1200)	8

Standard of Acceptance

- Anvil - fig. 281
- Unistrut - fig. P-3245

.5 Concrete inserts – channel type;

- .1 single hanger or multiple hangers support,
- .2 2.75 mm (12 Ga) thick channels, hot-dipped galvanized, with concrete embedment tabs, open bottom channel allowing multiple support points and lateral position adjustment,
- .3 with back plates, end caps and closure strips to prevent concrete spillage into channel space,
- .4 minimum point load spacing: 300 mm (12 in.)
- .5 maximum tension load rating for single hanger support:

Channel Length mm (in.)	Tension Load kN (lbf)	Tension Load kN/m (lbf/ft)	Single Pipe Size Limit NPS
200 (8)	4.4 (1000)	---	6
300 (12)	6.6 (1500)	---	8
450 (18)	17.8 (4000)	23.8 (2000)	12

Standard of Acceptance

- Unistrut - fig. P-3249 to P-3270 series.

2.3 Upper Attachments – Anchors for Existing Concrete

.1 General:

- .1 upper hanger attachment for anchoring into existing concrete decks, for piping or equipment supports,
- .2 designed to receive USS coarse thread hanger rods.

.2 Drop-in anchors:

- .1 zinc-plated carbon steel drop-in friction anchor design, with matched drill bit and setting tool,
- .2 not to be used for seismic restraints or hanger rods at pipe hangers having seismic restraint,
- .3 rated for uncracked concrete,
- .4 listed to CAN/UL 203 for fire protection piping, for pipe NPS ¾ through NPS 8,
- .5 capacity rating with 4:1 safety factor to ultimate load,
- .6 minimum load rating in tension based on connected rod size:

Rod Nominal Size	Tension Load kN (lbf)	Single Pipe Size Limit NPS
Ø3/8	2.82 (635)	2
Ø1/2	4.2 (945)	3
Ø5/8	8.34 (1875)	4
Ø3/4	11.1 (2500)	8

Standard of Acceptance

- Hilti - fig. HDI, HDI+, HDI-L+

.3 Wedge anchors:

- .1 anchor-end wedging action on concrete, and not relying on friction between side of bolt and concrete hole wall,
- .2 zinc-plated carbon steel wedge anchor design with load washer and nut,
- .3 wedge anchor capacity as specified herein to be rated for cracked concrete having not less than 20 MPa (2900 psi) strength.
- .4 rated for cracked and uncracked concrete,
- .5 listed for seismic tension and shear loads in accordance with ACI 355.2 and ICC-ES AC193.
- .6 listed to CAN/UL 203 for fire protection piping, for pipe NPS ¾ through NPS 8,
- .7 extra-long bolt length to allow attachment of hanger rod coupling with full thread engagement in the coupling, while providing required load engagement length,
- .8 standard rating: minimum load rating in tension based on connected rod size:

Rod Nominal Size	Tension Load kN (lbf)	Single Pipe Size Limit NPS
Ø3/8	4.85 (1090)	2
Ø1/2	7.52 (1690)	3
Ø5/8	12.1 (2715)	4
Ø3/4	15.5 (3495)	8

Standard of Acceptance

- Hilti - fig. Kwick Bolt series

- .9 high-capacity rating: minimum load rating in tension based on connected rod size:

Rod Nominal Size	Tension Load kN (lbf)
Ø3/8	14.0 (3150)
Ø1/2	20.8 (4675)
Ø5/8	29.1 (6535)
Ø3/4	40.6 (9135)
Ø7/8	53.4 (12,000)

Standard of Acceptance

- Hilti - fig. HSL-3 series

2.4 Upper Attachment – Mounting Plates

- .1 Surface mounting plates to underside of concrete decks:
 - .1 for installation post concrete pour with either concrete inserts or drilled anchors,

- .2 surface mount carbon steel plate, with either clevis hanger with pin (for use with hanging rod-eye) or for attachment of hanger rod and load nut,
- .3 mounting holes in four corners of plate, sized for fastening bolts to achieve rated capacity,
- .4 minimum load rating in tension based on connected rod size:

Rod Nominal Size	Tension Load kN (lbf)	Single Pipe Size Limit NPS
Ø3/8	3.25 (730)	2
Ø1/2	6.0 (1350)	3
Ø5/8	9.6 (2160)	4
Ø3/4	14.4 (3230)	8
Ø7/8	19.9 (4480)	12
Ø1	26.2 (5900)	18
Ø1-1/4	42.3 (9500)	20
Ø1-1/2	61.4 (13,800)	30

Standard of Acceptance

- Anvil - fig. 49 clevis plate,
- Anvil - fig. 52 load nut,
- Taylor - fig. 166 clevis plate,
- Taylor - fig. 167 load nut

2.5 Upper Attachments – Steel Structure

- .1 Steel beam clamp (bottom flange), pipe size NPS 8 and smaller:
 - .1 hanger clamp attachment to beam or joist bottom flange, applying concentric loading to the beam/joist web,
 - .2 for hanger rod sizes Ø3/8 to Ø7/8 in.,
 - .3 malleable iron or carbon steel, symmetrically loading beam clamp to MSS SP-58, type 30,
 - .4 listed to CAN/UL 203 for fire protection piping,
 - .5 minimum load rating in tension: 6.1 kN (1365 lbf)
 - .6 with extension piece swivel attachment to receive hanger rod.

Standard of Acceptance

- Anvil - fig. 218 with fig. 157 extension swivel.
- Taylor - fig. 410 with fig. 411 extension swivel.

- .2 Steel beam clamp (bottom flange), pipe size NPS 2½ to 24:
 - .1 hanger clamp attachment to beam or joist bottom flange, applying concentric loading to the beam/joist web,
 - .2 for hanger rod sizes Ø5/8 to Ø1-1/2 in.,
 - .3 forged steel, symmetrically loading heavy duty beam clamp, to MSS SP-58, type 28 or 29.
 - .4 load rating based on standard hanger rod load capacities in accordance with MSS SP-58,

.5 with weldless eye nut.

- Anvil - fig. 228
- Taylor - fig. 450

.3 Steel beam (top flange) - for conduit, piping NPS 6 and smaller, and ductwork:

- .1 hanger clamp attachment to the top flange of beam or joist, applying an eccentric loading to the beam/joist,
- .2 carbon steel, hook rod with locking jaw, fasteners and lock washers, to MSS SP-58, type 25,
- .3 for hanger rod sizes Ø3/8 to Ø3/4 in.,
- .4 minimum load rating in tension:

Rod Nominal Size	Tension Load kN (lbf)	Single Pipe Size Limit NPS
Ø3/8	3.2 (730)	2
Ø1/2 to Ø3/4	4.2 (940)	6

.5 listed to CAN/UL 203 for fire protection piping (rod size Ø3/8 and Ø1/2 in.)

Standard of Acceptance

- Anvil - fig. 227

.4 Steel joists (joist bottom chord) – for piping NPS 2 and smaller:

- .1 steel washer plates for installation of support rod within the interstice space of double-channel steel joists and open-web steel joints, installed on top and bottom surface of the joist and secured with load nut (top washer plate) and locking nut (bottom washer plate).
- .2 load rating based on standard hanger rod load capacities in accordance with MSS SP-58,
- .3 carbon steel washer plates with locking nuts,

Standard of Acceptance

- Anvil - fig. 60
- Taylor - fig. 80

2.6 Upper Attachments – Wall Brackets

.1 Medium and heavy-duty wall mounting brackets:

- .1 welded carbon steel plate or channel assembly, designed to allow at least 75 mm (3 in.) of horizontal adjustment of hanger rod position, to MSS SP-58, Types 32 and 33,
- .2 carbon steel backplates for through bolting of concrete walls where required by supported load and wall material,
- .3 for bolting into concrete wall, concrete block, or welding to building structure (where permitted by structural engineer),
- .4 minimum load rating:
 - (a) medium duty: 6.7 kN (1500 lbs).
 - (b) heavy duty: 13.4 kN (3000 lbs).

Standard of Acceptance

- Anvil - fig. 195 and 199
- Taylor - fig. 801 and 802.

.2 Light-duty wall mounting brackets:

- .1 welded carbon steel plate or channel assembly, single point rod support, to MSS SP-58, Types 31,
- .2 with carbon steel backplates for through bolting of concrete walls where required by supported load,
- .3 FM approved,
- .4 for bolting into concrete wall, concrete block, or welding to building structure,
- .5 minimum load rating: 3.35 kN (750 lbs).

Standard of Acceptance

- Anvil - fig. 194

2.7 Upper Attachment - Swivels

.1 Clevis swivel:

- .1 to allow rotation movement of suspended clevis hangers,
- .2 forged steel clevis with hanger pin, threaded rod socket, to MSS SP-58 type 14,
- .3 tension load capacity not less than the connected rod load capacity,
- .4 threaded end connected to concrete insert, with clevis end connected to weldless eye nut or welded eye rod.

Standard of Acceptance

- Anvil - fig. 299
- Taylor - fig. 63

.2 Weldless eye nut swivel:

- .1 to allow rotation movement of suspended clevis hangers,
- .2 forged steel eye nut, threaded rod socket, to MSS SP-58 type 17,
- .3 tension load capacity not less than the connected rod load capacity.
- .4 for connection to top of rod hanger, suspended from a clevis.

Standard of Acceptance

- Anvil - fig. 290
- Taylor – fig. 64

2.8 Hanger Rod

.1 Continuous threaded rod:

- .1 carbon steel, USS coarse thread,
- .2 tension load ratings to meet or exceed MSS SP-58.

Standard of Acceptance

- Anvil - fig. 146

- Taylor – fig. 54

.2 Welded eye rod:

- .1 carbon steel, USS course thread,
- .2 tension load ratings to MSS SP-58,
- .3 tension load ratings to meet or exceed MSS SP-58 for hanger rod.

Standard of Acceptance

- Anvil - fig. 278
- Taylor - fig. 53

.3 Rod connectors:

- .1 carbon steel, USS course thread,
- .2 with mid-point site hole,
- .3 tension load ratings to meet or exceed MSS SP-58.

Standard of Acceptance

- Anvil - fig. 135i
- Taylor - fig. 62S

2.9 Horizontal Pipe Support - Clevis

.1 Clevis support:

- .1 applicable piping materials:
 - (a) carbon steel and stainless steel pipe, schedule 10 to 80,
 - (b) cast iron DWV piping,
- .2 carbon steel, adjustable clevis, with clevis bolt reinforcing tube, to MSS SP-58 Type 1,
- .3 adjustable hanger height while under load,
- .4 listed to CAN/UL 203 for fire protection piping,
- .5 applicable pipe size:
 - (a) steel pipe: NPS ½ to NPS 16
 - (b) ductile or cast iron drainage pipe: NPS 3 to 24

Standard of Acceptance

- Anvil - fig. 260
- Anvil - fig. 590 (for ductile or cast iron drainage pipe)
- Taylor – fig. 24
- Taylor – fig. 27AC (for ductile or cast iron pipe)

.2 Clevis support with extended yoke for where yoke is located inside of pipe insulation:

- .1 applicable piping materials:
 - (a) carbon steel and stainless steel pipe, schedule 10 to 80,
 - (b) cast iron DWV piping,
- .2 carbon steel, adjustable clevis, with clevis bolt reinforcing tube, to MSS SP-58 Type 1,
- .3 adjustable hanger height while under load,

- .4 yoke sized for outside dimension of pipe only, with extended yoke to clear pipe insulation,
- .5 applicable pipe size:
 - (a) steel pipe: NPS $\frac{3}{4}$ to NPS 12

Standard of Acceptance

- Anvil - fig. 300
- Taylor – fig. 24L

- .3 Clevis support with integral non-metallic insulation saddle:
 - .1 alternate to using standard clevis hanger specified above with separate high density insulation inserts or pipe insulation saddles,
 - .2 applicable piping materials:
 - (a) insulated carbon steel and stainless steel pipe, schedule 10 to 80,
 - (b) insulated cast iron drainage piping.
 - .3 carbon steel, adjustable clevis, with clevis bolt reinforcing tube, to MSS SP-58 Type 1,
 - .4 adjustable hanger height while under load,
 - .5 listed to CAN/UL 203 for fire protection piping,
 - .6 with glass-reinforced polypropylene saddle, sized to allow up to 50 mm (2 in.) insulation thickness,
 - .7 yoke and clevis sized for outside dimension of pipe and insulation,
 - .8 applicable pipe size:
 - (a) steel pipe: NPS $\frac{1}{2}$ to NPS 8,
 - (b) copper tube: NPS $\frac{1}{2}$ to NPS 8.
 - .9 piping system design temperature limits: 4.4 to 100°C (40 to 212°F).

Standard of Acceptance

- Anvil - fig. 260 ISS

- .4 Clevis support for copper pipe and tube:
 - .1 for copper tube, NPS $\frac{1}{2}$ to 4,
 - .2 zinc-plated carbon steel yoke and clevis, adjustable clevis to MSS SP-58, type 1, copper plated or felt lined finish,
 - .3 applicable tube size: NPS $\frac{1}{2}$ to NPS 4,
 - .4 sized for outside dimension of pipe/tube, or outside diameter of pipe and insulation as applicable.

Standard of Acceptance

- Anvil - fig. CT-65 or 260F
- Taylor – fig. 52

2.10 Horizontal Pipe Support – Clevis for Fire Protection

- .1 Pipe size range: NPS 2 to NPS 8.
- .2 Light-duty, side-opening clevis support:
 - .1 for fire protection service only,

- .2 pipe size range: NPS 2 to 8,
- .3 galvanized carbon steel, adjustable clevis with fixed yoke,
- .4 listed to ULC/ORD-C203 or UL 203 for fire protection piping,
- .5 sized for outside dimension of pipe (and insulation if applicable).
- .6 sized for outside dimension of pipe (and insulation where applicable),
- .7 nominal pipe size: NPS 2 to NPS 8.

Standard of Acceptance

- Hilti - fig. MH-SLC Speed Lock

2.11 Horizontal Pipe Support – Swivel Ring Hanger

- .1 For non-insulated drain-waste-vent piping, gas piping, and chemical piping.
- .2 Pipe swivel ring hangers:
 - .1 carbon steel ring strap, zinc plated, adjustable knurled swivel nut, to MSS SP-58 Type 10,
 - .2 copper plated or epoxy-coated for use on copper tubing,
 - .3 listed to ULC/ORD-C203 or UL 203 for fire protection piping,
 - .4 nominal pipe size: NPS ½ to NPS 4.

Standard of Acceptance

- Anvil - fig. 69, CT-69
- Taylor – fig. 41, 43

2.12 Pipe Straps

- .1 General:
 - .1 for non-insulated drain-waste-vent piping, gas piping, and chemical piping.
 - .2 pipe size: NPS 4 and smaller.
- .2 Zinc plated carbon steel U-loop straps for mechanical fastening to structure.

Standard of Acceptance

- Anvil - fig. 262

- .3 Hot-dipped galvanized carbon steel U-loop with clip-in or bolt-on attachment to modular channel supports.

Standard of Acceptance

- Unistrut

2.13 Horizontal Pipe Support – Pipe Roller (Type 41, 43, 44)

- .1 Suspended support pipe roller – trapeze hanger style:
 - .1 adjustable height, pipe roller support for overhead support, to MSS SP-58 type 41,
 - .2 dual-hanger rod trapeze style,
 - .3 pipe size range: NPS ½ to NPS 16, with or without insulation.

Standard of Acceptance

- Anvil - fig. 171
- Taylor – fig. 95

.2 Suspended support pipe roller – clevis hanger style:

- .1 adjustable height, pipe roller support for overhead support, to MSS SP-58 type 43,
- .2 single rod clevis style,
- .3 pipe size range: NPS ½ to NPS 8, with or without insulation.

Standard of Acceptance

- Anvil - fig. 181
- Taylor – fig. 93

.3 Bottom support pipe roller:

- .1 adjustable height, pipe roller with bottom support rods, to MSS SP-58 type 41,
- .2 for bottom support of piping,
- .3 with mounting rods and upper/lower retention nuts at both ends,
- .4 pipe size range: NPS ½ to NPS 16, with or without insulation.

Standard of Acceptance

- Anvil - fig. 177
- Taylor – fig. 95S

.4 Bottom support pipe roller with stand:

- .1 pipe roller with cast iron support stand, to MSS SP-58 type 44,
- .2 for bottom support of piping,
- .3 fixed height and adjustable height variants,
- .4 base drilled for fastening to supporting element,
- .5 pipe size range: NPS ½ to NPS 18, with or without insulation.

Standard of Acceptance

- Anvil - fig. 271 (fixed), fig. 274 (adjustable)
- Taylor – fig. 279S (fixed), fig. 280S (adjustable)

2.14 Horizontal Pipe Support – Slides

.1 Structural slide bases – welded attachment:

- .1 Tee or H shaped pipe support for welding to pipe, to allow axial and lateral movements,
- .2 carbon steel, structural shape or fabricated, to ANSI/MSS SP-58 Type 35,
- .3 operating temperature range: -28 to 200°C (-20 to 400°F),
- .4 pipe insulation thickness clearance: up to 75 mm (3 in.),
- .5 pipe size and load rating in accordance with the following table:

Slide Base Type	Vertical Support Load Rating	Lateral Restraint Load Rating	Uplift Restraint Load Rating	Pipe Size Range NPS
-----------------	------------------------------	-------------------------------	------------------------------	---------------------

	kN (lbf)	kN (lbf)	kN (lbf)	Water	Steam, Gas
T	35.0 (8000)	9.0 (2000)	3.6 (800)	½ to 18	½ to 30
H	53.0 (12,000)	13.0 (3000)	5.3 (1200)	6 to 8	½ to 30
	53.0 (12,000)	18.8 (4000)	7.1 (1600)	10 to 20	
	107 (24,000)	26.0 (6000)	10.7 (2400)	24 to 30	

Standard of Acceptance

- Anvil - figs. 257A, 436A, 439A
- Taylor – figs. 257A

.2 Structural slide base assemblies with PTFE pads – welded attachment:

- .1 for piping with design temperatures greater than 121°C (250°F), including steam at pressures greater than 103 kPa (15 psig),
 - (a) may also be used for lower temperatures,
- .2 as specified above for slide bases and as follows,
- .3 PTFE bonded to underside of slide,
- .4 matching lower steel plates with bonded PTFE element (for fastening to structural support beam),

Standard of Acceptance

- Anvil - figs. 257, 436, 439
- Taylor – figs. 257

.3 Restraint variants for slides:

- .1 lug restraints to limit lateral movement due to thermal expansion of between 6 mm to 25 mm (1/4 to 1 in.),
- .2 where seismic restraint is required, lug restraints designed to limit lateral and vertical uplift movement to not more than 6 mm (1/4 in.),
 - (a) exception: if lateral movement of greater than 6 mm (1/4 in.) is shown, then the seismic design load is to be two (2) times the seismic load as shown in Specification section 20 05 49.

.4 Clamp for T and H slides supporting cold piping:

- .1 galvanized steel clamp for insulated cold piping, sized for outside dimension of insulated pipe,
- .2 rolled from structural plate steel with bolting flanges,
- .3 continuous single clamp for length of slide, or two (2) individual clamps at each end of the slide,
- .4 bottom half of clamp welded to T or H slides,
- .5 top half of clamp mechanically fastened to bottom half.

Standard of Acceptance

- Anvil - fig. 212 (2 clamp) 432 (continuous clamp)

2.15 Horizontal Pipe Support – Trapeze

.1 Manufactured trapeze support:

- .1 load ratings as per manufacturers data sheets,
- .2 carbon steel, double-C channel (strong-backs), HSS shape and equal-leg angles.

Standard of Acceptance

- Anvil - fig. 45, 46, and 50
- Taylor – fig. 170

.2 Fabricated trapeze support:

- .1 custom designed trapeze hangers of either hollow structural sections, double C channels (strongbacks), single C channel or unequal lengths angle channels, to support one or more pipes, conduits or ducts,
- .2 design of custom trapeze supports to conform to the requirements of MSS SP-58,
- .3 designed and sealed by a professional engineer licensed in the jurisdiction of the work.
- .4 design criteria:
 - (a) static design load: deadweight of supported services plus 1.5 kN (250 lbf) point load at the mid-span,
 - (b) dynamic loads: include for seismic loads where system is subject to seismic restraint, and for wind and snow loads where located outdoors, superimposed on static design load,
 - (c) maximum trapeze deflection at any point: 1/250 (0.4%) of trapeze span,
 - (d) design load for carbon steel materials: not to exceed 28% of minimum tensile strength nor exceed 50% of minimum yield strength in tension/compression and bending,
 - (e) design load for stainless steel and low alloy steel materials: not to exceed 20% of minimum tensile strength and 45% of minimum yield strength in tension/compression and bending.
- .5 for concurrent tension/compression loads and bending loads, the sum of the ratio of the stresses to allowable stress shall not exceed 1.0.

$$\frac{\text{Stress in Tension or Compression}}{\text{Allowable Tension or Compression Stress}} + \frac{\text{Stress in Bending}}{\text{Allowable Bending Stress}} \leq 1.0$$

.3 Hanger rods:

- .1 minimum of two support rods per trapeze,
- .2 rod size selected not to exceed 80% of the allowable maximum rod tensile load rating in accordance with MSS SP-58,

.4 Pipe restraint:

- .1 restrain pipes from lateral movement with:
 - (a) bolt-on angle brackets or pipe U-bolts for manufactured hangers, or
 - (b) welded-on angles for fabricated hangers,
- .2 restraints to permit axial linear movement and axial-rotation, except where otherwise shown to be an anchor.

2.16 Horizontal Pipe Support – Drainage MJ

- .1 For support of horizontal cast iron drainage piping, as an alternative to clevis hangers.
- .2 Designed to support each end of the pipe on both sides of a drainage MJ joint, and at intermediate supports, elbows and tees.
- .3 Carbon steel, plain finish.

- .4 Pipe size: NPS 2 to NPS 6

Standard of Acceptance

- Anvil - fig. 250
- Taylor – fig. 25

2.17 Vertical Pipe Stanchions

- .1 Pipe support stanchion, with welded attachment:

- .1 fixed height, or telescoping two-piece design with height adjustment, field-welded to pipe elbow or horizontal pipe,
- .2 carbon steel, structural cylinder shape,
- .3 designed for static loads of pipe and contents, as well as dynamic loads and anchor loads as shown,
- .4 nominal pipe size: NPS 2 to NPS 18.

Standard of Acceptance

- Anvil - fig. 62

2.18 Vertical Pipe Riser Clamps

- .1 Steel pipe, cast iron pipe:

- .1 carbon steel clamps for carbon steel piping and cast iron piping,
- .2 stainless steel clamps for stainless steel piping,
- .3 listed to ULC/ORD-C203 or UL 203 for fire protection piping,
- .4 supplied with field-welded pipe support lugs of same material as supported steel pipe (not including cast iron pipe).
- .5 floor supported pipe riser clamps, to ANSI/MSS SP-58, type 8,

Standard of Acceptance

- Anvil - fig. 261
- Taylor – fig. 82

- .6 suspended pipe riser clamps, 4 or 6 bolt patterns, to ANSI/MSS SP-58, type 42,

Standard of Acceptance

- Anvil - fig. 40, 40SS
- Taylor – fig. 82HCopper pipe and tube:

- .7 floor supported pipe riser clamps, carbon steel with copper plated finish, to ANSI/MSS SP-58, type 8,

Standard of Acceptance

- Anvil - fig. CT-121
- Taylor – fig. 85

2.19 Vibration Isolation Supports

- .1 Refer to specification section 20 05 48.

2.20 Variable Spring Load Supports

- .1 General:
 - .1 variable spring load supports to maintain supported load under pipe thermal movement conditions, so that the variation in supported load does not exceed 25% of the operating load.
 - .2 selected for piping loads and estimated travel under service conditions.
- .2 Construction:
 - .1 carbon steel housing and spring, to MSS SP-58 types 51, 52 and 53.
 - .2 pre-compressed spring to be within 80% of the calculated in-service load,
 - .3 load indicator,
 - .4 welding to ASME Section IX
 - .5 welded attachment points
 - .6 finish: semi-gloss primer coat.

Standard of Acceptance

- ° Anvil – fig 82, 268, 98

2.21 Constant Load Supports

- .1 General:
 - .1 maintains constant support load under variable pipe displacements,
 - .2 deviation in supported load due to thermal movement does not exceed 6% of the operating load,
 - .3 selected for piping loads and estimated travel under service conditions, with a minimum safety factor of 25 mm (1 in) extra travel or 20% of total travel, whichever is greater.
- .2 Construction:
 - .1 carbon steel housing and spring, to MSS SP-58 types 54, 55 and 56
 - .2 combination hanger moment arm and balancing spring design,
 - .3 horizontal and vertical arrangements,
 - .4 load adjustment and load indicator scale,
 - .5 factory set for load and travel,
 - .6 welding to ASME Section IX
 - .7 welded attachment points
 - .8 finish: semi-gloss primer coat.

Standard of Acceptance

- ° Anvil – fig R 80-V, 81-H
- ° Taylor – fig. RCS

2.22 Cast Iron Pipe Joint Restraint

- .1 Joint restraint rodding assembly for cast iron and asbestos cement drain waste and vent pipe, for each branch, tee, wye and clean-out fittings on drainage piping NPS 5 and over.
- .2 Clamp and rod joint restraint:

- .1 carbon steel pipe clamps with four bolt fasteners and rod washers, plain finish, to MSS SP-58, Type 8,
- .2 carbon steel threaded rods and load nuts,
- .3 two pipe clamps and two restraint rods required for each joint.

Standard of Acceptance

- Taylor – fig. 35

2.23 Insulation Shields

- .1 Insulation shields:
 - .1 galvanized steel protection shield, thickness and length as applicable to pipe size, to MSS SP-58 type 40
 - .2 designed to meet MSS SP-58 maximum support spans with insulation inserts having a compressive strength of 620 kPa (90 psi).
 - .3 pipe size: NPS ½ to 24,
 - .4 insulation thickness: 12 mm to 50 mm (1/2 in. to 2 in.).
 - .5 gauge: minimum 18 ga.
 - .6 sleeve width: minimum 180 degree arc of insulation exterior surface
 - .7 minimum sleeve length:
 - (a) pipe NPS ½ to 4: 300 mm (12 in.)
 - (b) pipe NPS 6: 450 mm (18 in.)
 - (c) pipe NPS 8 to 24: 600 mm (24 in.)

Standard of Acceptance

- Anvil - fig. 167 (up to NPS 24)
- Anvil - fig. 168 (up to NPS 8)
- Taylor – fig. 69H

- .8 sleeve length exemption: sleeve lengths may be reduced where shield is supplied as an integrated part of a high density insulation insert system. – refer to Specification section 20 07 19.
- .2 Heavy-duty insulation shield:
 - .1 for piping NPS 18 and larger installed on roller hangers and trapeze hangers,
 - .2 insulation shield as specified above plus a heavy duty support plate as follows,
 - .3 support plate fabrication: 6 mm (1/4 in.) thick ASTM A36 galvanized steel rolled plate, inside diameter to fit outer radius of insulation shield,
 - .4 size:
 - (a) width: minimum 120 degrees arc of mating insulation shield,
 - (b) length: not more than 100 mm (4 in.) shorter than the primary shield.
 - .5 Support plate tack welded to the insulation shield.

2.24 Insulation Pipe Saddles

- .1 Carbon steel or stainless steel (to match pipe material) saddle welded to pipe with insulation inserted between saddle and pipe, to MSS SP-58 type 39.
- .2 For pipe sizes NPS ¾ to 36.

- .3 Insulation thickness range: 25 to 140 mm (1 to 5.5 in.)

Standard of Acceptance

- Anvil - fig. 160 to 166
- Taylor – fig. 70 to 77

3 EXECUTION

3.1 General

- .1 Where the specific requirements for pipe supports are specified in other sections of Division 20 to 23, the requirements of those sections take precedence over the requirements of this specification section.

3.2 Coordination with Concrete Work

- .1 Supply, deliver and install concrete inserts in ample time to be built into the work of Division 03.
- .2 Correctly position and set concrete inserts onto concrete formwork for pipes and equipment hangers. Secure inserts firmly to formwork before concrete is poured.
- .3 Do not use explosive drive pins in any section of the Work without obtaining prior approval from the Consultant.

3.3 Support and Hanger Installation – General Requirements

- .1 Support piping directly on or from structural building elements. Do not support pipe directly from other services. Multiple piping services may be supported on a common trapeze support.
- .2 Provide all miscellaneous materials including nuts, washers, and backing plates to make a complete installation.
- .3 Where wall brackets are used, select brackets and size mounting bolts and backing plates to suit the supported load, allowing for a safety factor by not loading the bracket more than 80% of its published load rating.
- .4 Do not support piping or tubing in direct contact with hangers or supports of dissimilar metallic material. Select hangers to include an electrical insulating material between the hanger and the pipe, or provide electrical insulating material.
- .5 Coordinate location of pipe supports with pipe flexible connectors, pipe guides and pipe anchors provided under specification section 20 05 16.
- .6 In steel framed construction, support piping from structural members. Where structural members are not suitably located for upper hanger attachment locations, and where inserts of adequate capacity cannot be installed in concrete slabs, provide supplementary steel framing members;
 - .1 fabricate supplementary steel from standard HSS sections, single EL section, double C “strongback” sections, or pipe lengths,
 - .2 size supporting steel to limit horizontal span deflection to 1/250 (0.4%) between connecting points to the structure,
 - .3 mechanically fasten supplementary steel to structural steel to prevent axial and transverse displacement, and rotation.
- .7 It is permissible to offset hangers and displace the hanging rod so that in the final operating position, the hanging rods are within 4° of vertical.
- .8 Provide a pipe support within 300 mm (12 in.) of;
 - .1 an elbow or tee,

- .2 a concentrated load, including but not limited to valves, strainers and flanges,
- .3 a connection to equipment.
- .9 Where hanger rods are used, provide load nuts on top and load nuts on the underside of attachment to the pipe support, including clevis hangers, roll supports, roll yoke hangers, and trapeze hangers.

3.4 Horizontal Pipe Support Spacing and Hanger Rod Size

- .1 Provide horizontal pipe supports at the spacing as detailed in the Schedule "A" included at the end of this Specification section, unless specified otherwise in other sections of Division 20 to 23.
 - .1 Schedule "A" includes alternate hanger rod size and support spans for reduced rod sizes.
- .2 Use threaded rod of the size based on pipe type and horizontal pipe hanger spacing as stated in the Schedule "A" for single rod hangers. Where the pipe hanger type requires two rods, the rod size may be reduced by one trade size but shall not be less than Ø3/8 in.
- .3 For piping using flexible roll-groove joints, there shall be not less than one hanger between pairs of joints.
- .4 Support plastic and other special piping, including anchors and guides, in accordance with the pipe manufacturer's requirements.

3.5 Horizontal Pipe Hanger and Support Selection

- .1 Select horizontal pipe hanger and support type based on pipe size and fluid service temperature in accordance with Schedules "B(1)" and "B(2)" at the end of this section.
- .2 For fire protection piping;
 - .1 use clevis hangers for all pipe sizes,
 - .2 swivel ring pipe hangers may be used for fire protection piping NPS 4 and smaller.
- .3 Swivel ring pipe hangers may only be used for;
 - .1 drain waste and vent (DWV) piping and tubing, NPS 4 and smaller,
 - .2 medical gas piping and laboratory gas piping, NPS 4 and smaller,
 - .3 compressed air piping and tubing located downstream of a refrigerated dryer, NPS 2 and smaller,
 - .4 chemical treatment piping NPS 2 and smaller.
- .4 For cast iron drainage and vent piping;
 - .1 use clevis hangers for suspended supports,
 - .2 drainage MJ type hangers may be used on hub-less cast iron piping,
 - .3 use roller or slide type supports for bottom supported piping. For slide supports, use a variant incorporating pipe band clamps in lieu of welded attachment.
- .5 For other piping, select pipe support types in accordance with Schedule B at the end of this section.
- .6 For pipe size NPS 16 to 24, a clevis hanger may be used to support a concentrated load, provided it is used only to locally support the concentrated load and there is a separate pipe run support within one-third of the maximum allowable span on each side of the concentrated load.
- .7 The use of a half-section of a suspended pipe clamp to support a horizontal pipe using two threaded rods is prohibited unless the manufacturer has written installation instructions permitting such use. The use of a pipe riser clamp for this purpose is prohibited.

3.6 Clevis Hangers

- .1 Where clevis hangers are used for cold piping, select clevis to fit the outside dimension of pipe and associated insulation.
- .2 Where clevis hangers are used for heating piping;
 - .1 select clevis to fit the pipe diameter only (clevis located inside of insulation) for small diameter piping in accordance with Schedule "C" at the end of this section,
 - .2 for larger diameter piping, select clevis to fit the outside dimensions of pipe and insulation – refer to Schedule "C" at the end of this section,
 - .3 where the distance from the building support element to the clevis pin is less than the value shown in the standard details at the end of this section, use an alternative method of support;
 - (a) exception: where the pipe is installed tight to the structure, the exposed length between the structural attachment and the top of the clevis shall not exceed 25 mm (1 in.).
- .3 Where clevis hangers are used for stainless steel pipe or tube and for copper tube;
 - .1 use copper or epoxy finished carbon steel clevis hangers for copper pipe/tube,
 - .2 use stainless steel or alloyed steel clevis hangers (for stainless steel pipe/tube), or
 - .3 use a standard clevis hanger with integral non-metallic insulation saddles, and select hanger size for outside of the pipe and insulation.
- .4 Adjust clevis hangers to provide the required drainage slope and direction for each pipe.
- .5 Where the project requires seismic bracing of piping systems, add a Schedule 40 pipe over the clevis bolt, sized to provide at least 6 mm (1/4 in.) inside diameter clearance to the clevis bolt. This applies only where a transverse or longitudinal brace is attached to the clevis hanger.

3.7 Roll Hangers and Supports

- .1 For roll hangers, provide load and lock nuts to allow final adjustment of roll hanger to allow pipe drainage.
- .2 For roll supports supported above the structure element, the length of exposed threaded pipe between the roll support and the structural element shall not exceed 10 times the outside diameter of the rod.

3.8 Trapeze Hangers

- .1 Provide U-bolts or fabricated angles to restrict lateral pipe movement, while allowing pipe thermal axial motion and rotation;
 - .1 fasten U-bolts or angles to the trapeze hanger with top and bottom nuts,
 - .2 fabricated retention angles to extend vertically at least one-quarter the outside pipe/insulation diameter, and mechanically fasten to the trapeze,
 - .3 where seismic restraint is required, only use U-bolts.
- .2 Adjust trapeze hangers to provide the required drainage slope and direction for each pipe. If the trapeze serves multiple pipes having different drainage slopes or directions, provide shims under each pipe as necessary to provide required slope. Mechanically fasten or tack-weld the shim plates to the trapeze.

3.9 Slide Supports

- .1 For hot piping, weld the T or H slide directly to the pipe.
- .2 For cold piping, weld the T or H slide to the bottom half of a carbon steel clamp assembly.
- .3 Use slides with integral lateral movement limit lugs at pipe supports required to function as a guide. Movement clearance to be between 6 mm and 25 mm (1/4 to 1 in.).

- .4 Where seismic restraint is required, use slides with integral lateral and vertical-up movement limit lugs so that the maximum allowable movement does not exceed 6 mm (1/4 in.).
- .5 For fluid service temperatures of 121°C (250°F) and less, apply grease with a service temperature of not less than 200°C (392°F) over the entire bottom of the T or H slide.
- .6 For fluid service temperatures greater than 121°C (250°F) use a PTFE slide pad bonded to the underside of the slide and a matching PTFE slide pad bonded to the top of the structural steel support.

3.10 Vertical Pipe Supports

- .1 Pipe riser clamps:
 - .1 provide pipe riser clamps for non-insulated pipes NPS 4 and smaller at every second floor level for vertical pipe risers passing through two or more floors, unless other vertical pipe support types are shown,
 - .2 for steel pipe, provide support lugs welded to steel piping so that pipe lugs bear on the top-surface of the riser clamp,
 - .3 for copper tube and pipe, arrange vertical piping so that a pipe joint bears on the top-surface of the riser clamp.
- .2 Fabricated pipe riser supports:
 - .1 support piping NPS 6 and larger, using fabricated riser support brackets complete with reinforcing gusset plates welded or clamped to piping, designed not to exceed the maximum allowable local pipe stress at a load of not less than 200% of the supported load of:
 - (a) for the lowest support point of the riser, the supported pipe plus insulation weight for the lowest support interval plus the total water weight of the entire riser.
 - (b) except at the lowest support point of the riser, the pipe plus insulation weight for each support interval (except at the bottom of the riser).
- .3 Support vertical cold piping and hot piping for riser heights that are 25 m (82 ft) or less in height as follows:
 - .1 provide spring vibration isolators in accordance with specification section 20 05 48, attached to pipe riser supports at intervals of every 2nd storey or 10 m (32 ft), whichever is less,
 - .2 provide a pipe anchor at the base of the riser or the mid-height of the riser.
- .4 Support vertical cold piping and hot piping for riser heights that are greater than 25 m (82 ft) but do not exceed 50 m (165 ft) in height as follows:
 - .1 provide a custom engineered support system utilizing variable spring isolators,
 - .2 provide pipe anchors at the mid-point of the riser, and
 - .3 provide at least one spring support per riser section above and below the anchor point.
- .5 Support vertical cold piping and hot piping for riser heights greater than 50 m (165 ft) as follows:
 - .1 provide a custom engineered support system utilizing constant load supports for each pipe section located between expansion joints,
 - .2 variable spring supports may be used at intermediate locations between main constant load supports,
 - .3 provide pipe anchor supports at the base of the riser, and at intermediate locations along riser length at locations as shown,
 - .4 provide in-line expansion joints between each pair of pipe anchors on the same riser in accordance with Specification section 20 05 16,

- .5 design pipe anchors to withstand pressure thrust created by the expansion joints, unless pressure-balanced expansion joints are used,
- .6 Design riser anchors to support the deadweight of the riser pipe, fluid contents and insulation. Where seismic restraint is required, the anchors may also be designed to resist the seismic horizontal and vertical loads.
- .7 Where custom engineering riser supports are required, they are to be designed to meet the following criteria:
 - .1 the maximum vertical movement of a horizontal branch pipe is not to exceed 20 mm (0.75 in) from its installation temperature to its in-service temperature,
 - .2 the maximum vertical movement of the horizontal mains pipe at the base or top of the riser is not to exceed 40 mm (1.5 in.) from its installation temperature to its in-service temperature, provided that the horizontal piping adjacent to the riser are also supported on variable spring supports for the first three horizontal support points.

3.11 Pipe Saddles and Shields

- .1 Provide pipe saddles and shields for insulated piping in accordance with Schedule "C" at the end of this section.
- .2 Provide pipe shields for uninsulated glass and plastic piping NPS 1-1/2 and larger.
- .3 Where piping is insulated and requires pipe shields, install the shields between pipe insulation and pipe support. Provide high-density insulation insert between pipe and insulation shields of the designation type as shown in Schedule "C" and as specified in accordance with specification section 20 07 19.
- .4 Where piping is not insulated and requires a pipe shield, install the shields between the pipe and the pipe support.
- .5 Where clevis hangers with integral insulation saddles are used, apply insulation sealant to the polypropylene saddle in accordance with the pipe hanger manufacturer's instructions;
 - .1 for hot piping, coordinate with the pipe insulation contractor to apply sealant coating to the integral saddle at the time pipe insulation is installed,
 - .2 for cold piping, seal the saddle's pipe contact surfaces with vapour-barrier sealant before the piping is installed. Finish sealing the remainder of the saddles' exposed faces when pipe insulation is installed.

3.12 Rooftop Supports

- .1 For manufacturer rooftop pipe supports, conform to Specification section 20 05 06.

3.13 Vibration Isolation Supports

- .1 Provide vibration isolators at pipe supports for horizontal piping in accordance with specification section 23 05 48.
- .2 Provide vibration isolators at vertical pipe (riser) supports in accordance with specification section 20 05 48.
- .3 When installed with clevis hangers, install the vibration isolators below the top surface of the clevis; do not attach the vibration isolator to the structural element.

3.14 Variable Load Supports

- .1 Provide variable load supports on piping connections NPS 10 or larger at motorized equipment as follows:

- .1 locate the support as close as possible to the equipment connection, and beyond any flexible connector (where required),
 - .2 select the support to have a static displacement to be equal to the static displacement of the equipment vibration isolator, but not less than 20 mm (0.75 in),
 - .3 set the support load so that the total pipe weight imposed on the equipment connection does not exceed the maximum allowable load as defined by the equipment manufacturer.
- .2 Provide variable load supports for vertical pipe supports as shown.
 - .3 Provide variable load supports in mechanical rooms where piping transitions from horizontal to vertical where it enters a vertical service shaft. Provide vibration isolation hangers for other locations in accordance with Section 20 05 48 Vibration Isolation.

3.15 Constant Load Supports

- .1 Provide constant load supports for vertical pipe supports as shown and as follows:
 - .1 pipe risers, located at the top of the riser, and intermediate riser locations,
 - .2 first hanger support for main steam piping connections NPS 6 and larger to steam boilers,
 - .3 first hanger support for water piping connections NPS 10 and larger to hot water boilers,
 - .4 first hanger support for water piping connections NPS 12 and larger to refrigeration equipment,
 - .5 first hanger support inside the building for water piping NPS 12 and larger for condenser water piping to a cooling tower.]

3.16 Temporary Supports for Steam Piping

- .1 Where steam piping support spacing is in accordance with Schedule A for steam and gas piping, provide temporary intermediate supports for hydrostatic pressure testing so that the support spans do not exceed the values in Schedule A for water filled pipe.

3.17 Set-up After Installation

- .1 Adjust hangers to equalize hanger loads, to support piping true to line and grade, and to minimize loads transferred through connections to equipment and outlets.

3.18 Schedules

- .1 The following appended schedules form part of this Specification section.
 - .1 Schedule A1(a) Horizontal Pipe Support Loads and Support Spans – Schedule 20 to 80 Pipe
 - .2 Schedule A1(b) Alternate Hanging Rod Sizes and Support Spans for Schedule 20 to 80 Pipe
 - .3 Schedule A2(a) Horizontal Pipe Support Loads and Spans – Schedule 10/10S Stainless Steel Pipe
 - .4 Schedule A2(b) Alternate Hanging Rod Sizes and Support Spans for Schedule 10/10S Stainless-steel Pipe
 - .5 Schedule A3 Horizontal Pipe Support Loads and Spans – Copper and Stainless Steel Tube
 - .6 Schedule B Pipe Support Type Selection Requirements
 - .7 Schedule C Insulation Protection Requirements

3.19 Standard Details

- .1 The following standard details are appended to the end of this Specification section.
 - .1 20 05 29-010 Cold Piping and Dual-Temperature Piping – Clevis Hanger Detail
 - .2 20 05 29-011 Cold Piping and Dual-Temperature Piping – Roll Hanger Detail
 - .3 20 05 29-012 Cold Piping and Dual-Temperature Piping – Trapeze Hanger Detail
 - .4 20 05 29-013 Cold Piping and Dual-Temperature Piping – Slide Support Detail
 - .5 20 05 29-020 Hot Piping – Clevis Hanger Detail
 - .6 20 05 29-021 Hot Piping $\leq 100^{\circ}\text{C}$, Small Size Piping – Clevis Hanger Details
 - .7 20 05 29-022 Hot Piping – Roll and Trapeze Hanger Detail
 - .8 20 05 29-023 Hot Piping – Slide Support Detail
 - .9 20 05 29-030 Slide Supports – Guides and Seismic Restraint

Schedule A1(a)

**Horizontal Pipe Support Spacing
for
Carbon Steel, Galvanized Steel, Stainless-steel Piping
Schedule 20 to 80 Inclusive**

Notes for Schedule A1(a) and A1(b):

[1] Hanging rod size for single support. Where two supports are used, the rod size may be reduced by one size but not less than Ø3/8 in..

[2] Subject to load capacity of hanger components other than the hanging rod.

[3] Where piping is hydrostatically tested with water, temporary pipe supports are required to limit pipe span to the "liquids" values.

[4] For trapeze hangers only.

Pipe Size NPS	Rod Diameter Single Support [Note 1] Inches	Maximum Support Spacing, Liquids [Note 2] m (ft)	Maximum Support Spacing Steam, Gases [Note 2, 3] m (ft)
½	Ø 3/8	1.8 (6)	1.8 (6)
¾ to 1¼	Ø 3/8	2.1 (7)	2.1 (7)
1½	Ø 3/8	2.7 (9)	2.7 (9)
2	Ø 3/8	3.0 (10)	4.0 (13)
2½	Ø ½	3.3 (11)	4.3 (14)
3	Ø ½	3.3 (12)	4.6 (15)
4	Ø 5/8	4.2 (14)	5.2 (17)
6	Ø ¾	5.1 (17)	6.4 (21)
8	Ø ¾	5.7 (19)	7.3 (24)
10	Ø 7/8	6.7 (22)	7.9 (26)
12	Ø 7/8	7.0 (23)	9.1 (30)
14	Ø 1	7.5 (25)	9.8 (32)
16	Ø 1	8.0 (27)	10.7 (35)
18	Ø 1 [Note 4]	8.4 (28)	11.3 (37)
20	Ø 1-1/4 [Note 4]	9.0 (30)	11.9 (39.0)
24	Ø 1-1/2 [Note 4]	9.6 (32)	12.8 (42.0)
30	Ø 1-1/2 [Note 4]	10.0 (33)	13.4 (44.0)

Schedule A1(b)

**Alternate Rod Sizes and Pipe Spans
For Pipe Sizes NPS 10 to 16
Carbon Steel, Galvanized Steel, Stainless-steel Piping
Schedule 20 to 80 Inclusive**

The following table provides alternate combinations of rod hanger size and associated support spacing for select pipe sizes.

Pipe Size NPS	Rod Diameter Single Support [Note 1] Inches	Maximum Support Spacing, Liquids [Note 2] m (ft)	Maximum Support Spacing Steam, Gases [Note 2, 3] m (ft)
10	Ø 3/4	4.0 (13)	6.7 (22)
12	Ø 3/4	3.0 (10)	5.8 (19)
14	Ø 3/4	2.7 (9)	5.2 (17)
	Ø 7/8	5.8 (19)	9.1 (30)
16	Ø 3/4	2.1 (7)	4.6 (15)
	Ø 7/8	4.9 (16)	7.9 (26)

Schedule A2(a)
Horizontal Pipe Support Spacing
For
Stainless-steel Pipe
Schedule 10/10S

Notes for Schedule A2(a) and A2(b):

[1] Rod size for single support. Where two supports are used, the rod size may be reduced by one size but not less than Ø 3/8 in..

[2] Subject to load capacity of hanger components other than the hanging rod.

[3] Where piping is hydrostatically tested with water, temporary pipe supports are required to limit pipe span to the "liquids" values.

[4] For trapeze hangers only.

Pipe Size NPS	Rod Diameter Single Support [Note 1]	Maximum Spacing, Liquids [Note 2] m (ft)	Maximum Spacing Steam, Gases [Note 2, 3] m (ft)
½	Ø 3/8	1.83 (6)	2.45 (8)
¾	Ø 3/8	2.1 (7)	2.75 (9)
1	Ø 3/8	2.45 (8)	2.75 (9)
1¼	Ø 3/8	2.75 (9)	2.75(9)
1½	Ø 3/8	2.75 (9)	3.65 (12)
2	Ø 3/8	3.10 (10)	4.0 (13)
2½	Ø 1/2	3.35 (11)	4.3 (14)
3	Ø 1/2	3.65 (12)	4.6 (15)
4	Ø 5/8	4.25 (14)	5.2 (17)
6	Ø 3/4	4.9 (16)	6.4 (21)
8	Ø 3/4	5.5 (18)	7.3 (24)
10	Ø 7/8	5.8 (19)	7.9 (26)
12	Ø 7/8	6.1 (20)	9.2 (30)
14	Ø 1	7.0 (23)	9.7 (32)
16	Ø 1	7.3 (24)	10.7 (35)
18	Ø 1 [Note 4]	7.3 (24)	11.3 (37)
20	Ø 1-1/4 [Note 4]	7.6 (25)	11.9 (39)
24	Ø 1-1/2 [Note 4]	7.3 (25)	11.9 (42)
30	Ø 1-1/2 [Note 4]	8.5 (28)	12.8 (44)

Schedule A2(b)

**Alternate Rod Sizes and Pipe Spans
For Pipe Sizes NPS 10 to 16
Stainless-steel Pipe
Schedule 10/10S**

The following table provides alternate combinations of rod hanger size and associated support spacing for select pipe sizes.

Pipe Size NPS	Rod Diameter Single Support [Note 1] Inches	Maximum Spacing, Liquids [Note 2] m (ft)	Maximum Spacing Steam, Gases [Note 2, 3] m (ft)
10	Ø 3/4	4.9 (16)	4.9 (16)
12	Ø 3/4	3.7 (12)	3.7 (12)
14	Ø 3/4	2.7 (9)	2.7 (9)
	Ø 7/8	5.2 (17)	6.1 (20)
16	Ø 3/4	2.4 (8)	2.4 (8)
	Ø 7/8	4.3 (14)	5.2 (17)

Schedule A3

**Horizontal Pipe Support Spacing
For
Copper Tube and Stainless-steel Tube**

Notes for Schedule A3:

[1] Rod size for single support. Where two supports are used, the rod size may be reduced by one size but not less than M10 (3/8 in.).

[2] Subject to load capacity of hanger components other than the hanging rod.

Pipe Size NPS	Rod Diameter Single Support [Note 1] Inches	Maximum Spacing, Liquids and Gases [Note 2] m (ft)
½	Ø 3/8	1.5 m (5 ft)
¾ to 1¼	Ø 3/8	1.8 m (6 ft)
1½	Ø 3/8	2.4 m (8 ft)
2	Ø 3/8	2.4 m (8 ft)
2½	Ø 1/2	3.0 m (10 ft)
3	Ø 1/2	3.0 m (10 ft)
4	Ø 5/8	3.0 m (10 ft)
6	Ø ¾	4.3 (14)
8	Ø ¾	4.9 (16)

Schedule B

Pipe Support Type Selection Requirements

The following tables B(1) and B(2) lists hanger types which are to be used based on pipe size and service temperature. Refer to Schedule C for additional requirements concerning insulation protection.

Pipe Support Type Legend

CL	Clevis hanger
CL(EY)	Clevis hanger with extended yoke for installation under pipe insulation
CL(IS)	Clevis hanger with integral insulation saddle
CL(LD)	Clevis hanger, light duty
SW	Swivel hanger
RS	Roll support
RH	Roll hanger with clevis
RB	Roll support with integral base
TS	T slide
HS	H slide
TZ	Trapeze

Application Legend

A	Acceptable
---	Not permitted

Table B(1):
Pipe Support Type Selection Requirements
For Fluid Service Temperatures up to 100°C (212°F) or Less

Pipe/Tube Size NPS	CL	CL (EY)	CL (IS)	CL (LD)	SW [Note 1]	RS	RH	RB	TS	HS	TZ
½ - ¾	A	A	A	A	A	---	---	---	---	---	A
1 - 4	A	A	A	A	A	A	A	A	A	---	A
6	A	A	A	---	---	A	A	A	A	A	A
8	A	A	A	---	---	---	A	A	A	A	A
10	A	A	---	---	---	---	A	A	A	A	A
12	A	A	---	---	---	---	A	A	A	A	A
14	A	---	---	---	---	---	A	A	A	A	A
16	A	---	---	---	---	---	---	A	A	A	A
18	---	---	---	---	---	---	---	A	A	A	A
20	---	---	---	---	---	---	---	---	A	A	A
24	---	---	---	---	---	---	---	---	---	A	A
30	---	---	---	---	---	---	---	---	---	A	A

Notes:

[1] For uninsulated ambient piping/tubing only.

Table B(2):

Pipe Support Type Selection Requirements
Fluid Service Temperatures greater than 100°C (212°F)
Including Steam at All Pressures

Pipe/Tube Size NPS	CL	CL (EY)	CL (IS)	CL (LD)	SW	RS	RH	RB	TS	HS	TZ
½ - ¾	A	---	---	A	---	---	---	---	---	---	A
1 - 4	A	---	---	A	---	A	A	A	A	---	A
6	A	---	---	---	---	A	A	A	A	A	A
8	A	---	---	---	---	---	A	A	A	A	A
10	---	---	---	---	---	---	A	A	A	A	A
12	---	---	---	---	---	---	A	A	A	A	A
14	---	---	---	---	---	---	A	A	A	A	A
16	---	---	---	---	---	---	---	A	A	A	A
18	---	---	---	---	---	---	---	A	A	A	A
20	---	---	---	---	---	---	---	---	A	A	A
24	---	---	---	---	---	---	---	---	---	A	A
30	---	---	---	---	---	---	---	---	---	A	A

Schedule C

**Insulation Protection Requirements
For Pipe Hanger/Support**

Notes for Schedule C:

[1] For the column Hanger Support Position, "Insulation" means hanger or support element is outside of the pipe and insulation. "Pipe" means hanger or support element is in direct contact with the pipe and is encased in the pipe insulation.

[2] "Pipe" position only applies to clevis hangers. For all other pipe supports, use the "Insulation" hanger/support position.

[3] Include heavy-duty support plate welded to shield.

[4] Restrictions apply to minimum length of hanger rod for heating piping at this temperature range. Refer to standard details.

[5] Refer to specification section 20 07 19 Piping Insulation for type P-21, P-22 and P-23 high-density insert specifications.

[6] Where ambient piping is required to be insulated under section 20 07 19, insulation is to be protected in accordance with the requirements for Low Temperature Piping.

[7] Insulation for Dual Temperature Piping is to be protected in accordance with the requirements for Cold Piping.

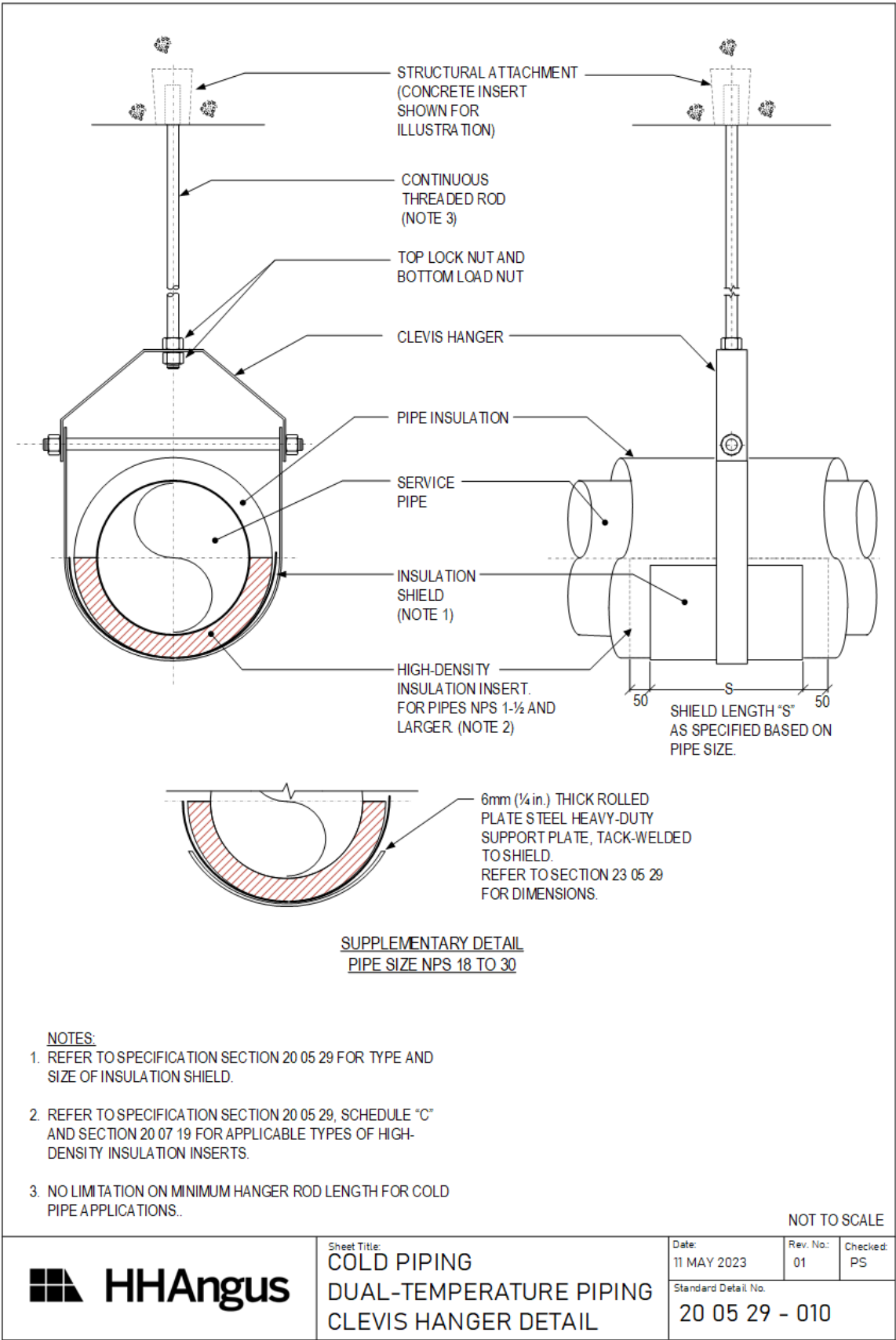
Application Legend for Insulation Saddle and Shields

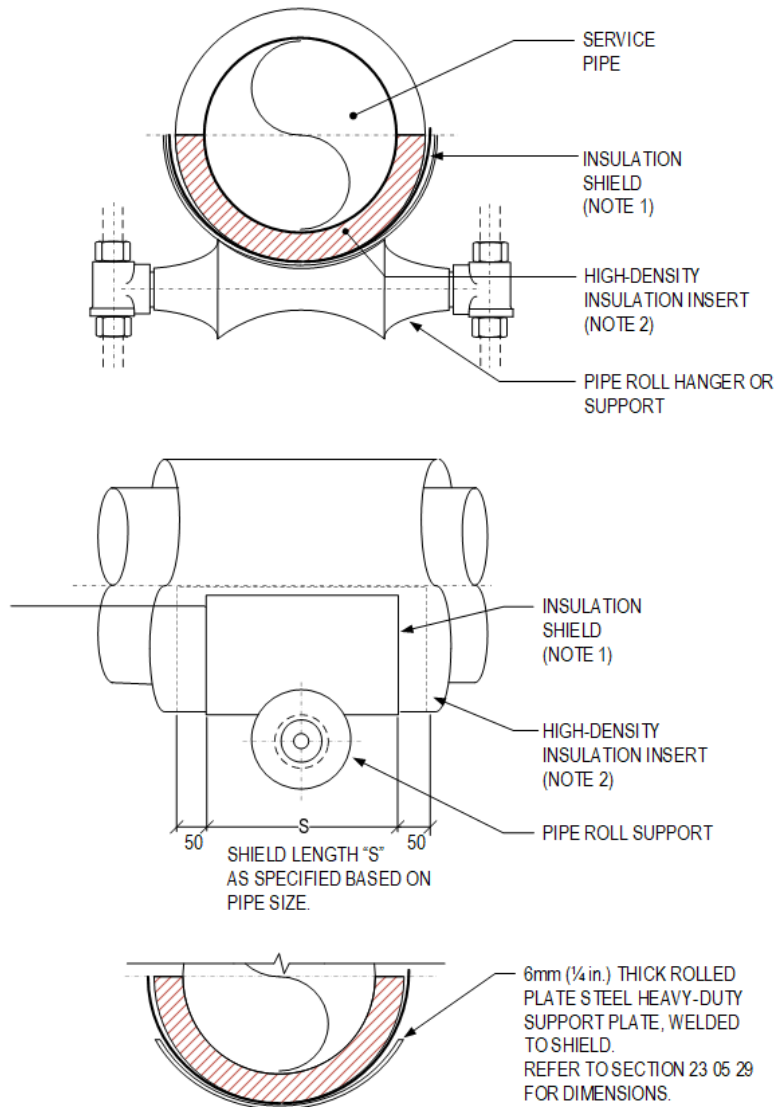
REQ	Required
ALT	Acceptable Alternate
	Not Applicable

Service Temperature °C (F)	Pipe Size NPS	Hanger/ Support Position [Note 1, 2]	Pipe Saddle	Insulation Shield	
				Shield	High-Density Insert Type [Note 5]
Hot Piping > 121 to ≤ 205 (> 250 to ≤ 400) Including steam >103 kPa (15 psi)	≥ 6	Insulation	REQ		
	>1-1/4 and ≤ 4	Insulation	ALT		
				ALT	P-23
	≤ 1-1/4	Insulation		REQ	
Hot Piping > 100 to ≤ 121 (> 212 to ≤ 250) Including steam ≤ 103 kPa (15 psi)	≥ 6	Insulation	REQ		
	>1-1/4 and ≤ 4	Insulation	ALT		
				ALT	P-21, P-22, or P-23
	≤ 1-1/4	Insulation		REQ	

Schedule C (Con't)

Service Temperature °C (F)	Pipe Size NPS	Hanger/ Support Position [Note 1, 2]	Pipe Saddle	Insulation Shield	High- Density Insert Type
Hot Piping 61 to 100 (141 to 212)	≥10 and ≤ 30	Insulation	REQ		
	≥ 6 and ≤ 16	Insulation	ALT		
				REQ	P-21, P-22, or P-23
	≥ 1-1/2 and ≤ 4	Insulation		ALT	P-21, P-22, or P-23
		Pipe [Note 4]	ALT		
	≤ 1-1/4	Insulation		ALT	
		Pipe [Note 4]	ALT		
Low Temperature Water 40 to 60 (104 to 140) [Note 6]	≥18 and ≤ 30	Insulation		REQ [Note 3]	P-21, P-22, or P-23
	≥ 6 and ≤ 16	Insulation		REQ	P-21, P-22, or P-23
	≥ 1-1/2 and ≤ 4	Insulation		ALT	P-21, P-22, or P-23
		Pipe	ALT		
	≤ 1-1/4	Insulation		ALT	
		Pipe	ALT		
Cold Piping 4 to 16 (39 to 61) [Note 7]	≥18 and ≤ 30	Insulation		REQ [Note 3]	P-21 or P-22
	≥ 1-1/2 and ≤ 16	Insulation		REQ	P-21 or P-22
	≤ 1-1/4	Insulation		REQ	
Fire protection piping	≥ 1-1/2	Pipe			
	≤ 1-1/4	Pipe			
MRI Quench Piping	All	Insulation		REQ	P-22





SUPPLEMENTARY DETAIL
PIPE SIZE NPS 18 TO 30

NOTES:

1. REFER TO SPECIFICATION SECTION 20 05 29 FOR TYPE AND SIZE OF INSULATION SHIELD.
2. REFER TO SPECIFICATION SECTION 20 05 29, SCHEDULE "C" AND SECTION 20 07 19 FOR APPLICABLE TYPES OF HIGH-DENSITY INSULATION INSERTS.
3. NO LIMITATION ON MINIMUM HANGER ROD LENGTH.

NOT TO SCALE



Sheet Title:
**COLD PIPING AND
DUAL-TEMPERATURE PIPING
ROLL HANGER DETAIL**

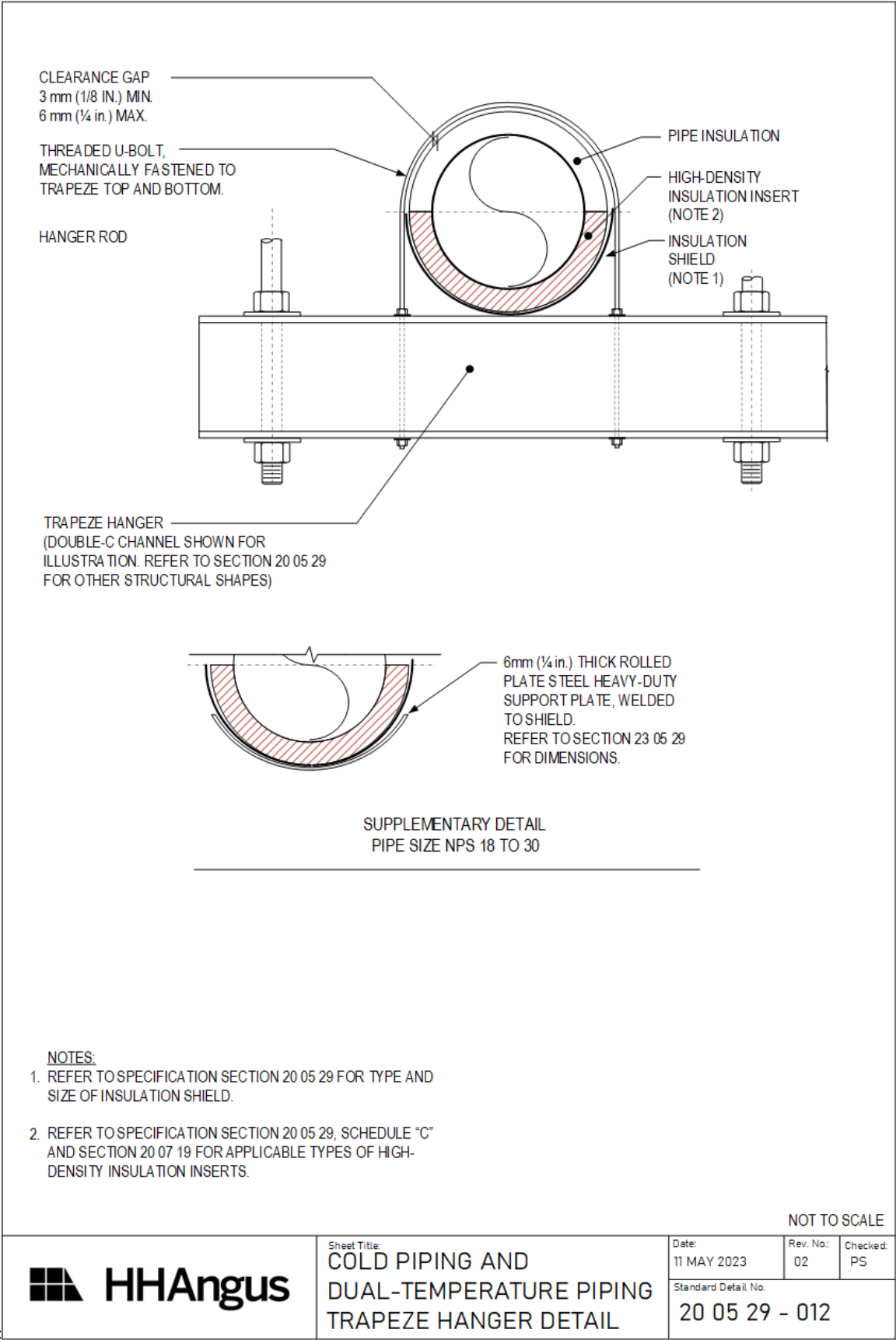
Date:
11 MAY 2023

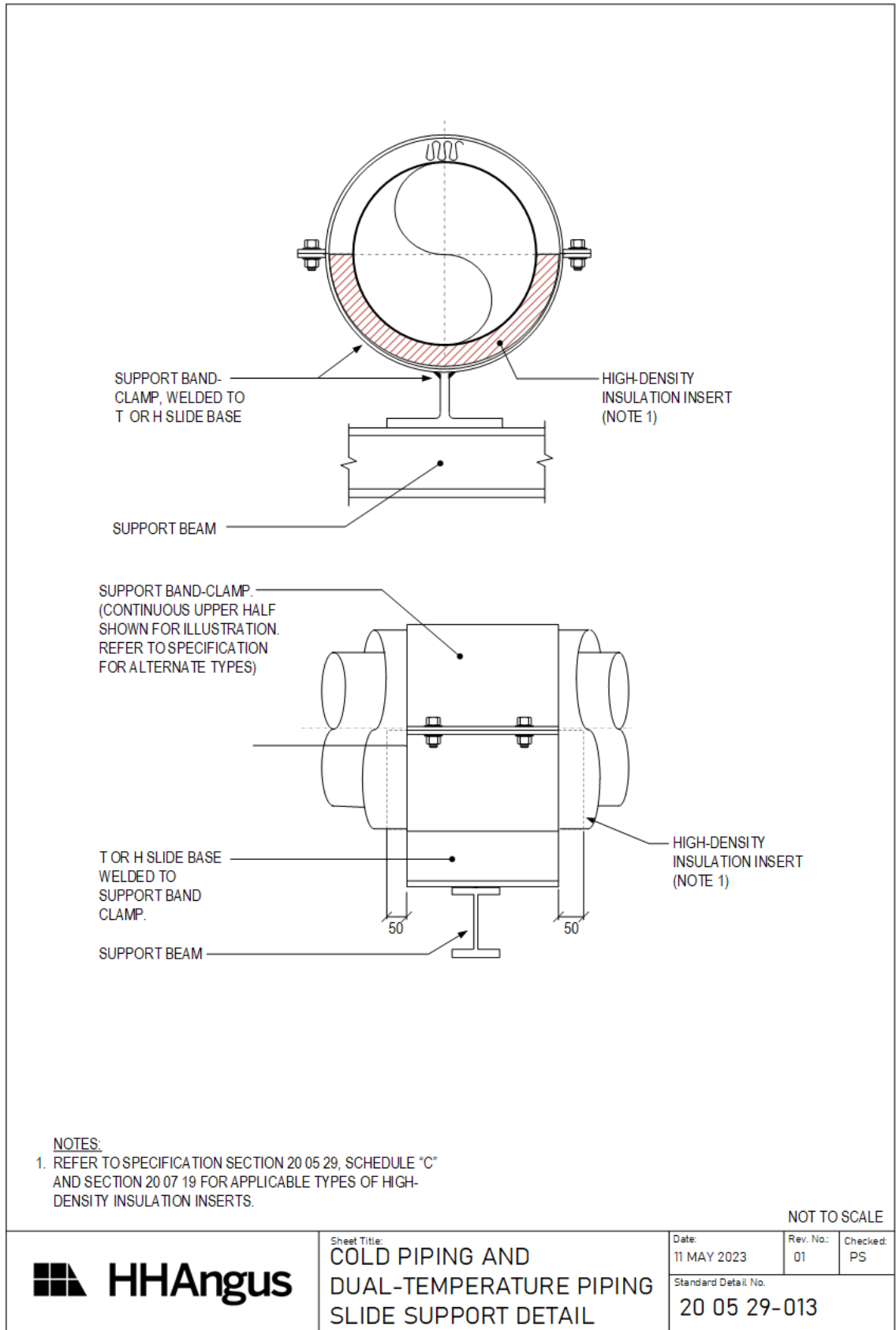
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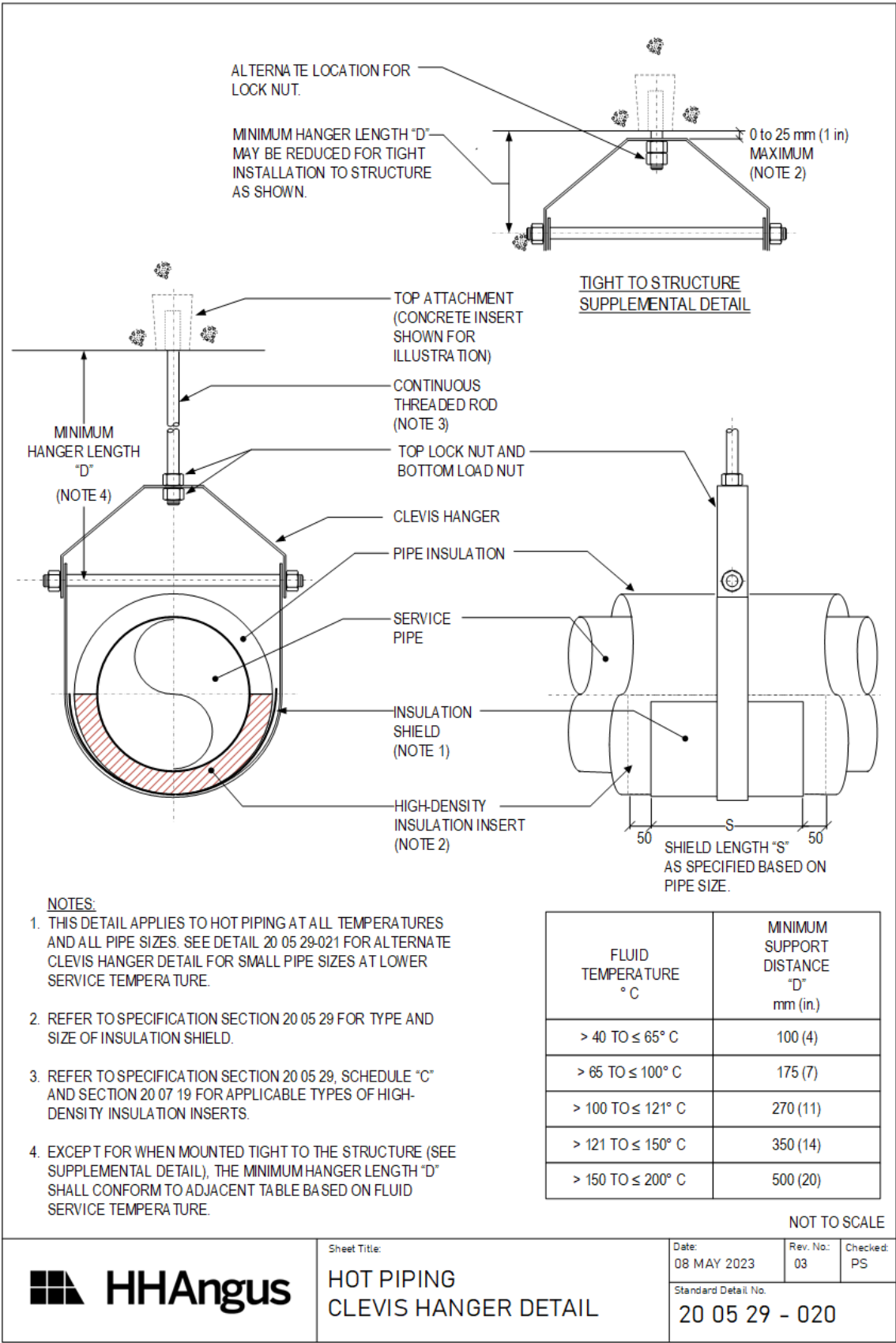
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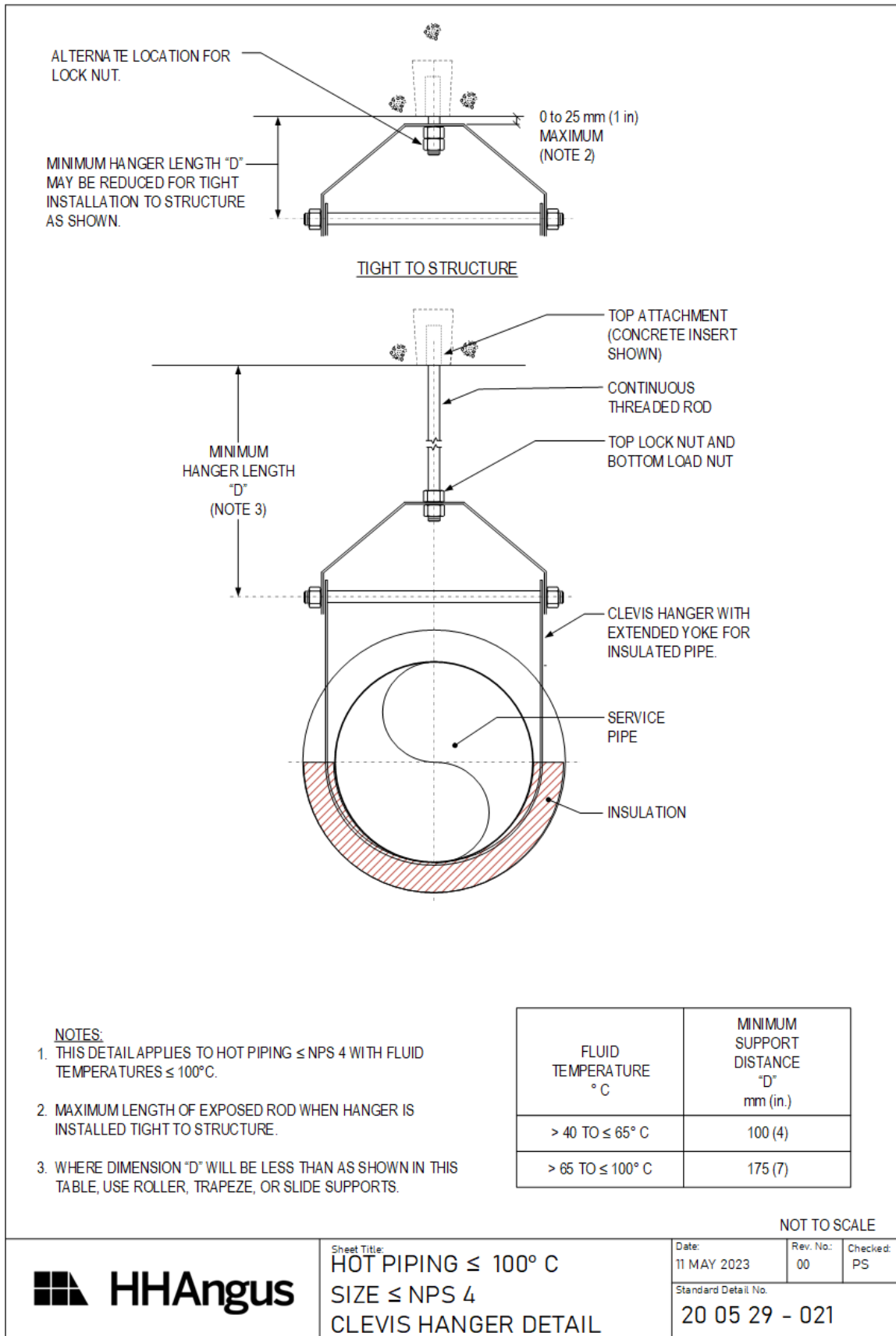
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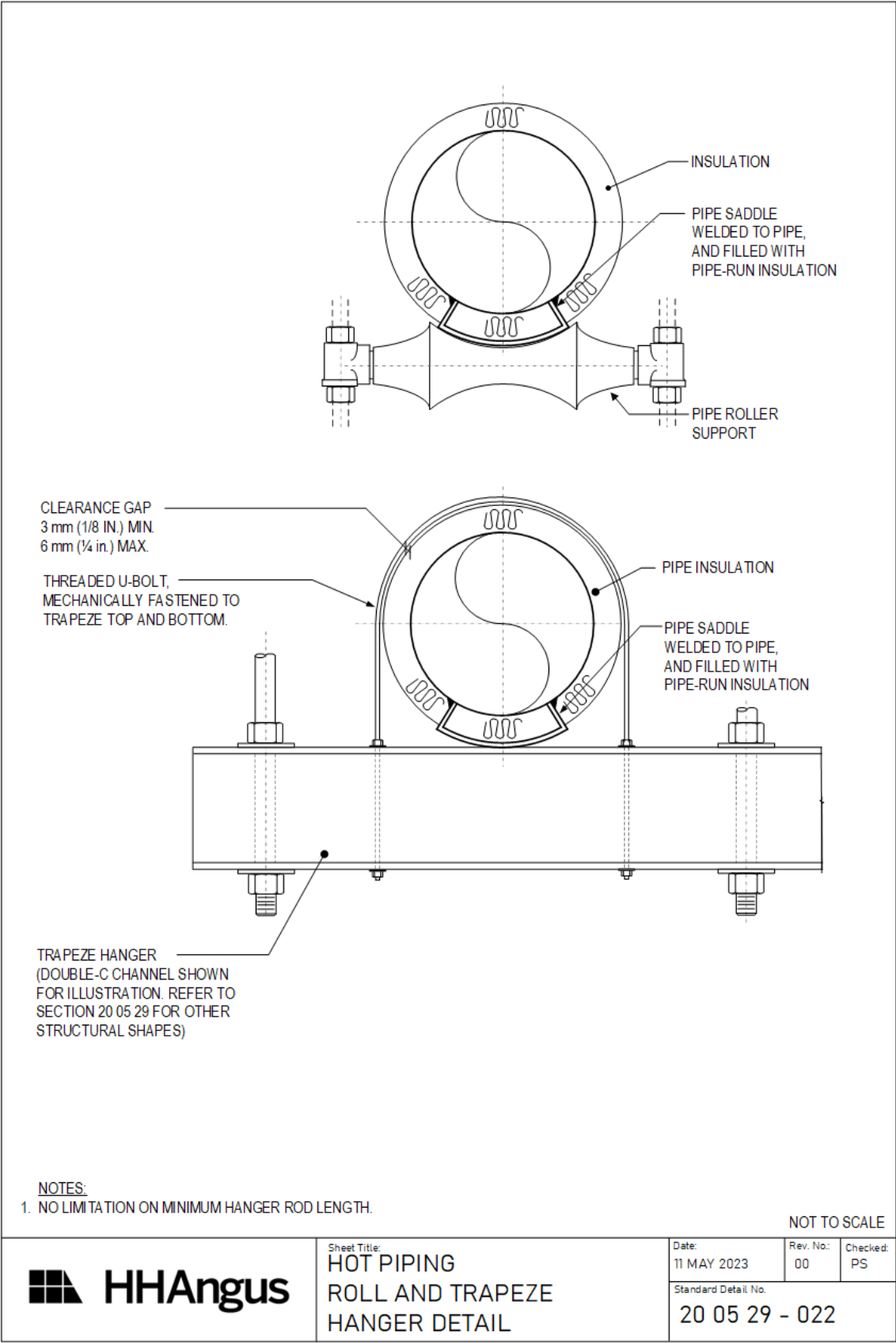
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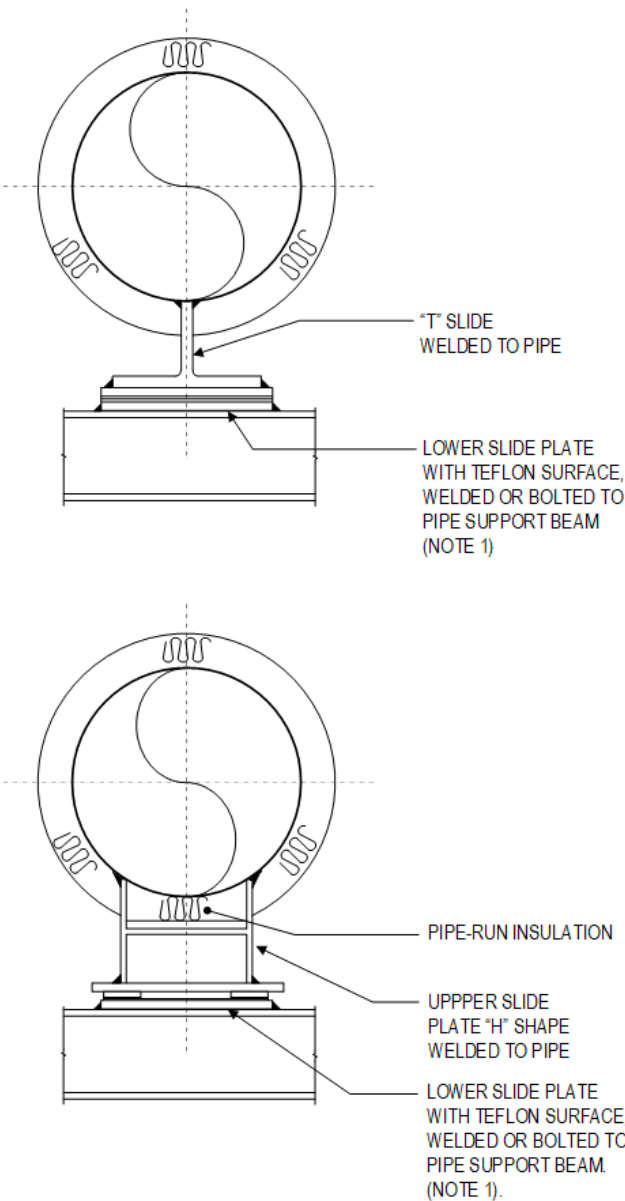












NOTES:

1. TEFLON SLIDE PLATES ONLY REQUIRED FOR HOT PIPING WITH
SERVICE TEMPERATURE > 121° C, INCLUDING STEAM AT
PRESSURES > 103 kPa.

NOT TO SCALE



HHA Angus

Sheet Title:

**HOT PIPING
SLIDE SUPPORT DETAILS**

Date:

11 MAY 2023

Rev. No:

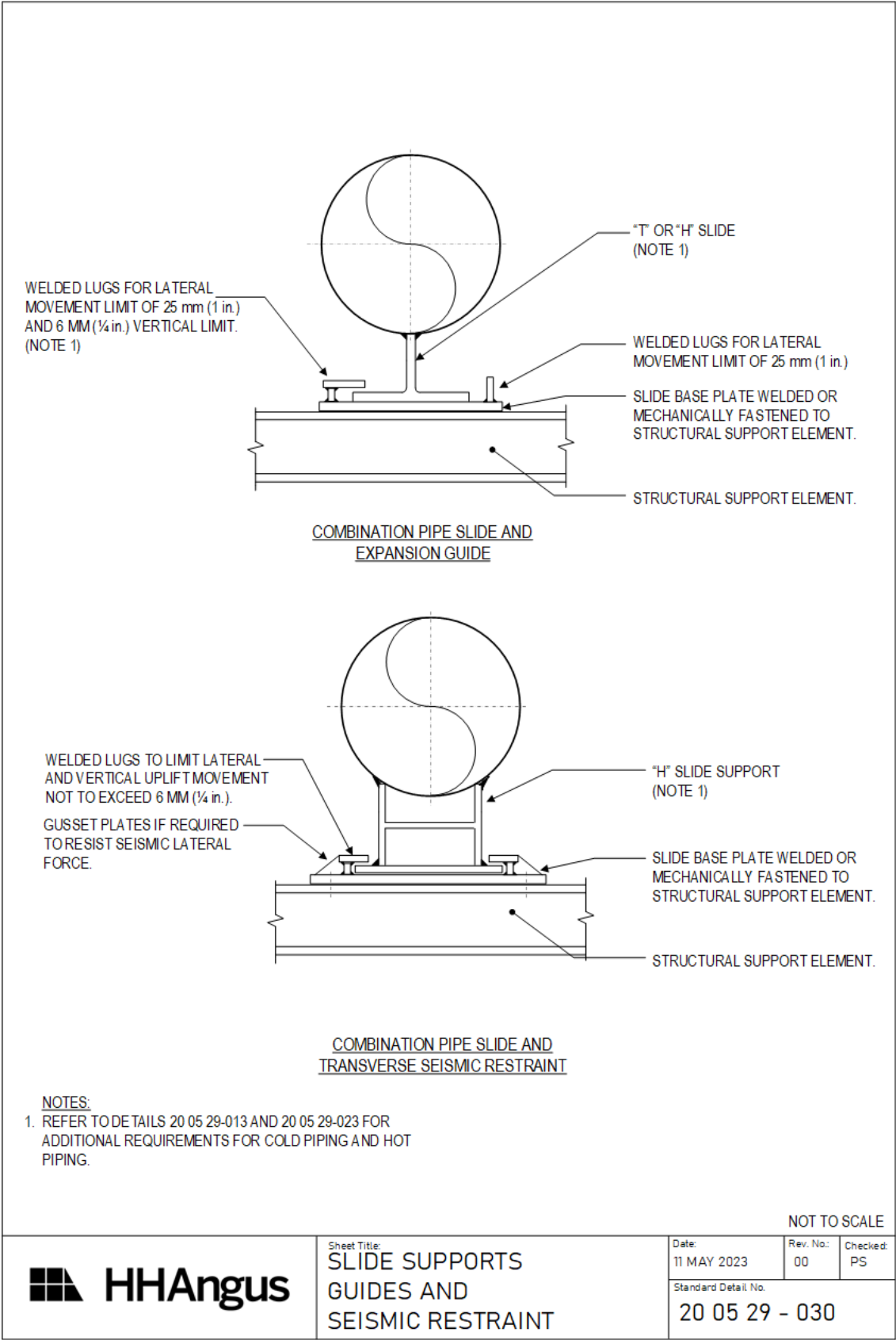
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Standard Detail No.

20 05 29 - 023



END OF SECTION

VIBRATION ISOLATION

20 05 48

1 GENERAL

1.1 Scope

- .1 Provide vibration isolation equipment for;
 - .1 vibration control for motor-driven mechanical equipment,
 - .2 vibration control for piping and ductwork connected to motor drive equipment,
 - .3 movement control for piping due to thermal movement, and
 - .4 movement control for piping due to building movement.
- .2 Provide engineering services associated with the design, analysis and selection of vibration isolation supports, including pipe riser supports.
- .3 Refer to specification section 20 05 29 for installation requirements for variable and constant load supports for pipe riser in excess of 25 m (82 ft) in height.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 12 Wiring Requirements for Mechanical Services
 - .2 20 05 29 Common Hanger and Support Requirements for Piping
 - .3 20 05 49 Seismic Restraint
 - .4 20 05 16 Flexible Connections, Expansion Joints, Anchors & Guides
 - .5 23 33 05 Duct Accessories

1.3 Applicable Codes and Standards

- .1 Product standards:
 - .1 ASTM A653-19 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
 - .2 ASTM B117 Standard Practice for Operating Salt Spray (Fog) Apparatus

1.4 Design Criteria

- .1 Isolator and base type designations are taken from the current ASHRAE Applications Handbook.
- .2 Base type, isolator type and minimum static deflection are shown in equipment schedules and/or equipment selection sheets.
- .3 Information shown in equipment schedules is to establish minimum standards and vibration isolation equipment to be selected to maintain noise levels in building below RC levels in following schedule.

AREA	NOISE CRITERIA (NC level)
Offices - private	32 to 34
-open plan	36 to 38
-business machine areas	40 to 42

AREA	NOISE CRITERIA (NC level)
-conference/boardrooms	30 to 32
Operating Rooms	25 to 27
Private Bedrooms	26 to 28
Hospital Wards	30 to 32
Public Areas	38 to 40

- .1 Provide a completely engineered design of pipe riser vibration isolated supports to minimize the pipe anchor loads under normal operating conditions, with engineering documents sealed by a professional engineer licensed in the jurisdiction of the Work.
- .2 Coordinate vibration isolation with seismic requirements under specification section 20 05 49.

1.5 Submittals

- .1 Submit shop drawings consisting of;
 - .1 product data sheets for isolation components,
 - .2 a schedule (or similar document) of vibration isolators selected for each piece of equipment, including equipment weight and isolator static deflection;
 - (a) where a common selection is used for multiple instances of the same equipment type, a single submission identifying all applicable equipment units is sufficient,
 - .3 drawing details for equipment bases, specific to each piece of equipment,
 - .4 fabrication details, location and size of anchor bolts and concrete requirements for inertia bases.
- .2 Submit shop drawings for the completely engineered pipe riser vibration isolation supports and pipe anchors;
 - .1 for each isolator, identify the estimated supported static loads, estimated supported operating loads (at temperature), spring deflections at static and operating conditions, spring deflections at static and operating condition, spring selections, and riser anchor design, including anchor loads at static and operating conditions,
 - .2 shop drawings to be sealed by a professional engineer licensed in the jurisdiction of the Work.

2 PRODUCTS

2.1 General Requirements

- .1 Provide vibration isolation equipment by one manufacturer.

Standard of Acceptance

- Vibro-Acoustics (Swegon NA)
- Kinetics
- BVA
- Korfund Mason
- Tecoustics

2.2 Resilient Isolator Pads – Type P1

- .1 Elastomer-in-shear pads:
 - .1 rubber waffle or ribbed pads:

- (a) 45 or 60 durometer neoprene depending on loading, minimum of 22 mm (7/8 in) thick,
- (b) load rating: up to 5 mm (0.19 in) static deflection and up to nominally 4400 kg (9700 lbs.) load,
- .2 rubber-steel-rubber pads:
 - (a) two layers of rubber waffle or ribbed pad, 13 mm (½ in) thick, as specified above,
 - (b) bonded to 6 mm (¼ in) steel plate, with holes sleeved and fitted with isolation washers.
- .3 Neoprene jacketed pre-compressed moulded fiberglass pads.

2.3 Elastomeric Mounts – Type M1

- .1 Molded neoprene mount:
 - .1 one piece, molded neoprene mount, with cast-in-top threaded steel load insert, and two hold down bolt openings on the bottom plate,
 - .2 load rating: up to 13 mm (0.5 in) static deflection and up to nominally 1800 kg (3960 lbs.) load,

2.4 Isolator Springs – Type S1

- .1 Open spring isolator:
 - .1 free-standing, open (un-enclosed) spring isolator, selected for static deflections as shown,
 - .2 upper load plate and leveling assembly, and bottom load plate with non-skid noise isolation pad and bolt holes for fastening to the floor,
 - .3 load rating: up to 50 mm (2 in) static deflection and up to nominally 8000 kg (17,600 lbs.) load,
 - .4 ratio of lateral spring stiffness to vertical spring stiffness: 1.0 or greater,
 - .5 overload capacity: 50% minimum,
 - .6 springs coated in a colour-coded corrosion protection finish and tested with a 1000 hour salt spray rating to ASTM B117.

2.5 Isolator Springs – Type S2

- .1 Enclosed spring isolator:
 - .1 free-standing, enclosed (housed) spring isolator, selected for static deflections as shown,
 - .2 suitable for equipment subject to wind loads, large changes in mass due to change in water content, torque loads, and/or seismic loads,
 - .3 load rating: up to 100 mm (4 in) static deflection and up to nominally 8000 kg (17,600 lbs.) load,
 - .4 housing: fabricated and welded steel members, hot-dipped galvanized after fabrication, with;
 - (a) top load plate with adjusting and leveling bolts,
 - (b) vertical restraints with isolation washers,
 - (c) bottom plate with non-skid noise isolation pads and bolt holes for fastening to the floor,
 - .5 ratio of lateral spring stiffness to vertical spring stiffness:
 - (a) 1.2 or greater for equipment installed outdoors,
 - (b) 1.0 or greater for equipment installed indoors,
 - .6 overload capacity: 50% minimum,
 - .7 springs coated in a colour-coded corrosion protection finish and tested with a 1000 hour salt spray rating to ASTM B117.

2.6 Isolation Springs - Type S3

- .1 Restrained open spring isolator:
 - .1 free-standing, open (un-enclosed) spring isolator, with vertical limit stops, selected for static deflections as shown,
 - .2 suitable for equipment subject to changes in mass due to change in water content,
 - .3 load rating: up to 50 mm (2 in) static deflection and nominally 1500 kg (3300 lbs.) load,
 - .4 spring assembly:
 - (a) top load plate with adjusting and leveling nut and bolt,
 - (b) integral vertical restraint limit with elastomeric washer,
 - (c) bottom fastening plate with noise isolation pad and mounting holes.
 - .5 ratio of lateral spring stiffness to vertical spring stiffness: 0.8 or greater.
 - .6 overload capacity: 50% minimum,
 - .7 springs coated in a colour-coded corrosion protection finish and tested with a 1000 hour salt spray rating to ASTM B117.

2.7 Isolator Springs – Type S4

- .1 Open spring thrust restraint isolators:
 - .1 horizontal arrangement, with equipment and structure mounting plates,
 - .2 open spring, with load plate and isolator bushing,
 - .3 static deflection to match equipment isolator.

2.8 Isolation Hangers – Type H1

- .1 Spring isolation hanger:
 - .1 open (un-enclosed) spring isolator for connection to upper and lower hanger rods, selected for static deflections as shown,
 - .2 a stamped or welded hanger bracket mount with elastomeric washer isolating the spring,
 - .3 bracket and spring: polyester powder coat finish,
 - .4 swivel arrangement to permit hanger box or rod to move through 30° of arc without metal to metal contact,
 - .5 load rating: 10 mm (0.4 in) to 50 mm (2 in) static deflection and up to nominally 1450 kg (3190 lbs.) load,
 - .6 ratio of lateral spring stiffness to vertical spring stiffness: 1.0 or greater,
 - .7 overload capacity: 50% minimum.,

2.9 Isolation Hangers – Type H2

- .1 Spring isolation hanger with elastomer-in-shear insert:
 - .1 Same as type H1 except as follows.
 - .2 includes a neoprene elastomer-in-shear insert on the upper load connection, in series to the spring,
 - .3 load rating: up to 100 mm (4 in) static deflection and up to nominally 1700 kg (3740 lbs.) load,

2.10 Isolation Hangers – Type H3

- .1 Neoprene isolation hanger:
 - .1 neoprene isolator for connection to upper and lower hanger rods,
 - .2 a stamped hanger bracket mount with isolator and load washer, with galvanized steel finish
 - .3 bracket and spring: polyester powder coat finish,
 - .4 swivel arrangement to permit hanger box or rod to move through 30° of arc without metal to metal contact,
 - .5 load rating: up to 15 mm (0.57 in) static deflection and up to nominally 900 kg (1980 lbs.) load,
 - .6 ratio of lateral spring stiffness to vertical spring stiffness: 1.0 or greater,
 - .7 overload capacity: 50% minimum.

2.11 Equipment Base – Type A

- .1 Vibration isolators attached directly to equipment,
- .2 No supplementary base required.

2.12 Equipment Base – Type B

- .1 Fabricated steel frame or rails (except cooling towers, evaporative fluid coolers, and evaporative condensers):
 - .1 prefabricated steel base for fans and other equipment requiring motor support,
 - .2 welded assemblies from structural sections,
 - .3 reinforced for motor and drive with;
 - (a) isolation elements attached to base brackets and
 - (b) adjustable motor slide rails.
 - .4 use height-saver isolator mounting brackets wherever possible,
 - .5 minimum vertical section of base selected on basis of motor size from following;

Motor Size Horsepower	Motor Size kW	Vertical Side mm (in)
up to 3	up to 2.2	75 (3)
7.5	5.5	100 (4)
20	15	150 (6)
50	37	200 (8)
over 50	37	250 (10)

2.13 Equipment Base – Type B-CT

- .1 Fabricated steel frame or rails – for cooling towers, evaporative fluid coolers, and evaporative condensers:
 - .1 prefabricated supplementary steel base for cooling towers, evaporative fluid coolers and evaporative condensers,
 - .2 fabricated from structural steel shapes, specifically designed for each equipment operating weight and support point locations,

- .3 maximum beam deflection: not greater than 1/360 of span and not to exceed 12.5 mm (1/2 in),
- .4 welded and/or bolted structural connections,
- .5 hot-dipped galvanized grade Z700 (G235) to ASTM A653 after fabrication,

2.14 Equipment Base – Type C

- .1 Concrete filled inertia base:
 - .1 Type B base and as follows,
 - .2 full depth perimeter structural section or formed plate channel frame with;
 - (a) welded in place reinforcing rods running in both directions and
 - (b) 1 mm (20 ga) metal pans,
 - (c) base section filled with concrete, vibrated into place.
 - .3 spring mount units carried by height-saver gusseted brackets welded to frame and
 - .4 'T' shaped bases to support horizontal pump elbows.

2.15 Equipment Base - Type D

- .1 Roof curb isolation rails:
 - .1 manufactured with structural steel or aluminum upper and lower members, with continuous flexible reinforced water and air-tight seal fastened to upper and lower members,
 - .2 protected by removable metal weather shield,
 - .3 supported from lower members by stable steel springs,
 - .4 maximum static deflection: 50 mm (2 in),
 - .5 closed cell neoprene gaskets,
 - .6 constructed with neoprene cushioned restraints to resist wind load in any direction.]

2.16 Acoustic Barriers for Anchors and Guides

- .1 Manufactured from 25 mm (1 in) thick neoprene isolation with ductile reinforcing material.

3 EXECUTION

3.1 General

- .1 Install vibration isolation equipment in accordance with manufacturer's instructions and locate isolation for equipment to provide stable support under saddles, frames and projections of equipment.
- .2 Select thrust restraints for equipment mounted on vibration isolation to limit movement during start-up and normal operation.

3.2 Equipment Bases

- .1 Provide equipment bases for equipment as shown on equipment schedule drawings.
- .2 Block and shim bases level at correct operating height. Set the bottom of bases to clear housekeeping pads under full static load conditions by:
 - .1 25 mm (1 in) minimum for type C bases, and
 - .2 50 mm (2 in) minimum for type A and B bases.

3.3 Equipment Vibration Isolation

- .1 Provide vibration isolators with required static deflection for motorized equipment as shown on equipment schedule drawings, except as otherwise specified herein.
- .2 Provide Type H1 isolators for in-line duct fans and fan-powered terminal boxes.
- .3 Provide Type H3 isolators for suspended unit heaters.
- .4 Provide Type S4 horizontal thrust restraints for horizontal discharge fans developing over 1.5 kPa (6 in wg) total static pressure, arranged symmetrically on either side of unit and attached at the center-line of thrust.
- .5 Provide vibration isolation rubber washers where isolator is bolted to floors, housekeeping pads or overhead structure.

3.4 Vibration Isolation for Service Connections to Vibration Isolated Equipment

- .1 Make ductwork connections to vibration isolated air handling equipment with flexible connections in accordance with specification section 23 33 05.
- .2 Make electrical connections to vibration isolated equipment with flexible liquid tight conduit in accordance with specification section 20 05 12.
- .3 Make pipe connections to vibration isolated equipment in accordance with specification section 20 05 16.

3.5 Vibration Isolation Piping Supports – General Requirements

- .1 Provide vibration isolators on pipe supports where piping is connected to motorized equipment that is supported on vibration isolators of any type, in accordance with the following table.

Location	Pipe Size NPS	Isolator Type	Static Deflection mm (in)
The first two pipe supports adjacent to the vibration isolated equipment	≥ 10	Variable support hanger to section 20 05 29	Equal to the equipment isolator static deflection, but not less than 20 (0.75)
	< 10	S1 or H2 [Note 1]	
The third pipe support adjacent to the vibration isolated equipment	All	S1 or H2	Equal to the equipment isolator static deflection, but not less than 20 (0.75)
The 4 th and 5 th support point from the vibration isolated equipment	≥ 6	S1 or H2	20 (0.75)
The 6 th support point from the vibration isolated equipment	≥ 10	S1 or H2	20 (0.75)
Within 15 m (50 ft) pipe-run distance of outdoor equipment	All	S1 or H2	20 (0.75)

Notes:

[1] Order springs pre-compress to suit the installed weight of the pipe filled with the operating fluid.

- .2 Provide acoustic barrier materials at pipe anchors and guides, located within pipe shafts, duct shafts, equipment and fan rooms, and up to the first anchor outside of these rooms or areas.

3.6 Vibration Isolation Piping Supports – Critical Areas

- .1 In addition to the above general requirements for piping support vibration isolation, provide isolation hangers for piping located in the following areas:

Location	Pipe Size NPS	Isolator Type	Static Deflection mm (in)
<<description of noise/vibration critical space>>	All	H2 or H3	15 (0.57) minimum
All other pipe supports in mechanical service rooms	All	H2 or H3	15 (0.57) minimum

3.7 Thermal Expansion Supports for Pipe Risers

- .1 Unless otherwise shown for pipe riser supports to use variable or constant load pipe hangers in accordance with section 20 05 29, provide spring isolators for pipe supports to accommodate pipe thermal movement for vertical pipe (risers) as follows.
- .2 Support vertical cold- and hot-piping for riser heights that are 25 m(82 ft) or less in height on spring isolators attached to the pipe riser supports;
 - .1 select springs so that the initial spring deflection is at least four (4) times the expected thermal movement at each support point,
 - .2 provide the design and fabrication of brackets at the riser spring mount as well as at the pipe attachment where standard riser clamps are not sufficient, and
 - .3 in accordance with specification section 20 05 29.
- .3 For support of vertical cold- and hot-piping for riser heights greater than 25 m (82 ft), refer to specification section 20 05 29.
- .4 Provide spring isolators on horizontal branch piping or the horizontal pipe mains connecting to the riser as follows:
 - .1 type S2 or H2 isolators on the first three supports on horizontal piping connecting to the pipe risers,
 - .2 spring isolators on the horizontal piping is not required where the horizontal pipe connection is within 4 m (13 ft) of a pipe riser anchor or fixed riser base support.
 - .3 select spring isolators with a static deflection of that is four (4) times the expected thermal movement of the riser pipe at the location of the horizontal pipe connection.

3.8 Pipe Movement Isolation Supports at Building Expansion Joints

- .1 Where piping crosses building expansion joint, provide spring hangers at first two support locations of piping at either side of the construction joint line.

3.9 Start-up and Set-up

- .1 After installation of connections to resiliently mounted equipment;
 - .1 remove shims and blocking and adjust mountings to level equipment,

- .2 adjust connections, hangers, snubbers, and restraints,
- .3 ensure that there is no physical contact between isolated equipment and building structure.
- .2 On completion of installation and start-up of equipment;
 - .1 make arrangements for manufacturer/supplier of vibration isolation equipment to visit site, check the performance of the vibration isolation systems, inspect their installation, and submit written report,
 - .2 make corrections to installation in accordance with manufacturer/suppliers recommendations,
 - .3 provide notice 24 hours in advance of this site visit.

3.10 Testing

- .1 Engage and pay for an experienced sound and vibration professional to take measurements of sound and vibration generated by HVAC systems where specified in accordance with specification section 23 05 93.33 and 23 05 93.36.
- .2 Co-operate with manufacturer/supplier of Sound Attenuation equipment in this measurement and testing.

END OF SECTION

SEISMIC RESTRAINT FOR MECHANICAL SERVICES 20 05 49

1 GENERAL

1.1 Scope

- .1 Provide restraint devices to limit movement of piping, ducts, conduits, and equipment under seismic force and movement conditions and, where applicable, wind loads.
- .2 Provide engineering services for the design, selection of materials, installation instructions, and inspection of seismic restraint devices.
- .3 The requirements under this Specification section are in addition to the requirements for equipment, piping and duct supports and vibration isolation specified in other sections of Division 20.
- .4 Where specifications of materials of this section differ from those in other sections of Division 20, this section governs.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 16 Flex Connections, Expansion Joints, Anchors & Guides
 - .2 20 05 29 Common Hanger and Support Requirements
 - .3 20 05 48 Vibration Isolation
 - .4 26 05 49 Seismic Restraints for Electrical Services

1.3 Definitions

- .1 The following definitions apply for the purpose of this section.

Transverse restraint - restraint(s) applied to limit motion perpendicular to the centerline of the pipe, duct or conduit.

Longitudinal restraint - restraint(s) applied to limit motion parallel to the centerline of the pipe, duct or conduit.

Restraint: a device which limits movement of object due to imposed seismic forces acting on the object.

Brace: a restraint directly connected to an object that reacts against both tension and compression seismic loads.

Cable restraint: a restraint consisting of cables that reacts against only tension seismic forces, and that may have a small amount of slack to prevent vibration isolation short-circuiting during normal operation.

Snubber (restraint): a restraint that does not come into contact with the object under normal operating conditions.

- .2 The following abbreviations apply to this section:

"C_p" the horizontal seismic force coefficient as defined in NFPA 13.

“ K_s ” horizontal seismic force coefficient (equal to $0.3 F_a S_a(0.2) I_E S_p$, as defined in the National Building Code of Canada.

“ K_v ” vertical seismic force coefficient.

“ W_p ” the weight of the component subject to a seismic force.

.3 Interpretation:

- .1 In this specification, the parameter “ S_s ” (spectral response acceleration at 5 Hz) in NFPA 13, ASHRAE, SMACNA and MSS SP-127 used for estimating the horizontal seismic force, has the same meaning as the parameter “ $S_a(0.2)$ ” for the spectral response acceleration value at 0.2 seconds as defined in the National Building Code of Canada.

1.4 Applicable Codes and Standards

.1 Installation standards and codes:

- | | | |
|----|----------------|--|
| .1 | ASHRAE D-90316 | Practical Guide to Seismic Restraint |
| .2 | ANSI/SMACNA | Seismic Restraint Manual Guidelines for Mechanical Systems, 3 rd edition. |
| .3 | MSS SP-127 | Bracing for Piping Systems: Seismic - Wind - Dynamic Design, Selection, |
| .4 | NFPA 13 | Installation of Sprinkler Systems |

.2 Product standards:

- | | | |
|-----|--------------|--|
| .1 | ACI 355.2 | Qualification of Post-Installed Mechanical Anchors in Concrete |
| .2 | ASHRAE 171 | Method of Testing Seismic Restraint Devices for HVAC&R Equipment |
| .3 | ASTM A492 | Standard Specification for Stainless Steel Rope Wire |
| .4 | ASTM A1023 | Standard Specification for Stranded Carbon Steel Wire Ropes for General Purpose |
| .5 | ICC-ES AC01 | Expansion Anchors in Masonry Elements |
| .6 | ICC-ES AC106 | Predrilled Fasteners (Screws) in Masonry |
| .7 | ICC-ES AC156 | Acceptance Criteria for Seismic Certification by Shake-Table Testing of Non-structural Components |
| .8 | ICC-ES AC193 | Mechanical Anchors in Concrete Elements |
| .9 | ICC-ES AC308 | Post-Installed Adhesive Anchors in Concrete Elements |
| .10 | MSS SP-58 | Pipe Hangers and Supports – Materials, Design, Manufacture, Selection, Application, and Installation |

.3 Other documents:

- | | | |
|----|--------|--|
| .1 | ASCE 7 | American Society of Civil Engineers, Minimum Design Loads and Associated Criteria for Buildings and Other Structures |
|----|--------|--|

1.5 Seismic Analysis, Design and Inspection Services

- .1 Provide the services of a professional engineer, licensed in the province or territory of the Work and who specializes in seismic restraint of building services and equipment (the “Seismic Engineer”), for the design of seismic restraints and to provide inspection services of the completed installation.
- .2 Seismic Engineer design services;
- .1 Provide the design of seismic restraint systems, including seismic restraint calculations for all connections of equipment to the structure.

- .2 Provide design drawings showing locations of restraints and details of construction and attachment of restrains. Mark-ups of Consultant drawing or Contractor installation drawings may be used for this purpose.
- .3 Analysis of dead loads, static seismic loads and capacity of materials utilized for connections to equipment and structure. Analysis to detail anchoring methods, bolt diameter, embedment and/or welded length. All seismic restraint devices shall be designed to accept, without failure, the seismic forces acting on the equipment or components and their support and restraint attachments to the building structure.
- .3 Seismic Engineer inspection services;
 - .1 At periods during installation and at completion of the installation of the seismic restraint devices, the Seismic Engineer shall inspect the installation, identify and report deficiencies (if any) which are observed, and re-inspect the installation after deficiencies have been corrected.
 - .2 Seismic Engineer to submit periodic inspection reports and a final inspection report after all work is completed and deficiencies have been corrected, confirming the installation conforms to the seismic design requirements. Prepare and submit any required declarations or similar document to this effect where required by local legislation.
- .4 Shop drawings of custom restraints, required calculations, and reports shall be sealed by the specialist seismic professional engineer.
- .5 Prepare and submit reports of inspections of the installation and a final general review report of the completed seismic installation.

1.6 Manufacturer's Services – Seismic Restraints

- .1 Manufacturer of seismic control equipment are responsible for:
 - .1 determining seismic restraint sizes and locations,
 - .2 provide calculations and supply materials for restraint of vibration isolated and non-isolated equipment,
 - .3 provide installation instructions, drawings and trained field supervision to ensure proper installation and performance including welding details,
 - .4 field inspection of manufactured support systems including roof curbs and other rooftop equipment supports at time of installation.
- .2 Seismic restraint products shall either be:
 - .1 approved by a government agency and indicate maximum restraint ratings, or
 - .2 provided with test results verified by an independent testing laboratory which state the maximum restrain ratings.

1.7 Manufacturer Services – Pipe Risers

- .1 Notwithstanding the requirements of section 20 05 29, engineered design services for pipe riser supports are required for all pipe risers.
- .2 Manufacturer of pipe riser supports are responsible for:
 - .1 complete engineering design of pipe riser support system including design and selection of pipe riser anchors, riser guides and riser isolators,
 - .2 provide calculations and supply materials for support of pipe risers to accommodate dead loads, dynamic loads and static seismic loads.
 - .3 Provide installation instructions, drawings and trained field supervision to ensure proper installation and performance including welding details.

1.8 Design Criteria

- .1 Design seismic restraint systems to conform to the provincial or territorial building code as applicable for the place of the Work. Seismic calculation and restraint methods as described in ASHRAE D-90316, SMACNA seismic guideline and MSS SP-127 are acceptable as the baseline requirement.
- .2 Design of seismic restraints to be based on actual equipment data (dimensions, weight, center of gravity, etc.,) obtained from submittals or the manufacturers of the equipment.
- .3 Testing and calculations of seismic restraints shall include both shear and tensile loads as well as one test or analysis at 45° to the weakest mode.

- .4 Site design parameters:

Item	Description	Abbrev.	Value
1	Soil Class	--	C
2	Building Category	---	Post Disaster
3	Building Importance Factor	I _E	1.5
4	Spectral response acceleration factor	S _a (0.2)	0.249
5	Peak Ground Acceleration factor	PGA	0.160
6	Interstorey displacement factor	---	0.025

- .5 Building seismic force coefficient data;

- .1 seismic horizontal force coefficients "K_s" and seismic vertical uplift force coefficient "K_v" for building service are listed in Schedule A attached to the end of this Section. These coefficients are the maximum values independent of the type of equipment or service being restrained. It is permitted to calculate a lower K_s coefficient where the C_p, A_r and R_p values, as defined in the building code specific to the actual equipment or service being restrained, are used.
- .2 seismic force coefficient "C_p" for fire protection piping is listed in Schedule A attached to the end of this Section.

- .6 Seismic force calculation (except fire protection piping);

- .1 the horizontal seismic force "V_p" applied to a component is:

$$V_p = K_s \times W_p,$$

- .2 the vertical seismic force "V_{PV}" applied to a component is:

$$V_{pv} = K_v \times W_p$$

- .7 Seismic force calculation for fire protection piping, including automatic sprinklers constructed in accordance with NFPA 13 and fire standpipes constructed in accordance with NFPA 14;

- .1 the horizontal seismic force applied to a component is

$$F_p = C_p \times W_p \times 1.15,$$

- .2 the vertical seismic force applied to a component is:

$$F_v = 0.15 \times C_p \times W_p \times 1.15.$$

- .8 For suspended equipment, the building elevation height is measured to the level of the floor above the suspended equipment.

- .9 For vibration isolated equipment, where the clearance distance (air gap) between the equipment support frame and the restraint (e.g. snubber or integral limit stop) exceeds 6 mm (1/4 in.), the seismic horizontal force V_p is to be increased by 100%.
- .10 Where adhesive anchors for concrete are used, the seismic force for the restrained equipment is to be increased by multiplying the horizontal seismic force coefficient specified in Schedule A of this Specification section by the " R_p " equipment category as defined in article 4.1.8.18 of the National Building Code of Canada specific to the equipment being restrained.

$$K_{s,adhesives} = K_s \times R_{p,applicable\ equipment}$$

- .11 Where concrete inserts are used, the seismic force for the restrained equipment is to be increased by multiplying the horizontal seismic force coefficient specified in Schedule A of this Specification section by the " R_p " equipment category as defined in article 4.1.8.18 of the National Building Code of Canada specific to the equipment being restrained and divided by the value of 1.5.

$$K_{s,inserts} = K_s \times \frac{R_{p,applicable\ equipment}}{1.5}$$

1.9 Seismic Qualification of Equipment

- .1 Applies where other specifications of Division 20 to 25 require equipment to be seismically qualified.
- .2 Design unitary or package equipment to withstand the seismic force criteria as specified herein.
- .3 Design the equipment base frame to allow anchoring of the packaged equipment to the supporting structure by use of through-bolt anchors.
- .4 Seismically qualify and certify complete unitary or packaged equipment by the shaker table method in accordance with ICC ES-AC156 and ASCE 7 for validating continued operation after the test seismic movement.
- .5 For clarity, calculation of seismic forces for use with ASCE 7 are subject to the following for installations in Canada:
 - .1 calculate seismic forces in accordance with the building code at the place of the Work, or in its absence the National Building Code of Canada,
 - .2 under ASCE 7, the " S_{DS} " parameter is equivalent to NBCC value equal to " $2/3 \cdot F_a(0.2) \cdot S_a(0.2)$ "
 - .3 under ASCE 7, the Component importance factor is to be read as the Building Importance Factor in accordance with the National Building Code of Canada,
 - .4 unless otherwise specified in the product technical Specification section, the building height factor under ASCE 7 of " z/h " is the same as NBCC " h_x/h_n " and is to have a value of 1.0.
 - .5 other factors in conformance with this Specification section.]

1.10 Submittals

- .1 Submit shop drawings in accordance with Division 1 and as follows.
- .2 Seismic restraints:
 - .1 Provide test certificates for each seismic restraint device, identifying maximum tested load capacities.
 - .2 Provide calculations for each piece of restrained equipment, lengths of braced piping, ductwork and conduit, including seismic forces, restraint selection, and selection data.
 - .3 Provide a calculation analysis summary (spreadsheet is acceptable) for each piece of equipment, including the following information:
 - (a) Equipment ID,
 - (b) Floor level,

- (c) Horizontal seismic force factor,
 - (d) Equipment weight,
 - (e) Horizontal seismic force,-
 - (f) Vertical uplift seismic force (where applicable),
 - (g) Design condition (worst case) overturning moment,
 - (h) Number of restraint fastenings,
 - (i) Pull-out tension for worst case restraint,
 - (j) Compression for worst case restraint (vibration isolated equipment),
 - (k) Horizontal shear per fastener,
 - (l) Worst case simultaneous tension and shear loads at each restraint and snubber,
 - (m) Pull-out tension load rating per fastener,
 - (n) Horizontal shear rating per fastener.
- .4 Provide drawings for each type of restraint assembly, including details for connections to building structure, and associated bill of materials, and (where applicable) full welding details of field welds to structural elements.
- .5 For building connections in concrete, provide concrete anchor sizes and nominal and effective embedment depth.
- .6 Provide floorplan layout drawings indicating location of each restraint, identifying each restraint type in a manner to identify the restraint detail.
- .7 Provide layout and construction details for reinforced housekeeping pads based on actual equipment to be restrained and selected concrete anchors. Shop drawings to include:
- (a) minimum housekeeping pad plan dimensions and height, including reinforcement,
 - (b) details for securing the housekeeping pad to the structural floor slab,
 - (c) dimensioned position of restraint devices or combination isolator/restraint devices,
 - (d) minimum distance from concrete anchors to edge of housekeeping pad.
- .8 Calculations and designs shall be sealed by a Professional Engineer licensed in the province or territory of the location of the project.
- .3 Pipe riser support system:
- .1 Provide engineered layout drawings of pipe supports including anchors, guides and isolators, with supporting load calculation including dead loads, dynamic loads and static seismic loads, and reaction loads at building connection.
- .2 Include:
- (a) riser drawing indicating location of each support element for each for each piping system,
 - (b) installation instructions for presetting of pipe guides and isolators,
 - (c) riser clamp products or fabrication details of pipe brackets,
 - (d) riser clamping details as applicable for each riser pipe material.

1.11 Quality Assurance

- .1 Without limiting Contractors responsibility for quality assurance of the Work, the following minimum quality control processes are required.
- .2 Pre-Construction meeting;

- .1 Request and arrange a meeting with the Seismic Engineer and Consultant to review seismic restraint approach, prior to any restraint installation. Obtain approval from the Consultant before commencing work.
- .3 Initial installation and review;
 - .1 Install the first three transverse and three longitudinal braces for each fire protection systems, one (1) building service piping system, and one (1) ductwork system.
 - .2 Request and arrange for a review of the installation by the Seismic Engineer and Consultant. Obtain approval of the installation before commencing remainder of the work.
- .4 Provide services of the manufacturer's technical representative to conduct site inspections of the Work in progress, and to conduct a final inspection of the Work. Provide a copy of the final inspection report to the Consultant for review. For clarity, these inspections are separate from those performed by the Seismic Engineer.
- .5 Provide services by the Seismic Engineer to conduct periodic reviews of the work in progress, and final review of the completed seismic restraint installation, before any ceilings are installed or work is otherwise concealed.
- .6 All deficiencies identified by the Seismic Engineer, manufacturer, or Consultant are to be rectified before equipment or services are concealed.

2 PRODUCTS

2.1 General

- .1 Seismic restraint materials to be provided by manufacturers specializing in the field of seismic restraint.

Standard of Acceptance

- Vibro-Acoustics (Swegon North America)
 - Kinetics Noise Control Inc.
 - B.V.A. Systems
 - Korfund (VMC)
 - Tecoustics
 - Hilti
 - nVent
- .2 Manufactured seismic restraints, anchors and related materials to be tested in accordance with ICC ES AC156 for loads meeting or exceeding the applied seismic forces of the Work.
 - .3 Seismic restraints for equipment supported by vibration isolators to be either:
 - .1 vibration isolators as specified in section 20 05 48 and provided with separate seismic snubbers, or
 - .2 combination vibration isolators with integral seismic snubbers.
 - .4 The following product articles describe the more common type of restraint devices. Other restraint devices are permissible provided they are qualified by 3rd party testing laboratories for seismic force restraint.

2.2 Seismic Snubbers

- .1 Type "SS1" – Single-Axis/Single Direction Snubbers:
 - .1 ASHRAE Type "I", designed to restrict movement in one axis,
 - .2 carbon steel construction with epoxy or electrostatic paint finish, attached to floor or housekeeping pad with minimum of two bolts, faced with minimum 6.4 mm (1/4 in.) thick neoprene pad of compounded to bridge bearing quality,

.2 Type "SS2 / SS3" – Multi-Axis/Multi-Direction Snubber Assemblies:

- .1 ASHRAE Type "G" and "F", designed to restrict movement in two (2) lateral ("SS2") or three (3) axis ("SS3"),
- .2 interlocking steel construction, attached to equipment structure and equipment, maximum of 6 mm (¼ in) seismic movement,
- .3 minimum 6 mm (¼ in) thick resilient neoprene pads compounded to bridge bearing specifications, to prevent metal-to-metal impact,
- .4 minimum two bolt attachments to the floor,

2.3 Seismic Restraint Brackets

.1 Type "SRB" – Rigid Equipment Restraint Brackets:

- .1 suitable for connection to equipment bases and tank bases,
- .2 carbon steel "L" sections with epoxy or electrostatic paint finish, for fastening to both the floor structure/housekeeping pad and the equipment base,
- .3 structure bolt opening equipped with neoprene bushing, compounded to bridge bearing quality,
- .4 minimum two bolt fastening to equipment base using screws,
- .5 suitable for equipment direct contact to floor with or without isolation pads,

2.4 Seismic Vibration Isolators

.1 Type "2-S" – All Direction Neoprene Isolator:

- .1 ASHRAE Type "E", designed to restrict movement in all directions with no metal-to-metal contact.
- .2 molded, oil resistant neoprene compounded to bridge bearing quality, with encapsulated cast-in-place top steel load plate, and steel base plate with anchor holes,

.2 Type "3-S" – Restrained Spring Isolator – Constant Load:

- .1 ASHRAE Type "B", designed to restrict movement in all directions,
- .2 colour coded seismic-controlled spring isolator, single or multiple spring coils, with minimum 6 mm (¼ in.) neoprene pad,
- .3 removable coil spring element without having to disturb supported equipment,
- .4 lateral stiffness greater than 1.2 times rated vertical stiffness,
- .5 minimum 50% overload capacity,
- .6 non-welded spring elements: epoxy coated, with a minimum 1000-hour rating when tested in accordance with ASTM B-117,
- .7 steel housing design to limit lateral and vertical movement of the supported equipment,
- .8 neoprene snubber, to limit maximum equipment movement in any direction to 6 mm (¼ in.),
- .9 location of snubbers designed to minimize prying action on floor bolts,
- .10 adaptor base suitable sized for larger anchors, when required to suit anchorage capacity.

.3 Type "4-S" – Restrained Spring Isolator – Variable Load:

- .1 colour coded seismic-controlled spring isolator, single or multiple spring coils, with minimum 6 mm (¼ in) neoprene pad mounted under spring(s),
- .2 removable coil spring element without having to disturb supported equipment,

- .3 lateral stiffness greater than 1.2 times rated vertical stiffness,
- .4 minimum 50% overload capacity,
- .5 non-welded spring elements: epoxy coated, with a minimum 1000-hour rating when tested in accordance with ASTM B-117,
- .6 steel housing design to limit lateral and vertical movement of the supported equipment,
- .7 top load plate with adjustable and leveling bolts,
- .8 adjustable vertical restraints to allow unloading of water-bearing equipment,
- .9 isolation washers,
- .10 bottom load plate with anchor holes,
- .11 hot dipped galvanized for outdoor installations,
- .12 neoprene snubber compounded to bridge veering quality, to limit maximum equipment movement in any direction to 6 mm (¼ in),
- .13 adaptor base suitable sized for larger anchors, when required to suit anchorage capacity.

2.5 Restraints and Braces for Distribution Services

.1 Type "SCR" – Cable Restraints:

- .1 manufactured system consisting of cable, building attachment, and vertical hanger rod reinforcement assembly,
- .2 field-built assemblies are not acceptable,
- .3 steel wire strand cables:
 - (a) galvanized steel aircraft cable to ASTM A1023, or stainless steel to ASTM A492
 - (b) sized for seismic load with a safety factor of 2,
 - (c) arranged for restraint in both longitudinal and transverse directions under tension loads only,
 - (d) connector strength rating equal to 90% of cable breaking strength rating.
- .4 building and equipment attachment brackets:
 - (a) carbon steel assemblies, designed to permit rotation to the final installation angle, or 45° bent steel plates with holes to allow attachment of cable loops,
 - (b) protective loop thimbles at contact with connectors,
 - (c) rope connections: overlap wire "U" clips with at least two (2) bolt fasteners, or, tool-less wedge insert lock connectors,
 - (d) selected to exceed the cable working design load by 50%,
 - (e) single sided "C" beam clamps are not acceptable.
 - (f) fasteners to building structure designed to withstand simultaneous shear and tension loads, including prying action due to the bracket.

.2 Type "SSB" – Solid Braces:

- .1 factory-built or field assembled solid braces, consisting of structural-shapes, building attachment, and vertical hanger rod reinforcement assembly.
- .2 sized for seismic load with a safety factor of 2,
- .3 arranged for restraint in both longitudinal and transverse directions.
- .4 building and equipment attachment brackets:
 - (a) carbon steel assemblies, designed to permit rotation to the final installation angle, or 45° bent steel plates with holes to allow attachment of cable loops,

- (b) selected to exceed the working design load by 50%,
 - (c) single sided "C" beam clamps are not acceptable.
 - (d) fasteners to building structure designed to withstand simultaneous shear and tension loads, including prying action due to the bracket.
- .3 Vibration isolators for suspended pipes and ducts:
- .1 applies where vibration isolators are specified for pipes or ducts in Specification section 20 05 48.
 - .2 type "H2" spring hanger in accordance with Specification section 20 05 48 and with two (2) travel-limit stops of neoprene washers with integral steel inserts which are located:
 - (a) on the top of the isolator housing, with an air gap of 6 mm (1/4 in.) between the neoprene washer and the structure connection point,
 - (b) on the underside of the isolator housing, supported by a nut on the hanger rod, and provided with an air gap of 6 mm (1/4 in.) between the underside of the isolator housing and the top of the neoprene washer.
 - .4 Bracing of vertical hanger rods for SCR restraints and SRB braces:
 - .1 hanger rods braced to avoid potential for buckling;
 - (a) structural steel angle or formed channel brace selected to prevent support rod buckling,
 - (b) brace attached to support rod with a series of adjustable clips, without the use of hand-tools.
 - .2 hanger rods are not required where two SRB braces are provided at each seismic restraint location, and are installed at 180° opposition to each other.

2.6 Seismic Pipe Riser Support System for Piping Subject to Thermal Expansion

- .1 Application: for piping subject to thermal expansion including HVAC water systems, steam, domestic hot and cold water.
 - .1 not applicable to: drainage and vent piping systems, compressed gas and vacuum systems.
- .2 Complete engineered riser support system by support manufacturer.
- .3 Pipe riser anchors:
 - .1 outboard-mounted all-direction pipe anchors, designed for load bearing of pipe by means of pipe riser clamps or pipe support brackets,
 - .2 carbon-steel interlocking plates with bridge bearing quality neoprene pads, and painted finish,
 - .3 top-side loading plate with threaded UNC tapped mounting hole, for attachment by bolting to pipe riser clamp or welded to pipe bracket,
 - .4 variants for mechanical anchoring to concrete floor or field-welding to structural steel framing,
 - .5 one pair of guides per guide location.

Standard of Acceptance

- ° Vibro-Acoustics - fig. PRA, PRA-S
- .4 Pipe riser guides:
- .1 outboard-mounted pipe guides, designed for load bearing of pipe by means of pipe riser clamps or pipe support brackets,
 - .2 carbon-steel sliding guides with EPDM lateral bushings and bridge bearing quality neoprene end pads, and painted finish,

- .3 top-side loading plate with threaded UNC tapped mounting hole, for attachment by bolting to pipe riser clamp or welded to pipe bracket,
- .4 one pair of guides per guide location.

Standard of Acceptance

- Vibro-Acoustics - fig. PRG, PRG-S

.5 Pipe riser isolators:

- .1 open spring assembly, with neoprene base and equipment loading plate, and mounting bolt hole for attachment by bolting to pipe riser clamp or welded to pipe bracket.
- .2 springs selected for four times the riser expansion or contraction at the supported location, to not exceed a maximum 25% load change between installed and operating condition.

Standard of Acceptance

- Vibro-Acoustics - fig. FST series

.6 Pipe riser clamps:

.1 Carbon steel pipe:

- (a) NPS 1-1/2 and under – carbon steel riser clamps, ANSI/MSS SP-58 type 8.

Standard of Acceptance

- Anvil - fig. 261

- (b) NPS 2 to 24 – 4 or 6 bolt carbon steel riser clamps, ANSI/MSS SP-58 type 42.

Standard of Acceptance

- Anvil - fig. 40

.2 Stainless steel pipe:

- (a) NPS ½ to NPS 12 – T304 stainless steel, ANSI/MSS SP-58 type 8.
- (b) special pattern with extended ears and 4 bolts to allow bearing on pipe riser anchors, guides and isolators.

Standard of Acceptance

- Anvil - fig. 261SS special.

.3 Copper tube:

- (a) NPS ½ to NPS 4 – carbon steel with copper plated finish, ANSI/MSS SP-58 type 8.
- (b) special pattern with extended ears and 4 bolts to allow bearing on pipe riser anchors, guides and isolators.

Standard of Acceptance

- Anvil - fig. CT-121 special.

.7 Pipe brackets:

- .1 purpose engineered, carbon steel structural shapes with reinforcing gussets, for full welding attachment to pipe and to load plates on pipe anchors, guides or isolators.
- .2 painted finish.

2.7 Seismic Pipe Riser Supports – Piping not Subject to Thermal Expansion

- .1 Use pipe riser clamps and guides in accordance with Specification section 20 05 29, except select components to have a load capacity equal to at least two times the combined dead weight, dynamic load and seismic load.

2.8 Mechanical Anchors

- .1 General:
 - .1 Post-installed mechanical anchors in concrete to be seismically qualified for installation in cracked concrete in accordance with ACI 355.2 by testing for seismic tension and shear loads in cracked concrete in accordance with ICC-EC AC193, and qualified by an ICC-ES seismic evaluation report.
 - .2 Anchors installed in concrete masonry units to be seismically qualified in accordance with TMS 402/602 by testing for seismic tension and shear loads in accordance with ICC-ES AC01 or AC106, and be qualified by an ICC-ES seismic evaluation report.
 - .3 Anchors to be selected for concurrent shear and tension loads with a safety factor not less than 2.0 times estimated load.
- .2 Undercut anchors for post-concrete installation:
 - .1 zinc-plated carbon steel bolt, nut, washer and cone-shape bearing-bell, with tungsten-tipped cutting radial edges, to create bearing force by keying into concrete,
 - (a) for outdoor use, all materials are to be stainless steel.
 - .2 special undercut stop-drill bit and installation setting tool,
 - .3 marking system to indicate when the anchor is completely installed,
 - .4 designed for pre-setting of anchors and/or fastening of anchors through the equipment attachment opening,

Standard of Acceptance

- Hilti - fig. HDA (indoor), HDA-R (outdoor)

- .3 Expansion wedge anchors for post-concrete or masonry unit installation:
 - .1 zinc-plated carbon steel bolt, nut, washer, expanding segments and wedge mandrel, to create restraint force by friction and keying against/into adjacent concrete,
 - (a) for outdoor use, all materials are to be stainless steel.
 - .2 torque- loading to determine complete installation,

Standard of Acceptance

- Hilti - fig. KB-TZ2 (concrete and masonry)
- Hilti - fig. HSL-3 (concrete only)

- .4 Screw anchors for masonry units:
 - .1 Zinc-plated carbon steel masonry screw with hex washer head, to create restraint force by keying into concrete masonry units.
 - (a) for outdoor use, all materials to be stainless steel.

Standard of Acceptance

- Hilti - fig. KH-EZ series.

- .5 Housekeeping pad anchors:

- .1 for installation prior to pouring of the housekeeping pad and post-installation of the structural floor,
- .2 tapered ductile iron body, with openings sized for two runs of Ø10mm (#3) reinforcing bar, and body NC threaded receiver for connection to undercut or expanding wedge anchors,
- .3 two pieces of Ø10mm (#3) reinforcing bar, of sufficient length to tie into housekeeping pad reinforcement,
- .4 undercut or expanding wedge anchor for connection to the structural floor slab.

Standard of Acceptance

- Mason Industries - fig. HPA

2.9 Adhesive Anchors

- .1 Adhesive anchors for post-concrete installation:
 - .1 seismically qualified for installation in cracked concrete in accordance with ACI 355.2 by testing for seismic tension and shear loads in cracked concrete in accordance with ICC-EC AC308.
 - .2 to have an ICC-ES seismic evaluation report, and be suitable for installation in cracked and uncracked normal- and light-weight concrete.
 - .3 anchors to be selected for concurrent shear and tension loads with a safety factor not less than 2.0 times estimated load.
 - .4 injectable, two-component hybrid adhesive, matching threaded rod and accessories.

Standard of Acceptance

- Hilti - fig. HIT-HY 200

3 EXECUTION

3.1 General Requirements

- .1 Design and construct seismic restraints to;
 - .1 keep equipment and distribution services in place during and following seismic events,
 - .2 resist vertical loading simultaneously with transverse or longitudinal seismic loading.
- .2 Give special consideration to design for adjacent connections, insulation treatment, thermal movement, vibration isolation, and relation to building seismic joints.
- .3 Select restraint fastening systems so that full restraint will be provided assuming one failed fastener.
- .4 Install seismic restraint devices in accordance with manufacturer's instructions and Seismic Engineer's installation shop drawings.
- .5 Secure each transverse or longitudinal brace to the building structure, and not any other building service.
- .6 Restraint installation:
 - .1 install cable restraints with slack not exceeding a deflection of 12 mm (1/2 in.) measured at its midpoint, where equipment being restrained is supported on/by vibration isolators or for piping which is subject to thermal expansion,
 - .2 install cable restraints snug in all other applications,
 - .3 use solid braces only in rigidly supported situations,
 - .4 brace hanger rods forming a part of a seismic restraint to accept resulting compressive loads,

- .5 install transverse and longitudinal braces at angles between 45 and 60° measured from the horizontal, unless the seismic bracing details by the Seismic Engineer states otherwise.
- .7 Concrete or masonry walls may be used as transverse duct restraints (but not pipe restraints), provide the wall is not a fire separation requiring the duct to be installed with a fire damper, and the annual space on any side of the duct does not exceed 12 mm (1/2 in.). Where the annual space exceeds this value, provide separate braces or use angle channels to secure the duct to the wall.
 - .1 drywall partitions, including demountable partitions, are not to be used for restraint.
- .8 Trapeze support and racks piping systems may have the rack braced (transverse and longitudinally) provided each pipe supported by the rack is restrained to the rack, while allowing thermal expansion as necessary.

3.2 Use of Pre-Engineered Bracing Details for Distribution Services

- .1 Use of pre-engineered restraint and bracing details in accordance with SMACNA (for ducts, piping and conduit) or MSS-SP-127 (for piping) is permitted. Where the installation of these services exceeds the limits of these documents, provide specific engineering restraint devices and systems.
 - .1 for SMACNA details, refer to the seismic hazard level ("SHL") by floor level in Schedule A of this Specification Section.
- .2 Fire protection automatic sprinkler systems and fire standpipe systems are to be braced in accordance with NFPA 13.
- .3 Provide cable restraints or bracing for transverse and longitudinal seismic restraints at spacing and locations as specified in the above referenced standards.
- .4 Exemptions for seismic restraints for distribution services (pipes, ducts, conduit) described in ASHRAE, SMACNA or MSS SP-127 are limited to the explicit exemptions described herein.

3.3 Exemptions for Duct Seismic Restraints

- .1 Except as described in paragraph .2 below, the following ductwork is not required to have seismic restraints where all the following conditions are met;
 - .1 ducts and duct supports are constructed to SMACNA duct construction standards,
 - .2 the extent of the free movement of the duct under seismic forces will not cause the duct to come into contact with other building services or building elements,
 - .3 HVAC ducts having a cross-sectional area of 0.56 m² (6 ft²) or less or have a linear weight for ducts and any insulation of 248 N/m (17 lb/ft) or less are exempt,
 - .4 HVAC or process ducts supported on trapeze assemblies with rod hangers, where the duct and any insulation have a linear weight of 146 N/m (10 lb/ft) or less are exempt,
 - .5 for other ducts not described in items.3 or .4 above are exempt where:
 - (a) an individual duct is supported by hangers where the support height measured from the structural support to the top of the duct is 305 mm (12 in.) or less, and the hanger is attached to the duct within 50 mm (2 in.) of the top of the duct with a #10 sheetmetal screws, and
 - (b) rod hanger at the connection to the support structure are provided with a swivel in accordance with Specification section 20 05 29 to prevent bending of the hanger rod. Where such a device only provides rotation of the hanger rod in one plane, it shall be installed to allow transverse movement of the hanger rod.
- .2 Ducts conveying toxic or flammable gases, chemical or biological exhaust, or ducts used for smoke control or smoke venting are to be seismically restrained – no exemptions apply.

3.4 Exemptions for Pipe Seismic Restraints

- .1 Except as described in paragraph .2 below, the following piping is not required to have seismic restraints where all the following conditions are met;
 - .1 the pipe is supported by hangers where the support height measured from the structural support to the top of the pipe is 305 mm (12 in.) or less,
 - .2 piping is supported on a trapeze where the support height measured from the structural support to the top surface of the trapeze is 305 mm (12 in.) or less,
 - .3 the rod hanger at the connection to the support structure is provided with a swivel in accordance with Specification section 20 05 29 to prevent bending of the hanger rod. Where such a device only provides rotation of the hanger rod in one plane, it shall be installed to allow transverse movement of the hanger rod, and
 - .4 the extent of the free movement of the piping under seismic forces will not cause the pipe to come into contact with other building services or building elements.
- .2 Piping conveying fuel oil, natural gas, propane gas and liquid, medical gases and compressed gases are to be seismically restrained – no exemptions apply.

3.5 Building Structural Connections

- .1 Select building connection devices based on seismic loads for actual equipment purchased.
- .2 For connection to concrete structures;
 - .1 Select building structure anchors as follows:
 - (a) post-installed undercut anchors or wedge-expansion anchors,
 - (b) concrete inserts may be used in new construction but only where complete seismic design is completed and seismic forces are adjusted to suit,
 - .2 Spacing between anchors: not less than 3 x the effective embedment of the greatest embedment length.
- .3 Where adhesive anchors or concrete inserts are used, the anchors are sized for an increased seismic force as described in article "Design Criteria".
- .4 For connection to steel structures:
 - .1 use double sided beam clamp, loaded to the centerline of the beam web, or
 - .2 were permitted by the building structural engineer, specifically designed welded or bolted connection may be used.
 - .3 the use of single sided "C" type beam clamps is not permitted for the connection to the building steel structure for hanger rods and seismic restraints.

3.6 Construction of Housekeeping Pads

- .1 Do not construct housekeeping pads until equipment restraint and anchors are designed and selected by the Seismic Engineer and/or seismic restraint manufacturer, and housekeeping pads detailed design are provided by the Seismic Engineer.
- .2 Provide housekeeping pads with integral reinforcement and structural anchors to the floor slab to withstand applied shear loads and anchor pull-out tension loads.
 - .1 provide reinforcing bar both directions on equal centers, and interior and perimeter floor anchors,
 - .2 in pre-installation construction, "Z-bar" shapes may only be used when housekeeping pad layouts are known prior to construction of the structural floor slab,
 - .3 in post-installations, use tapered housekeeping pad anchor assemblies,

- .4 in post-installations, "L-rebar" shapes with adhesive anchors may be used, except the seismic forces in Schedule A of this Specification section must be increased as described above for adhesive anchors.
- .3 Pre-engineered details of construction for housekeeping pads as shown in chapter 6 of ASHRAE *Practical Guide to Seismic Restraint* may be used within its defined limits of application including but not limited to:
 - .1 housekeeping pad sizes are limited to 37 m² (400 ft²) or less,
 - .2 equipment center of gravity height does not exceed the width of the housekeeping pad,
 - .3 the ASHRAE maximum load rating includes the weight of the restrained equipment, vibration isolation equipment, support rails and bases, and the housekeeping pads,
 - .4 for values of "Fp" in ASHRAE, substitute the horizontal seismic force "Vp" as defined in the National Building Code of Canada for non-structural components (based on the seismic force coefficient "Ks" in Schedule A of this Specification section).
- .4 Size the housekeeping pad so that the distance from the equipment anchors to the edge of the pad is not less than 1.5 times the effective embedment depth of the equipment anchor, unless the anchor manufacturer requires greater separation distance.

3.7 Duct Restraints General Requirements

- .1 Use cable restraints or braces. Do not mix cable restraints and rigid bar restraints on the same duct system.
- .2 Use cable restraints for ductwork suspended on vibration isolators. Provide a small amount of slack in the cable to prevent vibration short-circuiting, with the slack not exceeding a lateral displacement of 12 mm (1/2 in.) at the center point of the cable.
- .3 Provide reinforcement of hanging rods to prevent buckling of the rod.

3.8 Piping Restraints General Requirements

- .1 Use cable restraints for piping subject to thermal expansion, including but not limited to chilled water, heating water, steam and glycol heating/cooling water.
- .2 Use cable restraints for piping supported on vibration isolation hangers or supports.
- .3 Use cable restraints or braces for all other piping.
- .4 Thermal expansion pipe anchors and guides on piping systems may be used as both a transverse and longitudinal seismic restraint where they are designed for concurrent thermal and seismic loadings.
- .5 Provide reinforcement of hanging rods to prevent buckling of the rod.
- .6 Where clevis hangers are used, provide a brace for the clevis cross bolt consisting of Schedule 40 pipe of the smallest size to fit over the clevis cross bolt, of a length to provide a 6 mm (1/4 in.) total gap between the reinforcement and the clevis frame.
- .7 For trapeze hangers, provide U-bolts over piping to limit lateral and vertical movement, but allow approximately 6 mm (1/4 in.) total clearance to allow pipe thermal expansion movement.
- .8 Attach restraints to pipe hangers and trapezes. For existing piping, restraints may be attached to the pipe using pipe clamp assemblies manufactured for this purpose.
- .9 Where pre-engineering restraints in accordance with SMACNA or MSS SP-127 are used, the spacing for transverse and longitudinal restraints are to be reduced to 50% of the stated spans in these documents for the following piping systems:
 - .1 steel piping with threaded joints,
 - .2 plastic piping including but not limited to PVC, CPVC, PP, and PVDF,

- .3 fiberglass-reinforced pipe,
- .4 cast iron drainage piping with no-hub connectors,
- .5 glass drainage piping.

3.9 Piping Movement Control at Equipment Connections

- .1 Provide flexible connectors at piping connections to equipment in accordance with Specification section 20 05 16 except/and as follows.
- .1 The following table for pump connectors takes precedence over the requirements of Specification section 20 05 16.

Service	Pump Type	Limits	Connector Type
Heating pumps Glycol Heating pumps Condensate pumps	Base Mount	Flange NPS 6 to NPS 14	Bellows
		Flange NPS 4 and smaller	Corrugated
	Vertical In-Line	All	Corrugated
	Circulator	All	Flexible Metal Hose
Steam Feedwater pumps	Base Mount or Multi-stage	NPS 3 and larger	Bellows
		NPS 2 ½ and smaller	Flexible Metal Hose
Chilled water pumps Glycol cooling pumps	Base Mount	Flange NPS 10 to NPS 14	Bellows
		Flange NPS 8 and smaller	Corrugated
	Vertical In-Line	All	Flexible Metal Hose, Double-arch flexible rubber
	Circulator	All	Flexible Metal Hose
Condenser water pumps	Base Mount	All	Corrugated, Double-arch flexible rubber
	Vertical In-Line	All	Corrugated, Double-arch flexible rubber
Domestic Booster pumps	All	All	Corrugated
Sump pumps (sanitary and storm)	All	All	Flexible Metal Hose
Fire pumps	All	All	Flexible Metal Hose

- .1 The following table for equipment connectors takes precedence over the requirements of Specification section 20 05 16.

Equipment Type	Limits	Connector Type
Refrigeration Water Chillers	Chilled Water Piping	Corrugated connector, Double-arch flexible rubber
	Condenser Water Piping	Corrugated Connector, Double-arch Flexible Rubber
	Refrigerant Relief Piping	Corrugated Connector
Cooling Towers	Condenser Water Piping	Double-arch Flexible Rubber (indoors) Corrugated Connector (outdoors)
	Domestic Water Piping	Corrugated Connector
Refrigeration Condensing Units and Condenser Units	All	Flexible Metal Hose
Steam, heating and cooling coils, and humidifiers	All	Flexible Metal Hose, Corrugated Connector
Hot water reheat coils, Fan Coil units	All	Flexible Metal Hose, Flexible Non-Metallic Hose
Duct mounted humidifiers	All	Flexible Metal Hose, Flexible Non-Metallic Hose
Heat Exchangers	All	Flexible Metal Hose, Corrugated Connector
Domestic Hot Water Tanks	All	Flexible Metal Hose, Corrugated Connector
Medical Air Compressor, Medical Vacuum Pumps, Medical Gas cylinders	All	Flexible Metal Hose (bronze internals)
Air compressors, Compressed gas cylinders	All	Flexible Metal Hose
Other equipment not specifically listed	NPS 2 and smaller	Flexible Metal Hose
	NPS 2-1/2 and larger	Corrugated Connector

- .2 Provide seismic restraints at ends of piping where connected to equipment, to limit pipe movement so that it does not cause the flexible connector devices at the equipment to exceed their lateral movement rating;
 - .1 For pipe drops to equipment, provide a pipe guide on the pipe immediately above the flexible connector device, with clearance of not more than the lateral deflection rating of the flexible connector. Line the pipe guide with 6 mm (1/4 in.) neoprene pads of bridge bearing equality. Support the guide from the floor level.
 - .2 this requirement applies to piping that is otherwise exempt from seismic restraints.

3.10 Piping Risers Restraints

- .1 Use pipe anchors and guides for seismic restraints of vertical pipe risers. Do not use separate cable restraints or braces.

- .2 For horizontal seismic forces acting on vertical pipe risers, use the seismic force coefficient "Ks" value at the floor location of the pipe anchor or guide (as applicable), and the restrained weight is to include 50% of the pipe and fluid content weight between the anchor or guide and the next anchor or guide, in both vertical directions.
- .3 For piping subject to thermal expansion:
 - .1 provide fully engineered pipe riser support system,
 - .2 for steel pipe;
 - (a) provide an anchor at the location shown,
 - (b) construct the anchor assembly using heavy-duty pipe riser clamps or pipe brackets with full-welded connections to the pipe, and full-welded or bolted connections to the anchor. Use mechanical anchors to bolt the pipe anchor to concrete floor, and weld pipe anchors to steel framing.
 - (c) unless otherwise shown, use a heavy-duty pipe riser clamp with a load capacity not less than two times the combined dead weight of pipe and water, dynamic load and seismic loads.
 - .3 for copper tube,
 - (a) attach a copper sleeve that matches the OD of the tube and fully braze the sleeve to the tube.
 - (b) alternatively, use a slip-on flange over the tube and fully-braze the flange to the tube,
 - (c) position the sleeve or flange immediately above and bearing on a pipe riser clamp, which is bolted to the riser anchor.
 - .4 based on engineered support design, provide intermediate isolator supports.
- .4 For piping not subject to thermal expansion;
 - .1 provide pipe guides and riser clamps for piping not subject to thermal expansion in accordance with Specification section 20 05 29,
- .5 For all piping;
 - .1 for cast iron DWV pipe, plastic DWV pipe, and glass DWV pipe, provide a guide at each floor level.
 - .2 for all other piping, provide guide or riser clamp at every other floor but not to exceed 7.6 m (25 ft) spacing, unless engineering design determines other spacing dimensions,

3.11 Conduit Restraints

- .1 Conduits for mechanical wiring are to be restrained in accordance with the requirements of section 26 05 49.

3.12 Floor Mounted Equipment Restraints

- .1 Anchor floor mounted equipment with anchor bolts, minimum four bolts for rectangular equipment bases, and three bolts for circular equipment bases.
 - .1 friction due to gravity loads shall not be considered to provide resistance to seismic forces.
- .2 For non-isolated equipment, secure equipment directly using equipment base supports or use SRB brackets. Alternatively, use type SS1 or SS2 snubbers where equipment is not subject to overturning moments. Use type SS3 snubbers where equipment is subject to overturning moments;
 - .1 for type SS1 snubbers, provide a minimum of eight (8) snubbers for each piece of equipment, with two units placed on each corner of the equipment base frame.
 - .2 for type SS2 and SS3 snubbers, provide a minimum of four (4) snubbers for each piece of equipment, with one unit placed on each face of the equipment base frame.
- .3 For round equipment bases, such as expansion tanks with floor-support ring without mounting flanges, use type SS3 snubbers or purpose-constructed clamps to positively attach to the equipment base and

anchored to the floor. Welding to the equipment base is permitted only where the equipment manufacturer information permits this method of attachment.

- .4 Provide resilient neoprene bushings and washers between equipment and anchor bolts where equipment is secured rigidly to floor or housekeeping pad.
- .5 Install snubber devices only after equipment is installed and operating, to ensure no metal-to-metal contact. Adjust snubbers so that any clearance gaps do not exceed 6 mm (1/4 in.).
- .6 For floor mounted equipment with vibration isolators;
 - .1 select basic vibration isolator in accordance with Section 20 05 48.
 - .2 select seismic restraint for each piece of equipment of either:
 - (a) integrated seismic vibration restraint type 2-S, 3-S or 4-S, or
 - (b) vibration isolator in accordance with Section 20 05 48 combined with seismic snubbers SS1, SS2 or SS3 as applicable to suit overturning moment.
 - .3 Do not mix type of restraint on the same piece of equipment.
 - .4 Where the equipment is not provided with a structural base to transfer seismic forces, provide a structural-shape or formed steel channel base or a Type C inertia base as a complete steel frames suitably cross braced in both horizontal directions to withstand seismic induced shear force and bending moments.

3.13 Suspended Equipment Restraints

- .1 For isolated equipment, select basic vibration isolator in accordance with Section 20 05 48.
- .2 Provide restraints for equipment independent of restraints provided on connecting ductwork or piping.
- .3 Provide reinforcement of hanger rods to prevent buckling.
- .4 Provide SCR type longitudinal and transverse restraints at each corner of the equipment (total of eight (8) cables). Alternatively, a single SCR cable can be installed at each corner of the equipment, positioned at 45° to both transverse and longitudinal direction and sized for concurrent transverse and longitudinal loads.

3.14 Rooftop Fans

- .1 Fasten vibration isolators (where applicable) and seismic restraints to roof curbs or sleepers with mechanical fasteners of the type determined by the seismic restraint manufacturer.
- .2 Fasten roof curbs or sleepers to the roof structure with bolted angles positioned at each restraint. Fastening of curbs or sleepers to roof with roofing adhesive only is not acceptable.

3.15 Equipment Restraints - Surface Wall-Mounted Equipment and Panels

- .1 Application: for non-rotating mechanical equipment, electrical panels, control panels, motor controllers, and other electrical distribution equipment.
- .2 Attach equipment to horizontal galvanized steel channels and fasten with bolts equipped with neoprene isolation grommet washers. Channels to extend past the side of the equipment to allow anchoring to wall. Select bolts for concurrent shear dead-weight without deduction for uplift load, and tension restraint load.
- .3 Attach channels to concrete or masonry walls with not less than four (4) anchors with each anchor having a not less than a 1.5 safety factor.

3.16 Equipment Restraints - Recessed Wall-Mounted Equipment

- .1 Application: for non-rotating mechanical equipment, electrical panels, control panels, motor controllers, and other electrical distribution equipment.
- .2 Mount recessed equipment through the top, bottom and sides of the equipment housing to adjacent block wall or wall studs.

3.17 Inspection, Testing, Adjustment and Reporting

- .1 For equipment supported on vibration isolators, field measure air gaps on each restraint and if necessary adjust the restraint so that the clearance air gap does not exceed 6 mm (1/4 in.). Provide a written report identifying the results of each test and adjustment, to the Seismic Engineer and Consultant for review.
- .2 Arrange for the seismic restraint manufacturer to inspect and report on the installation at completion of the work. Make corrections of deficiencies identified by the manufacturer. This work is to be performed prior to the final field review by the Seismic Engineer.
- .3 Arrange for Seismic Engineer to conduct a final inspection prior to substantial performance of the Work. Make corrections of deficiencies identified by Seismic Engineer. This work is to be performed prior to the final field review by Consultant.
- .4 Make corrections of deficiencies identified by Consultant.
- .5 Submit the following reports prior to application for substantial performance of the Work, or where applicable, ready-for-takeover of the Work:
 - .1 Seismic Engineer periodic and final inspection reports,
 - .2 seismic restraint manufacturer inspection reports,
 - .3 Seismic Engineer declaration of general review.

3.18 Schedules

- .1 The following schedules are attached to and form part of this Specification section.
 - .1 Schedule A Seismic Force Coefficients and SMACNA SHL Class
 - (a) Table 1 Horizontal Seismic Force Factor, K_s
 - (b) Table 2 Vertical Seismic Force Factor, K_v
 - (c) Table 3 Seismic Force Coefficient C_p for Fire Protection Piping

Schedule A –Seismic Force Coefficients and SMACNA SHL Class

Table 1 – Horizontal Seismic Force Coefficient (except fire protection piping)		
Building Level	Horizontal Seismic Force Coefficient (except fire protection)	SMACNA SHL Class
	K_s	---
Roof		
7 th floor Service Room, (high level)		
7 th floor Service room, (floor level)		
6th Floor		
5th Floor		
4th Floor		
3 rd Floor		
2 nd Floor		
Ground Floor		
Basement		
Basement Service Room, (high level)		
Basement Service Room, (floor level)		

Table 2 – Vertical Seismic Force Coefficient (except fire protection piping)	
Building Level	Vertical Seismic Force Coefficient
	K_v
All Floors	

Table 3 – Seismic Force Coefficients for Fire Protection Piping	
Building Level	Coefficient
	C_p
All Floors	

END OF SECTION

COMMON REQUIREMENTS FOR MECHANICAL INSULATION 20 07 11

1 GENERAL

1.1 Scope

- .1 Common requirements for insulation of mechanical services provided under Division 20 to 25 of the Work. The requirements of this specification section apply to separate specification sections for insulation of ductwork, equipment and piping.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 29 Common Hanger and Support Requirements for Piping
 - .2 20 07 13 Duct Insulation
 - .3 20 07 16 Equipment Insulation
 - .4 20 07 19 Piping Insulation
 - .5 20 05 29 Common Hanger and Support Requirements for Piping

1.3 Definitions and Abbreviations

- .1 The following definitions apply to this section.
 - .1 **Ambient:** as applied to temperatures means the interior or outdoor air temperature at time of installation.
 - .2 **Coating:** light-consistency compound for indoor applications used in conjunction with reinforcing membrane, to provide either a breathable or vapour barrier finish to insulation.
 - .3 **Cold services:** means cold ductwork, equipment and/or equipment.
 - (a) **Cold ductwork:** mechanical ductwork with a service temperature greater than 1°C and up to and including 16°C (34°F to 61°F).
 - (b) **Cold equipment:** mechanical equipment with a service temperature of 16°C (61°F) or less,
 - (c) **Cold piping:** mechanical piping with a service temperature of 16°C (61°F) or less,
 - .4 **Concealed (services):** mechanical services that are located: in the space above opaque suspended ceilings; within trenches not located in service rooms; within pipe and/or duct shafts; or in non-accessible chases and wall cavities.
 - .5 **Conditioned air:** air supplied from air handling units that heats, cools, dehumidifies, or humidifies the air.
 - .6 **Conditioned space:** an enclosed space or room that is heating, cooled, dehumidified and/or humidified.
 - .7 **Dual temperature services:** means dual temperature ductwork, piping and/or equipment that operates, at different times, at both hot and cold temperatures.
 - (a) **Dual temperature ductwork:** mechanical ductwork that operates at temperatures greater than 1°C and up to and including 38°C (34°F to 100°F), at different times or at different locations in the duct system and includes cooling systems with terminal reheat.
 - (b) **Dual temperature equipment:** means mechanical equipment that operate, at different times, at cold equipment temperatures and at hot equipment temperatures.
 - (c) **Dual temperature piping:** mechanical piping that operate, at different times, at cold piping temperatures and at hot piping temperatures.

- .8 **Ductwork:** includes ducts, fans, air handling equipment casings, and plenums.
- .9 **Exposed (services):** mechanical services that are located in areas that are not "concealed" as defined above for concealed services. For greater certainty, the following locations are exposed services:
 - (a) services in tunnels,
 - (b) services in space beneath raised floors.
 - (c) trenches located in service rooms.
- .10 **Finish covering:** a field-applied protective layer for insulation that provides an aesthetic finish but that may also provide mechanical-impact protection, weather-protective, moisture and/or vapour barrier protection.
- .11 **Hot services:** means hot ductwork, equipment and/or equipment.
 - (a) **Hot ductwork:** mechanical ductwork with a service temperature greater than 28°C and up to and including 65°C (80 to 150°F) and does not have any mechanical cooling.
 - (b) **Hot equipment:** mechanical equipment with a service temperature 38°C (100°F) and greater.
 - (c) **Hot piping:** mechanical piping at service temperatures as shown in Table 1 of specification section 20 07 19.
- .12 **Jacket:** a factory-applied material used to contain insulation and may function as a vapour barrier. Jacketed insulation may also be further protected by covering with a finish covering.
- .13 **Mastic:** heavy-consistency waterproof compound for outdoor applications, used in conjunction with reinforcing membrane that remains adhesive and generally pliable with age, to provide either a breathable or vapour barrier finish for outdoor insulation.
- .14 **Mechanical services:** equipment, piping, ductwork and related accessories provided under Division 20 to 25 of the Work.
- .15 **Outdoor (services):** mechanical services located outside of the building envelope including services located beneath overhangs, located in unconditioned soffits, or exposed to any outdoor condition including temperature, sun exposure, or precipitation.
- .16 **Pure water:** water that has been treated with filtration equipment, including but not limited to reverse osmosis, deionization, ultra-filtration, ultra-violet, distillation or any combination of such or similar equipment, to achieve water quality significantly free of impurities.
- .17 **Service temperature:** the highest (for hot mechanical services) or the lowest (for cold mechanical services) gas or vapour design operating temperature, or the liquid supply operating temperature.
- .18 **Surface temperature:** for the purpose of this specification, has the same meaning as service temperature.
- .19 **Unconditioned (space):** rooms or spaces that are not conditioned spaces, and includes ceiling spaces which are not part of a ceiling return air plenum system.
- .20 **Wet area:** spaces subject to high humidity or where mechanical services may be exposed to direct contact with water, including not limited to: pools, shower rooms, tub rooms, medical device reprocessing, dishwashers, sterilizers, cart-washing, vehicle washing, and emergency showers.

1.4 Applicable Codes and Standards

- .1 Installation codes and standards:
 - .1 NFPA 90-A Installation of Air-Conditioning and Ventilating Systems
 - .2 ASHRAE/IES 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings
 - .3 NFPA 255 Test of Surface Burning Characteristics of Building Materials
- .2 Product standards:

- | | | |
|-----|-------------------|---|
| .1 | CAN/ULC-S102 | Standard Method of Test for Surface Burning Characteristics of Building Materials and Assemblies |
| .2 | CAN/ULC-S102.2 | Standard Method of Test for Surface Burning Characteristics of Flooring, Floor Coverings, and Miscellaneous Materials and Assemblies |
| .3 | CAN/ULC-S114 | Standard Method of Test for Determination of Non-Combustibility in Building Materials |
| .4 | ASTM B209 | Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate |
| .5 | ASTM B240 | Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications |
| .6 | ASTM C177 | Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded Hot-Plate Apparatus |
| .7 | ASTM C411 | Standard Test Method for Hot Surface Performance of High Temperature Thermal Insulation |
| .8 | ASTM C449 | Standard Specification for Mineral Fibre Hydraulic-Setting Thermal Insulation and Finishing Materials |
| .9 | ASTM C518 | Standard Test Method for Steady State Thermal Transmission Properties by Means of Heat Flow Meter Apparatus |
| .10 | ASTM C533 | Standard Specification for Calcium Silicate Block and Pipe Thermal Insulation |
| .11 | ASTM C534 | Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form |
| .12 | ASTM C547 | Standard Specification for Mineral Fiber Pipe Insulation |
| .13 | ASTM C552 | Standard Specification for Cellular Glass Thermal Insulation |
| .14 | ASTM C553 | Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications |
| .15 | ASTM C591 | Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation |
| .16 | ASTM C612 | Standard Specification for Mineral Fiber Block and Board Thermal Insulation |
| .17 | ASTM C795 | Standard Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel |
| .18 | ASTM C1126 (Gr.1) | Standard Specification for Faced and Unfaced Rigid Cellular Phenolic Thermal Insulation |
| .19 | ASTM C1290 | Standard Specification for Flexible Fibrous Glass Blanket Insulation Used to Externally Insulate HVAC Ducts |
| .20 | ASTM C1393 | Standard Specification for Perpendicularly Oriented Mineral Fiber Roll and Sheet Thermal Insulation for Pipes and Tanks |
| .21 | ASTM E84 | Standard Test Method for Surface Burning Characteristics of Building Materials |
| .22 | CGSB 51-GP-52MA | Vapour Barrier, Jacket and Facing Material for Pipe, Duct, and Equipment Thermal Insulation. |
| .23 | CGSB 51.53-95 | Poly(Vinyl Chloride) Jacket Sheeting, for Insulated Pipes Vessels and Round Ducts. |

1.5 Qualified Tradespersons

- .1 Work to be performed by a recognized specialist firm with an established reputation in this field.

Standard of Acceptance

- Custom Insulation Systems
- White & Greer Co Ltd
- Thermax Environmental Inc.
- ICON Insulation Inc.

1.6 Submittals

- .1 Submit manufacturer catalogue cut-sheets for the following materials in one bound submission;
- .1 insulation,
 - .2 coatings, mastics, and sealants,
 - .3 reinforcing membranes,
 - .4 finish covering materials,
 - .5 PVC fitting covers.
- .2 Submit an installation detail drawing indicating how insulation, coatings and vapour barriers are applied in general, and specifically for pipe fittings and equipment insulation.
- .3 Submit product sample boards:
- .1 sample assembly of each type of insulation and covering,
 - .2 mount samples on PVC coroplast board with typewritten label beneath each sample indicating service and material specification,
 - .3 include samples of vapor barrier installation including coatings (indoors), mastics (outdoors), reinforcing membranes, on a sample of a pipe butt joint and one elbow.]

1.7 Quality

- .1 Manufacturers and products are listed in this section to establish quality and manufacturing standards. Products from other manufacturers with explicitly similar characteristics may be acceptable but must be submitted as an alternative product submission.

2 PRODUCTS

2.1 General Requirements

- .1 Adhesives, coatings, finish coverings, lagging, sealers, and tapes:
- .1 maximum flame spread rating of 25 to CAN/ULC-S102/102.2 or ASTM 84.
 - .2 maximum smoke developed rating of 50 to CAN/ULC-S102/102.2 or ASTM 84.
 - .3 exception: vapor barrier mastics on mechanical services located outside of the building.

2.2 Adhesives, Fasteners, and Tape

- .1 Contact bond cement:
- .1 for quick setting for metal surfaces.
 - .2 Volatile Organic Content: maximum 80 g/L.

Standard of Acceptance

- Bakor - fig. 220-05

- Foster – fig. Drion 85-75
- .2 Adhesive for flexible closed cell foam insulation:
 - .1 Volatile Organic Content: maximum 80 g/L.
 - Standard of Acceptance*
 - Armacell - Armaflex 520 BLV
 - Armacell - Armaflex. Low VOC Spray Contact Adhesive
- .3 Lap seal adhesive:
 - .1 for joints and lap sealing of vapour barriers.
 - .2 Volatile Organic Content: maximum 250 g/L.
 - Standard of Acceptance*
 - Bakor - fig. 220-05
 - Childers - fig. CHIL-STIX FRN CP-82
- .4 Fibrous insulation adhesive:
 - .1 Volatile Organic Content: maximum 250 g/L
 - Standard of Acceptance*
 - Childers - fig. CHIL-STIX FRN CP-82
 - Foster - fig. 85-70
- .5 Vapour barrier tape:
 - .1 colour matched and foil faced
 - .2 listed to UL 181A.
 - Standard of Acceptance*
 - Johns Manville - fig. Zeston Z-Tape
 - MacTac Canada Ltd – fig. Vinyl Scrim or Foil Scrim Kraft
 - Compac Corp.
 - Fattal Canvas Inc. - fig. Insultape
- .6 Weld pins, studs, clips and washers:
 - .1 Galvanized steel or copper plated steel, stainless steel or aluminium to match ductwork material.
 - .2 Attachment method:
 - (a) welded for outdoor ducts,
 - (b) welded for indoor ducts,
 - (c) self-adhesive base may be used for vertical surfaces of rectangular ducts.
 - Standard of Acceptance*
 - Midwest - fig. Fasteners
 - Jordahl - fig. Studwelding
- .7 Staples:
 - .1 Monel, flare type, minimum size 12 mm (½ in).
- .8 Tie wire:
 - .1 1.6 mm (16 ga) stainless steel with twisted ends.
- .9 Caulking for sheetmetal finish covers (outdoor use only)
 - .1 fast-drying, aluminum colour finish, flexible butyl elastomer based vapour barrier sealant.

Standard of Acceptance.

- ° Foster - fig. 95-44

2.3 Coatings and Reinforcing Membranes

.1 Reinforcing membrane:

.1 synthetic fibre:

- (a) Leno weave,
- (b) indoor and outdoor use.

Standard of Acceptance

- ° Foster - fig. Mast-A-Fab

.2 glass-fibre fabric:

- (a) indoor use.

Standard of Acceptance

- ° Childers - fig. Chil-Glas #5/#10

.3 glass-fibre fabric for use with elastomeric closed cell foam:

- (a) indoor use.

Standard of Acceptance

- ° Childers - fig. Chil-Glass #10

.2 Breather coating - Indoors:

- .1 for breather coatings and lagging adhesive,
- .2 Volatile Organic Content: maximum 50 g/L
- .3 white in colour,

Standard of Acceptance

- ° Childers- fig. CP-50A HV2
- ° Foster - fig. 30-36

.3 Breather mastic - Outdoors:

- .1 for breather coatings and lagging adhesive,
- .2 abrasion resistive, flexible,
- .3 UV stabile,
- .4 grey in colour.

Standard of Acceptance

- ° Childers - fig. Vi-Cryl CP-10/11
- ° Foster - fig. 35-00 / 45-00
- ° Bakor - fig. 120-10

.4 Vapor barrier coatings - Indoors:

- .1 Volatile Organic Content: maximum 50 g/L.
- .2 for vapor barrier coatings and lagging adhesive except for elastomeric closed cell foam,
 - (a) permeance rating 0.02 perms maximum,
 - (b) white in colour

Standard of Acceptance

- Childers - fig. Chil Perm CP-34/35
- Foster - fig. 30-80, 30-90

.5 Vapor barrier mastic - Outdoors:

- .1 for vapor barrier coatings and lagging adhesive,
- .2 asphalt cutback,
- .3 permeance rating 0.02 perms maximum,
- .4 grey in colour.
- .5 for outdoor use only.

Standard of Acceptance

- Childers - fig. Chil-Pruf CP-22
- Foster - fig. 60-25/60-26

.6 Vapour barrier coatings – elastomeric foam insulation:

- .1 for indoor and outdoor use,
- .2 water bases sealer/finishing coat, water and UV resistant.
- .3 white in colour.

Standard of Acceptance

- Armacell - fig. ArmaFlex WB Finish

2.4 Insulation Finishing Cement

- .1 Mineral fibre, hydraulic-setting insulation cement, to ASTM C449
- .2 Temperature rating: 650°C (1200°F)

Standard of Acceptance

- Johns Manville - fig. CalCoat-127
- Ramco Insulation - fig. Ramcote 1200 (PKI Quick Cote)

2.5 Field Applied Coverings

.1 Fabric finish covering:

- .1 plain weave cotton fabric at 220 g/m2 (6 oz/sq yd), treated with fire retardant lagging adhesive, or
- .2 re-wettable fiberglass lagging fabric with water activated self-adhesive.
- .3 suitable for field painting.

Standard of Acceptance

- Fattal - fig. Thermocanvas
- Clairmont - fig. Diplag 60
- Newtex - fig. Zetex Rewettable

.2 PVC finish covering:

- .1 PVC sheeting, or pre-cut and rolled sheeting to suit OD of pipe and insulation, with UV inhibitor for white colour product,
 - (a) minimum thickness:
 - i) indoors: 0.5 mm (20 mil-in.),
 - ii) outdoors: 0.8 mm (30 mil-in.),

- (b) maximum operating temperature: 66°C (150°F) at the material,
- (c) listed to CAN/ULC-S102/S102.2 or ASTM E84,
- .2 PVC fitting covering with integral insulation inserts:
 - (a) minimum 0.5 mm (20 mil-in) thickness,
 - (b) pre-molded fitting covers, one or two piece,
 - (c) maximum operating temperature: 66°C (150°F) at the material,
 - (d) self-sealing longitudinal joints or field applied sealer adhesive,
 - (e) listed to CAN/ULC-S102/S102.2 or ASTM E84,
- .3 colour: [white][in accordance with the following:
 - (a) city water, domestic water, non-potable water: green
 - (b) HVAC water: green
 - (c) steam and condensate: grey
 - (d) RO water: green]
- .4 foam-glass or glass-fibre insulation molded insert, including for elbows, tees, valves, end-caps, and mechanical pipe couplings,
- .5 multiple layers where required for thicker pipe insulation thicknesses.
- .6 pressure sensitive, colour matching vinyl tape.

Standard of Acceptance

- Johns Manville - fig. Zeston 2000
- Proto PVC - fig. LoSMOKE
- ACWIL Insulations
- Sure Fit Systems

- .3 Metal finish covering:
 - .1 straight pipe, duct or plenum:
 - (a) stucco embossed aluminum 3105 or 3003 to ASTM B-209, not less than 0.45 mm (0.016 in) thick sheet, with integral 3 mil polyfilm moisture barrier on the interior surface, lock-forming quality,
 - (b) stainless steel type 304 to ASTM A-240, not less than 0.25 mm (0.010 in) thick sheet, lock-forming quality;
 - i) stucco embossed,
 - ii) 0.19 mm (3/16 in) corrugated.
 - .2 fittings:
 - (a) custom made swaged ring or lobster back covers on bends and die shaped fitting covers over pipe fittings, round duct fittings, valves, strainers, flanges, and grooved couplings.
 - .3 bands:
 - (a) 12 mm (½ in) wide stainless steel with mechanical fasteners.

Standard of Acceptance

- Alcan Canada Products - fig. Thermaclad Type 1
- Childers Products Inc. - fig. Fab Straps

- .4 Self-adhesive weather barrier finish cover (SAWB):
 - .1 self-adhering membrane of acrylic adhesive with siliconized release paper, not exceeding flame/smoke generation rating of 25/50, for indoor and outdoor use,

- .2 self-adhering membrane of rubberized asphalt compound with siliconized release paper, for outdoor use only
- .3 laminated to stucco-embossed aluminum foil,
- .4 self-sealing with penetration of self-tapping screws.
- .5 water vapour permeance 0.05 perms.

Standard of Acceptance

- VentureClad- fig. 1579CW - indoor and outdoor applications
- Bakor - fig. Foilskin (outdoor applications only)
- Polyguard Products fig. Alumaguard 60 (outdoor applications only)
-

- .5 Protective finish for elastomeric cellular foam insulation
 - .1 indoors and outdoors:

Standard of Acceptance

- Armaflex WB Finish

2.6 Insulation

- .1 Refer to specification sections for duct, equipment, and piping insulation.

3 EXECUTION

3.1 General Requirements

- .1 Apply insulation after pressure and leakage testing is completed and accepted, and heat tracing (if any) is installed.
- .2 Surfaces to be clean and dry before application of insulation.
- .3 Store and use adhesives, mastics, and insulation cements at ambient temperatures and conditions recommended by the product manufacturers.
- .4 Do not apply insulation on chrome plated surfaces of piping, valves, fittings, and equipment.
- .5 Cut and bevel insulation around nameplates and pressure vessel certification stamps, seals or similar markings.
- .6 Neatly finish insulation at supports, protrusions, and interruptions.
- .7 Where insulation media is exposed, seal the insulation with reinforced vapor barrier or breather coating or mastic.

3.2 Installation of Insulation

- .1 Refer to specification sections for duct, equipment, and piping insulation.

3.3 Sealing of Insulation – General Requirements

- .1 The following requirements apply to all mechanical insulation unless otherwise specified in each mechanical service insulation specification section. Refer to separate specifications for specific sealing requirements for ductwork, equipment and piping insulation.
- .2 Apply sealer coatings and mastic in accordance with the following:
 - .1 use breather coating/mastics for hot services:
 - .2 use vapour barrier coating/mastic for cold and dual temperature services:
 - .3 only use mastics on outdoor installations.

- .4 apply mastics and coatings when ambient temperature is above 4°C (40°F), unless manufacturer's instructions permit colder ambient installation conditions.
- .3 Maintain integrity of vapour barrier through sleeves, around fittings and at hangers and supports.

3.4 Insulation Finish Coverings

- .1 Where required to be provided by other mechanical insulation specification sections, install protective finish coverings in accordance with the following.
- .2 Install protective finish coverings on insulation after breather and vapor barrier sealing is completed.
- .3 For hot services that are exposed in wet areas, secure and seal coverings in accordance with the requirements for cold and dual temperature services.
- .4 Cut finish covering materials to allow 50 mm to 100 mm (2 in to 4 in) overlaps onto adjacent sheets. On vertical services, arrange circumferential overlaps to be on the lower end of each cover section.
- .5 PVC finish covering:
 - .1 Adhesives and sealers to be compatible with PVC material.
 - .2 Hot services;
 - (a) secure sheeting with colour matched tape around circumference, at least two places per section of sheet, and by stapling longitudinal and circumferential edges,
 - (b) except in wet areas, do not seal major joint edges with vapour barrier tape,
 - (c) seal PVC fitting covers at throat and heel seams by stapling and secure over adjacent insulation covers by banding or taping ends to adjacent finish covering with colour matched tape.
 - (d) Install PVC covers in accordance with the requirements for cold and dual temperature services.
 - .3 Cold and dual temperature services:
 - (a) seal longitudinal edges with vapor barrier coating adhesive or colour matched vapour barrier tape for the full length and depth of the overlap,
 - (b) seal circumferential butt edges of PVC fitting covers with reinforced vapour barrier coating adhesive extending over adjacent pipe insulation section with an overlap of at least 50 mm (2 in),
 - (c) seal PVC fitting covers at throat and heel seams by solvent bonding and secured over insulation with reinforced vapor barrier coating overlapping adjacent service insulation a minimum of 50 mm (2 in),
 - (d) neatly finish exposed edges with vapour barrier sealant/mastic.
- .6 Metal finish covering:
 - .1 use stucco embossed metal finish covers on round surfaces with diameter of 2.4 m (8 ft) and smaller; refer to applicable duct, equipment and piping specification sections for metal type.
 - .2 use corrugated stainless steel metal finish covers on flat surfaces, and on round surfaces with diameters greater than 2.4 m (8 ft).
 - .3 apply metal finish coverings over mechanical services, with a 60 mm (2-1/2 in) overlap,
 - .4 use lock-on systems or secure sheeting with bands 450 mm (18 in) apart.
 - .5 make-up curved surfaces with custom made swaged ring or lobster back covers.
 - .6 for indoor mechanical services;
 - (a) seal cover joints for cold and dual temperature services with clear or colour-matched calking.

- .7 on outdoor mechanical services;
 - (a) seal cover joints for cold and dual temperature services with clear or colour-matched calking to permit expansion of metal finish covers.
- .7 Fabric finish covering:
 - .1 Cotton lagging:
 - (a) apply cotton lagging with minimum two coatings of breather or vapor barrier coating adhesive as applicable to the piping system, and finish to provide a smooth surface free of wrinkles and sags.
 - (b) where cotton lagging with appropriate coating is used this satisfies the requirements of a sealer coating for cold and dual temperature services.
 - .2 Fiberglass lagging:
 - (a) apply re-wettable fiberglass lagging in accordance with manufacturer instructions, and finish to provide a smooth surface free of wrinkles and sags.
 - (b) for cold and dual temperature services, apply a finish coat of vapour barrier sealer.
 - (c) where re-wettable fiberglass lagging is used this satisfies the requirements of a breather coating for hot piping systems,

3.5 Mechanical Damage Protection - Indoors

- .1 Protect visible pipe insulation extending up through a floor sleeve at the floor line with 1.2 mm (18 ga) thick stainless steel protection shield approximately 100 mm (4 in) high, secured to floor slab. Conceal fastenings by use of a floor plate.
- .2 For piping systems using finishes, this protection cover is in addition to the specified pipe finish cover.

3.6 Field Quality Control

- .1 The Consultant reserves the right to have protective finish coverings removed on up to 1% of all cold service and dual temperature service surfaces, fittings, flanges, couplings, valves, and ductwork/pipeline accessories to review the installation of the insulation, at no additional cost.
- .2 If insulation sealing is found to be incorrect at any one sampled location, remove the protective finish on all fittings, flanges, couplings, valves, and pipeline accessories for review, at no additional cost.
- .3 Repair defective insulation sealing and replace protective coverings at no additional cost.

End of Section

PIPING INSULATION 20 07 19

1 GENERAL

1.1 Scope

- .1 Provide insulation, coatings, finishing coverings and mechanical protection of piping, valves, fittings, and pipeline accessories.
- .2 Conform to Specification section 20 07 11 for common requirements for mechanical insulation.
- .3 [][Provide fire rated insulation on piping as shown, including fire protection standpipes. Coordinate with the contractor under Division 21 for location and extent of standpipes to be protected.]

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other Specification sections, the work under this section directly integrates with or refers to the following Specification sections:
 - .1 20 05 29 Common Hanger and Support Requirements for Piping
 - .2 20 07 11 Common Requirements for Mechanical Insulation

2 PRODUCTS

2.1 General Requirements

- .1 Insulation, adhesives, eh coatings, finish coverings, lagging, sealers, and tapes:
 - .1 maximum flame spread rating of 25 to CAN/ULC-S102/102.2 or ASTM 84.
 - .2 maximum smoke developed rating of 50 to CAN/ULC-S102/102.2 or ASTM 84.
 - .3 exception: vapor barrier mastics on mechanical services located outside of the building

2.2 Pipe Insulation

- .1 Type P-1 (molded glass-fibre):
 - .1 factory molded rigid glass-fibre to ASTM C547,
 - .2 nominal pipe size: NPS 24 and smaller,
 - .3 service temperature, jacketed: -18°C (0°F) to 65°C (150°F),
 - .4 jacket: all-service-jacket (ASJ) of white kraft paper bonded to aluminum foil, reinforced with glass fibre yarn, and laminated to an interior kraft paper face,
 - .5 vapor transmission: maximum 0.02 perms to ASTM E96,
 - .6 listed to CAN/ULC-S102/S102.2 or ASTM E84,
 - .7 reduced environmental impact feature of either: bio-based binders, 25% minimum recycled glass content, and/or paper-free ASJ jacket material,
 - .8 not to exceed a maximum thermal conductivity at the following meant insulation temperatures:

Mean Temperature °C	Conductivity W/(m·°C)	Mean Temperature °C	Conductivity W/(m·°C)
24	0.034	93	0.040

Standard of Acceptance

- Johns Manville - fig. Micro-Lok HP (25% recycled content)
- Owens Corning - fig. Fiberglas Evolution (paper-free ASJ)
- Knauf Fiberglass - fig. Earthwool 1000 Ecosse (bio-based binders)

.2 Type P-2 (semi-rigid glass-fibre roll):

- .1 glass fibre semi-rigid roll insulation for tanks and pipes, to ASTM C1393 or ASTM C177,
- .2 glass-fibre oriented to maintain uniform thickness when installed on round surfaces,
- .3 density: 40 kg/m³ (2.5 lb/ft³),
- .4 nominal pipe size: NPS 14 and larger,
- .5 service temperature with jacket: up to 65°C (150°F),
- .6 jacket: all-service-jacket ("ASJ") of white kraft paper bonded to aluminum foil, reinforced with glass fibre yarn, and laminated to an interior kraft paper face,
- .7 vapor transmission: maximum 0.02 perms to ASTM E96,
- .8 listed to CAN/ULC-S102/S102.2 or ASTM E84,
- .9 not to exceed a maximum thermal conductivity at the following meant insulation temperatures:

Mean Temperature °C	Conductivity W/(m·°C)	Mean Temperature °C	Conductivity W/(m·°C)
24	0.035	93	0.046

Standard of Acceptance

- Johns Manville - fig. Micro-Flex Pipe and Tank Wrap
- Owens Corning - fig. Fiberglas Pipe and Tank
- Knauf Fibreglass - fig. KwikFlex Pipe and Tank

.3 Type P-3 (molded mineral fibre):

- .1 factory molded mineral fibre to ASTM C547,
- .2 density: 128 kg/m³ (8.0 lb/ft³),
- .3 nominal pipe size: NPS 30 and smaller,
- .4 service temperature: up to 650°C (1200°F),
- .5 jacket: integral foil skim-kraft (FSK) jacket of aluminium foil reinforced with glass fibre yarn, and laminated to kraft paper,
- .6 listed to CAN/ULC-S102/S102.2 or ASTM E84,
- .7 not to exceed a maximum thermal conductivity at the following meant insulation temperatures:

Mean Temperature °C	Conductivity W/(m·°C)	Mean Temperature °C	Conductivity W/(m·°C)
38	0.036	149	0.049

Standard of Acceptance

- Rockwool - fig. ProRox PS 960
- Johns Manville - fig. MinWool-1200
- Industrial Fiber-Tek - fig. IFT 1200 Pipe

.4 Type P-4 (molded mineral fibre, high temperature):

- .1 factory molded mineral fibre, high temperature, to ASTM C547,
- .2 density: 145 kg/m³ (9.1 lb/ft³),
- .3 nominal pipe size: NPS 6 and larger,
- .4 service temperature: up to 760°C (1400°F),
- .5 jacket: none,
- .6 compressive strength: 53 kPa (8 psi) at 10% compression,
- .7 listed to CAN/ULC-S102/S102.2 or ASTM E84,
- .8 not to exceed a maximum thermal conductivity at the following meant insulation temperatures:

Mean Temperature °C	Conductivity W/(m·°C)	Mean Temperature °C	Conductivity W/(m·°C)
38	0.039	149	0.049

Standard of Acceptance

- Rockwool - fig. ProRox PS 980

.5 Type P-5 (cellular glass):

- .1 fabricated pipe and fitting shapes, cellular glass to ASTM C552,
- .2 density: 120 kg/m³ (7.5 lb/cu ft),
- .3 minimum compressive strength perpendicular to pipe surface: 620 kPa (90 psi),
- .4 nominal pipe size: NPS 16 and smaller,
- .5 service temperature: -268°C (-450°F) to 480°C (900°F),
- .6 minimum compressive strength perpendicular to pipe surface: 620 kPa (90 psi),
- .7 jacket: none,
- .8 listed to CAN/ULC-S102/S102.2 or ASTM E84,
- .9 not to exceed a maximum thermal conductivity at the following meant insulation temperatures:

Mean Temperature °C	Conductivity W/(m·°C)	Mean Temperature °C	Conductivity W/(m·°C)
10	0.040	24	0.042

Standard of Acceptance

- Owens Corning - fig. Foamglas

.6 Type P-6 (elastomeric foam plastic):

- .1 flexible elastomeric closed cell foam, tubular with self-sealing seams, to ASTM C534,

- .2 nominal pipe size: NPS 2 and smaller,
- .3 service temperature: -183°C (-297°F) to 82°C (183°F),
- .4 jacket: none,
- .5 manufacturer specific sealer/adhesive,
- .6 listed to CAN/ULC-S102/S102.2 or ASTM E84,
- .7 not to exceed a maximum thermal conductivity at the following meant insulation temperatures:

Mean Temperature °C	Conductivity W/(m·°C)	Mean Temperature °C	Conductivity W/(m·°C)
24	0.035	32	0.037

Standard of Acceptance

- Armacell - fig. AP Armaflex SS Pipe Insulation
- KFlex USA - fig. Insul-Tube

.7 Type P-7 (calcium silicate):

- .1 fabricated pipe and fitting shapes, calcium silicate, asbestos-free, to ASTM C533 Type I,
- .2 density: 232 kg/m³ (14.5 lb/cu ft),
- .3 minimum compressive strength perpendicular to pipe surface: 620 kPa (90 psi),
- .4 integral corrosion inhibitor to reduce under insulation corrosion,
- .5 nominal pipe size: NPS 4 to NPS 24,
- .6 service temperature: 20 to 649°C (70 to 1200°F).
- .7 jacket: none,
- .8 listed to CAN/ULC-S102/S102.2 or ASTM E84,
- .9 non-combustible to CAN/ULC-S114 or does not flame, glow, smolder or smoke when tested to ASTM C411.
- .10 not to exceed a maximum thermal conductivity at the following meant insulation temperatures:

Mean Temperature °C	Conductivity W/(m·°C)	Mean Temperature °C	Conductivity W/(m·°C)
38	0.050	93	0.056

Standard of Acceptance

- Johns Manville - fig. Thermo-12 Gold

.8 Type P-8 (removable high-temperature insulated jackets):

- .1 custom fabricated, removable/reusable high temperature insulated jackets for hot surfaces,
- .2 suitable for indoor and outdoor use,
- .3 process surface temperature: as shown in Schedule A,
- .4 maximum outer jacket touch-safe temperature protection: 95°C (203°F),

- .5 jacket: silicone impregnated glass-fibre, for temperatures up to 260°C (500°F),
- .6 insulation: mineral or fibreglass insulation suitable for system operating temperature,
- .7 internal liner: silicone impregnated fibreglass fabric, or stainless steel knitted wire mesh,
- .8 fasteners:
 - (a) stainless steel laced wire, for pipe sections,
 - (b) stainless steel mesh straps with buckle rings, for valves, strainers, meters and similar pipeline accessories,
- .9 metal identification tag, referenced equipment served.

Standard of Acceptance

- Firwin Corporation
- Thermohelp Canada Inc.

2.3 Pipe Support Insulation Inserts

- .1 General:
 - .1 molded or fabricated high-density molded insulation inserts for pipe supports.
- .2 Type P-21 – factory insulated shields:
 - .1 factory assembled high-density insulation insert with insulation shield,
 - .2 nominal pipe size: NPS 1/2 to NPS 30,
 - .3 service temperature: -40 to +125°C (-40 to +275°F),
 - .4 insulation:
 - (a) rigid phenolic foam insulation, to ASTM C1126, Gr.2, Type III,
 - (b) thickness: to match thickness of adjacent pipe insulation,
 - (c) nominal density:
 - i) NPS 10 and under: 60 kg/m³ (3.75 lb/ft³),
 - ii) NPS 12 to 30: 80 kg/m³ (5.0 lb/ft³),
 - (d) minimum compressive strength perpendicular to pipe surface: 620 kPa (90 psi),
 - (e) pipe circumference coverage: 360°,
 - (f) insulation length: to extend at least 38 mm (1-1/2 in.) past each end of the integrated shield.
 - (g) vapour barrier jacket: three-ply composite polyester film and aluminium foil with self-securing lap-seal, with zero perm rating,
 - (h) listed to CAN/ULC-S102/S102.2 or ASTM E84.
 - .5 insulation shield:
 - (a) Z275 (G90) coating-weight galvanized steel to ASTM A653, with formed ribs to centre clevis hanger or strut,
 - (b) edges flared or hemmed to prevent damage to insulation,
 - (c) adhered to bottom of insulation insert,
 - (d) width: covering 180° arc of insulation,
 - (e) length and thickness: as required to not exceed the compression strength of the insulation insert when supporting piping filled with water based on the maximum pipe support spans as defined in MSS SP-58.
 - .6 heavy-duty insulation shield (designation P-21HD):

- (a) as specified above for insulation shield except/and as follows,
- (b) shield thickness: 2.75 mm (12 ga),
- (c) with structural steel plate welded to bottom of shield.

.7 sliding protection shield (designation P-21SL)

- (a) as specified above for insulation shield except/and as follows,
- (b) secondary shield located below the primary protection shield, with PTFE layer bonded to the upper surface of the secondary shield,
- (c) designed to allow relative movement between the primary shield and secondary shield.

Standard of Acceptance

- Buckaroos Inc. - fig. CoolDry Insulated Saddles
- Buckaroos Inc. - fig. CoolDry Heavy Duty Insulated Saddles
- Buckaroos Inc. - fig. CoolDry Sliding Insulated Saddles

.3 Type P-22 - cellular glass:

- .1 cellular glass to ASTM C552,
- .2 nominal pipe size: NPS 1-1/2 to NPS 24,
- .3 density: nominal 120 kg/m³ (7.5 lb/ft³),
- .4 minimum compressive strength perpendicular to pipe surface: 620 kPa (90 psi),
- .5 service temperature: -73°C to +121°C (-100°F to 250°F),
- .6 listed to CAN/ULC-S102/S102.2 or ASTM E84.

Standard of Acceptance

- Owens Corning - fig. Foamglas

.4 Type P-23 - calcium silicate:

- .1 calcium silicate to ASTM C533 Type I, with integral corrosion inhibitor to reduce under insulation corrosion, asbestos-free,
- .2 nominal pipe size: NPS 1-1/2 to NPS 24,
- .3 density: nominal 232 kg/m³ (14.5 lb/cu ft),
- .4 minimum compressive strength perpendicular to pipe surface: 620 kPa (90 psi),
- .5 service temperature: 20 to 649°C (70 to 1200°F),
- .6 thermal performance: 0.058 W/m/C @ 149°C (0.40 btu/hr/in/sq ft/F @ 300°F).

Standard of Acceptance

- Johns Manville - fig. Thermo-12 Gold

3 EXECUTION

3.1 General

- .1 Where repairs are made to existing insulated piping due to connections of new piping work, the insulation thickness for the existing piping is permitted to match the existing insulation nominal thickness, provided the extent of new insulation does not exceed a length of 1000 mm (39 in).

3.2 Applicable Systems – Hot piping

- .1 Insulate Hot piping systems including pipe, valves, fittings, and pipeline accessories in accordance with the Schedule A at the end of this Specification section.
 - .1 Table 1A for all piping except engine combustion gas exhaust piping,
 - .2 Table 1B for engine combustion gas exhaust piping.
- .2 Insulate condensate piping in accordance with the same criteria as its associated steam system.
- .3 Insulate piping for safety valves or safety relief valves that is located;
 - .1 less than 2.4 m (8 ft) above a floor or work surface, or
 - .2 within 1 m (39 in) horizontally of, and less than 2.4 m (8 ft) above, an elevated work surface.

3.3 Applicable Systems - Cold and Dual Temperature Piping

- .1 Insulate Cold and Dual temperature piping systems including pipe, valves, fittings, and pipeline accessories in accordance with Schedule B at the end of this Specification section.
- .2 Insulate the following drainage services or equipment:
 - .1 storm water drainage systems in the following locations:
 - (a) roof drain bodies,
 - (b) rainwater leaders (storm water piping) from roof drain bodies to the floor level below the drain body,
 - (c) rainwater leaders in or above data and telecommunication rooms,
 - (d) rainwater leaders in or immediately above wet areas.
 - .2 sanitary piping in the following locations:
 - (a) [horizontal sanitary drainage piping NPS 3 and larger in ceiling spaces,
 - (b) sanitary drainage piping in or above wet areas,
 - (c) sanitary drainage piping in or above data and telecommunication rooms,
 - (d) exposed sanitary drainage piping in service tunnels,
 - (e) exposed sanitary drainage piping serving spaces located in a parking garage,
 - (f) and where shown on drawings

3.4 Insulating Hot Piping

- .1 Insulate straight pipe sections by staggering adjacent longitudinal seams 1/4 turn for each butt joint.
- .2 Secure insulation for domestic hot water piping, domestic hot water recirculation piping, non-potable hot water piping and non-potable hot water recirculation piping in accordance with the requirements for insulating Cold and Dual Temperature piping.
- .3 Secure insulation with integral ASJ or FSK jackets by stapling the lap flap on 75 mm (3 in) centers or by use of self-sealing lap adhesive strip.
- .4 Secure insulation that does not have an integral ASJ or FSK jacket by use of stainless steel wire at not less than 300 mm (12 in) centers, or by a continuous wire helix on the same center spacing.
- .5 For type P-2 and P-4 insulation, or where the required pipe insulation thickness is greater than 50 mm (2 in);
 - .1 provide two layers of approximately equal thickness such that the total thickness is as specified,
 - .2 install straight pipe sections by staggering adjacent section longitudinal seams 1/4 turn for each section, and stagger butt joints between the first layer and second layer by at least 1/4 of the insulation section length, and

- .3 secure the first layer of insulation with stainless steel wire on 300 mm (12 in.) centers, and secure the second layer with band straps on 300 mm (12 in) centers.
- .6 Secure butt joints with vapour barrier tape or insulation butt strips.
- .7 For piping service temperatures greater than 121°C (250°F);
 - .1 apply insulation finishing cement at all exposed edges of insulation where the insulation is interrupted by valves, connections to other equipment, and piping supports and anchors.

3.5 Insulating Cold and Dual Temperature Piping

- .1 Insulate straight pipe sections by staggering adjacent longitudinal seams 1/4 turn for each butt joint.
- .2 Secure insulation with integral ASJ and FSK jackets by;
 - .1 sealing all lap flaps and butt strips with vapour barrier adhesive, or
 - .2 securing insulation with staples on 75 mm (3 in) centers and covering longitudinal seams with vapour barrier tape, or
 - .3 use of integral self-sealing vapour barrier jacket with lap flaps and butt strips.
- .3 Except for type P-6 insulation, secure insulation that does not have an integral ASJ or FSK jacket by:
 - .1 use of 12 mm (1/2 in.) wide reinforced filament tape on approximately 150 mm (6 in.) centers for piping NPS 4 and smaller, and use stainless steel banding on 225 mm (9 in.) centers for piping NPS 6 and larger, and
 - (a) apply an all-service-jacket with 100% coverage of adhesive suitable for the insulation material, with longitudinal and butt seams having a 50 mm (2 in) overlap, and seal the laps with vapour barrier adhesive/ coating, or
 - (b) apply a heavy brush coat of vapour barrier coating at the rate of 1.2 L/m² (2.5 Imp.gallon per 100 ft²), embed a layer of reinforcing membrane, and then applying a second heavy brush coat of vapour barrier coating at the rate of 1.0 L/m² (2.1 Imp.gallon per 100 ft²).
- .4 For type P-2 insulation, or where the required pipe insulation thickness is greater than 50 mm (2 in);
 - .1 provide two layers of approximately equal thickness such that the total thickness is as specified,
 - .2 install straight pipe sections by staggering adjacent section longitudinal seams 1/4 turn for each section, and stagger butt joints between the first layer and second layer by at least 1/4 of the insulation section length, and
 - .3 secure the first layer of insulation with stainless steel wire on 300 mm (12 in.) centers, and secure the second layer with stainless steel banding on 225 mm (9 in) centers.
- .5 Secure type P-6 insulation with field-applied adhesive or self-adhesive longitudinal edge seams, and apply vapour barrier adhesive/sealant to butt joints.
- .6 Secure butt joints with vapour barrier tape, unless otherwise sealed using vapour barrier adhesives and coatings.
- .7 For straight pipe runs greater than 15 m (50 ft) and at every 15 m (50 ft) length thereafter, provide an insulation expansion joint consisting of 50 mm (2 in) wide flexible glass-fibre insulation for full depth of pipe insulation. Seal adjacent pipe insulation ends with vapour barrier coating.
- .8 Where pipe anchors are attached to chilled water piping;
 - .1 cover exposed ends of cut insulation with reinforced vapour barrier coating, with the fabric and coating overlapping by at least 50 mm (2 in.) onto the pipe anchor,
 - .2 insulate the pipe anchor with type P- 6 insulation (in round or equivalent sheet form) to a distance equal to 10 times the largest outside dimension of the anchor structure element, but not less than 150 mm (6 in) beyond pipe insulation outer surface,

3.6 Insulation of Fittings, Flanges, and Couplings – Hot, Cold and Dual Temperature Piping

- .1 Insulate fittings including elbows and tees, other than flanges and grooved-couplings:
 - .1 NPS 1½ and smaller:
 - (a) miter cut insulation to create tight fit,
 - (b) where PVC covers are used, trim backside of insulation on elbows to suit cover but do not reduce total thickness less than that of adjacent pipe insulation.
 - .2 NPS 2 and larger:
 - (a) use matching preformed insulation inserts, or fabricate tightly-fitting mitered insulation segments made from the same material as pipe insulation,
 - (b) number of mitered segments to be sufficient to maintain thickness of insulation around throat of elbow or tee,
- .2 Insulate flanges and grooved-joint couplings:
 - .1 insulate with preformed inserts or build-up insulation with same material as on adjacent pipe:
 - (a) butt pipe insulation to each side of flange or grooved-joint coupling,
 - (b) build up rigid insulation blocking on each side of flange or grooved-joint coupling, with a width dimension same as pipe insulation thickness,
 - (c) apply insulation layer over the top of the flange or coupling to a thickness equal to pipe insulation thickness.
- .3 Where type P-5 or P-7 insulation is used;
 - .1 insulate as described above except use factory made insulation inserts, or fabricate inserts to suit the pipe fitting, flange or coupling.
- .4 Where type P-6 insulation is used;
 - .1 insulation as described above except adhere insulation to fitting, flange, or coupling with 100% coverage of adhesive,
 - .2 do not adhere insulation across bolted connections - insulate on each side of connection and add additional insulation layer across connection and fix in place with bands and seal joints.
- .5 Secure insulation with stainless steel wire (Hot piping), or vapour barrier tape (all piping), prior to application of coatings and finishes.

3.7 Insulation of Pipeline Accessories – Hot, Cold and Dual Temperature Piping

- .1 Insulate pipeline accessories depending on service temperature:
 - .1 valves,
 - .2 strainers,
 - .3 pressure reducing valves,
 - .4 control valves,
 - .5 meters,
 - .6 steam separators.
- .2 Insulate pipeline accessories for Hot piping systems with service temperatures greater than 93°C (200°F) as follows:
 - .1 insulated with type P-8 removable/reusable fitted insulation covers, designed to allow free movement of valve actuator,
 - .2 insulation is not required at this service temperature range for drain valves, blowoff/blowdown valves, and drip caps or plugs.

- .3 Insulate pipeline accessories for Hot piping systems with service temperature greater than 60°C (140°F) and up to 93°C (200°F) or less, as follows:
 - .1 insulated with:
 - (a) type P-8 removable/reusable fitted insulation covers designed to allow free movement of valve actuator, or
 - (b) insulated with fitted pipe insulation segments, or oversized sections of insulation arranged to permit its removal and reinstallation, or
 - (c) tightly placed flexible insulation and covered with PVC fitting covers.]
 - .2 insulation is not required at this service temperature range for drain valves, drain caps/plugs, and for pipeline accessories NPS 1 and smaller.
- .4 Insulation of pipeline accessories is not required for Hot piping with service temperatures less than 60°C (104°F).
- .5 Insulate pipeline accessories for chilled water, liquid refrigerant, and dual temperature heating/cooling systems as follows:
 - .1 detachable insulated box type with embossed aluminum or stainless steel jacket, with vapor barrier tape applied to seams when installed, and lined with one layer of 25 mm (1 in) P6 elastomeric blanket with no voids at corners or joints,
 - .2 alternatively, for accessories NPS 8 and larger, install one layer of 25 mm (1 in) type P-6 elastomeric blanket insulation adhered to pipeline accessories with 100% adhesive coverage, and all joints sealed with manufacturers sealant, including the joint between P-6 insulation and adjacent piping insulation,
 - (a) at locations requiring access, extend insulation to create a collar around bolted connection, and install a compression fit piece of insulation to cover equipment.
 - .3 alternatively, for accessories NPS 4 and smaller, insulate with fitted pipe insulation or mitered blocks with all joints sealed with two coats of vapour barrier coating complete with reinforcing membrane.
- .6 Insulate accessories for all other Cold and Dual Temperature Piping systems as follows:
 - .1 insulate with flexible blanket insulation, fitted pipe insulation or mitered block of same material and thickness of adjacent piping and seal all joints with two coats of vapour barrier coating complete with reinforcing membrane or vapour barrier tape.
- .7 At locations requiring access including valve handles, valve actuators, drain valves, etc. cut-back insulation and seal exposed edges.

3.8 Additional Requirements for Insulation of Engine Combustion Gas Exhaust Piping

- .1 In addition to the general requirements for Hot piping insulation installation specified herein, insulate field-fabricated engine combustion gas exhaust piping systems as follows:
 - .1 where the 1st insulation layer is ceramic fibre, install the 1st layer of insulation with at least 50 mm (2 in) longitudinal overlap;
 - (a) do not stretch-out the insulation.
 - (b) secure with stainless steel wire in a double helix at approximately 225 mm (9 in.) on centers and at an incline of approximately 45°,
 - .2 where the 2nd insulation layer is mineral wool, install the 2nd layer of insulation by compressing slightly the 1st layer and secure the 2nd layer insulation with stainless steel bands at not more than 225 mm (9 in) spacing,

- .3 where calcium silicate insulation is used, do not use adhesive to attach the insulation to the equipment,
- .4 provide type P-23 (calcium silicate) high-density insulation inserts at hanger support locations where clevis hanger or trapeze hangers are used.
- .5 for straight piping runs greater than 15 m and at every 15 m length thereafter;
 - (a) provide an insulation expansion joint consisting of 50 mm (2 in) wide type P-10 insulation for full depth of both insulation layers,
 - (b) where insulation expansion joint is concealed, secure with a stainless steel cover jacket that extends at least 50 mm (2 in) on each side of the insulation expansion joint.

3.9 Additional Requirements for Insulation of Drainage Systems

- .1 In addition to the general requirements for Cold and Dual Temperature piping insulation specified herein, insulate the underside of roof drain hoppers with flexible blanket insulation of same type as pipe insulation, and seal all joints with two coats of vapour barrier coating complete with reinforcing membrane or vapour barrier tape.

3.10 Additional Requirements for Insulation of MRI Quench Vent Piping

- .1 In addition to the general requirements for Cold and Dual Temperature piping insulation specified herein, insulate MRI quench vent piping in accordance with the following supplemental requirements:
 - .1 insulate piping located inside the building,
 - .2 insulate piping located outdoors as follows:
 - (a) insulate vertical vent piping to a height of 2.8 m (8 ft) above the roof or ground level,
 - (b) horizontal vent piping and discharge are not required to be insulated.
 - .3 provide two layers of insulation of applicable thickness as specified in the article Schedules at the end of this Section,
 - .4 stagger insulation joints between the layers so that no joint in one layer aligns with a joint on the other layer,
 - .5 provide vapour barrier sealing on the first (inner) layer using reinforced vapour barrier coating,
 - .6 cover the second insulation layer with jacket material as specified in the article Schedules at the end of this section.
 - .7 install insulation over expansion joints to allow removal to permit inspection of the expansion joint,

3.11 Insulation Protection at Pipe Supports

- .1 Installation of pipe insulation saddle protection for Hot piping:
 - .1 pipe saddles provided under Specification section 20 05 29,
 - .2 insulate the interior void spaces of pipe saddles, using the same material as adjacent pipe insulation,
 - .3 butt insulation up to sides and end of pipe saddle, and leave bottom surface of saddle exposed for direct contact with pipe support.
- .2 Installation of pipe insulation shield protection for hot and cold piping:
 - .1 pipe insulation shields are provided under Specification section 20 05 29 except where specified herein as a factory assembled insulation insert and shield.
 - .2 provide high-density insulation inserts at pipe hanger locations as specified herein and in accordance with Specification 20 05 29 subject to fluid service temperature and pipe size,

- (a) insert length: at least 50 mm (2 in) longer than the shield length to allow application of vapour barrier sealant or tape, but not less than the following:

Pipe Size NPS	Insulation Insert Length mm (in)
1 ½ to 4	400 (16)
6	550 (22)
8 - 24	700 (28)

- (b) arc width: one-half of the pipe diameter for type P-22 and P-23 inserts,
- .3 fabricate the high-density inserts so their thickness is the same as the adjacent installed pipe-run insulation, with finished surface thickness within +3 mm/-0 mm (+1/8 in / -0 in) of adjacent pipe insulation thickness,
 - .4 for cold water piping, apply insulation cover and vapour barrier sealant to fully cover and seal the high-density insert, and to overlap the adjacent pipe-run insulation by at least 50 mm (2 in) on all edges,
 - .5 install the insulation shield between the finished insulation and the support pipe; the pipe support is sized for the outside dimension of pipe and insulation.

3.12 Insulation at Floor and Wall Openings

- .1 Extend pipe insulation at full required thickness through floor and wall openings for Hot, Cold and Dual Temperature piping. Vapour barrier jackets for Cold and Dual Temperature piping are to extend unbroken through the wall or floor penetration. Finish coverings for Hot piping with service temperatures not exceeding 93°C (200°F) may terminate on each side of the opening.
- .2 Reduction in insulation thickness through floor or wall openings is not permitted except by prior approval of Consultant on specific exceptional case basis;
 - .1 exception: Hot piping with service temperature not exceeding 93°C (200°F) may be reduced by one-half the required thickness stated in Schedule A1 through wall and floor penetrations, but such thickness reduction shall not extend more than 25 mm (1 in.) on each side of the opening.
- .3 For penetrations through fire rated separations, provide finishes in accordance with fire stopping manufacturer's listing requirements.
- .4 For outdoor piping passing through exterior walls or roof, terminate mastic lagging at outside face of sleeve and provide storm flashing to protect insulation, caulked to lagging and to building structure.

3.13 Sealing of Insulation – Hot Piping

- .1 Seal hot piping insulation in accordance with Specification section 20 07 11 and/except as specified herein.
- .2 Indoor installation (except wet areas):
 - .1 except where a separate protective finishing jacket is used, apply vapour barrier tape to butt joints, overlapping by at least 50 mm (2 in) each side,
 - .2 do not tape lap joints except as required to secure the insulation,
 - .3 where a separate protective finishing jacket is provided, no additional sealing of the insulation is required.
- .3 Indoor installations – wet areas:

- .1 regardless of how insulation is secured, apply vapour barrier tape to:
 - (a) all longitudinal lap seams and butt edges,
 - (b) 100% coverage of insulation at pipe joints, fittings, couplings, etc.
- .4 Outdoor installation:
 - .1 apply two coats of breather mastic complete with reinforcing membrane to all lap edges and butt edges, overlapping joint by minimum 50 mm (2 in) each side, and to all insulation that does not have a factory installed jacket.

3.14 Sealing of Insulation – Cold and Dual Temperature Piping

- .1 Seal Cold and Dual Temperature piping insulation in accordance with Specification section 20 07 11 and/except as specified herein.
- .2 Indoor installation (except wet locations):
 - .1 except for chilled water and Dual Temperature piping, tightly seal insulation ASJ jacket longitudinal seams and butt joints;
 - (a) using factory or field fabricated lap seams and butt joint strips with adhesive, or
 - (b) by applying colour matched vapour barrier tape to all edges, overlapping joint by minimum 50 mm (2 in) each side,
 - (c) where factory lap seams are damaged, apply colour matched vapor barrier tape along the damaged edges,
 - .2 for chilled water and dual temperature piping insulation with ASJ jackets, tightly seal longitudinal seams and butt joints;
 - (a) with two coats of vapor barrier coating complete with reinforcing membrane,
 - (b) for pipe size NPS 6 and smaller, colour matched vapour barrier tape is permitted to be used depending on location of piping in accordance with the following table.

Insulation Joint Sealing – Pipes NPS 6 and Smaller		
Piping Location	Vapour Barrier Tape	Vapour Barrier Coating with Membrane
Mechanical Service Rooms	No	Required
Vertical Service Spaces (shafts)	No	Required
Tunnels and trenches	No	Required
Unconditioned spaces	No	Required
Conditioned Spaces	Permitted [Note 1]	Permitted
Ceiling spaces over Conditioned Spaces	Permitted [Note 1]	Permitted
IT rooms	No	Required

Notes:

[1] Pipe size NPS 6 and smaller only.

- (a) overlap insulation edges and butt joint by minimum 50 mm (2 in) each side,
- (b) seal the butt end of the insulation with vapour barrier coating, overlapping onto the piping, at every fourth length of piping, but not to exceed 4 m (13 ft) in pipe run length.
- .3 cover mechanical fastener penetrations including staples with colour matched vapour barrier tape, overlapping the fasteners by a minimum of 50 mm (2 in) in all directions.
- .4 seal insulation on pipe elbows, tees, flanges, joints, couplings, and other fittings;

- (a) with two coats of vapor barrier coating complete with reinforcing membrane,
 - (b) for pipe sizes NPS 6 and smaller, colour matched vapour barrier tape may be used in locations as described in the above table for piping.
- .3 Indoor installations – wet areas:
 - .1 in wet areas, tightly seal piping in accordance with the requirements for outdoor installation except use vapour barrier coatings.
- .4 Outdoor installation:
 - .1 tightly seal insulation with two coats of vapour barrier mastic complete with reinforcing membrane;
 - (a) at all lap edges and butt joints,
 - (b) 100% coverage of insulation of pipe elbows, tees, flanges, joints, couplings, and other fittings,
 - (c) to cover mechanical fastener penetrations including staples,
 - (d) in all cases overlapping the joint, fitting or fastener by a minimum 50 mm (2 in) each side.
- .5 In all locations;
 - .1 seal insulation that does not have a factory applied ASJ jacket with 100% coverage of two coats of vapor barrier coating/mastic complete with reinforcing membrane,
 - .2 seal high-density inserts for pipe supports with two coats of vapour barrier coating/mastic complete with reinforcing membrane, overlapping adjacent insulation a minimum of 50 mm (2 in).

3.15 Insulation Finish Covering

- .1 Provide insulation finish coverings selected in accordance with Schedule C at the end of this Specification section and installed in accordance with Specification section 20 07 11 and/except as specified herein.
- .2 Self-adhesive weather barrier (SAWB) coverings;
 - .1 apply SAWB in accordance with manufacturer's instructions,
 - .2 do not place an overlap within one-eighth pipe diameter on each side of a horizontal pipe top centerline,
 - .3 for vertical piping, overlap higher layers over lower layers with an overlap not less than 100 mm (4 in).

3.16 Mechanical Damage Protection - Indoors

- .1 Protect exposed pipe insulation extending up through a floor sleeve at the floor line with 1.2 mm (18 ga) stainless steel jacket approximately 200 mm (8 in) high, secured with rivets and mechanically fastened to the floor with countersunk stainless steel screws.
- .2 Where waterproof floor sleeves are required, the floor sleeve may be combined with this requirement.
- .3 For clarity, where piping systems use finish covering in accordance with Schedule C of this Specification section, this mechanical damage protection cover is in addition to the specified pipe finish cover.
- .4 Finish piping with canvas or fiberglass lagging for the following piping systems that are to be painted:
 - .1 piping inside of boiler and refrigeration rooms,
 - .2 piping inside of other mechanical service rooms,
 - .3 exposed piping in public areas including;
 - (a) public corridors
 - (b)

3.17 Fire Rated Pipe Insulation

- .1 Provide two (2) hour rating of type P-9 insulation on piping where shown.
- .2 Install insulation in accordance with fire-rated insulation manufacturer's listing requirements. Coordinate with the applicable piping contractor as to any pipe support requirements of the fire-rated insulation installation instructions.

3.18 Standard Details

- .1 Refer to Specification section 20 05 29 for illustration of coordination of insulation with pipe supports, unless otherwise shown on drawings.

3.19 Schedules

- .1 The following appended schedules form part of this Specification section.
 - .1 Schedule A1 Hot piping Systems, Insulation Type and Thickness
(excluding engine combustion gas exhaust piping)
 - .2 Schedule A2 Hot Equipment Insulation Type, Thickness, and Coverings For Engine
Combustion Gas Exhaust Piping
 - .3 Schedule B Cold and Dual Temperature Piping Systems, Insulation Type and
Thickness
 - .4 Schedule C Piping Insulation Protective Finishes.

Schedule A1
Hot Piping Insulation Type and Thickness
(excluding engine combustion gas exhaust piping)

System	Fluid Nominal Temp. °C (F)	Insulation Type	Nominal Pipe Size (NPS)				
			< 1	1 to 1¼	1½ to 3	4 to <8	≥ 8
			Insulation Thickness, mm (in)				
Steam and Condensate > 860 kPa (125 psi)	177 to 315°C (351 to 600°F)	P-3	115 (4.5) [Note 3]	125 (5) [Note 3]	125 (5)	125 (5)	125 (5)
		P-4	---	---	---	---	125 (5) [Note 1, 2]
		P-7	200 (8) [Note 3]	200 (8) [Note 3]	200 (8)	175 (7)	175 (7)
Steam and Condensate > 100 kPa (15 psi) and ≤ 860 kPa (125 psi) Boiler Feed Water	122 to 176 (251 to 350)	P-1 P-3	80 (3) [Note 3]	100 (4) [Note 3]	115 (4.5)	115 (4.5)	115 (4.5)
		P-2 P-4	---	---	---	---	150 (6) [Note 1, 2]
		P-7	125 (5) [Note 3]	175 (7) [Note 3]	175 (7)	175 (7)	150 (6)
Safety Relief Piping	122 to 176 (251 to 350)	P-1 P-3	40 (1½)	40 (1½)	40 (1½)	40 (1½)	40 (1½)
Steam and Condensate ≤ 100 kPa (15 psi) High temperature hot water heating	94 to 121 (201 to 250)	P-1 P-3	65 (2.5) [Note 3]	65 (2.5) [Note 3]	80 (3)	80 (3)	90 (3½)
		P-2 P-4	---	---	---	---	100 (4) [Note 1, 2]
		P-7	125 (5) [Note 3]	100 (4) [Note 3]	125 (5)	125 (5)	125 (5)
Hot Water Heating Glycol Heating Pumped Condensate	61 to 93 (141 to 200)	P-1 P-3	40 (1½) [Note 3]	40 (1½) [Note 3]	50 (2)	50 (2)	50 (2)
		P-2 P-4	---	---	---	---	65 (2½) [Note 1, 2]
		P-7	65 (2½) [Note 3]	65 (2½) [Note 3]	65 (2½)	65 (2½)	65 (2½)
Hot Water Heating (Buried)	61 to 93 (141 to 200)	P-5	50 (2) [Note 3]	50 (2) [Note 3]	65 (2.5)	65 (2.5)	65 (2.5)

...continued on next page

Schedule A1 (Continued)
Hot Piping Insulation Type and Thickness
(excluding engine combustion gas exhaust piping)

System	Fluid Nominal Temp. °C (°F)	Insulation Type	Nominal Pipe Size (NPS)				
			< 1	1 to 1¼	1½ to 3	4 to <8	≥ 8
			Insulation Thickness, mm (in)				
Pure Water (with heat sanitization)	25 to 93 (77 to 200)	P-1 P-3	25 (1)	25 (1)	25 (1)	25 (1)	25 (1)
Low Temperature Hot Water Heating Low Temperature Glycol Heating	41 to 60 (105 to 140)	P-1 P-3	25 (1)	25 (1)	40 (1½)	40 (1½)	40 (1½)
Domestic Hot Water Domestic Hot Water Recirculation Not-Potable Hot Water Non-Portable Hot Water Recirculation	41 to 60 (105 to 140)	P-1 P-3	25 (1)	25 (1)	40 (1 ½)	40 (1 ½)	40 (1 ½)
Condenser Water (outdoors)	16.5 to 40 (61 to 104)	P-3 P-4 P-5	40 (1½)	40 (1½)	40 (1½)	40 (1½)	40 (1½)
Fire protection Sprinkler piping and valves, Fire protection Standpipe piping and valves [Note 4]	4 to 40 (50 to 104)	P-1 P-3	25 (1)	25 (1)	40 (1 ½)	40 (1 ½)	40 (1 ½)

Notes:

[1] For NPS 14 and larger.

[2] Install in two layers of insulation to make up total thickness.

[3] For piping NPS 1-1/4 and smaller located in partitions within conditioned spaces, insulation thickness may be reduced by up to 25 mm, but final thickness shall not be less than 25 mm.

[4] For heat-traced fire protection piping only, including drum drip assemblies on dry systems.

Schedule A2
Hot Equipment Insulation Type, Thickness, and Coverings
For Engine Combustion Gas Exhaust Piping

Equipment Description	Exhaust Gas Service Temperature °C (°F)	1 st Layer Type x Thickness mm (in)	2 nd Layer Type x Thickness mm (in)	Protective Finishing Covering, Exposed Piping [Note 1]
Natural Gas Engine combustion gas exhaust piping	≤ 700 (≤ 1292)	P-10 50 (2)	P-3 90 (3.5)	Fabric
		P-10 50 (2)	P-3 150 (6) [Note 2]	Stainless Steel
Diesel Engine combustion gas exhaust piping	≤ 540 (≤ 1000)	P-10 25 (1)	P-3 50 (2)	Fabric
		P-10 50 (2)	P-3 90 (3.5)	Stainless Steel
		P-7 40 (1.5)	P-7 50 (2)	Fabric
		P-7 75 (3)	P-7 90 (3.5)	Stainless Steel

Notes:

[1] For exposed piping located indoors. See Schedule C for other locations.

[2] Made up of two equal thickness layers with a total thickness of the indicated value.

Schedule B
Cold and Dual Temperature Piping Insulation Type and Thickness

System	Fluid Nominal Temp. °C (°F)	Insulation Type	Nominal Pipe Size (NPS)				
			< 1	1 to 1¼	1½ to 3	4 to <8	≥ 8
			Insulation Thickness, mm (in)				
Dual Temperature Heating/Cooling	4 to 93 (39 to 200)	P-1 P-3	40 (1½)	40 (1½)	50 (2)	50 (2)	50 (2)
		P-2	---	---	---	---	65 (2½) [Note 1, 2]
Domestic Cold Water Non-potable Water	4 to 16 (39 to 61)	P-1 P-3	25 (1)	25 (1)	40 (1 ½)	40 (1 ½)	50 (2)
Storm and Sanitary Drainage	4 to 16 (39 to 61)	P-1	25 (1)	25 (1)	25 (1)	25 (1)	25 (1)
		P-6	15 (1/2)	20 (3/4)	25 (1) [Note 3]	---	---
Equipment Drains	4 to 16 (39 to 61)	P-6	15 (1/2)	20 (3/4)	25 (1) [Note 3]	---	---
Chilled Water, Glycol Heat Recovery	4 to 16 (39 to 61)	P-1 P-3 P-5	25 (1)	25 (1)	40 (1 ½)	40 (1 ½)	50 (2)
Chilled Water (Outdoors)	4 to 16 (39 to 61)	P-3	50 (2)	50 (2)	50 (2)	75 (3)	75 (3)
Chilled Water (Buried)	4 to 16 (39 to 61)	P-5	25 (1)	25 (1)	40 (1 ½)	40 (1 ½)	40 (1 ½)
Refrigerant Suction	< 4 (< 39)	P-6	25 (1)	25 (1)	25 (1) [Note 3]	---	---
MRI Quench Vent	-268 (-450)	P-3 (inner layer)	---	---	---	25 (1)	25 (1)
		P-6 (outer layer)	---	---	---	25 (1)	25 (1)

Notes:

[1] For NPS 14 and larger.

[2] Install in two layers of insulation to make up total thickness.

[3] Do not use on pipe size NPS 2-1/2 to 3.

Schedule C
Piping Insulation Finish Coverings

Location	Exposed/ Concealed	Piping System	Finish Covering
Indoors	Concealed	MRI quench vent piping	SAWB
		Engine combustion gas exhaust piping	Metal
		Piping with insulation types P-4, P-5, P-7, P-10	SAWB or PVC
		All other piping	None (factory jacket only)
	Exposed	Steam 345 kPa (50 psig) and over	[Fabric] [Stainless Steel]
		Wet Areas	PVC
		Piping (insulation) which will be painted	Fabric
		Fire Protection Piping	PVC (red in colour)
		Engine combustion gas exhaust piping	Refer to Schedule A2
		All other piping	[PVC] [Fabric] [Metal]
Outdoors	Any	Engine combustion gas exhaust piping	Stainless Steel
		MRI quench vent piping	Stainless Steel
		All other piping	[Stainless Steel] [SAWB]

END OF SECTION

START-UP AND PERFORMANCE TESTING REPORTING

20 08 01

1 GENERAL

1.1 Scope

- .1 Provide integrated reporting of start-up and performance testing of mechanical equipment and systems.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 08 05 Testing, Adjusting and Balancing
 - .2 [20 08 11 Testing of Integrated Mechanical Life Safety and Fire Protection Systems
 - .3 23 05 93.33 Acoustic Testing
 - .4 23 05 93.36 Rotating Equipment Vibration Testing
 - .5 25 08 00 Commissioning of Building Automation

1.3 Coordination

- .1 Coordinate the work of testing companies;
 - .1 schedule sufficient time so that testing and balancing can be completed before occupancy begins and coordinate with trades involved,
 - .2 keep testing and balancing firm informed of any major changes made during construction and furnish same with a set of project drawings and reviewed Shop Drawings,
 - .3 furnish balancing devices, test connections access openings, balancing probe inlets and plugs,
 - .4 clean and pre-run all equipment, filters, etc. and place all heating, ventilating and air conditioning systems into full operation and continue same during each working day of testing and balancing,
 - .5 provide labour from pertinent mechanical trades and tools, equipment and materials to make equipment and system alterations and adjustments, as required including control adjustments,
 - .6 Building Automation System technical representative to operate the BAS during air and water balancing testing,
 - .7 where required in applicable Specification sections, refrigeration machine manufacturer service representative conducts performance testing of the refrigeration equipment, and Testing and Balancing contractor to witnesses and records all test results.
 - .8 where required in applicable Specification sections, fuel-fired heating equipment manufacturer service representative, or other qualified service company technical representative, conducts performance testing of heating equipment and Testing and Balancing contractor to witnesses and records all test results.
- .2 Be responsible for systems constructed, installed and adjusted to provide optimum performance as required by design intent. Perform any re-adjusting required as the result of spot checks by the Consultant at no increase in Contract Price.

1.4 Submittals

- .1 Submit a report format template a minimum 14 days prior to start of air and water balancing on-site.
 - .1 submit proposed format of initial report,

- .2 include a complete list of instruments and tests for which they are to be used as they relate to this project, including date of last calibration

2 PRODUCTS

2.1 Not applicable.

3 REPORT FORMAT

3.1 General

- .1 Include the following information for each test report:
 - .1 Owner Name,
 - .2 Project Name,
 - .3 Contractor Name,
 - .4 Consultant Name,
 - .5 Name of Test Report,
 - .6 Name and signature of the person submitting the report,
 - .7 Date of report.
- .2 Submit two (2) copies of test reports in hardcopy form in 3-“D” ring binders, indexed for each type of report, separately bound from the Operations and Maintenance manuals. Provide two (3) copies of the same reports in Adobe Acrobat version 7 PDF format.

4 START-UP AND PERFORMANCE REPORTS

4.1 Required reports

- .1 Provide the following Start-Up and Performance Testing reports:
 - .1 Equipment start-up report,
 - .2 Authorities inspection reports,
 - .3 Air and water balancing report,
 - .4 Acoustic survey report,
 - .5 Vibration survey report,
 - .6 Controls / BMS operation report,
 - .7 Alternate Season test report.

4.2 Equipment Start-up Report

- .1 Provide a test report in spreadsheet format which summarizes the following data for each piece of equipment which is powered or has automatic controls:
 - .1 equipment ID and name,
 - .2 motor insulation megger test - result and initialed by contractor,
 - .3 motor rotation (bump test) - result and initialed by contractor,
 - .4 equipment start-up report - status and initialed by contractor,
 - .5 manufacturer Start-Up report – status and initialed by contractor,

- .6 test completion date.
- .2 Provide a test report in spreadsheet format which summarizes the following data for testing of piping systems, organized by each piping system:
 - .1 system name,
 - .2 system limits (if system is not tested in its entirety),
 - .3 type of test (pneumatic, hydrostatic),
 - .4 pressure at start of test,
 - .5 pressure at end of test,
 - .6 duration of test,
 - .7 contractor dated and initialed,
 - .8 expansion tank initial pressure,
 - .9 expansion tank final pressure,
 - .10 backflow preventers have been tested - status and initialed by contractor,
 - .11 pressure relief valves installed – record setpoint and initialed by contractor.
- .3 Provide a test report in spreadsheet format which summarizes the following data for testing of ductwork systems, organized by each ductwork system:
 - .1 system name,
 - .2 system limits (if system is not tested in its entirety),
 - .3 test pressure,
 - .4 duration of test,
 - .5 seal Class,
 - .6 tested duct surface area,
 - .7 allowable airflow leakage rate,
 - .8 estimated leakage rate,
 - .9 contractor dated and initialed.
- .4 Equipment/System Start-Up Test Report:
 - .1 Provide a separate start-up report for each piece of the following equipment. The SMACNA “Systems Ready to Balance Check List”, where applicable, may be used for this report.
 - (a) HVAC units,
 - (b) duct Systems,
 - (c) pumps,
 - (d) boilers, and boiler auxiliaries,
 - (e) heat exchangers,
 - (f) cooling towers,
 - (g) air compressors,
 - (h) refrigeration equipment,
 - (i) hydronic piping systems,
 - (j) steam piping systems,
 - (k) sprinkler systems (to NFPA 13),

(l) standpipe systems (to NFPA 14).

.5 Manufacturer's Start-Up Test:

- .1 Provide a separate start-up report for each piece of the following equipment, utilizing the manufacturer's start-up check list. This report may be prepared by the manufacturer's service representative:
 - (a) chemical water treatment - pipe cleaning,
 - (b) chemical water treatment - passivating and inhibition,
 - (c) refrigeration equipment,
 - (d) packaged AC equipment,
 - (e) heating boilers,
 - (f) steam boilers,
 - (g) deaerators,
 - (h) packaged humidity steam generators,
 - (i) domestic hot water heaters,
 - (j) air compressors,
 - (k) cooling towers,
 - (l) adjustable frequency drives,
 - (m) Building Automation Systems.

4.3 Authorities Inspection Reports

- .1 Submit copies of authorities-having-jurisdiction inspection and test reports, including:
 - .1 plumbing and drainage municipal inspector reports,
 - .2 AHJ for boiler, pressure vessels and pressure piping reports,
 - .3 AHJ for electrical safety inspection reports and, if applicable, field certification reports.
- .2 Where an AHJ inspects the work but does not issue an inspection report, provide a signed and dated written declaration of the name of the AHJ inspector, the date of their inspection, what they inspected, and any comments they provided orally or in writing (other than an inspection report).

4.4 Air and Water Balancing Reports

- .1 Provide air and water balancing reports in accordance with Specification section 20 08 05.

4.5 Acoustic Survey Report

- .1 Provide acoustic survey test report in accordance with Specification section 23 05 93.33.

4.6 Vibration Survey Report

- .1 Provide vibration survey test report in accordance with Specification section 23 05 93.36.

4.7 Controls / Building Management System Installation Report

- .1 Provide controls test reports in accordance with Specification section 25 08 00.]

5 SPECIFIC EQUIPMENT PERFORMANCE TESTS

5.1 Performance data

- .1 In addition to tests specified in other Specification sections of Division 20 to 25, perform the following equipment performance tests. If contractor's standard forms provide for additional data, also submit such additional data.
 - .1 Some equipment tests may need to be performed during the alternate season testing.
 - .2 Include nameplate data and as-tested results.
- .2 Water Chillers:
 - .1 peak kW power at peak tonnage load – at design condenser water and evaporator water temperature conditions,
 - .2 NPLV kW power at 0, 25, 50, 75 and 100% load, at design condenser water and evaporator water temperature, as per ARI 550/590-1998,
 - .3 IPLV kW power at 0, 25, 50, 75 and 100% load, as per ARI 550/590-1998,
 - .4 surge control setpoint at design condenser and evaporator water temperatures and flow,
 - .5 condenser water pressure differential/flowrate fault setpoint,
 - .6 evaporator water pressure differential/flowrate fault setpoint.
- .3 Fuel-fired Hot Water Heating Boilers
 - .1 peak kW heat output of at least one unit of each boiler model,
 - .2 fuel input rate at peak kW heat output rate,
 - .3 gross fuel-to-steam efficiency at peak heat output rate,
 - .4 combustion efficiency test at 25, 50, 76 and 100% maximum rated capacity,
 - .5 excess air percent (air, O₂) at minimum fire, 25, 50, 75, and 100% heat output,
 - .6 measured CO and CO₂ corrected to 3% O₂ dry-basis,

6 REPORT SUBMISSIONS

6.1 Deficiencies

- .1 Immediately report to Consultant, any deficiencies in the systems or equipment performance resulting in design requirements being unobtainable.

6.2 Draft Report

- .1 On completion of the start-up, testing, adjusting and balancing of all systems, submit to the Consultant, two (2) typewritten copies of a full report on all tests, adjustments, and balancing performed.
- .2 Attachments including systems schematics with numbered terminals for referring to data above.

6.3 Spot Checks

- .1 After review of the draft report by the Consultant, Consultant has the right to require a retest of up to 10% of all air and water balancing measurements in locations as directed by the Consultant, at no cost extra to the contract.
- .2 If results indicate unusual testing inaccuracy, omissions, or incomplete balancing/adjustment, in the opinion of the Consultant, re-balance entire affected system(s) at no increase in Contract Price.

6.4 Interim Report

- .1 After completion of any retesting described above, submit three (1) typewritten copies of the interim report bound in a 3-hole "D" style binder, and two (2) removable drives (thumb drive) of the report in PDF format.
- .2 This report is required to obtain Substantial Performance of the Contract.

6.5 Final Report

- .1 Submit to Consultant the final report following completion of alternate season testing and balancing. Submit two (2) typewritten copies bound in a 3-hole "D" style binder,, and two (2) removable drives (thumb drive) of the report in PDF format.

6.6 Acceptance

- .1 The Substantial Performance of the Mechanical Work will be considered reached when the interim Start-Up and Performance Testing report is reviewed by the Consultant and in the opinion of the Consultant all systems have been satisfactorily installed, operated tested, balanced, and adjusted to meet the specified and intended performance, except for deferred seasonal-dependent work or other deferred work agreed by the Owner.
- .2 The substantial performance is not dependent upon alternate season testing.
- .3 The total performance of the Mechanical Subcontract (Contract) will not be considered reached until the alternate season testing and balancing and any other deferred Work is completed and the final report submitted and reviewed by the Consultant.

6.7 Additional testing

- .1 The Consultant may request such additional testing in connection with this project as Consultant deems necessary.
- .2 Perform additional testing and balancing which is outside the scope of required testing in the Contract Documents as directed by Consultant, with costs allocated against the applicable Cash Allowance.

END OF SECTION

MECHANICAL COMMISSIONING

20 08 15

1 GENERAL

1.1 Scope

- .1 Provide commissioning of mechanical systems provided under Division 20.
- .2 Mechanical system installation, start-up, testing, balancing, preparation of Operating and Maintenance manuals and operator training are the responsibility of the Division 20 Contractors, with the coordination of the commissioning process the responsibility of the Contractor.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 08 01 Start-up and Performance Testing
 - .2 20 08 05 Testing, Adjusting and Balancing
 - .3 20 08 06 Acoustic Measurement
 - .4 20 08 11 Testing of Integrated Mechanical Fire Protection and Life Safety Systems
 - .5 20 08 13 Vibration Measurement

1.3 Definitions

- .1 The following definitions apply to this section.
 - .1 **Contractor** – means the general contractor or construction manager who is responsible for the management and overall execution of the Work as applicable to the type of project delivery method used.
 - .2 **Major deficiency** – an item which if not corrected renders the equipment or system unsuitable or un-safe for use by the Owner. Major deficiencies must be corrected as a condition for achieving Substantial Performance.
 - .3 **Minor deficiency** – an item which does not impact on the operation of the equipment or system and will allow the Owner to use the system safely. Minor deficiencies may be corrected before or after Substantial Performance, but will not prevent certification of Substantial Performance of the Work.

1.4 Applicable Codes and Standards

- .1 Installation codes and standards:
 - .1 ASHRAE Guide 0 The Commissioning Process
 - .2 ASHRAE Guide 1.1 HVAC&R Technical Requirements for the Commissioning Process
 - .3 ASHRAE Guide 1.2 Technical Requirements for the Commissioning Process for Existing HVAC&R Systems and Assemblies
 - .4 ASHRAE Guide 1.3 Building Operations and Maintenance Training for the HVAC&R Commissioning Process
 - .5 ASHRAE Guide 1.5 The Commissioning Process for Smoke Control Systems

1.5 Commissioning Process

- .1 The Commissioning process develops, coordinates, and documents the following:

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- .1 equipment start-up,
 - .2 control system calibration,
 - .3 testing and balancing,
 - .4 verification and Performance Testing,
 - .5 operation documentation,
 - .6 operator training.
- .2 The Commissioning Program is divided into the following parts:
- .1 Part 1: Pre-Start and Start-Up testing
 - .2 Part 2: Installation Verification testing
 - .3 Part 3: Performance Validation testing
 - .4 Part 4: Systems Operating Manuals
 - .5 Part 5: Operator Training

1.6 Work Included

- .1 Commissioning work of Division 20 includes, but is not limited to:
- .1 testing and start-up of equipment,
 - .2 testing, adjusting and balancing of hydronic and air systems,
 - .3 cooperation with the Commissioning Authority in developing and implementation of the commissioning plan,
 - .4 providing qualified personnel for participation in implementing commissioning test procedures, including seasonal testing required after the initial testing,
 - .5 providing equipment, materials, and labor as necessary to correct construction and/or equipment deficiencies found during the commissioning process,
 - .6 providing operation and maintenance manuals, and as-built drawings to the Commissioning Authority for verification,
 - .7 providing training and demonstrations for the systems specified in this Division.
- .2 Conduct complete and thorough evaluation and documentation of the operation and performance of all components, systems, and sub-systems, including the following equipment and systems:
- .1 electric heating systems,
 - .2 air distribution and exhaust systems,
 - .3 fire protection systems / suppression systems,
 - .4 constant speed motor controllers and variable frequency drives,
 - .5 building automation systems,
 - .6 fuel systems,
 - .7 medical gas systems,
 - .8 process gas and liquid systems,
 - .9 laboratory gas and liquid systems.

- .3 Commission equipment which has been pre-tendered, pre-purchased, or pre-ordered by the Owner or their Agent, and the value of which has been assigned to the Mechanical Contractor or their sub-trades and is included in the value of the Work.
- .4 Commission services to equipment, but not the equipment itself, where the supply of the equipment does not form part of the mechanical Work.
- .5 Provide the following commissioning documentation:
 - .1 recording completed Pre-start and Start-up procedures test results,
 - .2 recording completed Installation Verification and Performance Validation test results,
 - .3 as-built records.
 - .4 operation and maintenance manuals
- .6 The final commissioning report will be prepared by the Commissioning Authority.

1.7 Excluded Work

- .1 Unless otherwise specified, equipment which is not supplied by the mechanical contractor or their sub-trades, where the value for the supply of equipment is not included as part of the Work, such as:
 - .1 Supplied by Owner (SBO) equipment,
 - .2 Equipment marked Not in Contract (NIC) or Not in Mechanical Contract (NIMC).

1.8 Submittals - Commissioning Schedule

- .1 Provide a detailed commissioning schedule for consolidation into the main construction schedule.
- .2 Include:
 - .1 equipment and systems start-up predecessors
 - .2 time periods for pre-start and start up testing, verification and validation testing for each equipment and system.

1.9 Submittals - Documentation

- .1 Identify documents including test documents, binder covers, etc. using equipment ID numbers provided on equipment schedules.
- .2 Scan original signed test reports, including verification and performance test reports, manufacturers service reports, etc. in Adobe Acrobat *.pdf version 8 format. For original document chapters, provide Adobe chapter referencing.
- .3 Submit three (3) copies of each completed and accepted Verification and Functional Performance Test reports, both preliminary and final issues.
- .4 Collate final, accepted and signed test results in separate binders as follows:
 - .1 Fire Protection
 - .2 Plumbing and Drainage
 - .3 HVAC Systems
 - .4 Building Management Systems
- .5 Provide three (3) CD-R or DVD-R copies of commissioning documentation.

1.10 Substantial Performance

- .1 Application for Substantial Performance of the Work is precedent on the Work being ready for Owner's use which includes completion of the following commissioning elements:

- .1 start-up and testing, including TAB reports,
- .2 commissioning Verification testing including submission of completed records,
- .3 commissioning Performance Validation testing including submission of completed records, except for alternate season tests,
- .4 commissioning Controls Validation testing,
- .5 training of Owner's operations personnel,
- .6 as-built documentation issued for Consultant's review,
- .7 Operations and Maintenance manuals which have been reviewed by the Consultant and accepted by the Owner.

2 PRODUCTS

2.1 Test Equipment

- .1 Furnish tools and equipment required during the commissioning process.
- .2 Utilities (water, gas, fuel oil, electrical power) are provided by the Owner
- .3 Provide any proprietary test equipment and software required by equipment manufacturer for programming and / or start-up, whether specified or not.
- .4 Manufacturer provides test equipment, demonstrate its use, and assists in the commissioning process as needed.
- .5 Turn-over proprietary test equipment to the Owner upon completion of the commissioning process, where such requirement is specified in the relevant equipment specification sections.

3 EXECUTION

3.1 General

- .1 Perform commissioning in accordance with ASHRAE Guide 0, Guide [1.1][1.2] except/and as specified herein.
- .2 Complete all phases of work so that the systems can be started, tested, balanced, and owner's acceptance procedures be undertaken in a timely manner such that only one acceptance test is conducted at any one time.
- .3 Participate and assist in the development of the Commissioning Plan and schedule by the Contractor, by providing necessary information pertaining to the equipment and installation. Provide commissioning schedule information to be incorporated into the overall Construction Plan schedule.
- .4 Acceptance procedures may begin prior to completion of a system and/or sub-system. Start of acceptance procedures before system completion does not relieve the Contractor from completing those systems in accordance with the commissioning and construction schedule.

3.2 Participants

- .1 Commissioning Team consists of multiple parties with separate responsibilities.
- .2 Owner:
 - .1 establishes acceptance criteria,
 - .2 provides operations staff to receive training, and to witness any or all tests at their discretion,
 - .3 final acceptance of commissioning results.
- .3 Design Consultant:

- .1 responsible for the construction review activities in accordance with local building code requirements,
- .2 may participate in development and / or review of commissioning procedures,
- .3 reviews commissioning test results,
- .4 Commissioning Authority:
 - .1 develops commissioning plan and procedures,
 - .2 coordinates Owner's commissioning team members who witnesses tests,
 - .3 selectively witnesses commissioning tests on an audit basis to confirm compliance by the Contractor to the Commissioning Plan,
 - .4 reviews commissioning test results and makes recommendations to the Owner for acceptance.
- .5 Contractor:
 - .1 coordinates and manages commissioning activities,
 - .2 develops and integrates commissioning activities into the construction schedule,
 - .3 ensures commissioning procedures are completed and documented, and commissioning records including any required attachments are submitted.
- .6 Mechanical trades subcontractors:
 - .1 Provide the services of qualified technician(s) who are familiar with the construction and operation of the system, to start-up and debug equipment and systems within the Division 20 scope of Work. Include for labour, materials, and subsistence costs for these same technicians to assist the Commissioning Authority in completing the commissioning program.
 - .2 Provide access to the contract plans, shop drawings, and equipment cut sheets of all installed equipment.
 - .3 Ensure the qualified technician(s) are available and present during commissioning testing to complete the tests, make adjustments and to assist in problem resolutions.
 - .4 Should any equipment or system experience performance problems and/or reconstruction or replacement of components is required, include for additional technician time for subsequent retesting of systems until required system performance is achieved.
 - .5 The Commissioning Authority reserves the right to approve proposed technicians with regard to the technical skill level required for each type of equipment and/or system, and a willingness by the individual(s) to work within the Commissioning Group.
- .7 Controls subcontractor, in addition to the requirements described above:
 - .1 Provide test reports using own documentation formats, for wiring tests, loop testing, loop tuning, and sequence functional tests.
 - .2 Provide details of the control system, schematics, and a narrative description of control sequences of operation.
- .8 Electrical subcontractor:
 - .1 provide a foreman electrician familiar with the electrical interlocks, interfaces with emergency power supply, and interfaces with alarm and life-safety systems. Provide access to the contract plans, and all as-built schematics of sub-systems, interfaces and interlocks.
- .9 Equipment suppliers:
 - .1 provide the services of manufacturers' service personnel to provide assistance with pre-start and initial start-up of the equipment, as required.

3.3 Commissioning Meetings

- .1 Participate in periodic commissioning team meetings, and trade commissioning meetings.
- .2 Pre-construction:
 - .1 participate in a pre-construction meeting of commissioning team members, to familiarize parties with the commissioning process, and to ensure that the responsibilities of each party are clearly understood.
- .3 Construction and Post-Construction:
 - .1 participate in commissioning meetings as scheduled by the Contractor.
 - .2 participate in trade commissioning meetings as required, in addition to the regular commissioning team meetings,
 - .3 identify to the commissioning group problems relating to the commissioning schedule, identification of start-up issues, etc., and participate in the resolution of these problems.

3.4 Commissioning Procedures

- .1 The Owner's designated Commissioning Authority provides the commissioning procedures (checklists, etc.) for use by the Contractor and trade subcontractors.
- .2 Each commissioning procedure tests the equipment and systems, and consists of the following elements:
 - .1 Document sign-off
 - .2 Pre-start and Initial test
 - .3 Installation Verification - Equipment
 - .4 Installation Verification - Systems
 - .5 Performance Validation
 - .6 Controls Validation
 - .7 Appendices.
- .3 Document Sign-Off:
 - .1 each completed procedure is signed off by the following parties:
 - (a) Contractor, for testing,
 - (b) Commissioning Consultant, for review and witnessing,
 - (c) Owner, for test acceptance.
- .4 Pre-Start and Initial Test:
 - .1 Checklists included: confirmation of authorities inspections, pre-start safety checks (where applicable), system cleaning and pressure testing, and confirmation of availability of supporting systems.
- .5 Installation Verification - Equipment
 - .1 Checklists to verify the installation of equipment, including: design specification requirements, drawing requirements, manufacturer installation requirements, and other experience-related items.
 - .2 Use of pre-printed manufacturer installation and start-up checklists are permitted and encouraged; however, the commissioning procedure checklists may contain supplemental items.
- .6 Installation Verification - System:

- .1 Checklists to verify the installation of the system associated with the equipment.
- .7 Performance Validation:
 - .1 Specific test procedures and record documentation requirements for performance measurements of the various systems.
- .8 Controls Validation:
 - .1 Step-by-step testing methodologies to prove the functional operation of control systems, for normal and abnormal operating conditions, and alarm conditions.
- .9 Appendices:
 - .1 Collate test reports from authorities having jurisdiction, manufacturer start-up and test reports, balancing reports, etc.

3.5 Commissioning Test Methodology

- .1 Step 1: complete the pre-start, start-up and testing, and adjusting and balancing tests. On completion of this phase, complete the related documentation and submit to the Commissioning Authority and Consultant.
- .2 Steps 2 and 3: on completion of Step 1, conduct the Verification and Validation testing of the operating systems. Identify deficiencies and correct. After the deficiencies have been corrected, notify the Commissioning Authority and agree on dates to demonstrate the commissioned systems.
- .3 Step 4: where the Commissioning Authority identifies systems which require witness demonstration, repeat Steps 2 and 3. These demonstrations may be coordinated with training demonstrations of Owner's operations staff.
- .4 On completion of systems which do not require witness demonstration, finalize the report and submit to the Commissioning Authority and the Consultant for review.
- .5 On completion of systems which have been witness demonstrated, the Commissioning Authority is to sign-off the completed document, before they are issued for review.

3.6 Commissioning Implementation

- .1 Conduct operating tests and checks to verify that all components, equipment, systems, and interfaces between systems, operate in accordance with contract documents.
- .2 Demonstrate and verify operating modes, interlocks, specified control sequences, specific responses to abnormal or emergency conditions, and verification of the proper response of the Building Automation System.
- .3 Validate the results of the TAB report.
- .4 Roles and Responsibilities:

Organized by:	Contractor
Test sheets provided by:	Commissioning Authority
Testing conducted by:	Div. 20 trade subcontractors
Testing recorded by:	Div. 20 trade subcontractors
Tests witnessed by:	Commissioning Authority (selected tests) Design Consultant (selected tests)

Reports reviewed by:	Contractor Commissioning Authority Design Consultant Owner
Reports Accepted by:	Owner

3.7 Operating Checks

- .1 The Commissioning Authority witnesses selected equipment and system tests on an audit basis.
- .2 Set the system equipment into operating mode to be tested including but not limited to:
 - .1 Normal shut-down
 - .2 Normal auto position
 - .3 Normal manual position
 - .4 Unoccupied cycle
 - .5 Emergency power operation, including transition states.
 - .6 Alarm conditions
- .3 Inspect and verify the position of each device and interlock identified on the checklist.
- .4 Repeat the above tests for each operating cycle that applies to the system being tested.
- .5 Check the operating condition of the following elements during all modes of operation of the system:
 - .1 Safety interlocks
 - .2 Alarms
 - .3 Smoke control and smoke venting interlocks
 - .4 Life safety systems
- .6 For failed test items, provide appropriate comments to the checklist data sheet and classify whether it is a "Major" or "Minor" deficiency.
 - .1 The Consultant retains the right to make the final decision regarding classifications of deficiencies.
- .7 Verify the operational control of the systems through the Building Management System as follows:
 - .1 TAB airflow rates and calibrate terminal boxes in all modes of operation
 - .2 Equipment operation in both heating and cooling modes.
 - .3 Minimum outdoor air intake positions, air-side economizer cycles, and multi-set outdoor air damper positions as required for each operating sequence and mode.
 - .4 Building pressurization and other specialty programs
- .8 Verify the proper responses of instrumentation and control devices (actuators) as follows:
 - .1 For each controller or sensor, record the indicated monitoring and control system reading, and the test instrument reading.
 - .2 If the initial test indicates that the test reading is outside of the control range of the installed device, check the calibration of the installed device and adjust as required. Re-test the deficient device and record the results on the checklist data sheets.
- .9 The Commissioning Authority witnesses the field verification of the final TAB report as follows:

- .1 Select, at random, 10% of the report data for verification.
- .2 The TAB contractor will be provided advance notice of the date of retesting, but not the equipment to be tested.
- .3 The TAB contractor uses the same equipment and instruments used for collecting the original data.
- .10 Test failure is defined as:
 - .1 For all readings other than sound, a deviation of more than 10 percent from the TAB report results.
 - .2 For sound pressure readings, a deviation of 2 dB at any bandwidth, not including differences in background noise readings.
 - .3 A failure rate greater than 10% of the selected items (1% of all TAB test results) will result in rejection of the final TAB report.
- .11 Acceptance
 - .1 The final reports will be reviewed by the Commissioning Authority and the Consultant, to determine if verification is complete and the operating systems are functioning in accordance with the contract documents.
 - .2 The Commissioning Authority, in conjunction with the Consultant, reviews and makes final classification of all noted deficiencies. Correct deficiencies classified as "Major" before acceptance of the Verification stage.
 - .3 The Owner will make the final acceptance of test results.

3.8 Performance Validation Testing

- .1 Conduct performance tests and checks to validate that equipment and system components are providing the required heating and cooling performance (capacity), including but not limited to:
 - .1 Capability of the Chilled water system to deliver the required flow rate, and water temperature at design conditions.
 - .2 Capability of the hydronic and domestic water heating systems to deliver the required flow rate, and temperature.
 - .3 Capacity of electric heating systems at design temperatures.
 - .4 Confirm the ability of the HVAC systems to deliver the required cooling/heating services, at the design supply air temperature, required static pressure, and proper outside air ventilation rate.
- .2 Special testing requirements:
 - .1 Test water chillers in accordance with ARI 590 and 591, at design conditions for full load ratings, and IPLV ratings.

3.9 Problem Resolution

- .1 In the event that additional work is required to either correct systems, misapplied equipment, and/or deficient performance under varying load conditions, assist the Owner and Commissioning Authority in developing an acceptable resolution to the problem, including the resources of equipment suppliers.
- .2 The Owner has final approval over any additional work required to achieve the required level of performance.
- .3 Complete corrective work in a timely fashion to permit the completion of the commissioning process.

3.10 Acceptance

- .1 Any identified deficiencies will be reviewed by the Consultant in conjunction with the Contractor to determine if correction of the deficiency is as a result of a defect in the equipment or installation.
- .2 If it is determined the performance deficiency is as a result of a defect in the equipment or its installation, rectify the deficiency and repeat the performance test until the required performance levels are achieved.
- .3 If it is determined the equipment or system has been constructed in accordance with the contract documents, the Owner will decide whether to accept the performance as is, or, direct the installation contractor to make changes to the system as required to obtain performance levels which meet the design intent, and retest the system.

3.11 Seasonal Commissioning

- .1 Commence initial performance validation testing commissioning at the completion of the installation and verification testing phase. Conduct performance testing, which is weather dependent, as applicable to current seasonal conditions. Complete performance testing on non-weather dependent systems in accordance with the agreed commissioning plan schedule.
- .2 For out-of-season system performance testing, conduct initial performance tests to demonstrate off-peak load performance. Schedule peak load performance testing over the succeeding nine (9) months to ensure all equipment is tested at peak load prior to the expiry of the warranty period.
- .3 Test heating equipment/systems during winter design extremes.
- .4 Test cooling systems during summer design extremes with a fully occupied building.
- .5 Alternatively, provide temporary equipment (load banks, etc.) to simulate full load conditions. Submit proposed methodology for review by the Commissioning Authority and Consultant.

3.12 Additional Commissioning

- .1 Additional commissioning activities may be required after completion of system performance testing. Include in the tender cost a reasonable reserve to complete this work, including assistance from manufacturers' service technicians.

3.13 Systems Operating Manuals

- .1 Provide Operating and Maintenance Manuals in accordance with the requirements of section 20 01 01.
- .2 The Systems Operating Manuals (SOM) are in addition to the Operating and Maintenance Manuals (OMM) required under Section 20 01 01.
 - .1 Provided by Commissioning Authority and/or Consultant.

3.14 Training

- .1 Perform training in accordance with ASHRAE Guideline 1.3 except/and as specified herein.
- .2 Equipment Training:
 - .1 Provide equipment training in accordance with Section 20 01 01. The manufacturer's representative training will emphasize operating instructions and preventative maintenance.
- .3 Systems Training:
 - .1 In addition to the equipment training described above, provide additional training to describe the operational requirements and design intent of each system.
 - .2 Include classroom instruction, delivered by competent instructors. Place emphasis on overall systems diagrams and descriptions, and design criteria and conditions.

- .3 If required, obtain and pay for the services of the Design Consultant to provide the instructor services and to provide lecture material for inclusion in the training manual.
- .4 Training topics to include:
 - (a) Types of installed systems
 - (b) Design intent and design criteria
 - (c) Design constraints
 - (d) Different operating modes – occupied, unoccupied, emergency conditions, etc.
 - (e) Seasonal operating modes
 - (f) IAQ
 - (g) Energy efficiency
 - (h) System operation
 - (i) Automatic controls
 - (j) Service, maintenance, diagnostics and repairs
 - (k) Use of reports and logs
 - (l) Troubleshooting
- .5 Structure each session to start with the classroom instruction for the overall system, followed by hands-on instruction for each equipment, with the services of the manufacturers' representative as required. Demonstrate the start-up and shut-down of each system.
- .6 Organize and schedule each training session to deliver the required instruction in an efficient and effective manner on a schedule agreed upon with the Owner. Allow for two (2) training sessions for each topic, separated by approximately one week each, to allow for shift coverage.
- .7 Structure each training session based on type of maintenance personnel attending the training session, i.e. Plumbers, fitters, general maintenance, controls technicians, etc. Develop the proposed training plan and obtain approval from the Owner before commencing the training.
- .8 Complete the training as close to Substantial Performance as possible, so that the Owner's operations staff are prepared to operate the system after Substantial Performance is certified.
- .4 Training Manuals
 - .1 Provide training material hand-outs for each session.
 - .2 Collect training material and bind into separate binders.

END OF SECTION

CLOSEOUT REQUIREMENTS FOR MECHANICAL WORK 20 77 19.08

1 GENERAL

1.1 Scope

- .1 Provide documentation deliverables at completion of the Work for the following milestones:
 - .1 Occupancy permit (where applicable) (Form OP1M),
 - .2 Substantial Performance of the Work (Form SP2M),
 - .3 Total Performance of the Work (Form TP1M).

1.2 Definitions

- .1 The following definitions apply to this section.
 - .1 **Occupancy permit** – means either: (i) a permit issued by a regulatory authority to allow the Owner to occupy the building subject to the building permit, or (ii) a building permit close-out procedure where documentation must be submitted to the building authority for that purpose.

1.3 General

- .1 The prerequisites and submittal of supporting documentation for the aforementioned milestone events may be combined as a single submission at one point in time for the following combination of events:
 - .1 Occupancy Permit, and Substantial Performance.
- .2 Where a prerequisite is listed in more than one milestone event, it shall be included in the earliest-occurring milestone event unless expressly specified otherwise.

1.4 Occupancy Permit

- .1 Submit the reviewed final record of the Testing of Integrated Life Safety and Fire Protection Commissioning report two weeks prior to application for occupancy permit, where such a report is required.
- .2 Complete the Occupancy Permit Checklist and submit with required documentation to support the Owner's application for occupancy.

1.5 Substantial Performance

- .1 Complete the Substantial Performance Checklist and submit with required documentation when applying for Substantial Performance of the Work.
- .2 Where the work is sub-divided into separate scopes of Work, each requiring a separate Substantial Performance application, provide a separate checklist for each application.
- .3 Within five working days of the Consultant's review report which indicates that Substantial Performance of the Work has been achieved, provide a detailed schedule for completion and/or correction of the Work of all items described in the Contractors' and the Consultants' deficiency list.

1.6 Total Performance

- .1 Complete the Total Performance Checklist and submit with required documentation when applying for Total Performance of the Work.

Form OP1M: OCCUPANCY PERMIT CHECKLIST	
Project Name:	
Contract:	
Contract Scope:	
Application Date:	
Signed:	

The following requirements are completed and documentation included in this application. Where documentation has been issued directly to the Owner, a copy of the transmittal is enclosed.

- ☐ Building department inspection reports.
- ☐ AHJ pressure piping inspection reports (if applicable).
- ☐ AHJ fuel system inspection reports (if applicable).
- ☐ AHJ electrical systems inspection reports.
- ☐ Sprinkler installation certification report to NFPA 13.
- ☐ Standpipe installation certification report to NFPA 14.
- ☐ Fire pump installation and test certificate to NFPA 20.
- ☐ Integrated Fire Protection and Life Safety test report to ULC-S1001.
- ☐ Medical gas inspection report and certificate.
- ☐ Air and Water Balancing reports (Interim) for ventilation and heating.
- ☐ Equipment start-up reports (Interim).

Consultant Review	
Status:	<input type="checkbox"/> Reviewed <input type="checkbox"/> Incomplete or deficient - resubmit
Signed:	
Date:	

Form SP2M: SUBSTANTIAL PERFORMANCE APPLICATION CHECKLIST	
Project Name:	
Contract:	
Contract Scope:	
Application Date:	
Signed:	

The following requirements are completed and included in this application. Where documentation has been issued directly to the Owner, a copy of the transmittal is enclosed.

- ☐ Contractor has compiled and submitted a detailed deficiency list, identifying work still to be completed, incomplete, or requires correction.
- ☐ Occupancy permit has been issued by the AHJ (where applicable).
- ☐ Systems have been started-up, tested, and demonstrated to Owner or Consultant. Equipment start-up reports (final) have been submitted.
- ☐ First submission TAB reports have been submitted to Consultant.
- ☐ Acoustic survey report submitted to Consultant (if specified).
- ☐ Vibration survey report submitted to Consultant (if specified).
- ☐ Controls / BMS operation report submitted to Consultant (if specified).
- ☐ Equipment, pipeline, and valve identification completed.
- ☐ Final cleaning and waste removal completed.
- ☐ The portions of the building being turned over to the Owner can be secured by Owner.
- ☐ Spare parts and replacement parts turned over to Owner, transmittal attached.
- ☐ Warranty certificates issued to Owner.
- ☐ Delivery to Owner of draft Operating and Maintenance documents.
- ☐ Copies of up-to-date as-built drawings submitted.
- ☐ Final start-up, testing and balancing reports completed and submitted to Owner, including any items requiring corrections identified by Consultant.
- ☐ Demonstration and training are completed, or Contractor and Owner has agreed to a schedule to provide such training to be completed within one month after the date of Substantial Performance of the Work.
- ☐ All commissioning activities except for those activities that are identified or otherwise agreed by the Owner to be deferred commission activities which may be completed after the date of Substantial Performance of the Work.

Consultant Review	
Status:	<input type="checkbox"/> Reviewed <input type="checkbox"/> Incomplete or deficient - resubmit
Signed:	
Date:	

Form TP1M: TOTAL PERFORMANCE APPLICATION CHECKLIST
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Project Name:	
Contract:	
Contract Scope:	
Application Date:	
Signed:	

The following requirements are completed and included in this application. Where documentation has been issued directly to the Owner, a copy of the transmittal is enclosed.

- ☐ All final Operating and Maintenance documents have been delivered to Owner.
- ☐ All final up-to-date as-built drawings have been delivered to Owner.
- ☐ Any follow-up testing and balancing reports, including alternate season testing reports, have been submitted to Owner.
- ☐ All demonstration and training are completed.
- ☐ All commissioning activities are completed, including deferred alternate season commissioning activities.
- ☐ All known deficiencies have been corrected, including latent deficiencies reported by the Owner.
- ☐ All inspections and tests required to be performed by Contractor or manufacturer's prior to expiry of the warranty period have been completed, and documentation for those inspections and tests are included in this application.

Consultant Review	
Status:	<input type="checkbox"/> Reviewed <input type="checkbox"/> Incomplete or deficient - resubmit
Signed:	
Date:	

End of Section

COMMON WORK RESULTS FOR PLUMBING PIPING 22 05 01

1 GENERAL

1.1 Scope

- .1 Provide piping systems for plumbing, drain and vent systems for:
 - .1 potable (domestic) water systems,
 - .2 non-potable water piping systems,
 - .3 drainage system including:
 - (a) sanitary drainage and vent systems,
 - (b) storm water drainage systems,
 - (c) pumped sewage systems.
 - .4 other plumbing systems including:
 - (a) irrigation systems,
 - (b) grey water systems,
 - (c) specific duty piping systems otherwise specified in Division 22.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 73.13 Mechanical Services for General Facility Equipment
 - .2 22 05 19 Utility Water Meters

1.3 Applicable Codes and Standards

- .1 Legislation:
 - .1 Ontario Building Code
 - .2 Municipal bylaws regarding potable water, water services, and sewage systems.
- .2 Installation standards and codes:
 - .1 AWWA C651 Disinfecting Water Mains.
- .3 Product standards:
 - .1 CSA B272 Pre-Fabricated Self Sealing Roof Vent Flashings

1.4 Qualified Tradesmen

- .1 Work to be performed by qualified and recognized firm with an established reputation in this field, using tradesmen holding certificates of competency.

1.5 Design Criteria – Pressure Piping Systems

- .1 The following design conditions apply unless otherwise shown on drawings.
- .2 System design criteria:
 - .1 Domestic Cold Water Service (to building):
 - (a) Design pressure: 900 kPa (130 psig)
 - (b) Design temperature: 25°C (77°F)

- .2 Potable water:
 - (a) Design pressure: 900 kPa (130 psig)
 - (b) Design temperature: 107°C (225°F)
- .3 Non-potable water:
 - (a) Design pressure: 900 kPa (130 psig)
 - (b) Design temperature: 107°C (225°F)
- .4 Pumped sanitary and storm:
 - (a) Design pressure: [350 kPa (50 psig)][700 kPa (100 psig)]
 - (b) Design temperature: 65°C (150°F)
- .5 Grey water:
 - (a) Design pressure: 900 kPa (130 psig)
 - (b) Design temperature: 38°C (100°F)

2 PRODUCTS

2.1 Flashings

- .1 Through-roof penetration flashing, and other waterproofed areas:
 - .1 manufactured from composite material in accordance with CSA B272,
 - .2 minimum dimensions of 500 mm x 500 mm (20 in x 20 in),
 - .3 with sleeve extending at least 150 mm (6 in) above roof.

2.2 Dielectric Unions

- .1 Construction:
 - .1 Bronze or brass body with non-metallic fitting or coating the FNPT tailpiece.
 - .2 FNPT x Copper sweat connection.
 - .3 Pressure rating; ASME Class 3000 at 121°C (250°F)

Standard of Acceptance

- Hart Industrial Unions - fig. D-3136 or Polymer Composite Coating

2.3 Dielectric Flanges

- .1 Construction:
 - .1 ASME Class 150 or 300 carbon steel flange, Van-stone style with copper tube adapter tailpiece.
 - .2 Flange provided with a powder coated finish, and an EPDM insulator to isolate the copper tailpiece from contact with the flange.
 - .3 Minimum MCPR:
 - (a) Class 150: 1400 kPa (200 psi) at 121°C (250°F)
 - (b) Class 300: 2800 kPa (400 psi) at 121°C (250°F)

Standard of Acceptance

- CTS Flange Canada - fig. BF / WBG

3 INSTALLATION

3.1 Piping

- .1 Piping system routing is shown diagrammatically. Locate mains, risers and runouts concealed behind furrings or above ceilings except in mechanical equipment rooms and access spaces where piping is to be exposed.
- .2 Determine areas without ceilings from Architectural Drawings and Room Finish Schedules, and in these areas keep piping as high as possible.
- .3 Anchor, guide and support vertical and horizontal runs of piping to resist dead load and absorb thrust.

3.2 Domestic Cold Water System Distribution

- .1 Extend existing domestic cold water system with
 - .1 distribution pipe and fittings,
 - .2 valves,
 - .3 premises backflow isolation,
 - .4 zone or equipment backflow protection.

3.3 Dissimilar Metals Galvanic Isolation

- .1 Provide dielectric unions or flanges to separate copper and copper alloy tube and fitting materials from contact with carbon (plain and galvanized) steel material.
 - .1 For clarity, dielectric unions or flanges are not required when connecting copper to T304 or T316 stainless steel pipe or tubing.
- .2 Refer to specification section 23 05 01 for exemptions when connecting domestic water copper piping or stainless steel piping to HVAC piping systems.

3.4 Drainage

- .1 Provide roof drains and storm drainage piping system.
- .2 Provide waste and vent connections to plumbing fixtures and equipment.
- .3 Drainage fittings;
 - .1 do not use double hubs, straight crosses, double T's, or double TY's in soil or waste pipe below any fixture,
 - .2 do not use branch fittings other than full "Y" or "Y" and an eighth bend, on soil or waste pipe running in horizontal direction,
 - .3 do not use quarter bend placed on its side,
 - .4 do not use inverted joints below fixtures,
 - .5 do not install cleanouts above food preparation or patient treatment areas. In these areas carry rodding connection up to floor cleanout fitted with adjustable gasketed access cover and plug, with cleanout body cast in floor slab above,
 - .6 drainage fittings to match connected piping for quality and wall thickness.

3.5 Flashings

- .1 Provide flashing for piping penetrations through roofs and other waterproofed areas. Leave flashing ready for Roofing or Waterproofing Trades to make watertight connections.

3.6 Vent Termination (VTR)

- .1 Fit vents passing through roof with vent stack sleeve terminating not less than 150 mm (6 in) above roof, above flood level of roof, and 900 mm (3 ft) above or 3500 mm (11.5 ft) horizontally from any air intake, door, or operable window.

3.7 Water and Waste Connections

- .1 Provide hot and cold water, waste and vent connections to building service equipment. Provide connections to Owners equipment and equipment supplied by Divisions of the Work other than Division 20 to 25, as specified herein and in accordance with specification section 20 05 73.13.
- .2 Provide vacuum breakers and backflow preventers on equipment connections, and hose bibs, and on fixture connections without adequate air gaps.
- .3 Where hot and cold water supply pipes connect to combination supply fitting with shut-off valve on discharge, or where combination supply fitting is equipped with manual or thermostatic mixing valve, equip each hot and cold water supply pipe with composition disc swing check fitting.
- .4 Provide shut-off valve on each service line close to the apparatus and brass traps complete with cleanout on waste connection unless waste discharges directly into floor drain or funnel drain.
- .5 Where specific sizes are not shown, valves, and final connections to equipment to be one pipe size larger than equipment tapping size, and trap and drain size to be one pipe size larger than waste connection on apparatus.

3.8 Pressure Testing – Water Pressure Piping Systems

- .1 Pressure test piping before insulation is applied.
- .2 Initial pneumatic leak test:
 - .1 Conduct an initial pneumatic pressure test at a maximum pressure of 70 kPa (10 psig) prior to hydrostatic pressure test, to check for large leaks or incomplete joints.
 - .2 Remove compressed air source and maintain this pressure for the time necessary to inspect for leaks, but not less than 2 hours.
 - .3 Maintain pressure and examine each joint with commercial leak detector solution.

Standard of Acceptance

- Snoop
 - Leak-tec
- .4 Repair leaks where found prior to performing hydrostatic pressure tests.
 - .5 During pneumatic pressure tests, comply with the site safety requirements for notification and guarding during testing with compressed gasses.
- .3 Final hydrostatic pressure test:
 - .1 Use the system design pressure for the entire installation, unless different design pressures are indicated for each floor.
 - .2 Fill the system with water and gradually increase the system pressure to 150% of the design pressure and hold for 10 minutes, then reduce pressure to the design pressure.
 - .3 Inspect each pipe joint for leaks.
 - .4 As an alternative to inspection of each joint for leaks, conduct a 24 hour standing pressure test:
 - (a) raise the water pressure to 150% of the design pressure for 10 minutes, then reduce pressure to design pressure,

- (b) record the test pressure one (1) hour after establishing the system hydrostatic test pressure at the design pressure. Record ambient air temperature at the same time.
 - (c) at the end of the 24 hour standing test period, record the test pressure and ambient air temperature. Make adjustments to the measured end-of-test pressure to account for change in fluid density due to change in ambient air temperature,
 - (d) acceptance criteria: maximum pressure loss over 24 hours not to exceed 1% of test pressure, corrected for ambient temperature,
 - (e) where acceptance criteria is not met, inspect pipe joints for leaks.
- .5 Where leaks are found, repair leaks and retest piping as specified above.
- (a) for soldered or brazed joints, one attempt at repairing the joint is permitted. If joint continues to fail, cut-out and replace the fitting.

3.9 Pressure Test Report

- .1 Maintain a log of all pressure tests, including locating of where leaks have been repaired. Submit the log to the Consultant for review when requesting prior to substantial completion of the Work. Where a piping system is subject to AHJ inspection, provide evidence of such inspection by means of an AHJ inspection report or name of the AHJ inspector and the date they witnessed the pressure test.

3.10 Flushing and Disinfecting - Water Service Pipe

- .1 Complete piping pressure tests prior to flushing and disinfecting operations. Notify Consultant at least two days in advance of date when disinfecting operations are proposed, so that the Consultant may witness the tests.
- .2 Isolate the water service pipe inside the building at the point of entry, from the building water distribution system. Flush water service pipes for a minimum of 10 minutes to produce a water velocity of 1.5 m/s (5 fps) and discharge water to drain or other acceptable area.
- .1 Minimum flushing flow rates:

Pipe size	Minimum Flow	
	L/s	USGPM
2	3.3	52
2 1/2	4.7	75
3	7.3	115
4	12.6	200
6	23.4	450
8	49	780
10	76	1200
12	110	1750

- .3 Disinfect water service pipes NPS 4 and larger:
- .1 Provide chemicals and equipment to clean, disinfect and flush domestic water service pipes in accordance with AWWA C651.
 - .2 Drain down system to remove flushing water.

- .3 Isolate service water pipe from the building distribution system.
- .4 Disinfect water supply pipe by introducing chlorine close to point of connection to the municipal water supply and evenly add to water as water service pipe is refilling, to provide an initial concentration of 50 mg/L.
- .5 Close off drains and maintain chlorinated water in mains pipe for 24 hours.
- .6 At the end of 24 hours, arrange and pay for laboratory testing of water samples taken from newly disinfected main. If the residual chlorine is < 25 mg/L, drain down water and repeat disinfection for an additional 24 hours and lab testing until a residual of minimum 25 mg/L is obtained.
- .7 After the lab test indicates a residual of 25 mg/L, flush line to remove chlorine solution.

3.11 Flushing and Cleaning - Building Water Distribution Piping

- .1 Conduct first fill and pressure testing of building distribution piping only after completion of flushing and disinfection of water service pipe.
- .2 Complete piping pressure tests prior to flushing and cleaning operations.
- .3 Flush water distribution piping through available outlets with sufficient flow to produce velocity of 1.5 m/s, within pipe for 10 minutes, or until foreign materials have been removed and flushed water is clear.
- .4 Minimum flushing flowrates:

Pipe size	Minimum Flow	
NPS	L/s	USGPM
2	3.3	52
2 1/2	4.7	75
3	7.3	115
4	12.6	200

- .5 Open and close valves, hydrants and service connections to ensure thorough flushing.[]
- .6 When flushing has been completed to satisfaction of Consultant, introduce strong solution of chlorine into watermain and ensure that it is distributed throughout entire system:
 - .1 Drain down system to remove flushing water,
 - .2 Introduce Chlorine close to point of re-filling of system, and evenly add to water as system is refilling, to provide an initial concentration of 50 mg/L
 - .3 Operate valves, hydrants, and appurtenances while main contains chlorine solution.
 - .4 Flush line to remove chlorine solution after 24 hours contact time.
 - .5 Arrange and pay for laboratory testing of water samples taken from newly disinfected main.
 - .6 Where samples do not meet laboratory test standard for potable water, disinfection procedure and testing is to be repeated until satisfactory results are achieved.]

3.12 Testing and Balancing – Water Pressure Piping Systems

- .1 Balance domestic water piping systems where double regulating valves are installed, including hot water recirculation piping and as otherwise shown.

END OF SECTION

RAINWATER LEADERS – CAST IRON AND COPPER

22 14 16.13

1 GENERAL

1.1 Scope

- .1 Provide cast iron pipe and fittings and/or copper tube and fittings for rain water leaders (storm drainage piping) and downspout collector piping [for aboveground services.
- .2 This specification does not apply to downspouts; refer to Division 07.

1.2 Definitions

- .1 The following definitions apply to this section and referenced sections:
 - .1 **Downspout:** a pipe located on the outside of a building which conveys rainwater/snow meltwater from a roof or patio and discharges to another surface or to a downspout collector pipe.
 - .2 **Downspout collector pipe:** a pipe located at grade level which accepts rainwater/snow meltwater from a downspout and conveys it to the building storm drain or building storm sewer.
 - .3 **Rainwater leader:** means the piping located inside of a building which conveys rainwater/snow melt water from a roof drain, patio drain or similar collection device, to the building storm sewer and includes the building storm drain (storm drainage piping has the same meaning.)

1.3 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 25 Excavation and Backfilling
 - .2 20 05 29 Common Hanger and Support Requirements for Piping

1.4 Applicable Codes and Standards

- .1 Installation standards and codes:
 - .1 Cast Iron Soil Pipe Institute (CISPI) Technical Manual
- .2 Product standards:
 - .1 ASME B16.23 Cast Copper Alloy Solder Joint Drainage Fittings: DWV
 - .2 ASME B16.29 Wrought Copper and Wrought Copper Alloy Solder-Joint Drainage Fittings-DWV
 - .3 ASTM B32 Standard Specification for Solder Metal
 - .4 ASTM B306 Standard Specification for Copper Drainage Tube (DWV)
 - .5 ASTM C564 Standard Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings.
 - .6 ASTM C1540 Standard Specification for Heavy Duty Shielded Couplings Joining Hubless Cast Iron Soil Pipe and Fittings.
 - .7 ASTM B828 Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings.
 - .8 CSA B70 Cast Iron Soil Pipe, Fittings, and Means of Joining
 - .9 CSA-B125 Plumbing Fittings.
 - .10 CSA B158.1 Cast Brass Solder Joint Drainage, Waste, and Vent Fittings
 - .11 CSA B602 Mechanical Couplings for Drain, Waste, and Vent Pipe and Sewer Pipe.

2 PRODUCTS

2.1 Copper DWV Pipe and Fittings

- .1 Application: inside of buildings only. Do not use for buried drain.
- .2 Pipe:
 - .1 copper DWV tube to ASTM B306
 - .2 certification markings made by testing agency accredited by Standards Council of Canada.
- .3 Fittings:
 - .1 copper or copper alloy to ASME B16.23, or ASME B16.29.
- .4 Solder
 - .1 tin-antimony 95/5 to ASTM B32 alloy Sb5.

2.2 Cast Iron DWV Pipe and Fittings

- .1 Application: inside of buildings and buried drain.
- .2 Pipe and fittings:
 - .1 cast to CSA B70,
 - .2 with heavy bituminous coating for buried service,
 - .3 riser fittings with integral riser support ring for hub-less piping installed in vertical risers.
- .3 Joints below grade:
 - .1 [Plain end made up using mechanical sleeve joints to CSA B602 and ASTM C1540 with neoprene or butyl rubber compression gaskets to ASTM C564, with stainless steel sleeve and not less than four stainless steel drive clamps with stainless steel worm gears.
- .4 Joints above ground:
 - .1 Plain end made up using mechanical sleeve joints to CSA B602 and ASTM C1540 with neoprene or butyl rubber compression gaskets to ASTM C564, with stainless steel sleeve and not less than four stainless steel drive clamps with stainless steel worms.
 - .2 Hub and spigot made up neoprene gasket to ASTM C564 and lubricating compound.

3 EXECUTION

3.1 Installation General

- .1 Install rainwater leader drainage piping in accordance with the requirements of the plumbing code applicable at the project location.
- .2 Install suspended piping to grade, parallel and close to walls and ceilings to conserve headroom and space.
- .3 Install piping close to building structure to minimize furring. Group piping and run parallel to walls and ceilings.

3.2 Cast Iron Piping

- .1 Install cast iron drainage piping in accordance with Cast Iron Soil Pipe and Fittings (CISPF) Technical Manual.

- .2 Lay buried piping in bedding prepared in accordance with specification section 20 05 25. Support piping on 150 mm (6 in.) thick bed of clean sand, shaped to accommodate hubs and fittings, to line and grade as shown. Backfill with clean sand to 300 mm above top of pipe or to underside of floor slab whichever is less.
- .3 For suspended piping, provide hangers within 450 mm (18 in.) of each joint, at each change of direction, and within 450 mm (18 in.) of the terminal end of each pipe run.
- .4 Assemble and tighten mechanical sleeve joints to coupling manufacturers recommended torque value with torque wrench.
- .5 Install cast iron hub-and-spigot joints with neoprene compression gasket and lubrication in accordance with manufacturer requirements.
- .6 Provide thrust restraints consisting of pipe clamps and restraint rods installed across tees, elbows, and blind plugs (cleanouts), for cast iron drainage piping NPS 5 and larger.
- .7 Provide sway braces on all horizontal piping where the hanger length is greater than 450 mm (18 in) measured from the top of the pipe to the structure connection point, as follows:
 - .1 transverse brace at 12 m (40 ft) intervals,
 - .2 longitudinal brace at 24 m (80 ft) intervals,
 - .3 a transverse brace of one pipe section may act as a longitudinal brace for a second pipe section connected perpendicular to the first section, provided the brace is located within 600 mm (24 in) of the connection.
 - .4 for clarity, these braces are required even where seismic restraint is not required.

3.3 Copper Tubing

- .1 Cut copper tube square, ream tube ends and clean tubing and tube ends before joint assembly.
- .2 Before assembling solder joints, clean inside of solder fittings and outside of mating pipe with emery paper and coat with flux.
- .3 Solder joints in copper pipe with blow torch or oxy-acetylene flame.

3.4 Pipe Supports

- .1 Support piping in accordance with specification section 20 05 29 except as specified herein.
- .2 Support horizontal copper DWV tubing in accordance with Table 1A:

Table 1A: Horizontal Pipe Support Spacing for Copper Tube		
Pipe Size NPS	Rod Diameter	Maximum Spacing
½	M10 (3/8 in)	1.5 m (5 ft)
¾ to 1¼	M10 (3/8 in)	1.8 m (6 ft)
1½	M10 (3/8 in)	2.4 m (8 ft)
2	M10 (3/8 in)	2.4 m (8 ft)
2½	M12 (½ in)	3.0 m (10 ft)
3	M12 (½ in)	3.0 m (10 ft)
4	M16 (5/8 in)	3.0 m (10 ft)

- .3 Support horizontal cast iron DWV piping in accordance with Table 1B and as follows;
- .1 one pipe support for each end of the pipe, located at or within 150 mm (6 in) of each hub or mechanical joint,
 - .2 for mechanical joints, if the pipe length between adjacent fittings is 300 mm (12 in) or less, reduce the support spacing to a maximum of 1000 mm (39 in),
 - .3 where multiple joints occur within a 1000 mm (39 in) developed pipe length;
 - (a) support may be reduced to every other hub or mechanical joint, or
 - (b) where the pipe run is made of multiple fittings connected end-to-end, provide a 1.6 mm (16 ga) galvanized steel half sleeve underneath the pipe and fittings, and support the sleeve with a support at each end of the sleeve.

Table 1B: Horizontal Pipe Support Spacing for Cast Iron Drainage Piping			
Pipe Size NPS	Maximum Spacing	Clevis Hanger: Minimum Rod Diameter	MJ Hanger: Minimum Rod Diameter
1-1/2	3 m (9.8 ft)	---	M10 (3/8 in)
2	3 m (9.8 ft)	---	M10 (3/8 in)
3 to 4	3 m (9.8 ft)	M10 (3/8 in)	M10 (3/8 in)
6	3 m (9.8 ft)	M12 (1/2 in.)	M12 (1/2 in.)
8 to 12	3 m (9.8 ft)	M16 (5/8 in)	---
15	3 m (9.8 ft)	M20 (3/4 in)	---

- .4 Support vertical pipe and tube risers at the base (bottom) of the riser and as follows:
- .1 for cast iron drain and vent piping,

- (a) support piping at every floor level with a pipe clamp, arranged so that the pipe clamp is above the pipe section center of gravity,
 - (b) support the pipe below a hub, or support the pipe with a riser fitting for hub-less joints.
 - (c) support the base of a riser at a fitting hub, or for mechanical joints support the riser pipe at a riser fitting,
 - (d) for pipe sizes NPS 5 and larger, provide sway braces at the base support to limit movement in both horizontal directions.
- .2 for other piping, support piping at every other floor level with pipe riser clamps,
 - .3 for all piping and tubing, do not exceed a vertical spacing of more than 7.5 m (24.5 ft),
 - .4 in addition, for cast iron drainage piping provide lateral guides;
 - (a) at the base and top of the pipe riser,
 - (b) and at every 9 m (30 ft) except where the pipe riser clamp is restrained to prevent lateral movement.

3.5 Downspout Collector Piping

- .1 Construct downspout collector piping from cast iron drainage piping with an exposed hub. Extend pipe to be at least 200 mm (8 in.) above local finished grade level.
- .2 Connect downspout collector piping to the building storm sewer.
- .3 Extend downspout collector piping to at least 1200 mm (4 ft) below finished grade level. Rigidly support piping to the building foundation wall at 150 mm (6 in.) below finished grade level and at the bottom of the pipe. Construct supports using T304 stainless steel threaded rod, nuts and washers, with a stainless steel shelf angle bolted to foundation wall.
 - .1 The use of pipe clamps and threaded rod for this purpose is not acceptable.
- .4 Connect the downspout collector pipe to the building storm sewer.

3.6 Testing

- .1 Test drainage piping in accordance with the requirements of the plumbing code applicable at the project location.
- .2 Test before piping is concealed.
- .3 Cut-out and replace leaking soldered fittings, remake joints in cast iron piping, and retest.

END OF SECTION

STORM DRAINAGE FLEXIBLE MOVEMENT JOINTS

22 14 23.23

1 GENERAL

1.1 Scope

- .1 Provide flexible movement joints for storm drains;
 - .1 outside foundation walls at connections to sanitary sewers,
 - .2 inside the building as shown.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 22 13 19.23 Sanitary Drainage Flexible Movement Joints

2 PRODUCTS

2.1 Flexible Drainage Piping Expansion Joints

- .1 Conform to Specification section 22 13 19.23.

3 EXECUTION

3.1 Installation

- .1 Conform to Specification section 22 13 19.23.

End of Section

ROOF DRAINS 22 14 26.13

1 GENERAL

1.1 Scope

- .1 Provide storm drainage piping accessories for roof drains:

- .1 Conventional roof system,
- .2 IRMA roof system,
- .3 Green roofs – layered style.

1.2 Definitions

- .1 The following definitions apply to this specification section.
- .1 **Conventional roof:** a roof construction where the waterproof membrane layer lies on top of the roof insulation.
 - .2 **Grate:** the finished exposed element of the floor or area drain which is suitable for vehicle loads.
 - .3 **IRMA:** Inverted Roof Membrane Assembly – a roof construction method where the waterproofing layer is located underneath the (external) roof insulation layer. Inverted roof or protected membrane roof assembly has the same meaning.
 - .4 **Strainer:** the finished exposed element of the floor or area drain which is suitable for foot traffic only.
 - .5 **Strainer shank:** the strainer supporting element which connects to the drain body. Grate shank has the same meaning.
- .2 Load ratings of Light Duty, Medium Duty, Heavy Duty, Extra Heavy Duty and Special Duty: in accordance with CSA B72 / ASME A112.3.1 / ASME A112.6.3.

1.3 Applicable codes and standards

- .1 Product standards:
- .1 ASME A112.3.1 Stainless Steel Drainage Systems for Sanitary DWV, Storm, and Vacuum Applications, Above-ground and Below Ground
 - .2 ASME A112.6.4 Roof, Deck, and Balcony Drains
 - .3 CSA B79 Commercial and Residential Drains and Cleanouts

1.4 Submittals

- .1 Submit product data sheets for materials specified herein.

2 PRODUCTS

2.1 Roof Drains – Conventional Roof (type “RD”)

- .1 The following requirements apply to all roof drains except as otherwise specified.
- .2 Roof drains to be listed to CSA B79 and marked in accordance with ASME A112.3.1 (stainless steel roof drains), or ASME A112.6.4 (non-stainless steel roof drains).
- .3 Application: general purpose, conventional roofs with waterproofing membrane on top of roof insulation.

.4 Body:

- .1 coated cast or ductile iron body,
 - (a) NPS 2 to NPS 4 drain size: minimum Ø200 mm (8 in. dia.) anchor flange,
 - (b) NPS 6 to NPS 10 drain size: minimum Ø380 mm (15 in. dia.) anchor flange,
- .2 combination membrane/flashing clamp and gravel guard,
- .3 underdeck clamps,
- .4 18 ga galvanized steel deck plate,
- .5 bottom no-hub outlet pipe connection.

.5 Grate:

- .1 self-locking cast iron dome grate, minimum 200 mm (8 in.) high,

.6 Drain body pipe size as shown on drawings.*Standard of Acceptance*

- Watts - fig. RD-100
- Zurn - fig. Z100 series
- Mifab - fig. R1200 series
- Jay R. Smith - fig. 1010 series

2.2 Roof Drains – IRMA Roof (type “RDV”)

- .1 Application: IRMA roofs.
- .2 Type RD roof drain and/except as follows:
 - .1 Grate:
 - (a) extended height dome grate, minimum 200 mm (8 in.) high
 - (b) T304 stainless steel perforated gravel guard, with perforations not exceeding 13mm (1/2. in.), and a minimum height of 152 mm (6 in.).

2.3 Deck Drains (type “RDD”)

- .1 Application: flat roof terraces and decks for occupied use.
- .2 Load rating: Light Duty for foot traffic.
- .3 Type [RD][RDV] roof drain and/except as follows:
 - .1 Body:
 - (a) minimum 150 mm (6 in.) deep sump.
 - .2 Grate:
 - (a) epoxy coated ductile iron grate with maximum 10 mm (3/8 in.) wide slots,
 - i) NPS 2 to NPS 4: 200 mm (8 in.) square,
 - ii) NPS 6 to NPS 8: 325 mm (12-3/4 in.) square,
 - (b) adjustable grate shank to set grating between 65 mm (2-1/2 in.) and 105 mm (4 in.) above the level of the membrane clamp, and drainage slots.

2.4 Scupper drains

- .1 Application: roof scuppers for connection to internal rainwater leaders, or external downspouts.
- .2 Body: coated cast or ductile iron body with flashing clamp, reversible for either horizontal or vertical drainage.
- .3 Grate: bronze angled grate.

Standard of Acceptance

- Watts - fig. RD-270 series
- Zurn - fig. Z187 series
- Miffab - fig. R1310 series
- Jay R. Smith - fig. 1510 series

3 EXECUTION

3.1 Installation - General

- .1 Install storm drainage specialties in accordance with the applicable provincial plumbing code, and the requirements of the local authority having jurisdiction.
- .2 Install storm drainage specialties in accordance with the manufacturers installation instructions and as described herein.
- .3 Review architectural drawings to confirm roofing construction and build thickness prior to ordering of roof drains and accessories.

END OF SECTION

OIL SYSTEM DEMOLITION

23 11 05

1 GENERAL

1.1 Scope

- .1 Demolition, removal and disposal of:
 - .1 aboveground tanks and associated piping, and
 - .2 ancillary devices.
- .2 Removal and disposal of existing oil in tanks and piping.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 25 Excavation and Backfill
 - .2 23 11 13 Fuel Oil Piping and Accessories

1.3 Applicable codes and standards

- .1 Legislation:
 - .1 to section 23 11 13.
 - .2 SOR/2001-286 Transportation of Dangerous Goods Regulation
- .2 Installation standards, codes and guidelines:
 - .1 to section 23 11 13 and as follows.
 - .2 ISO 4406 *Hydraulic fluid power -- Fluids -- Method for coding the level of contamination by solid particles*

1.4 Qualified Tradesperson

- .1 Work to be done by a specialist firm with an established reputation in this field, employed as a subtrade under this contract.
- .2 Removal of storage tank systems and associated piping and ancillary equipment to be performed by a licensed petroleum equipment contractor of the applicable class for the equipment in accordance with:
 - .1 Ontario Regulation 215/01 *Fuel Industry Certificates* - OBT1
 - .2 Ontario Regulation 216/01 *Certification of Petroleum Mechanics* - PM2 and PM3 as applicable to the type of tank.

1.5 Submittals

- .1 Provide the following documentation for review by the Owner and Consultant, and for record purposes:
 - .1 documentation of disposal of storage tanks at a regulatory authority approved disposal site for such contaminated waste,
 - .2 laboratory test results of soil samples,
 - .3 laboratory test results of on-site water separation and oil filtration service for transferring of oil to a new tank,
 - .4 documentation of transfer of oil and/or residual oil/water/sludge to a regulatory authority licensed oil reclamation center,

- .5 documentation of disposal of contaminated soil (if found) to a regulatory authority licensed disposal site.

2 PRODUCTS

2.1 Section not used.

3 EXECUTION

3.1 General

- .1 After the new oil system is installed and operational, schedule the removal of existing tanks and piping systems to be demolished with the Owner.
- .2 Remove oil from storage tanks and piping prior to demolition of same, and as further specified herein.
- .3 Remove aboveground and underground tanks and piping systems in accordance to all legislation and government agency requirements.

3.2 Storage Tank and Piping - Liquid and Solids Removal

- .1 Drain existing oil piping to be demolished, by draining to the existing tank or to a remote location where oil can be collected for disposal.
- .2 Use a wire-drawn or pneumatic pipe cleaner (i.e a pipe cleaning pig) to remove residual oil film;
 - .1 If necessary to aid in moving oil, use dry nitrogen gas not to exceed 70 kPa (10 psig) at the remote end of the piping system to remove oil back to the tank wherever possible.
- .3 Remove the bulk of the fuel oil (except bottom sludge and water) and dispose of oil at a licensed reclamation center. Provide documentation of the liquid removal and its disposal in a final report

3.3 Sludge Removal

- .1 After removal of the bulk of the fuel oil, provide samples of remaining liquids from the existing storage tank to a qualified hazardous waste testing facility for laboratory analysis and approval for the disposal of the remaining liquids.
- .2 Remove the remaining liquid from the existing storage tank and arrange and pay for its proper disposal prior to removing the tank from the ground.
- .3 Provide documentation of the liquid removal and its disposal in a final report.

3.4 Site Environmental Assessment

- .1 If a release of fuel to the environment or inside the building occurs during the demolition of these tanks or piping system, the Contractor under this specification section is responsible for obtaining a further environmental assessment and to perform and pay for any remedial work to remove the released oil and to remediate any contaminated soil or surfaces

3.5 Storage Tank - Cleaning and Disposal

- .1 Transport the removed tank from the site. Transportation on public roads shall conform to the requirements of the Transportation of Dangerous Goods Regulation, except where the tank is cleaned in accordance with the following procedure prior to transport.
- .2 Measure levels of combustible vapors and oxygen, and initiate ventilation of the tank, if needed as follows:

- .1 ventilate tank using an explosion-proof gas exhauster until the vapor concentration is reduced to 10 percent or less of the lower explosive limit for diesel fuel (LEL = 0.6% by volume of air). Extract air from the bottom of the tank;
- .2 oxygen content of samples of exhaust air shall range from 19.5 to 23.5 percent;
- .3 cut access ports for cleaning into tank after vapor and oxygen concentrations have met the requirements noted above;
- .4 cut additional holes if necessary along the tank spring line, minimum of two (2) 200 mm x 200 mm (8 in x 8 in) holes both side of the tank;
- .5 clean the tank by mopping, scraping, and sweeping the interior of the tank, providing a final surface clean with solvents suitable for the removal of oil film;
- .6 ensure final vapor and oxygen concentration are within the requirements noted above before proceeding to cut and dismantle the tank for transport to a disposal facility;
- .3 Collect, contain and place residue in DOT approved portable containers for transporting and disposal.
- .4 Remove the dismantled tank to an approved disposal facility.
- .5 Obtain disposal facility receipts noting proper tank disposal.

END OF SECTION

METAL DUCTS 23 31 13.13

1 GENERAL

1.1 Scope

- .1 Provide metal HVAC ductwork including casings and plenums as shown.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 01 Basic Materials and Methods
 - .2 20 05 29.16 Hanger and Support Supplement for Mass Timber Buildings
 - .3 20 05 49 Seismic Restraint
 - .4 23 31 21 Protected Ductwork
 - .5 23 33 05 Duct Accessories.

1.3 Definitions and Abbreviations

- .1 The following definitions apply to this section and as applicable to related sections.
 - .1 **Casing(s)** – a fabricated metal construct of some combination of walls, roofs, and/or floors for the conveyance of air at relatively low air velocities (typically below 5 m/s (1000 fpm) and which encloses equipment such, as but not limited to, fans, coils, and filters.
 - .2 **Ductwork** – a network of metallic or flexible material distributed through a building or space for the conveyance of air: (a) from an HVAC unit to one or more spaces, or (b) exhausted from those spaces.
 - .3 **Plenums** – a form of ductwork for the conveyance of air at relatively low velocities (typically below 3.5 m/s (700 fpm)).
- .2 In SMACNA 006 - *HVAC Duct Construction Standard – Metal and Flexible*, a reference to requirements for construction of “casings” in chapter 9 applies equally to construction of plenums, except/and as specified herein.

1.4 Applicable Codes and Standards

- .1 Installation codes and standards:
 - .1 NFPA 90A Standard for the Installation of Air-Conditioning and Ventilating Systems.
 - .2 ASHRAE Letter and number designations, shown as “CR3-16” etc., are taken from ASHRAE Duct Fitting Data Base.(DFDB)
 - .3 ANSI/SMACNA 006 HVAC Duct Construction Standards - Metal and Flexible (4th edition)
 - .4 ANS/SMACNA 002 Rectangular Industrial Duct Construction Standards (2nd edition)
 - .5 ANSI/SMACNA 016 HVAC Air Duct Leakage Test Manual (2nd edition)
- .2 Product standards:
 - .1 ASTM A90 Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
 - .2 ASTM A653 Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot Dip Process

- | | | |
|-----|----------------|--|
| .3 | ASTM A924 | Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process |
| .4 | ASTM A1011 | Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength |
| .5 | ASTM A283 | Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates |
| .6 | ASTM A36 | Standard Specification for Carbon Structural Steel |
| .7 | ASTM A480 | Specification for General requirements for Flat Rolled Plate, Sheet, and Strip |
| .8 | ASTM A463 | Standard Specification for Steel Sheet, Aluminum-Coated, by the Hot-Dip Process |
| .9 | ASTM B209 | Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate |
| .10 | ANSI/MSS SP-58 | Pipe Hangers and Supports |

1.5 Qualified Tradesperson

- .1 Work to be performed by qualified, licensed and recognized firm with an established reputation in this field, using tradesperson holding applicable certificates of competency.

1.6 Design Criteria

- .1 Outdoor ductwork, rooftop duct support frames, and weather shields are to be designed to meet the local wind loading in accordance with the building code requirements at the location of the Work.
- .2 Seismic design loading for duct supports to conform to Specification section 20 05 49.

1.7 Submittals

- .1 Submit manufacturer's catalogue literature for:
 - .1 proprietary joints.
- .2 Submit fabrication shop drawings for the following ductwork elements:
 - .1 integral drain pans and external drain pans including drain pipe connection,
 - .2 water-resistant ductwork,
 - .3 casings and plenums.

1.8 As-Built Drawings

- .1 As work progresses, mark-up field drawings as to actual location of ductwork, balancing dampers and other duct accessories and submit as part of record of "As-Built" conditions.

2 PRODUCTS**2.1 Common Material**

- .1 Galvanized steel:
 - .1 Ducts and connectors: lock forming quality to ASTM A653 or ASTM A924, type Z180 (G60) or Z275(G90) as specified in Part 3 – EXECUTION.
 - .2 Miscellaneous pipe, angles, strips and threaded rod in contact with ductwork: galvanized with a minimum thickness equal to ASTM A653 - Z180 (G60).

- .2 Stainless steel:
 - .1 to ASTM A480, Type 304L,
 - .2 finish: 2B mill, except where otherwise shown.
- .3 Aluminum:
 - .1 To ASTM B209;
 - (a) alloy 3003-H14 or 5052-H32 for sheet material.
 - (b) alloy 6061-T6 for plate material
 - (c) alloy 6061-T4 or T6 for shapes material.
- .4 Plain mild carbon steel:
 - .1 To ASTM A1011, A283, A572 and A36 as applicable.

2.2 Joints

- .1 Fabricated joints: to ANSI/SMACNA 006 as applicable to duct pressure class, duct size, duct-wall thickness, and reinforcing requirements.
- .2 Bolted companion flange – rectangular ductwork:
 - .1 formed flanges, corner pieces, integral edge seals, gaskets and cleats.
 - .2 material to match that of ductwork being joined,
 - .3 Neoprene gaskets.

Standard of Acceptance

- Ductmate – fig. System 25/35/45
- Hardcase (Carlisle) – fig. Nexus

- .3 Barrel-rim clamped companion flange – round ductwork:
 - .1 roll-formed companion flanges, field installed, mechanically fastened and sealed to ends of duct,
 - .2 barrel ring clamp with bolted or no-tool cam locking clamp,
 - .3 Neoprene gaskets.

Standard of Acceptance

- Ductmate - fig. Spiralmate
- Nordfab - fig. Quick-Fit Ducting

2.3 Sealant and Tape

- .1 To Specification section 23 33 05.

2.4 Hangers and Supports

- .1 Upper hanger attachments;
 - .1 in new concrete: manufactured concrete inserts.

Standard of Acceptance

- Myatt Fig. 485

- .2 for steel joist: galvanized joist clamps or steel plate washer.

Standard of Acceptance

- Anvil Fig. 61 or 86
- Anvil Fig. 60 for plate washer

.3 for steel beams: galvanized beam clamps.

Standard of Acceptance

- Anvil Fig. 60

3 EXECUTION

3.1 General Fabrication and Installation Requirements

- .1 Construction details, sheet gauges, reinforcing, and bracing for ductwork, casings, and plenums to be in accordance with SMACNA 006, except/and as otherwise shown.
- .2 Material selection: refer to Schedule A at the end of this section where otherwise shown.
- .3 Rectangular ductwork seams and joints:
 - .1 longitudinal seams: Pittsburgh Lock, with specified sealant applied prior to hammering of joint,
 - .2 transverse joints: to SMACNA HVAC standards based on pressure class and reinforcement used, and for sealing requirements.
- .4 Round ductwork seams and joints, 500 Pa (2 in wg) pressure class and higher:
 - .1 spiral flat type longitudinal seam, button punched.

3.2 Sheet-Metal Casings

- .1 Provide sheet-metal casings to enclose equipment as shown.
- .2 Construct casings in accordance with SMACNA 006 except/and as follows.
- .3 Design pressures:
 - .1 suction side of fan: [500 Pa (2 in.w.c.)][750 Pa (3 in.w.c)]
 - .2 discharge side of fan: in accordance with the supply duct system pressure class.
 - .3 where suction pressure is 750 Pa (3 in.w.c.) or greater, casings may be constructed in accordance with SMACNA 002.
 - .4 design and construct casings:
 - (a) to withstand 133% of the design pressure without structural failure,
 - (b) so that walls and roof do not exceed a deflection of more than 1.0 mm/m (1/8 in./ft.) of width at design pressures.
- .4 Construct casing as:
 - .1 double-wall construction where enclosed equipment includes cooling coils, or as otherwise shown,
 - .2 single-wall construction for all other enclosed equipment.
- .5 For single wall construction, fabricate panels with reinforcement on the outside of the casing (not within the airstream).
- .6 Construct double-wall casings as follows:
 - .1 minimum 50 mm (2 in.) thick wall-cavity construction,
 - .2 outer skin: galvanized steel of required wall thickness for general casing construction.

- .3 inner skin (liner):
 - (a) [0.76 mm (22 GA.) type Z275 (G90) galvanized steel][0.81 mm (20 GA) aluminium][0.8 mm (22 GA) stainless steel];
 - (b) solid liners in wet-areas including cooling coils dehumidification equipment, and humidifiers, or where shown to be suitable for wash-down.
 - (c) 40% perforated liners in all other areas
- .4 insulation:
 - (a) same nominal thickness as the wall cavity,
 - (b) rigid-board glass-fibre insulation, 48 kg/m³ (3.0 lb/ft³) density, 0.35 W/m°C at 38°C (0.24 BTU·in/hr·ft²·°F at 100°F) mean temperature,
 - (c) foil backed with vapour barrier positioned on inner wall side.
- .5 casing flanges turned inwards to occupy the insulation cavity;
 - (a) where the required casing flange dimension exceeds the minimum specified wall-cavity thickness, increase the wall-cavity thickness to suit
- .6 thermal break:
 - (a) construct casing flanges and internal channels to create a thermal break between inside and outer casing skins (no continuous metal contact between inner and outer skins), for walls and roof panels,
 - (b) provide continuous 3 mm (1/8 in.) neoprene gasket between casing panels and attachment to building structure.
- .7 spot weld panels to bracing and reinforcement flanges, and provide inside corner and outside corner trim angles to close-off joints,
- .8 provide internal and external cover plates to cover panel joints, imbedded in sealant and mechanically fastened to panel channels.
- .7 Drains:
 - .1 where casings have an integral metal floor (bottom surface), construct the casing floor as an integral drain pan as specified herein.
 - .2 drain pan material: same as casing material
- .8 Access doors:
 - .1 provide access doors at locations as shown.
 - .2 door size: 500 W x 1375 H mm (20 W x 54 H in) unless otherwise shown,
 - .3 arrange doors to open against the differential pressure,
 - .4 door frames:
 - (a) fully-welded angle or C-channel frame, minimum 1.6 mm (16 GA) thick, with mitered corners that are welded and ground flush, and mechanically fastened to adjacent casing panels,
 - (b) adjacent casing panels provided with additional reinforcing to stiffen the casing wall opening,
 - (c) continuous sealant between door frame and adjacent casing.
 - .5 door construction:
 - (a) door panel thickness:
 - i) outer panel: 0.85 mm (22 GA.)
 - ii) inner panel (for double-wall construction): 0.70 mm (24 GA).
 - (b) door edge reinforcement: either rolled door edges or welded angles,

- (c) where casing is required to be double wall construct, provide doors with 25 mm (1 in.) thick insulation covered with inner panel,
 - (d) hinges:
 - i) design pressure not exceeding 500 Pa (2 in.w.c.): three (3) mechanically fastened 75 mm (3 in.) wide butt hinges per door, or continuous piano hinge,
 - ii) design pressures greater than 500 Pa (2 in.w.c.): three (3) 75 mm (3 in.) wide butt hinges, welded to door panel.
 - (e) two (2) latch handles per door,
 - (f) continuous neoprene automotive gaskets at contact areas between door and door frame.
- .9 Casing penetrations:
- .1 for penetrations of pipe or conduit through casing walls,
 - .2 fabricated single-piece circular or square escutcheon plate, , with opening closely sized to suit OD of pipe or conduit,
 - .3 6 mm (1/2 in.) thick neoprene gasket with opening for conduit and pipe opening sized as an interference fit,
 - .4 escutcheon plate mechanically fastened to casing wall with bolts, nuts and washers at not less than four (4) locations per plate.

3.3 Integral Drain Pans

- .1 Where shown or specified, construct the bottom portion of a duct, casing or plenum as a watertight drain pan.
- .2 Materials: same material as the associated duct, casing or plenum unless otherwise shown.
- .3 Break the bottom panel in two-directions to allow water to drain to a low-point drain outlet,
- .4 Provide continuous welded joints along bottom of plenum, and extend welds up vertical joints at least 50 mm (2 in.).
 - .1 For galvanized steel materials, touch-up ductwork where galvanization is damaged during welding with zinc-rich paint.
 - .2 For stainless steel materials, mechanically grind or chemical pickle to remove the welding tint in the heat affected zone (HAZ).
- .5 Provide a NPS 3/4 x 75 mm (3 in.) long stainless steel drain tube connected to the duct drain pan at the low-point drain outlet.

3.4 External Drain Pans

- .1 Provide external drain pans where shown.
- .2 Materials: T304 stainless steel.
- .3 Fabricate drain pan with 50 mm (2 in.) high side walls.
- .4 Break the bottom panel in two-directions to allow water to drain to a low-point drain outlet,
- .5 Provide welded-on hanger attachments to allow support by hanger rod or support the underside of the drain pan.
- .6 Provide continuous welded joints along bottom of plenum, and extend welds up vertical joints. Mechanically grind or chemical pickle both the interior and exterior surfaces at the welds to remove the welding tint in the heat affected zone (HAZ).

- .7 Provide a NPS 3/4 x 75 mm (3 in.) long stainless steel drain tube connected to the duct drain pan at the low-point drain outlet.

3.5 Finishing, Fastening and Supports

- .1 Hammer edges and slips to leave smooth finished surface inside duct.
- .2 Support vertical ducts with steel angles riveted to duct and bearing on building structure;
- .1 design and fabricate duct riser supports using supplementary structural steel supports in accordance with SMACNA 006 and Specification section 20 05 01.
- .2 use plain carbon steel for duct riser supports located indoors,
- .3 use galvanized carbon steel for duct riser supports located outdoors.
- .3 Duct hangers;
- .1 for ducts with both dimensions not exceeding 500 mm (20 in):
- (a) supported with strap hangers of same material as duct but one sheet metal thickness heavier, or on steel angles as specified below.
- (b) extend strap hangers down duct side and turn under 50 mm (2 in) fastening securely to side and underside of duct.
- .2 for ducts with any dimension greater than 500 mm (20 in):
- (a) supported with trapeze hangers constructed from galvanized steel angle with steel rods in accordance with table 1;

Table 1 : Duct Hangers		
Duct size mm (in)	Angle size mm (in)	Rod size mm (in)
up to 750 (up to 30)	25x25x3 (1x1x1/8)	6 (1/4)
750 to 1050 (30 to 40)	40x40x3 (1 1/2x1 1/2x1/8)	6 (1/4)
1050 to 1500 (40 to 60)	40x40x3 (1 1/2x1 1/2x1/8)	10 (3/8)
1500 to 2400 (60 to 90)	50x50x3 (2x2x1/8)	10 (3/8)
2400 and over (90 and over)	50x50x6 (2x2x1/4)	10 (3/8)

- .3 maximum hanger spacing: 2.4 m (8 ft) on centre.
- .4 For additional requirements for seismic restraints, refer to Section 20 05 49.

3.6 Pressure Classification and Seal Class

- .1 Low pressure ductwork construction classification in accordance with Table 2.

Table 2: Duct Pressure Classification			
Pressure class Pa (in wg)	Operating pressure Pa (in wg)	Velocity m/s (fpm)	Leakage Test Pressure Pa (in wg)
125 (1/2)	up to 125 (1/2)	10.0 (2000)	125 (1/2)
250 (1)	125 to 250 (1/2 to 1)	12.5 (2500)	250 (1)
500 (2)	250 to 500 (1 to 2)	12.5 (2500)	500 (2)

Table 2: Duct Pressure Classification			
Pressure class Pa (in wg)	Operating pressure Pa (in wg)	Velocity m/s (fpm)	Leakage Test Pressure Pa (in wg)
750 (3)	500 to 750 (2 to 3)	15.0 (3000)	750 (3)
Greater than 750 (3)	High Pressure Ductwork		Not less than 1000 (4)

.2 Assemble ductwork seams and joints with joint sealant as shown in table 3.

.3 Sealant application:

- .1 store duct sealant at room temperature for 24 hours before use,
- .2 apply sealant on seams as noted in table 1, and brush or extrude sealant to cover fasteners,
- .3 on bell and spigot style joints apply sealant on male section with caulking gun and spread sealant evenly on mating surface with brush,
 - (a) insert fitting and secure with sheet metal screws
 - (b) brush sealant onto outside of assembled joint in 50 mm (2 in) wide band covering fastener heads,
- .4 allow 40 hours curing time before pressure testing.

Table 3: Duct System Pressure and Seal Class

No.	Ductwork System	Static pressure construction class Pa (in.wg.)	Seal class	Sealing requirements Notes (1)(2)(3)(4)
1	Induction unit systems: supply duct from fan discharge to induction unit plenum box inlet.	+1000 (4) and higher	A	Transverse joints, longitudinal seams, ductwall penetrations, and other connections
2	Supply duct risers in vertical service space (duct shafts).	+1000 (4)		
4	Return/exhaust air ductwork between a Heat Recovery Wheel and suction side of fan.	-1000 (4)		
5	Supply, return and exhaust ductwork located outdoors.	All classes as otherwise specified herein		
6	Return air and general exhaust risers in mechanical rooms and in vertical service spaces (duct shafts).	-750 (3)	B	Transverse joints, longitudinal seams, and other connections
7	Return air and general exhaust air ductwork on suction side of fans <u>other than</u> in mechanical rooms and vertical service spaces.	-500 (2)	C	Transverse joints and other connections

Table 3: Duct System Pressure and Seal Class

No.	Ductwork System	Static pressure construction class Pa (in.wg.)	Seal class	Sealing requirements Notes (1)(2)(3)(4)
8	Supply air ductwork downstream of terminal units or reheat coil	+250 (1)	C	Transverse joints only
9	Relief air ductwork on discharge side of return fan; Fan coil units, suction and discharge.	+250 (1)	C	Transverse joints only

Table 3: Duct System Pressure and Seal Class – Healthcare and Laboratories

No.	Ductwork System	Static pressure construction class Pa (in.wg.)	Seal class	Sealing requirements (1)(2)(3)(4)
1	Supply duct risers in vertical service space (duct shafts).	+1000 (4)	A	Transverse joints, longitudinal seams, ductwall penetrations, and other connections
3	Supply air ductwork from discharge side of fan to inlet of terminal units or reheat coil	+1000 (4)		
4	Return/exhaust air ductwork between a Heat Recovery Wheel and suction side of fan.	-1000 (4)		
5	Supply, return and exhaust ductwork located outdoors.	All classes as otherwise specified herein		
6	Autopsy exhaust ductwork.	-1000 (4)		
7	Process exhaust air ductwork between exhaust HEPA filters and suction side of fan.	-1000 (4)		
8	Process exhaust upstream of exhaust filters, or upstream of exhaust fan if there are no exhaust filters	-750 (3)		
9	Chemical fume hood exhaust ductwork on suction side of exhaust fan	-750 (3)		
10	Biohazard exhaust ductwork	-750 (3)		

Table 3: Duct System Pressure and Seal Class – Healthcare and Laboratories

No.	Ductwork System	Static pressure construction class Pa (in.wg.)	Seal class	Sealing requirements (1)(2)(3)(4)
11	Exhaust ductwork on discharge side of fans for: autopsy exhaust, process exhaust, chemical fume hood exhaust, biohazard exhaust	+500 (2)		
12	Perchloric Acid exhaust system on suction side of exhaust fan	-1500 (6)		
13	Perchloric Acid exhaust system on discharge side of exhaust fan	+500 (2)		
14	Return air and general exhaust risers in mechanical rooms and in vertical service spaces (duct shafts).	-750 (3)	B	Transverse joints, longitudinal seams, and other connections
15	Supply air ductwork upstream of HEPA filters, including diffusers with integral HEPA filters. ⁽⁵⁾	+750 (3)		
16	Supply air ductwork downstream of terminal units or reheat coil with terminal HEPA filters	+500 (2)		
17	Return air and general exhaust air ductwork on suction side of fans <u>other than</u> in mechanical rooms and vertical service spaces.	-500 (2)	C	Transverse joints and other connections
18	Supply air ductwork downstream of terminal units or reheat coil.	-250 (1)	C	Transverse joints only
19	Relief air ductwork on discharge side of return fan; Fan coil units, suction and discharge.	+250 (1)	C	Transverse joints only

Notes for table 3:

- (1) *Transverse joints* are connections of two duct or fitting elements oriented perpendicular to flow,
- (2) *Longitudinal seams* are joints oriented in direction of flow,
- (3) *Duct wall penetrations* are openings made by screws, non-self-sealing fasteners, pipe, tubing, rod and wire,
- (4) *Other connections* such as spin-ins taps and other branch fittings inserted into cut openings in duct, access door frames, insertion type control elements and duct joints at equipment are to be treated as *transverse joints*.
- (5) *This pressure class also applies to supply ductwork downstream of a terminal unit or reheat coil which serve diffusers with integral HEPA filters.*

3.7 Fittings - Rectangular Ductwork

- .1 Refer to Schedule B at the end of this section for illustrations of referenced fitting types.

.2 Elbows:

.1 Elbows are to be installed as shown, or if not shown, in descending order as listed in table 4.

(a) for clarity, elbows types are to be selected based on the highest order number (where 1 is the highest) which will fit the available space.

Table 4: Rectangular Duct, Elbows						
Order No.	ASHRAE Fitting No.	Description	Throat Radius Ratio R/W	Duct Width Limit mm (in)	Minimum Throat Radius mm (in)	Remarks
1	CR3-1	Smooth radius Un-vented elbow	1.5	≤ 300 (12)	---	Default
			1.0	> 300 (12)	---	
2	CR3-3	Smooth radius Vented elbow	0.75	≤ 900 (36)	150 (6)	One full radius single thickness splitter vane
	CR3-4	Smooth radius Vented elbow	0.75	> 900 (36) ≤ 1500 (60)	150 (6)	Two full radius single thickness splitter vane
	CR3-5	Smooth radius Vented elbow	0.75	> 1500 (60)	150 (6)	Three full radius single thickness splitter vane
3	CR3-15	Square Mitred Vented elbow	Square throat; Square heel.	--	---	Double thickness turning vanes; 50 (2) heel radius vane; 54 mm (2.125 in) vane spacing.
4	CR3-2	Radius Heel Sharp Throat	0.5	---	---	Double thickness turning vanes as per CR3-3, 4 or 5 depending on duct width

.2 First elbow on discharge side of fan:

(a) fitting CR3-1, un-vented elbow with throat radius 1.0 times duct width, with the required upstream effective length L_e of straight length of duct in accordance with fitting type SR7-5 or SR7-9 as applicable.

.3 Wye and tee branch fittings - Supply air systems:

.1 Wye and tee branch fittings are to be installed as shown, or if not shown, as selected from table 5.

Table 5 : Rectangular Duct, Wye and Tee Branch Fittings - Supply Air Systems			
Ref. No.	Supply Ductwork System	Fitting Type	ASHRAE Fitting No
1	For 750 Pa (3 in.wg) pressure class and above: branch take-off from ducts in shafts, and ducts upstream of terminal boxes, filters and reheat coils	Smooth radius wye; diverging	SR5-1
		Dovetail wye	SR5-14

Table 5 : Rectangular Duct, Wye and Tee Branch Fittings - Supply Air Systems			
Ref. No.	Supply Ductwork System	Fitting Type	ASHRAE Fitting No
2	Supply ducts downstream of terminal boxes, fan coil units, reheat coils or heat pumps	Divided flow fittings	(SMACNA) 4A or 4B
		45° entry branch diverging	SR5-13
		Tee, rectangular main to round conical tap	SR5-12
		Tee, 45° entry branch diverging	SR5-13
		Smooth radius wye; diverging	SR5-1

.4 Wye and tee branches - Return/Exhaust air systems:

- .1 Wye and tee branch fittings are to be installed as shown, or if not shown, as selected from table 6.

Table 5 : Rectangular Duct, Wye and Tee Branch Fittings - Return/Exhaust Air Systems			
Ref. No.	Return/Exhaust Ductwork System	Fitting Type	ASHRAE Fitting No
1	All pressure classes including branch connections at duct shafts	Smooth radius wye; converging	ER5-1
		Dovetail wye	ER5-4
		Divided flow fittings	(SMACNA) 4A or 4B
		45° entry branch diverging, where shown on drawings	ER5-3

.5 Transitions (Rectangular and Round):

- .1 converging: maximum 20° angle between duct side and direction of flow,
.2 diverging: maximum 15° angle between duct side and direction of flow.

.6 Fabricate duct offsets using elbows selected in accordance with table 2 and as follows:

- .1 single offset in single plane, less than duct height: made up with two 45° elbows,
.2 single offset, of greater displacement, made up with 90° elbows,
.3 double offset in single plane, less than duct height, made up with four 45° elbows,
.4 double offset in single plane, of greater displacement than duct height, made up with 90° elbows.

.7 Obstructions passing through duct:

- .1 covered by round nosed streamline enclosure where free area of duct is reduced by less than 15%,
.2 fitted in round nosed streamline enclosure with duct width increase, SMACNA HVAC FIG 2-10, Detail E , with converging and diverging transition angle requirements as specified above.

3.8 Temporary Protection of Duct Openings

- .1 Cap off ends of unfinished ducts while plastering, drywall and other finishing operations are in progress,
- .2 Cover open ends or registers of active exhaust/return ducts with 25 mm (1 in) thick filter media secured with tape. Maintain media until dust producing finishing operations are completed.

3.9 Duct Pressure Testing

- .1 Duct pressure testing must be completed to the satisfaction of Consultant before ductwork is insulated or concealed.
- .2 Pressure test air duct systems for leaks at 1.33 times the system, or portion of the system, pressure class specified and as follows;
 - .1 between supply air handling units and terminal units,
 - .2 between supply air handling units and final connection to supply outlets on supply systems without terminal units (excluding flexible ductwork)
 - .3 between inlet grilles and the exhaust/return fan inlet,
 - .4 between the return fan discharge outlet and the mixing plenum on recirculating return systems,
 - .5 between the exhaust fan discharge outlet and the point of discharge before leaving the building, but only for process exhaust systems conveying any materials other than general building exhaust air,
- .3 The following parts of system are exempt from pressure testing;
 - .1 short duct runs of 15 metres (45 feet) or less, operating at 37 Pa (1/8 in) SP or less.
 - .2 ductwork installed downstream of terminal boxes and fan coil units.
- .4 Conduct test in accordance with Associated Air Balance Council (AABC) recommended procedures.
- .5 Where audible air noise is detected during test, remove test, pressure apply sealant to leaking joints and seams, and retest after 48 hours. Continue testing and sealing until leaks are inaudible.

3.10 Duct Leakage Testing

- .1 Duct leakage testing must be completed to the satisfaction of Consultant before ductwork is insulated or concealed.
- .2 Conduct duct leakage tests in accordance with SMACNA *HVAC and Duct Leakage Test Manual* and as specified herein.
- .3 For each duct systems, calculate the maximum allowable ductwork airflow leakage rate based on duct surface area, pressure class and duct seal class in accordance with the following:

$$L = F \times D_{SA}$$

$$\text{and } F = K \times C_L \times P^{0.65}$$

where these parameters are unique to each section of duct:

- | | |
|----------|--|
| L | is the maximum allowable leakage airflow rate, |
| D_{SA} | is the duct surface area, |
| F | is the leakage rate coefficient, |
| C_L | is the duct leakage class, and is listed in Table 10, |
| P | is the duct design pressure, |
| K | is a conversion factor depending on the units of measure and is listed in Table 9. |

Table 9: Duct Leakage Measurement Units			
	Parameter	Flow Measurement Units	
		L/s	CFM
L	Allowable leakage units	L/s	CFM
D _{SA}	Duct surface area units	m ²	ft ²
F	leakage rate coefficient	L/s per m ²	CFM per 100 ft ²
C _L	Leakage Class	Refer to table 10 below	Refer to table 10 below
P	Duct Class pressure units	Pa	in.w.c.
K	unit conversion (multiplier)	1.4 x 10 ⁻³	1

Table 10: Leakage Coefficient, C_L			
Duct Type	Seal Class		
	C	B	A
Rectangular metal	24	12	6
Round Metal	12	6	3
Unsealed rectangular metal duct	48	48	48
Unsealed round or oval metal duct	30	30	30

- .4 Conduct duct leakage tests for each duct system at an air pressure equal to the duct system pressure class. Where a duct system has multiple pressure classes for different sections, test each section of the system independently.
- .5 If leakage rate exceeds the calculated maximum allowable value, examine ductwork for excessive leakage, re-seal and then repeat the leak test until the measured leakage rate is less than the calculated maximum allowable value for the section of the system under test.
 - .1 for clarity, where a duct system consists of multiple sections of different pressure classes, the acceptance criteria is based on not exceeding the aggregate of the calculated maximum allowable leakage of all sections in the same duct system.
- .6 Maintain a set of drawings on site, coloured each day during testing to indicate extent of duct satisfying leakage criteria under test.
- .7 Submit a written report, verified by the TAB Agent, identifying each segment of duct system tested, showing calculation of maximum allowable leakage (duct surface area, pressure class, seal class, leakage class "C_L" and calculated leakage air flow rate for the section), along with the test pressure and measured leakage airflow rate, and certifying that leakage testing has been satisfactorily completed.
- .8 Submit the report for review by Consultant before duct insulation is installed and branch take-offs are made for terminal units.

3.11 Duct Cleaning

- .1 Cleaning to be performed by agent specializing in this field of work, be a member in good standing with National Air Duct Cleaners Association (NADCA), and to comply with NADCA standards.

- .2 Clean new horizontal and vertical ducts (supply, return, exhaust, transfer), as well as existing supply and return ductwork connected to new fan systems.
- .3 Clean ductwork using high powered vacuum system, hand tools and mechanical brushing systems such that metal surfaces are visibly clean.
- .4 Reset balancing dampers to original settings if moved during work. Have TAB Agent confirm damper settings.
- .5 Maintain set of drawings on site, coloured each day during cleaning to indicate extent of duct cleaning completed.
- .6 Submit a written report, verified by TAB Agent, identifying extent of duct system cleaning and certifying that NADCA standards have been met.

3.12 Schedules

- .1 The following schedules form part of this specification section.
 - .1 Schedule A – Ductwork, Casings and Plenum Materials
 - .2 Schedule B – Illustrations of Referenced Fittings.

Schedule A – Materials for Ductwork, Casings and PlenumsLegend

"Yes" means permitted material

"---" means not permitted

Where more than one material is indicate as permitted for a particular application or location,
than any of those permitted materials may be used.

Application or Location	Galvanized Steel Z180 (G60)	Galvanized Steel Z275 (G90)	Stainless Steel	Aluminum	Notes
Outdoors	---	Yes	Yes	---	[1]
Intake air plenums	---	Yes	Yes	---	[1]
Exhaust air plenums	---	Yes	Yes	---	[1]
Parking garages	---	Yes	Yes	---	[1]
Indoor swimming pools and spas	---	---	Yes	Yes	[2]
Shower rooms	---	---	Yes	Yes	
Indoor painted ductwork	---	Yes	---	---	
Owner Process Equipment Exhaust	---	---	Yes	---	[2]
Duct-mounted humidifiers	---	---	Yes	---	
Shower exhaust ducts	---	---	Yes	Yes	
Buried ductwork	---	PVC Coated	Yes	---	
All other indoor locations	Yes	Yes	---	---	

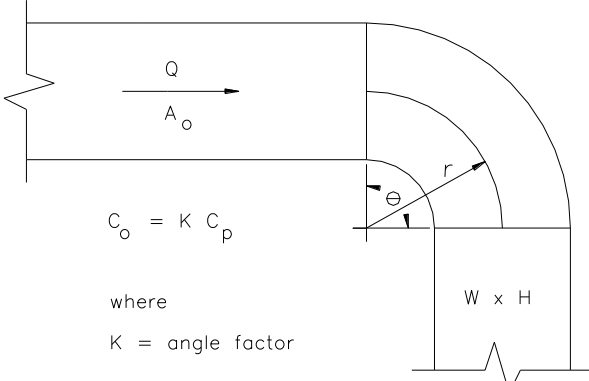
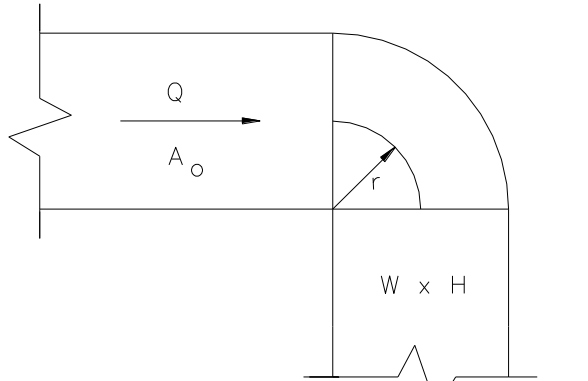
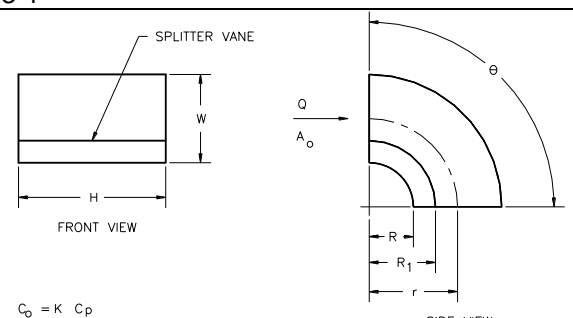
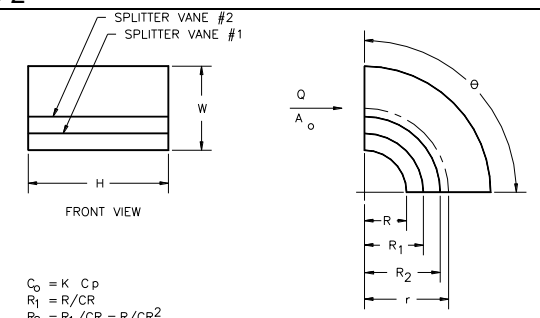
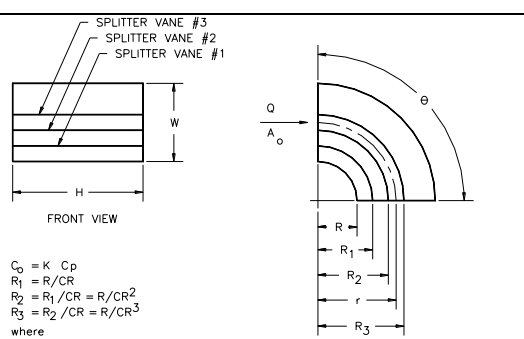
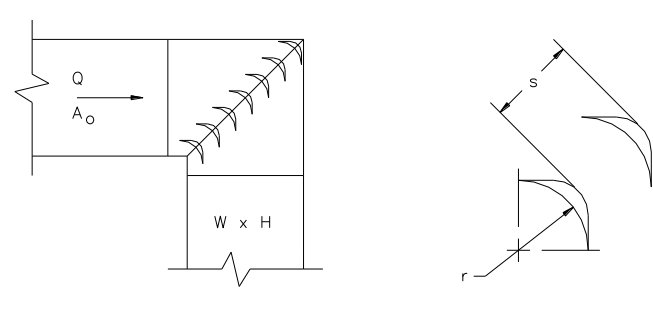
Notes:

[1] For both insulated and uninsulated ductwork.

[2] No. 4 brushed finish for exposed ductwork and hoods, No. 2B mill finish for concealed ductwork.

Schedule B – Illustration of Referenced Fittings

Rectangular Elbows (see Table 4 in Part 3.)

 <p>$C_o = K C_p$</p> <p>where $K = \text{angle factor}$</p> <p>$W \times H$</p>	 <p>$W \times H$</p>
<p>CR3-1</p>  <p>$C_o = K C_p$ $R_1 = R/CR$</p> <p>where $R = \text{throat radius}$ $R_1 = \text{splitter vane radius}$ $CR = \text{'CURVE RATIO'}$ $K = \text{angle factor}$</p> <p style="text-align: right;">CR3-3</p>	<p>CR3-2</p>  <p>$C_o = K C_p$ $R_1 = R/CR$ $R_2 = R_1/CR = R/CR^2$</p> <p>where $R = \text{throat radius}$ $R_1 = \text{splitter vane \#1 radius}$ $R_2 = \text{splitter vane \#2 radius}$ $CR = \text{'CURVE RATIO'}$ $K = \text{angle factor}$</p> <p style="text-align: right;">CR3-4</p>
<p>CR3-3</p>  <p>$C_o = K C_p$ $R_1 = R/CR$ $R_2 = R_1/CR = R/CR^2$ $R_3 = R_2/CR = R/CR^3$</p> <p>where $R = \text{throat radius}$ $R_1 = \text{splitter vane \#1 radius}$ $R_2 = \text{splitter vane \#2 radius}$ $R_3 = \text{splitter vane \#3 radius}$ $CR = \text{'CURVE RATIO'}$ $K = \text{angle factor}$</p> <p style="text-align: right;">CR3-5</p>	<p>CR3-4</p>  <p>$r = 2.0 (50), s = 2.125 (60) \text{ in. (mm)}$</p> <p style="text-align: right;">CR3-15</p>

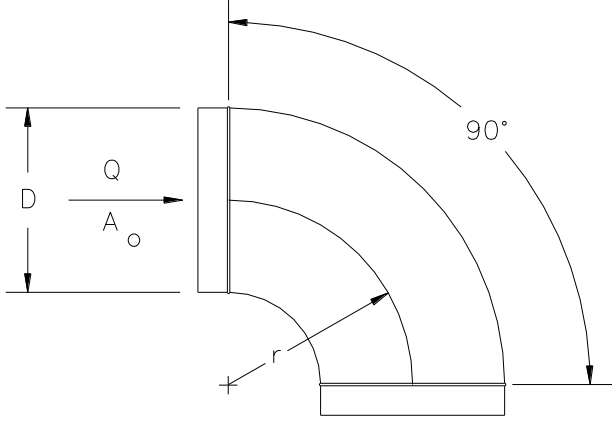
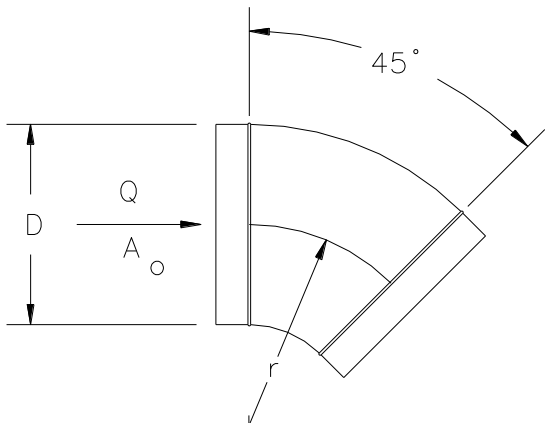
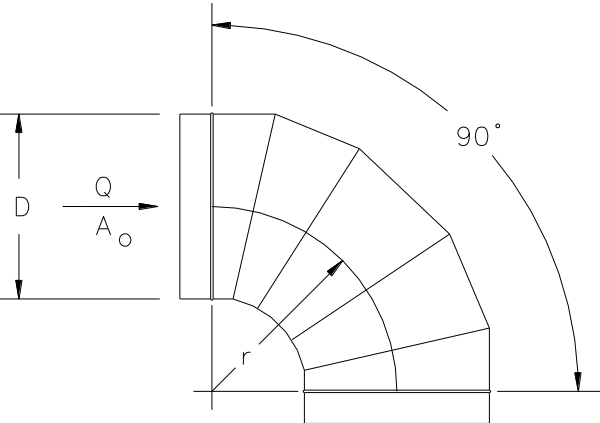
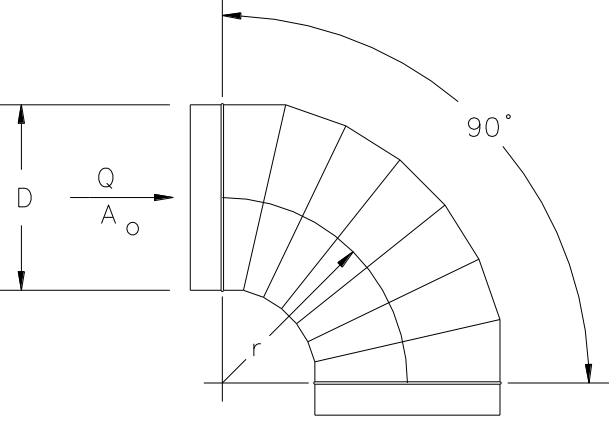
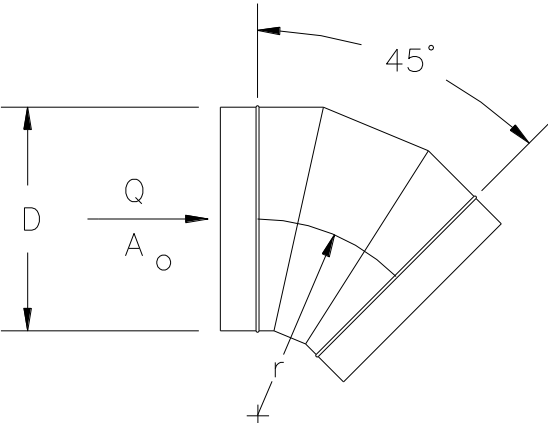
Rectangular Wyes and Tee's – Supply Ductwork (see Table 5 in Part 3)

<p> $A_s = A_b \geq A_c$ $r/W_b = 1.0$ </p>	<p> $L = 4 \text{ in. (100 mm)}$ </p>
<p>SR5-1</p> <p> $L = 0.25W_b, 3 \text{ in. (75 mm) min.}$ </p>	<p>SR5-12</p> <p> $r/W_c = 1.5$ $Q_{s1}/Q_c = Q_{s2}/Q_c = 0.5$ $W_{s1} = W_{s2} = W_b$ </p>
<p>SR5-13</p> <p> $L = 0.25W_b, 3 \text{ in. (75 mm) min.}$ </p>	<p>SR5-14</p> <p> $L = 0.25W_b, 3 \text{ in. (75 mm) min.}$ </p>

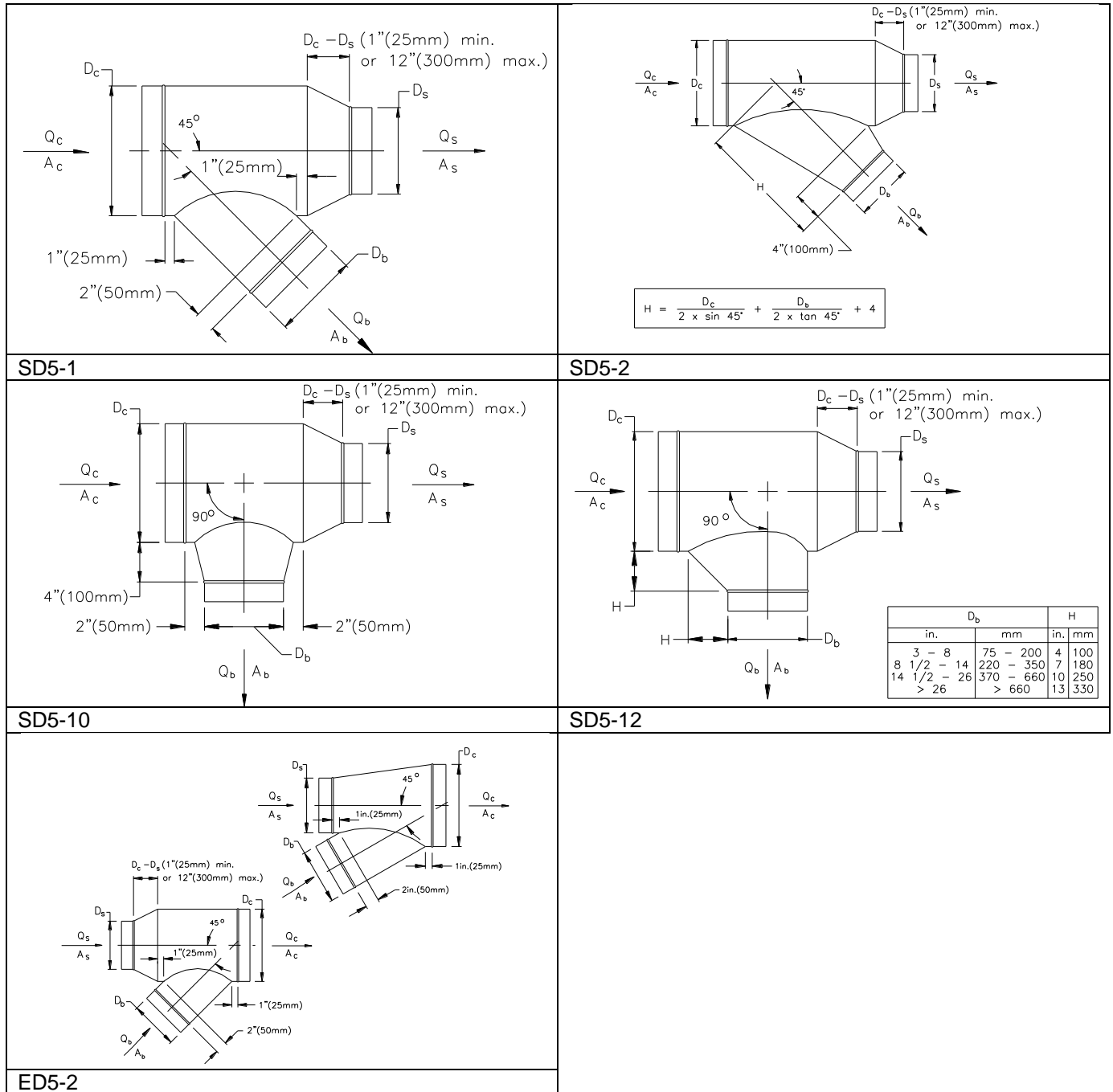
Rectangular Wyes and Tee's – Return/Exhaust Ductwork (see Table 5 in Part 3)

<p> $A_s + A_b \geq A_c$ $r/W_b = 1$ </p>	<p> $L = 0.25 W, 3 \text{ in. (75 mm) min.}$ $A_s = A_c$ $A_b/A_c = 0.5$ </p>
<p>ER5-1</p> <p> $r/W_c = 1.5$ $Q_{b1}/Q_c = Q_{b2}/Q_c = 0.5$ $W_{b1} = W_{b2} = W_b$ </p>	<p>ER5-3</p>
<p>ER5-4</p>	

Round Elbows (see Table 6 in Part 3)

	
CD3-1	CD3-3
	
CD3-9	CD3-10
	
CD3-14	

Round Wyes and Tees (see Table 7 in Part 3)



END OF SECTION

DUCT ACCESSORIES

23 33 05

1 GENERAL

1.1 Scope

- .1 Provide duct accessories as shown.
- .2 Access doors for kitchen grease ducts to conform to Specification section 23 31 13.23.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 23 31 13.23 Kitchen Grease Ductwork.

1.3 Applicable Codes and Standards

- .1 Product standards:
 - .1 LEED v4 New Construction, Low-Emitting Materials credit
 - .2 UL 1978 Grease Ducts
 - .3 ULC-S110 Standard Methods of Test for Air Ducts

1.4 Submittals

- .1 Submit product data sheets for:
 - .1 flexible fan connectors,
 - .2 sealants,
 - .3 tapes,
 - .4 duct access doors and hardware,
 - .5 instrument test ports.

2 PRODUCTS

2.1 Flexible Fan Connectors

- .1 Neoprene, non-insulated:
 - .1 fabric material: fire resistant, self-extinguishing, neoprene-coated glass fabric, density 0.653 kg/m² (0.13 lb./sq. ft),
 - .2 attachment frames: galvanized 0.66 mm (24 ga.) sheet metal frame, with fabric clenched with double locked seams,
 - .3 operating temperature: -40°C to 90°C (-40°F to 194°F),
 - ° Duro-Dyne - fig. Durolon
 - ° Ventfabric - fig. Ventglas
 - ° Elgin - fig. Neoprene
- .2 Vinyl coated, insulated:
 - .1 fabric material: flame resistant, 0.56 mm (0.022 in) thick vinyl coated fabric, encapsulating minimum 25 mm (1 in.) thick, 21 kg/m³ (1.34 lb./cu ft) fiberglass insulation,

- .2 attachment frames: galvanized 0.66 mm (24 ga.) sheet metal frame, with fabric clenched with double locked seams,
- .3 operating temperature: 82°C (180°F) continuous and 93°C (200°F) intermittent,

Standard of Acceptance

- Duro-Dyne - fig. Insulflex

- .3 Silicon rubber, non-insulated:

- .1 silicon rubber-coated woven fiberglass fabric, density of 0.461 kg/m² (0.094 lb./sq. ft),
- .2 attachment frames: galvanized 0.66 mm (24 ga.) sheet metal frame, with fabric clenched with double locked seams,
- .3 operating temperature: up to 260°C (500°F).

Standard of Acceptance

- Duro-Dyne - fig. Thermafab

2.2 Duct Sealant

- .1 Water-based polymer emulsion type, flame resistant duct sealing compound.
- .2 Operating temperature range: -29°C to 93°C (-20°F to 200°F).
- .3 Operating pressure: tested to operate at 2.5 kPa (10 in.w.c.) duct static air pressure,
- .4 Meets requirements for SMACNA Class A, B and C duct sealing requirements.
- .5 Listed to ULC-S102 with flame-spread rating of 25 or less and smoke-development classification of 50 or less.
- .6 LEED requirements:
 - .1 meets requirements for LEED BD+C v4 credit for low emitting material – Paints and Coatings.
 - .2 manufacturer to supply documentation demonstrating compliance.

Standard of Acceptance

- Bakor - fig. Duck-Seal
- RCD - fig. #6 Mastic
- Childers - fig. CP-146
- McGill Air Seal - fig. United Duct Sealer (Water Based)
- Duro Dyne - fig. DWN (water based)

2.3 Tape

- .1 Polyvinyl treated open weave glass fibre tape, 50mm (2") wide.

2.4 Access Doors for Standard-Duty Ducts

- .1 Application: for general purpose HVAC ductwork.
- .2 Low-pressure access doors:
 - .1 manufactured duct access doors, of same material as associated duct,
 - .2 pressure rating: 500 Pa (2 in.w.c.) positive and negative pressure,
 - .3 door panel:
 - (a) double-wall construction encapsulating 25 mm (1 in.) thick fibreglass insulation,

- (b) minimum 0.7 mm (24 ga.) sheet thickness for both inner and outer panel,
- (c) inside face of access door does not protrude into interior space of duct,
- .4 door frame: minimum 0.7 mm (24 ga.) thick channels, with mounting tabs and neoprene door gasket,
- .5 door size: 150x150 mm (6 x 6 in.) up to 600x600 mm (24x24 in.)
- .6 door hardware:
 - (a) hinge: continuous length, galvanized steel piano hinge of same material as door,
 - (b) latch - standard: galvanized steel cam-latch,
 - (c) latch – secured: common-key operated latch,
 - (d) security chain when only provided with cam-latches.

Standard of Acceptance

- ° Ductmate
- ° Duro-Dyne

- .3 High-pressure access doors – framed style:
 - .1 similar construction as for low-pressure framed access doors, except/and as specified below,
 - .2 pressure rating: 2500 Pa (10 in.w.c.) positive and negative pressure without measurable leakage under laboratory testing,
 - .3 hardware: cam-latch only,
 - (a) one (1) latch per door edge (total of 4) for 150x150 mm (6 x 6 in.) doors,
 - (b) two (2) latches per door edge (total of 8) for larger doors.

Standard of Acceptance

- ° Ductmate
- ° Duro-Dyne

- .4 High-pressure access doors – frameless style:
 - .1 manufactured duct access doors, of same material as associated duct, for rectangular, round and flat-oval ducts,
 - .2 pressure rating: 2500 Pa (10 in.w.c.) positive and negative pressure without measurable leakage under laboratory testing,
 - .3 door panel:
 - (a) inner sandwich double-wall construction, encapsulating 25 mm (1 in.) thick fibreglass insulation, spot-welded seams, with smooth-faced finish where exposed to the airstream,
 - (b) outer pressure panel: stamped reinforced-exterior panel,
 - (c) neoprene gasket applied to inner panel face, positioned for positive or negative pressure applications,
 - (d) inside face of access door does not protrude into interior space of duct,
 - .4 door frame: none.
 - .5 door size: 200x100 mm (8 x 4 in.) up to 600x450 mm (24 x 18 in.)
 - .6 door hardware:
 - (a) two (2) spring-loaded pressure-retaining bolting system, with tool-less polypropylene knobs.

Standard of Acceptance

- Ductmate - fig. Sandwich Access Doors

2.5 Access Doors for Plenums

- .1 Shop fabricated doors:
 - .1 double-wall construction, fully encapsulating 25 mm (1 in.) thick glass-fibre insulation,
 - .2 same material as duct, with both inner and outer panels of same thickness as associated plenum wall but not less than 0.6 mm (26ga.) thick,
 - .3 door frame: structural angles, galvanized steel minimum 2.0 mm (14 ga.) thickness, with continuous welded joints,
 - .4 gasket: automotive-style Neoprene gaskets bonded to door frame,
 - .5 door size: 500 mm wide x 1370 mm high (20 in. x 54 in.) except as otherwise shown,
 - .6 door swing:
 - (a) inwards for positive pressure plenums,
 - (b) outwards for negative pressure plenums.
- .2 Door hardware:
 - .1 hinges: continuous piano hinge, zinc-plated steel or stainless-steel,
 - .2 handles: two (2) handles operable from both sides.

Standard of Acceptance

- Duro-Dyne - fig. SP-20 (door handles)

2.6 Instrument Test Ports

- .1 Manufactured test ports:
 - .1 nominal size: Ø25 mm (1 in) minimum inside diameter, length to suit insulation thickness,
 - .2 extended body to accommodate 25 and 50 mm (1 and 2 in.) insulation thickness as applicable to the duct system,
 - .3 1.6 mm (16 ga.) thick steel body zinc plated after manufacture,
 - .4 chain-secured neoprene expansion plug with cam lock handle,
 - .5 Neoprene mounting gasket: flat for rectangular duct and moulded for round duct.

Standard of Acceptance

- Duro-Dyne - fig. TH1 or IP2

- .2 Sealant for test port: high temperature silicone.

Standard of Acceptance

- Duro-Dyne - fig. Red High Temperature Silicon

3 EXECUTION

3.1 Flexible Fan Connectors

- .1 Provide flexible fan connectors to isolate air handling equipment and fans from ductwork, and as shown.
 - .1 minimum length: 75 mm (3 in) length of fabric measured in direction of air flow,

- .2 minimum distance between metal parts when system is in operation: 25 mm (1 in).
- .2 Use insulated type where connected ductwork is insulated.
- .3 Use silicon-rubber type for laboratory exhaust ducting, and other process exhaust ducting conveying chemical vapours and gases.
- .4 Do not install flexible fan connectors on NFPA 96 kitchen grease duct systems.

3.2 Sealant and Tape

- .1 Apply sealant to ductwork joints and seams as detailed in other sections.
- .2 Use of tape is limited to low-pressure systems requiring Class C

3.3 Access Doors for Standard Ducts

- .1 Provide access doors in HVAC standard ducts in accordance with the following table:

Access Point	Location
Reheat coils	Both sides of coil
Fire dampers - replaceable thermal link type	Either side of damper
Motorized fire dampers, smoke dampers and combination smoke fire	On actuator side of damper
Motorized Dampers	Either side of damper
Duct smoke detectors	Across from or beneath sensor tube
Bottom of duct risers	Bottom of duct riser, or on backside of elbow

- .2 Weld door frames in place for high velocity ductwork having air velocities in excess of 10 m/s (2500 fpm).
- .3 Access door sizes:
 - .1 as large as possible, with 1:1.5 aspect ratio, for duct sides up to and including 360 mm (14 in),
 - .2 300 mm x 380 mm (12 in x 15 in) for duct sides 380 mm (15 in) and larger,
 - .3 1500 mm (60 in) high by 450 mm (18 in) wide in casings and plenums.

3.4 Access Doors for Plenums

- .1 Provide access doors to plenums and casing in locations as shown.
- .2 Weld door frames in place for plenums and casings.

END OF SECTION

DAMPERS - OPERATING

23 33 13.13

1 GENERAL

1.1 Scope

- .1 Provide motorized control dampers as shown.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 23 73 13 Modular Air Handling Units
 - .2 23 73 23 Custom Air Handling Units
 - .3 25 30 13 Building Automation Actuators and Operators
 - .4 25 30 23.13 Building Automation Control Dampers

1.3 Applicable Codes and Standards

- .1 Product standards:
 - .1 AMCA 511 Product Rating Manual for Air Control Devices

1.4 Submittals

- .1 Submit product data sheets for materials specified herein and include:
 - .1 performance charts, pressure drop vs approach velocity for range of blade angles from 0 to 90°,
 - .2 torque requirements,
 - .3 construction details.

2 PRODUCTS

2.1 Multi-Blade Operatable Control Dampers

- .1 Performance:
 - .1 control dampers listed to AMCA 511.
 - .2 leakage in closed position: AMCA Class 1A at 250 Pa (1 in.wc.) and Class 1 at 1000 kPa (4 in.w.c.).
 - .3 pressure drop in open position: maximum 12 Pa (0.05 in wg) differential at 5 m/s (1000 fpm).
 - .4 operating temperature range: -40 to 149°C (-40 to 300°F)
- .2 Construction:
 - .1 non-insulated dampers:
 - (a) blades: [extruded aluminum][formed galvanized steel][formed stainless steel] interlocking blades,
 - (b) frame: [extruded aluminum][formed and welded galvanized steel],
 - .2 insulated dampers:
 - (a) blades: extruded aluminum interlocking double thickness insulated blades,
 - (b) frame: extruded aluminum, thermally broken,

- .3 seals: extruded vinyl seals, and spring stainless steel side seals,
- .4 bearings: bronze oiltite inner bearing and outer bearing,
- .5 maximum blade width: 150 mm (6 in),
- .6 maximum blade length: 1200 mm (4 ft).
- .7 blade linkage: aluminium and zinc-plated steel tie rods, brass pivots and steel brackets, for parallel blade and opposed blade operation as required for damper control operation.

2.2 Bubble-Tight Isolation Dampers

- .1 Single blade type for modulating and two position service.
- .2 Performance:
 - .1 leakage in closed position: maximum 0.01% of rated air flow at 7 kPa (28 in wg) differential across assembly,
 - .2 linear characteristic with 20:1 turndown,
 - .3 sized using Cv numbers in 65% open position for pressure drop of less than 150 Pa (0.6 in wg) differential at 5 m/s (1000 fpm),
- .3 Construction:
 - .1 body: 316L stainless steel,
 - .2 trim: 316L stainless steel,
 - .3 shaft: 316L stainless steel, and Teflon packing glands,
 - .4 seal: silicon blade seal and external adjustable double-packing gland shaft seals,
 - .5 seat: elastomer seat compatible with paraformaldehyde and ethylene gas,
 - .6 flanged gasketed connections for 7 kPa (28 in wg) service,
 - .7 actuator torque requirement: maximum 205 Nm. (150 lb. Ft) to seat and unseat.

Standard of Acceptance

- Ruskin - fig. BT092 (rectangular ducts)
- Ruskin - fig. BTR92 (round duct)]

3 EXECUTION

3.1 Damper Movement Style Selection

- .1 Blade movement type (for control function other than recirculating air handling units):
 - .1 parallel blade style for two position operation.
 - .2 opposed blade style for modulating applications.
- .2 Blade movement type for air handling units with recirculating air dampers;
 - .1 select damper type based on AHU function in accordance with the following table.

System Type	AHU Systems	Minimum Outdoor Air	Economizer Outdoor Air	Exhaust Damper	Recirculating Damper
[Fixed Outdoor Air	All	Parallel	N/A	Parallel	Parallel]
[Air Economizer	All	Parallel	Opposed	Opposed	Opposed]

System Type	AHU Systems	Minimum Outdoor Air	Economizer Outdoor Air	Exhaust Damper	Recirculating Damper
[Air Economizer – Enhanced	All	Parallel	Parallel	Parallel	Parallel]

3.2 Installation

- .1 Secure dampers within ductwork, air handling units and at air inlets and exhaust outlets.
- .2 Caulk around frames and between multiple damper modules with UL listed silicone-free duct sealant.

3.3 Start-Up and Testing

- .1 Stroke dampers fully open and fully closed ten times. Check for free movement of damper blades. Check dampers full close along blade edge seals and end seals.

End of Section

DAMPERS - FIRE AND SMOKE

23 33 13.16

1 GENERAL

1.1 Scope

- .1 Provide fire dampers, smoke dampers, combination smoke/fire dampers, and ceiling fire stop flaps.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 13.16 Wiring Requirements for Mechanical Services

1.3 Definitions

- .1 The following definitions apply for this specification section:
 - .1 **Damper:** means a smoke damper, motorized fire damper or combination smoke/fire damper.
 - (a) **Balancing damper:** : a damper with an electric actuator that is listed for operation as a modulating damper in normal service, to allow setting the damper at a position between open and closed, for system air balancing purposes.
 - (b) **Dynamic damper:** a fire damper rated to close with airflow through damper at specified air velocities and operating pressure.
 - (c) **Modulating damper:** a damper with an electric actuator that is listed for operation as a modulating damper in normal service, to allow modulating control of the damper in response to a normal (non-emergency) process control requirement.
 - (d) **Reopenable damper:** a motorized fire damper of combination smoke/fire damper that can be electrically re-opened by bypassing the primary heat detection device.
 - (e) **Static damper:** a fire damper rated only to close with essentially no airflow through the damper.

1.4 Applicable Codes and Standards

- .1 Installation codes and standards:
 - .1 NFPA 80 Installation, Testing, and Maintenance of Fire Dampers
 - .2 NFPA 105 Standard for the Installation of Smoke Door Assemblies and Other Opening Protectives
- .2 Product standards:
 - .1 AMCA 500-D Laboratory Methods of Testing Dampers for Ratings.
 - .2 ANSI/CAN/UL/ULC 33 Heat Responsive Links for Fire-Protection Services
 - .3 CAN/ULC - S112 Standard Method of Fire Test of Fire Damper Assemblies
 - .4 CAN/ULC - S112.1 Standard for Leakage Rated Dampers for Use in Smoke Control Systems
 - .5 CAN/ULC - S112.2 Standard Method of Fire Test of Ceiling Firestop Flap Assemblies
 - .6 ULC-S505 Standard for Fusible Links for Fire Protection Services
 - .7 CSA C22.2 No. 14 Industrial Control Equipment

1.5 Submittals

- .1 Submit manufacturer catalogue cut-sheets for the following materials;
 - .1 fire dampers,
 - .2 smoke dampers,
 - .3 combination smoke and fire dampers,
 - .4 motorized fire and smoke damper control accessories,
 - .5 fire stop flaps.
- .2 When requested by an AHJ for building safety, submit confirmation data that the fusible link is listed to ULC-S505 or ANSI/CAN/UL/ULC 33.

2 PRODUCTS

2.1 General

- .1 Approvals:
 - .1 Fire dampers and combination smoke/fire dampers listed to CAN/ULC-S112.
 - .2 Smoke dampers and combination smoke/fire dampers listed to CAN/ULC-S112.1.
 - .3 Ceiling fire stop flaps listed to CAN/ULC-S112.2.
 - .4 Fusible links for fire dampers listed to ULC-S505 or ANSI/CAN/UL/ULC 33.

2.2 Fire and Smoke Dampers - General Requirements

- .1 Curtain damper styles:
 - .1 Type A: blade pack and frames in airstream,
 - .2 Type B: blade pack out of airstream,
 - .3 Type C:
 - (a) blade pack and frame out of airstream,
 - (b) for rectangular, round and flat oval ductwork, and
 - (c) sleeve joints and damper/sleeve joints sealed.
- .2 Fire damper fire-resistance rating:
 - .1 Fire separation ratings 2 hr and less: 1-1/2 hrs.
 - .2 Fire separation rating 3 hr or more: 3 hr.
- .3 Installation orientation:
 - .1 Dynamic and static dampers suitable for installation in vertical and horizontal separations.
 - .2 Dampers that are only listed for one orientation are not permitted.
- .4 Rating class, dynamic dampers:
 - .1 Standard performance;
 - (a) air velocity, maximum 10 m/s (2000 fpm),
 - (b) operating static pressure, maximum 1000 Pa (4 in.w.c.)
 - .2 Extended performance ("EPxx");
 - (a) air velocity, maximum 15 m/s (3000 fpm),

- (b) operating static pressure, maximum 1000 Pa (4 in.w.c.)
- .3 High velocity performance ("HVxx");
 - (a) air velocity, maximum 20 m/s (4000 fpm),
 - (b) operating static pressure, maximum 1000 Pa (4 in.w.c.)
- .5 Manufacturers:

Standard of Acceptance

- Nailor
- EH Price (National Controlled Air)
- Ruskin

2.3 Fire Dampers - Multiblade Type

- .1 Construction:
 - .1 Type: dynamic.
 - .2 Frame: G60 galvanized steel hat channel.
 - .3 Blades: airfoil multiblade type, interlocking blades, G60 galvanized steel;
 - (a) Parallel blade for Open-Closed operation,
 - (b) Opposed blade for modulating control or balancing control.
 - .4 Blade linkage: plated steel, concealed in frame (out of airstream).
 - .5 Bearings:
 - (a) On-Off control, and balancing: self-lubricated oil-tight bronze,
 - (b) modulating control: stainless steel.
 - .6 Jackshaft: cadmium plated steel.
 - .7 Internal locking quadrant for balancing maximum opening position.
 - .8 Sleeve: same material as damper frame, length to suit application with steel enclosure and transition collars, and retaining angles.
 - .9 Sleeve type: type A, B, or C as per listing requirements.
 - .10 Notwithstanding the above, the frame, sleeve, and blades to be stainless steel where damper is installed in a duct system that is stainless steel.
- .2 Operator - fusible link:
 - .1 Torsion spring, with 74°C (165°F) fusible link unless otherwise shown.
- .3 Operator – electric damper actuator:
 - .1 Factory installed electric damper actuator in accordance with article on Damper Actuators as required
 - (a) by certification listing for large dampers/damper bank applications, or
 - (b) where otherwise shown.
 - .2 Electric resettable heat detection switches, Normally Closed contacts opening on temperature rise above setpoint;
 - (a) setpoint temperature, reopenable damper:
 - i) primary switch: 74°C (165°F),
 - ii) secondary switch: 176°C (350°F).

2.4

2.5 Damper Actuators - Electric

- .1 Actuators listed as part of the smoke and/or fire damper assembly.
- .2 Actuators, components, wiring leads and position switches rated for 176°C (350°F).
- .3 Two-position dampers:
 - .1 Spring return, fail-safe to a closed damper position.
 - .2 Open-Closed operation, with reduced motor load at holding (open) position, allowing continuous operation at open position without overheating or overload.
 - .3 Visual position indicator.
 - .4 Motor running time (to open): maximum 30 seconds.
 - .5 Spring running time (to close): maximum 30 seconds.
 - .6 Maximum power demand (motor driving): 40 VA.
 - .7 Power supply: 120 VAC, 60 Hz.
- .4 Damper position switches:
 - .1 Provided as part of each actuator.
 - (a) Exception: where more than one actuator is mounted to the same damper shaft for torque rating requirements, only one actuator connected to a damper shaft is required to have the damper position switch.
 - .2 Required for both two-position dampers and modulating dampers.
 - .3 Integral or factory installed damper position switches;
 - (a) 2 x SPST switches, 3 A resistive rating @ 120 VAC,
 - (b) prove damper open,
 - (c) prove damper closed.

2.6 Local Damper Test Control Panel (Type "SD-1")

- .1 Construction:
 - .1 Damper manufacturer accessory product.
 - .2 Listed to CSA C22.2 No. 14, or conforms to applicable provincial electrical safety code for field approval or inspection.
 - .3 Momentary-action, normally closed switch (pushbutton or key operated), to spring return to damper Open position.
 - .4 Two damper proof-of-position indicating lights – Open and Closed.
 - .5 Enclosure: NEMA 1 (minimum) or galvanized steel face-plate for mounting on standard galvanized steel 100 x 100 mm electrical junction box.
 - .6 Suitable for field installation at or near the damper.
 - .7 Fuse holder and overcurrent protection fuse sized to suit damper actuator power requirements.
 - .8 Power supply: 120 VAC.

2.7 Identification Labels

- .1 For field application to control panels.
- .2 Thermal transfer printing, 300 dpi, black lettering on white background,
- .3 Label text font height: minimum 36 point
- .4 Self-adhesive polyester tape.

Standard of Acceptance

- Brady

3 EXECUTION

3.1 Installation – General Requirements

- .1 Install fire dampers and fire stop flaps throughout supply, return and exhaust air systems in fire separations marked as having a fire resistance rating and as shown.
- .2 Install smoke dampers and combination smoke/fire dampers at locations as shown and as follows:
 - .1 install smoke dampers and combination smoke/fire dampers for an air-transfer opening in the plane of the fire separation,
 - .2 install duct-mounted smoke dampers and combination smoke/fire dampers:
 - (a) in the plane of the fire separation, or
 - (b) within 610 mm (24 in.) of the plane of the fire separation, provided there are no inlet or outlet grilles or diffusers between the damper and the fire separation. The distance is measured from the centerline of the damper to the closest face of the fire separation.
- .3 Install fire, smoke, and combination smoke/fire dampers in accordance with manufacturer's instructions, with sleeve, duct connections and angle supports to comply with terms and conditions of listing or classification and maintain integrity of fire wall and/or fire separation.
- .4 Install stainless steel dampers in stainless steel duct systems and/or wherever ductwork is specified to be watertight construction.

3.2 Fire Damper Selection

- .1 Select fire damper types as follows:
 - .1 "Dynamic" - all locations unless otherwise shown,
 - .2 "Static" - restricted to un-ducted transfer air openings.
- .2 Select curtain-type fire damper styles as follows:
 - .1 For dynamic and static dampers:
 - (a) duct height in the following tables is the duct dimension perpendicular to blade length orientation.

Damper Velocity Class	Duct Height mm	Curtain Damper Style
Standard Performance (≤ 10 m/s)	> 300	A
	≤ 300	B
Extended Performance (10 to ≤ 12.5 m/s)	> 200	B
	≤ 200	C

Damper Velocity Class	Duct Height mm	Curtain Damper Style
High Velocity Performance (> 12.5 m/s)	Any	C

Damper Velocity Class	Duct Height In.	Curtain Damper Style
Standard Performance (≤ 2000 fpm)	> 12	A
	≤ 12	B
Extended Performance (2000 to ≤ 2500 fpm)	> 8	B
	≤ 8	C
High Velocity Performance (> 4000 fpm)	Any	C

3.3 Fire Damper Installation

- .1 Where the duct size exceeds the maximum listing size of a multiple curtain damper assembly, provide multiblade fire dampers.
- .2 Where fire dampers are shown to be motorized, provide multiblade fire damper with electric operator.

3.4 Damper Sleeves

- .1 Provide factory-made damper sleeves in accordance with damper listing requirements, and as described herein.
- .2 For multiblade dampers, smoke dampers, and combination smoke/fire dampers, fabricate sleeve style based on damper size listing requirements.
- .3 Install damper sleeves with retaining angles in accordance with the damper manufacturer instructions.
- .4 Where a diffuser or grille is shown at a fire damper, smoke damper or combination smoke/fire damper, provide sleeves specifically listed for single sided retention angles and which provide brackets for securing of the grille or diffuser to the sleeve.
- .5 Where permitted by the damper manufacturer installation instructions, smoke dampers may be fastened directly to the duct without requiring the use of a sleeve.

3.5 Damper Access Doors

- .1 Provide duct access door at each fire damper to permit visual inspection and replacement of fusible link. Do not locate access doors in a vertical service space (shaft).
- .2 Provide duct access door at each smoke damper and combination smoke/fire damper, to permit visual inspection and service of fire detection/actuation mechanism. Provide such access doors even where dampers are provided with electrically supervised damper position indication.
- .3 For curtain-type fire dampers in vertical ducts, the preferred access location is from the floor above the damper.
- .4 For motorized fire dampers, smoke dampers and combination smoke/fire dampers installed in vertical ducts, position the damper actuator assembly so that it is not located in a vertical service space (shaft). Preferred position in order of priority and applicability are:
 - .1 above floor level in a service room,

- .2 in the ceiling space below the bottom of a vertical service space.
- .5 Install damper actuator assemblies on the room side of a damper isolating the room from a corridor, except where the duct ends at a wall grill.

3.6 Damper Power Supplies; Controlled Dampers

- .1 This article applies to smoke dampers and combination smoke/fire dampers. This article also applies to motorized fire dampers identified on drawings as ("MFD") which are required to be used as control dampers otherwise.
- .2 Power supply to these damper actuators is provided by Division 26.

3.7 Local Damper Test Control Panel Installation (Type "SD-1")

- .1 Unless otherwise shown, install damper test control panel (Type "SD-1") in close proximity of the applicable damper, and mounted as follows:
 - .1 [on the wall immediately above an accessible ceiling][behind a wall-access panel located just below the ceiling.][behind a lockable wall access panel located at 1500 mm (5 ft) above the floor], or
 - .2 wall mounted in a janitors closet or service room, located with LDTCP centerline at 1500 mm above the floor level.
- .2 Mounting the damper test control panel at the smoke damper is not permitted, except when authorized on a case-by-case basis by the Engineer.
- .3 Provide an identification label on each test switch, identifying the smoke damper, motorized fire damper or combination smoke/fire damper by the duct service (supply, return, exhaust) and room or space served.

3.8 Identification

- .1 Provide an identification label on each damper interface control panel, identifying the damper(s) by the duct service (supply, return, exhaust fan number) and room or space served. Coordinate with the supplier of any damper interface control panel to provide matching labeling.

3.9 Testing

- .1 Conduct installation tests of all fire dampers, smoke dampers, and combination smoke/fire dampers in accordance with NFPA 80, NFPA 90A and NFPA 105 as applicable to damper type and summarized as follows.
- .2 Field test all fire dampers, smoke dampers, combination smoke/fire dampers and fire stop flaps as follows:
 - .1 operate dampers to demonstrate unobstructed operation of the damper from open-to-close-to open state. These tests are to be performed while the fan systems are not in operation (static test),
 - .2 for dynamic dampers, confirm air velocity through the open dampers under normal HVAC system operation, once air balancing is completed. Select dampers to confirm operation for ducts operating within 80% of the maximum air velocity of the damper listing,
 - .3 confirm accessibility to components of fire damper to permit maintenance and testing,
 - .4 where a damper is provided with an indicating device, confirm device functions and annunciates to the supervised location or system when the damper is in both the open and closed state, as applicable.
- .3 In addition, for multiblade fire dampers with electric operators, smoke dampers or combination smoke/fire dampers, cycle test dampers under normal HVAC operating conditions (dynamic test).

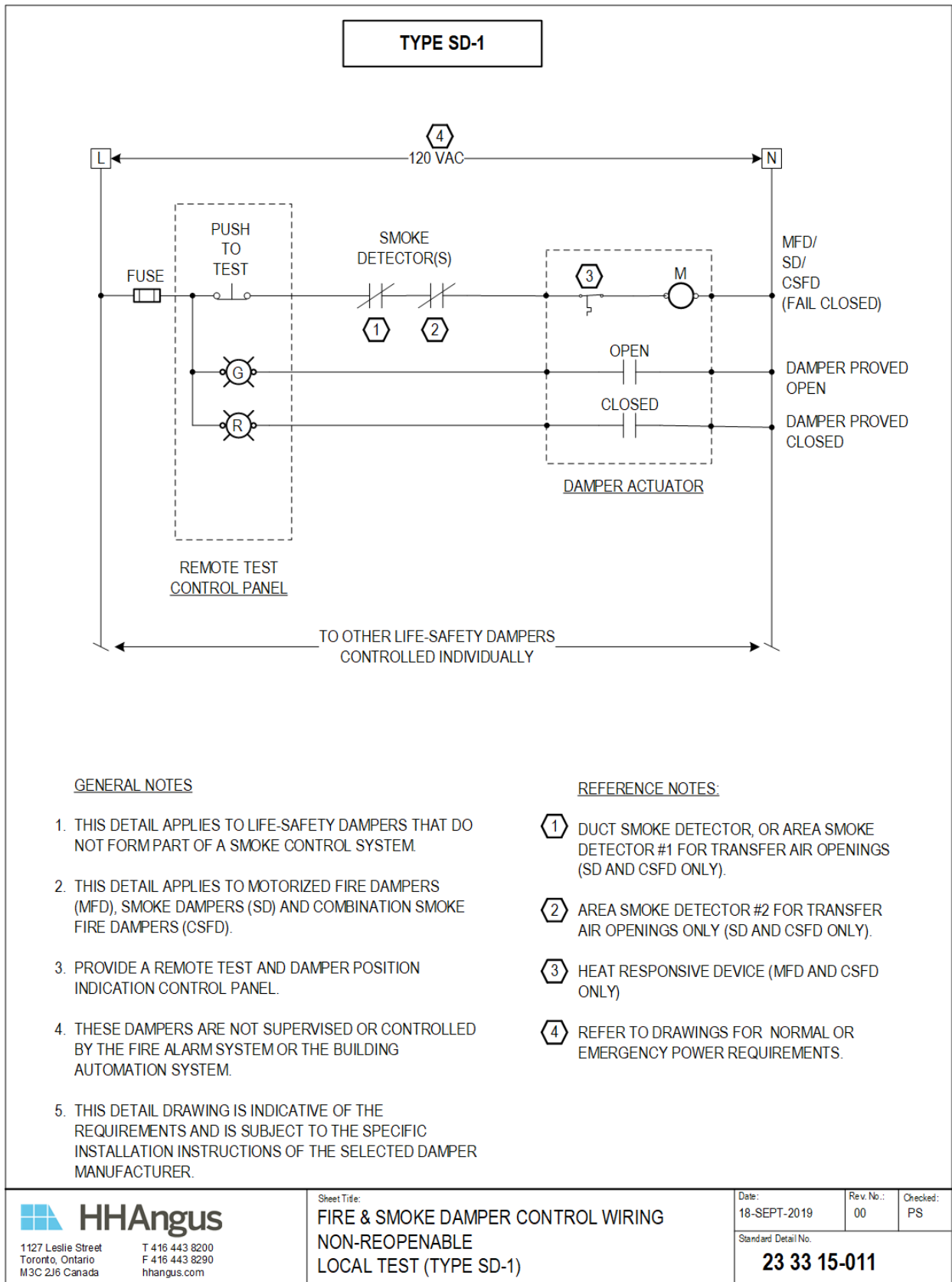
- .4 Record test results as per the attached test form or similar containing the same information, and submit to Owner and Consultant as part of the Operations and Maintenance manual.
- .5 Upon completion of testing, provide labour and resources necessary to conduct a demonstration re-test for up to 10% of curtain-type dampers on each floor as selected and witnessed by Engineer.
- .6 Upon completion of testing, provide labour and resources necessary to conduct a demonstration re-test of 100% of all motorized fire dampers, smoke dampers and combination smoke/fire dampers. This test may be combined as part of the demonstration test of a smoke control system or a smoke exhaust system used to air fire fighters.

3.10 Standard Details

- .1 Refer to the following standard detail for wiring of dampers with type SD-1 local test control panel.
23 33 15-011 Fire & Smoke Damper Control Wiring / Non-Reopenable / With Local Test
(Type SD-1)

3.11 Test Form

- .1 Test form follows at the end of this section.



Fire, Smoke, and Fire/Smoke Damper Test Record

Project							System		
Testing Company							Technician Name		
Damper location	Inspection Date YYYY-MM-DD	Damper Type ⁽¹⁾	Static Op. Test ⁽²⁾	Dyn Op. Test ⁽³⁾	Access Test ⁽⁴⁾	Air Flow ⁽⁵⁾	Confirmed/ Deficiencies	Deficiency Corrected	Damper Audited

(1) Damper Type : FD, MFD, SD, or CSFD
(2) Static Operating Test without airflow
(3) Dynamic Operating Test with balanced airflow; multiblade FD, SD and CSFD only.
(4) Damper and components are accessible for inspection and testing
(5) Identify which damper air velocity is checked in accordance with the test selection criteria.

END OF SECTION

Master revised: 14 December 2022

LOUVRES

23 33 63

1 GENERAL

1.1 Scope

- .1 Provide louvres as shown.

1.2 Submittals

- .1 Submit manufacturer's data sheets for wall louvres with model numbers, design data, support and anchor details and outline dimensions.

2 PRODUCTS

2.1 Louvres

- .1 Performance:
 - .1 free area not less than 40% of nominal size,
- .2 Construction:
 - .1 material: extruded aluminum alloy 6063-T5,
 - .2 exposed joints ground flush and smooth,
 - .3 storm proof pattern blade with centre watershed, reinforcing bosses and maximum blade length of 1500 mm (60 in),
 - .4 frame, head, sill and jamb: 150 mm (6 in) deep one piece extrusions, minimum 3 mm (1/8 in) thick with integral caulking slot,
 - .5 mullions: at 1500 mm (60 in) maximum centres.
 - .6 fasteners: stainless steel to (Society of Automotive Engineers) SAE-194-AF with SAE-194-SFB nuts and resilient neoprene washers between aluminum and head of bolt or between nut, stainless steel washer and aluminum body,
 - .7 screen:
 - (a) 2 mm (14 ga) wire in formed U-frame,
 - (b) exhaust louvres: 12 mm (1/2 in) mesh,
 - (c) intake louvres: 25 mm (1 in) mesh.
 - .8 finish: clear anodized satin.

Standard of Acceptance

- Construction Specialties - Model 6110
- Airolite - CB638
- Alumavent - AL-445-5
- Carnes -
- K.N. Crowder - Canadian Louvres 411S
- Leo Lisi - Series 445]

3 EXECUTION

3.1 Installation

- .1 Confirm opening size and co-ordinate location of louvres with other Trades.

- .2 Where blank-off openings at back of louvre are oversized, install 1.2 mm (18 ga) reinforced galvanized sheet steel blank-offs, sealed with fire resistant mastic between galvanized steel and aluminum.

END OF SECTION

HVAC POWER VENTILATORS

23 34 23

1 GENERAL

1.1 Scope

- .1 Provide powered ventilation fans as shown, including:
 - .1 roof and wall mounted exhaust fans,
 - .2 propeller fans,
 - .3 roof curbs and acoustic roof curbs.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 01 Basic Materials and Methods
 - .2 20 05 13 Common Motor Requirements for Mechanical Equipment.
 - .3 20 05 49 Seismic Restraint

1.3 Applicable Codes and Standards

- .1 Product standards:
 - .1 AMCA 204 Balance Quality and Vibration Levels for Fans
 - .2 AMCA 210 Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating
 - .3 AMCA 211 Certified Ratings Program – Product Rating Manual for Fan Air Performance
 - .4 AMCA 300 Reverberant Room Method for Sound Testing of Fans,
 - .5 AMCA 311 Certified Ratings Program – Product Rating Manual for Fan Sound Performance
 - .6 AMCA 320 Laboratory Methods of Sound Testing Fans Using Sound Intensity
 - .7 ASME B117 Standard Practice for Operating Salt Spray (Fog) Apparatus
 - .8 CSA C22.2 No. 113 Fans and Ventilators

1.4 Seismic Qualification

- .1 Seismically qualify (certify) fans (excluding motors) used for smoke control or smoke venting, including dedicated and non-dedicated fans used for this purpose, to remain operational after being subjected to the design seismic forces assuming a building height factor (NBCC) $A_x = 3.0$ with equipment flexibly mounted, by the shaker table method in accordance with Specification section 20 05 49.

1.5 Submittals

- .1 Shop drawings:
 - .1 submit product data sheets for materials specified herein.
 - .2 provide equipment model numbers, performance and design data, outline dimensions, power requirements, prefabricated curb details, support and connection details and unit weights.

1.6 Quality Control

- .1 Fan performance for airflow rate, fan pressure, fan power, air density, fan RPM and fan efficiency: certified and bear the AMCA seal to AMCA Publication 211 when tested in accordance with AMCA Standards 210.
- .2 Fan acoustic performance: certified and bear the AMCA seal to AMCA Publication 311 when tested in accordance with AMCA Standard 300 or AMCA Standards 320.
- .3 Fan vibration: fans balanced in accordance with AMCA Standard 204.

2 PRODUCTS

2.1 General

- .1 Roof and wall fans, propeller fans, sound curbs and air intake cowls to be products from current catalogue of one manufacturer.

Standard of Acceptance

- Penn Ventilator
 - Greenheck
 - Carnes
 - Loren Cook
 - Irving Fan & Ventilator
- .2 Fans listed to CSA C22.2 No. 113.
 - .3 Coatings to meet 1000 hour salt exposure test to ASTM B117, unless otherwise shown.
 - .4 Fan/motor drives and guards:
 - .1 pulleys and drive belts to conform to Section 20 05 01,
 - .2 guards for fan/motor belt-drive and couplings, to conform to Section 20 05 01,
 - .3 guards for fan inlet openings to conform to Section 20 05 01.
 - .5 Fan motors:
 - .1 motors to conform to Section 20 05 13,
 - .2 minimum motor power rating: not less than motor kW (horsepower) shown in equipment schedules.
 - .3 motor slide rails to conform to Section 20 05 01,

2.2 Roof and Wall Fans

- .1 Construction:
 - .1 drive type: belt drive
 - .2 discharge orientation: as shown on equipment schedules,
 - .3 fan wheel: aluminum construction, centrifugal backward-inclined wheel, statically and dynamically balanced,
 - .4 housing: minimum 1.3 mm (16 ga) spun aluminum housing, with removable top cap for access to the motor,
 - .5 wheels finished with a baked polyester or epoxy powder coating.
 - .6 motor and adjustable motor slide base,

- .7 curb cap: continuously welded [[insulated]aluminum curb or wall cap, continuous curb gasket and stainless steel fastenings,
- .8 lubricated ball bearing shaft and motor mounted in compartment isolated from air stream, with ABMA L₁₀ bearing service life of 40,000 hours.
- .9 motor feeder conduit mounted internal to the housing and curb cap,
- .10 adjustable pitch bel-drive (where available) with automatic spring loaded belt tensioner,
- .11 vibration isolation between static and rotating components,
- .2 Accessories:
 - .1 motor disconnect switch mounted in motor compartment,
 - .2 bird screen,
 - .3 dampers: Motorized inlet damper provided under Controls and Instrumentation Section.

2.3 Propeller Fans

- .1 Construction:
 - .1 belt-driven or direct drive, bolted and welded construction,
 - .2 fabricated multi-bladed steel propellers positioned in bell mouth entrance,
 - .3 fabricated steel support frame, with motor and blade guard on exposed side,
 - .4 finish: baked polyester or epoxy powder coating,
 - .5 mounted with grease lubricated ball bearings suited for operation in any position, with ABMA L₁₀ bearing service life of 40,000 hours.
 - .6 motor and adjustable motor slide base,
- .2 Accessories:
 - .1 OSHA safety guard for motor, drive-set and fan blades,
 - .2 dampers: Motorized inlet damper provided under Controls and Instrumentation Section.

2.4 Roof Curbs

- .1 Curbs designed for seismic restraint of the curb and associated fan, in accordance with seismic loads defined in Section 20 05 49
- .2 Construction:
 - .1 supplied to match roof fan curb-cap dimensions,
 - .2 curb frame: minimum 1.27 mm (18 ga) thick galvanized steel curb, continuously welded corners, with integral roofing cant angles,
 - .3 flashing flange: minimum 50 mm (2 in),
 - .4 base angle: supplied for flat roofs, or pitched roofs as applicable to actual roof slope,
 - .5 curb insulation: minimum 38 mm (1-1/2 in) thick, 48 kg/m³ (3 lb/ft³) thermal/acoustic, with internal galvanized steel liner to separate insulation from the air stream,
 - .6 wood nailing strip, minimum 38 mm (1-1/2 in) high,
 - .7 minimum curb height: [225 mm (9 in)][500 mm (20 in)]
 - .8 finish: baked polyester or epoxy powder coating, with UV stabilizer top coat.
- .3 Accessories:

- .1 integral damper tray.

2.5 Acoustic Roof Curbs

.1 Construction:

- .1 as specified above for "Roof Curbs", except as follows,
- .2 curb insulation: minimum 25 mm (1 in) thick, 48 kg/m³ (3 lb/ft³) acoustic insulation, with internal perforated aluminium liner to protect the insulation.
- .3 acoustic streamlined baffles in the airstream, with acoustic insulation and perforated aluminum liners,
- .4 pressure loss at rated air flow of not more than 37 Pa (0.15 in wg).

.2 Acoustic performance:

- .1 constructed and selected to meet sound attenuation spectrum as follows;

Octave band	1st	2nd	3rd	4th	5th	6th	7th	8th
Attenuation in dB	3	5	11	16	22	20	17	13

2.6 Air Intake Cowls

.1 Construction:

- .1 supplied to match roof and/or wall exhauster silhouette and base dimensions,
- .2 pressure loss at rated air flow of not more than 37 Pa (0.15 in wg),
- .3 bird screen and Motorized inlet damper provided under Controls and Instrumentation Section.

3 EXECUTION

3.1 Installation

.1 Install fans, curbs and inlet cowls in accordance with manufacturer instructions and as follows:

- .1 set the curb in roofing cement, and mechanically secure to the roof structure with mechanical fasteners of the type, capacity and quantity as determined by the equipment manufacturer installation instructions.
- .2 provide, or coordinate with roofing contractor to provide, roof flashing to cover curb roof flange and to extend up and over the curb nailing strip,
- .3 if the roof flashing does not extend over the top of the curb, provide a counterflashing that covers the top of the curve and extends down and overlaps the roof flashing by at least 50 mm (2 in),
- .4 provide a sealer gasket between the fan curb-cap and the curb,
- .5 where the horizontal gap between the fan curb-cap and the curb is greater than 20 mm (3/4 in), fill the gap with wood filler strips,
- .6 secure the fan to the curb with mechanical fasteners of the type, capacity and quantity as determined by the equipment manufacturer installation instructions.

.2 Interlock motorized dampers with fan operation, to open with fan ON, closed with fan OFF.

3.2 Startup and Testing

- .1 Check direction of fan rotation and adjust variable pitch drives during balancing.

END OF SECTION

PARTICULATE AIR FILTERS

23 41 11

1 GENERAL

1.1 Scope

- .1 Provide particulate filters as shown, including:
 - .1 particulate air filters,
 - .2 filter holding frames,
 - .3 side-access filter housing,
 - .4 filter gauges.

1.2 Definitions

- .1 Abbreviations
 - .1 **MERV**: minimum efficiency reporting value in accordance with ASHRAE 52.2
 - .2 **HEPA**: High Efficiency Particulate Air
 - .3 **ULPA**: Ultra Low Particulate Air

1.3 Applicable Codes and Standards

- .1 Product standards:
 - .1 ASHRAE 52.2 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.
 - .2 CAN/ULC-S111 Standard Method of Fire Tests for Air Filter Units.
 - .3 IEST-RC-CC001 HEPA and ULP Filters
 - .4 IEST-RC-CC021 Testing HEPA and ULPA Filter Media
 - .5 IEST-RC-CC034 HEPA and ULPA Filter Leak Tests

1.4 Submittals

- .1 Submit manufacturer's catalogue literature for filters showing:
 - .1 pressure drop vs air flow rate,
 - .2 filter efficiency rating,
 - .3 media area in each cell,
 - .4 filter dimensions,
 - .5 maximum recommended pressure drop at filter change,
 - .6 product test report including all details as prescribed in ASHRAE 52.2,
 - .7 product test report confirming filters are rated as MERV-A when tested in accordance with Appendix J of ASHRAE 52.2, at the same specified MERV rating value.
- .2 In addition, for HEPA and ULPA filters, submit test certification reports.

2 PRODUCTS

2.1 General Requirements

- .1 Filter efficiency performance (except HEPA and ULPA filters): certified to conform to ASHRAE 52.2 for MERV ratings and with equal MERV-A ratings as tested in accordance with Appendix J of ASHRAE 52.2.
- .2 Filters listed as a Class 2 product to CAN/ULC-S111.
- .3 Filters to be suitable for continuous exposure to air at the following conditions as applicable:

Filter Position	Minimum Air Temperature °C (°F)	Relative Humidity %RH
Before first heating coil	-25 (-13)	90%
After cooling coil	+3°C (37°F)	100%
All other locations	+3°C to 50°C (37°F to 122°F)	10% to 95%

- .1 maximum air temperature: 50°C (122°F).
- .4 Filter sizes: as shown on equipment schedules or as specified in specification sections for air handling equipment.

Standard of Acceptance

- AAF
 - Camfil
 - Airgaord (Parker)
- .5 [Where filter manufacturer and models are listed herein, they represent those filters that meet the minimum specification requirements but which might not have MERV-A ratings. Where both MERV and MERV-A ratings are required, the contractor or vendor shall select products that are certified to equal MERV/MERV-A ratings.

2.2 MERV 8 – Panel Filter

- .1 Performance:
 - .1 filter style: Panel, disposable
 - .2 capacity: 945 L/s at 2.5 m/s (2000 CFM at 492 fpm) @ 600 x 600 mm (24 x 24 in) filter size; prorated for other sizes.
 - .3 filter depth: 100 mm (4 inch) , nominal
 - .4 efficiency: MERV 8 at 2.5 m/s (492 fpm)
 - .5 initial air resistance: 75 Pa (0.30 in.w.c.), maximum
 - .6 final air resistance: 250 Pa (1 in.w.c.), minimum at change out
- .2 Construction:
 - .1 media; synthetic
 - .2 frame: fibre board with moisture inhibitors
 - .3 face gasket: none.

Standard of Acceptance

- Camfil - Farr 30/30 or Aeropleat III
- AAF - fig. VP-MERV8 SC

2.3 Filter Holding Frames

.1 Construction:

- .1 modular framing system,
- .2 minimum 1.27 mm (18 ga) thick galvanized steel with 20 mm (3/4 in) wide filter sealing flange, pre-drilled for frame-frame fastener attachments,
- .3 replaceable Neoprene gasket on frame face for filters not provided with integral gaskets,
- .4 gasketing between adjacent frames and between frames and plenum walls,
- .5 high-tensile spring clips filter-fasteners.

Standard of Acceptance

- AAF - fig. PF-1 Pureframe, Universal Holding Frames and Latches
- Camfil - fig. FastFrame (upstream filter loading)
- Camfil - fig. Type 8 Frame (downstream filter loading)

2.4 Side Access Housings

.1 Construction:

- .1 1.6 mm (16 ga) galvanized steel frame with Z-channel support members, with inlet and outlet mounting flanges for connection to ductwork or plenums,
- .2 filter tracks: aluminium, with lever locking to full face of frame,
- .3 doors: galvanized steel door, continuous or two point hinges, locking knobs, sealed with full perimeter neoprene gaskets, and seals the filter side facing the door,
- .4 tracks and doors fully gasketed,
- .5 50 mm (2 in) thick, double wall, insulated construction,
- .6 capable of holding pre-filter and final filters, or separate racks for each filter bank,
- .7 filter depth:
 - (a) 50 mm to 100 mm (2 to 4 in) for panel filters,
 - (b) 150 mm to 915 mm (6 to 26 in) for all filters

Standard of Acceptance

- AAF - fig. SureSeal (two-stage), SurePlea (panel filters)

2.5 Air Filter Gauges

.1 Pneumatic magnehelic gauge:

- .1 cast aluminium housing, with acrylic cover, 100 mm (4 in) diameter dial face,
- .2 connections: NPS 1/8 NPT,
- .3 dual scale Pa, and inch water column,
- .4 0-250 Pa (0-1 in wg) range for panel filters,
- .5 0-750 Pa (0-3 in wg) range for other filter banks,

- .6 installation kit with static pressure tips and isolation valves.

Standard of Acceptance

- ° Dwyer - fig. 2001D, 2003D

3 EXECUTION

3.1 Filter Banks

- .1 Install in plenums, ducts, and air intakes in filter racks or filter housings as shown, where not provided as an integral part of an air handling unit.
- .2 Made up using one size of cell throughout. Mixed cells are not permitted.

3.2 Filter Gauges

- .1 Provide filter gauges at the following filter banks:
 - .1 each bank of filters over 1900 l/s (4000 cfm) capacity, and
 - .2 for each bank of HEPA and ULPA filters regardless of capacity.
- .2 Provide separate gauges for each filter bank.
- .3 Install and pipe static pressure tips and isolating valves to allow calibration of pressure gauges.

3.3 Filter Protection and Replacement

- .1 Provide temporary roughing filters ahead of filter banks during initial operation of air handling systems.
- .2 When building is turned over to the Owner;
 - .1 remove temporary filters and ensure that filter banks are fitted with full sets of filters.
 - .2 install new, full sets of filters for any air filter banks used during construction and loaded to more than 125% of initial clean pressure drop.

3.4 Inspection and Testing

- .1 Immediately prior to hand-over to the Owner,
 - .1 visually inspect the filters and filter frames to ensure there are no visible gaps in frame gaskets and blanking plates, that filters are set square and level in their frames, and retention clips are in place.
 - .2 with the air handling system operating at normal conditions, check and record the pressure drop across each filter bank, and submit a test report with the date of the test to the Owner and include in the operations and maintenance data.

END OF SECTION

INSULATED SECTIONAL CHIMNEYS 23 51 33

1 GENERAL

1.1 Scope

- .1 Provide chimneys and chimney connectors as shown for;
 - .1 heating oil fired appliances,
 - .2 natural gas fired appliances,
 - .3 dual-fuel gas/oil appliances.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 49 Seismic Restraint

1.3 Definitions

- .1 In this section the following definitions apply:
 - .1 **Chimney**: a vertical conduit conveying flue gases to the outside atmosphere,
 - .2 **Chimney connector**: has the meaning as defined in CSA B139
 - .3 **Gas**: means natural gas or propane gas.
 - .4 **Low heat appliances**: appliances with a flue gas outlet temperature of 540°C (1000°F) or less.
 - .5 **Vent**: (as it applies to a vent flue) has the meaning as defined in CSA B139 and CSA B149.1
 - .6 **Vent connector**: (as it applies to a vent flue) has the meaning as defined in CSA B139 and CSA B149.1

1.4 Applicable Codes and Standards

- .1 Installation standards and codes:
 - .1 CSA B139 Installation Code for Oil Burning Code, as amended by adopting legislation.
 - .2 CSA B149.1 Natural Gas and Propane Installation Code, as amended by adopting legislation.
- .2 Product standards:
 - .1 CAN/ULC-S604 Standard for Factory-Built Type A Chimneys
 - .2 CAN/ULC-S609 Standard for Low Temperature Vents Type L
 - .3 CAN/ULC-S629 Standard for 650°C Factory-Built Chimneys
 - .4 ULC/ORD-C378 Guide for the Investigation of Draft Equipment
 - .5 ULC/ORD-C959 540°C and 760°C Industrial Chimneys

1.5 Design Criteria

- .1 Chimney systems to be self-supporting without guy wires unless otherwise shown.
- .2 Design external chimneys to withstand wind loading in accordance with the applicable building code at the place of the Work.

- .3 Chimney systems to be seismically designed to restrain equipment when subjected to the seismic forces as determined in accordance with specification section 20 05 49.

1.6 Seismic Qualification

- .1 Seismically qualify (certify) equipment specified herein to remain operational after being subjected to the design seismic forces assuming a building height factor (NBCC) $A_x = 3.0$ with equipment rigidly mounted, by the shaker table method in accordance with Specification section 20 05 49.

1.7 Manufacturer Design Services

- .1 Manufacturer to provide engineering services for design of chimney and chimney connectors based on appliance layout and general routing of chimney and chimney connectors as shown. Include:
 - .1 layout and sizing drawings,
 - .2 bill of materials,
 - .3 thermal analysis including theoretical draft and available draft,
 - .4 wind loading restraint, seismic restraint, and structural support details.

1.8 Submittals

- .1 Submit shop drawing data sheets for manufactured products and standard fittings showing dimensions and describing construction.
- .2 Submit engineering shop drawings including layout and installation details.

2 PRODUCTS

2.1 General Requirements

- .1 Chimneys and chimney connectors to be manufacturer's catalogued products.
- .2 Chimney and chimney connector systems to include sectional pipe lengths, fittings and couplings, clean-outs, drain fittings, roof flashings, storm collars, Belmont top, roof and wall supports, roof and wall ventilated thimbles, guy sections, firestop spacers, and all other required mounting and installation accessories.

2.2 Industrial Chimneys

- .1 Application:
 - .1 industrial process gas-fire and/or oil fired equipment,
 - .2 gas or diesel stationary engine-driven equipment,
 - .3 gas or jet-fuel turbines.
- .2 General:
 - .1 listed to ULC/ORD-C959,
 - .2 maximum flue gas temperature: 750°C (1400°F) continuous,
 - .3 vent pressure: negative, neutral or positive pressure,
 - .4 fuels: gas, heating oil, diesel fuel, ATF jet fuel,
 - .5 size: Ø150 mm to Ø1200 mm (6 to 48 in. dia.) liner ID.,
 - .6 clearance to combustibles: 50 mm to 100 mm (2 in - 4 in) maximum depending on chimney size.
- .3 Construction:
 - .1 double wall construction for chimney and chimney connectors;

- (a) flue liner: T316 stainless steel,
- (b) outer casing: T316 stainless steel,
- (c) annular space insulation: mineral wool or ceramic fibre.
- (d) annular minimum insulation thickness: 25, 50 and 100 mm (1, 2 and 4 in.) as specified under Part 3 – EXECUTION.
- .2 joints: veebands and sealant for liner flanges and draw band for shell flanges, or proprietary band joints, as per listing requirements.
- .3 joint sealant: manufacturer's product suitable for the flue gas temperature specified herein,
- .4 Special fittings:
 - .1 expansion joints:
 - (a) low-spring rate expansion bellows,
 - (b) with internal flow liner,
 - (c) with outer shell cover,
 - (d) suitable for installation in the vertical or horizontal position.
 - .2 overpressure relief valves:
 - (a) spring-loaded and guided overpressure relief disc,
 - (b) bolting flange, with gaskets, bolts, nuts and washers to fastening to matching flange on chimney pipe.

Standard of Acceptance

- Selkirk – fig. IPSC1, IPSC2, IPSC4
- Van-Packer – fig. DWPlus
- Metal-Fab – fig. IPIC
- Schebler – fig. P1, P2, P4

2.3 Barometric Draft Control for Non-Draft Hood Applications

- .1 Construction:
 - .1 listed to ULC/ORD-C378.
 - .2 single acting, for natural gas,
 - .3 dual acting for natural gas and oil fired applications,
 - .4 80% of full size of breeching area,
 - .5 fabricated from 3.5 mm [10 ga.] steel.

Standard of Acceptance

- Wing DA and SA
- Field M and MG2

3 EXECUTION

3.1 General

- .1 Chimneys and chimney connectors serving gaseous fuel and liquid fuel appliances to be installed by tradesmen certified for installation of fuel fired appliances.
- .2 Select chimney type base on flue gas temperature and required chimney size in accordance with the following table:

Type of Appliances	Maximum Flue Gas Temperature Limit	Appliance Flue Outlet Size or Manifolded Chimney Connector Size ⁽¹⁾	Chimney Type	Annular Insulation Thickness
Building Heating appliances	$\leq 300^{\circ}\text{C}$ (570°F)	≤ 200 mm (8 in)	L Vent	As specified
		>200 mm (8 in)	Building Heating Appliance Chimney	As specified
	$\leq 540^{\circ}\text{C}$ (1000°F)	All sizes	Building Heating Appliance Chimney	As specified
Process appliances	$\leq 250^{\circ}\text{C}$ (480°F)	All sizes	Industrial Chimney	25 mm (1 in.)
	$\leq 300^{\circ}\text{C}$ (570°F)	All sizes	Industrial Chimney	50 mm (1 in.)
	$\leq 600^{\circ}\text{C}$ (1100°F)	All sizes	Industrial Chimney	100 mm (4 in.)
Stationary Engines ⁽²⁾	$\leq 750^{\circ}\text{C}$ (1400°F)	All sizes	Industrial Chimney	100 mm (4 in.)
Turbines	$\leq 750^{\circ}\text{C}$ (1400°F)	All sizes	Industrial Chimney	100 mm (4 in.)

Notes:

- .1 *Whichever is greater.*
- .2 *Includes but not limited to diesel-generators, fire pumps, compressors, etc.*

3.2 Installation – General Requirements

- .1 Install chimney system in accordance with chimney manufacturer and appliance manufacturer installation requirements.
- .2 Maintain clearance between chimney connectors and combustible materials or building insulation in accordance with product installation instructions.
- .3 Position chimneys inside of enclosures to maintain minimum clearances to:
 - .1 combustible material in accordance with chimney listing requirements, and
 - .2 non-combustible materials as follows:
 - (a) 50 mm (2 in) for chimney OD size less than or equal to 450 mm (18 in)
 - (b) 100 mm (4 in) for chimney OD size larger than 450 mm (18 in).
- .4 Support chimneys at roof penetrations and provide roof flashing and counter-flashing.
- .5 Provide anchors, guides and expansion joints as required to maintain chimney system true-in-line both during operation and not in operation, and to control forces imposed on associated appliances and the building structure.
- .6 Erect chimneys true and plumb to within 1 in 1200.
- .7 For multiple appliances, manifold the chimney connectors in accordance with manufacturer installation requirements.
- .8 Where an offset is required, make offset with 45° elbow fittings whenever possible.

- .9 Provide clean-outs at base of chimney and provide access to clean-outs.
- .10 Seal double wall pressure stacks and breechings:
 - .1 seal inner joints bead of high temperature sealant,
 - .2 fill channel of vee band with high temperature sealant and install and tension vee-band,
 - .3 install insulation filler strips in air space between inner and outer walls, and secure outer shell with draw band,
 - .4 caulk upper edge of drawbands exposed to the weather with silicone sealant.
- .11 Make connector connection to equipment, flue gas outlet with slip type joints and mechanically fasten with a minimum of three (3) screw fasteners.
- .12 Where chimney passes through combustible floor or wall construction, provide fire-stop fitting.
- .13 Where breeching system is designed to absorb thermal expansion make connection with flange adaptor.

3.3 Guy Wires

- .1 Where guy wires are permitted to be used as shown;
 - .1 provide aircraft grade stainless steel wire, turnbuckles and roof anchor points of sufficient structural capacity to withstand wind loadings and seismic movement.
- .2 Install guy wire anchor points and secure to building structure;
 - .1 for concrete roofs, fasten guy wire anchors with bolt anchors directly bolted to the concrete roofs, fastened below the roofing insulation and membrane,
 - .2 for steel-deck roofs, provide anchors with load plates sitting on top of the steel deck, with threaded rod passing through the deck and secured to supplementary steel on the underside of the roof deck. Include for supplementary steel, including connection to main roof structural steel, and all required fasteners.
 - (a) welding of guy wire anchors to supplementary steel, or supplementary steel to building structural steel, may be used where approved by the structural engineer.

3.4 Overpressure Relief Fitting Installation

- .1 Provide overpressure relief fittings on chimney systems serving engines and turbines;
 - .1 install relief fitting as close as possible to the outlet of the appliance or the outlet of any flue-gas sound attenuating equipment,
 - .2 the relief valve may be installed within the service room containing the engine or turbine, or be located outdoors,
 - (a) where located inside of the service room, position the relief valve so that it may be readily visible to allow inspection of the discharge opening.

3.5 Start-Up and Testing

- .1 Refer to applicable gas appliance specification section for appliance-specific testing requirements for the gas venting system.
- .2 Measure and record the outdoor air temperature and the draft at the appliance flue connection under the following load conditions:
 - .1 appliance maximum rated capacity, dedicated venting
 - .2 appliance maximum rated capacity with no other common vented appliances operating,
 - .3 appliance maximum rated capacity with all other common vented appliances operating to meet the load conditions at the time of the test,

- .4 appliance minimum rated capacity (modulating burners and two-stage burners), single appliance operation only.

3.6 Test and Installation Records

- .1 Refer to applicable gas appliance specification section for appliance-specific test and installation records requirements for the gas venting system.

END OF SECTION

ELECTRIC UNIT HEATERS

23 82 39.23

1 GENERAL

1.1 Scope

- .1 Provide forced-air electrically-heated terminal heating equipment as shown, for:
 - .1 wall and ceiling mounted unit heaters,
 - .2 cabinet unit heaters,
 - .3 door curtain heaters.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 12 Common Electrical Requirements for Mechanical Services
 - .2 20 05 14.13 Constant Speed Motor Controllers

1.3 Applicable Codes and Standards

- .1 Product standards:
 - .1 ANSI/AMCA 220 Laboratory Methods of Testing Air Curtains for Aerodynamic Performance Ratings.
 - .2 CSA C22.2 No. 236 Heating and Cooling Equipment

1.4 Submittals

- .1 Submit manufacturer's data sheets for unit heaters with:
 - .1 equipment model numbers,
 - .2 performance and design data,
 - .3 outline dimensions,
 - .4 power requirements,
 - .5 support and connection details,
 - .6 equipment weights.

2 PRODUCTS

2.1 General

- .1 Heating equipment capacities as shown.
- .2 Heating equipment listed to CSA C22.2 No. 236.
- .3 Performance:
 - .1 heat output as shown,
 - .2 entering air temperature: 18°C (65°F)
- .4 Manufacturers:

Standard of Acceptance

- Ouellet
- Stelpro
- Modine

2.2 Horizontal and Vertical Projection Unit Heaters

- .1 Application: wall-mounted or ceiling hung installation.
- .2 Voltage: as shown
- .3 Enclosure
 - .1 casing: minimum 1.2 mm (18 ga.) thick cold-rolled steel, with threaded connections for hanger rods or support pipes,
 - .2 die-formed venturi fan shroud,
 - .3 horizontal projection unit outlet: four-way adjustable air outlet louvres,
 - .4 vertical project unit outlet: adjustable multi-vane diffusers
 - .5 finish: epoxy/polyester powder-coated paint,
 - .6 finish colour: manufacturer's standard colour.
- .4 Heating elements:
 - .1 nickel-chromium or stainless steel tubular heating element with aluminium fins,
- .5 Fans:
 - .1 spark-proof aluminium blades with steel hub, factory balanced,
 - .2 directly connected to resiliently mounted motors,
 - .3 fan guards: finger-proof construction of welded steel rod,
- .6 Motors:
 - .1 rated for 40°C (104°F) ambient air temperature over motor,
 - .2 single phase:
 - (a) totally-enclosed, permanently lubricated bearings, three-speed, permanent split-split capacitor AC motors, with integral automatic-resetting thermal overload protection, or
 - (b) electrically-commutated DC motor with 2- 10 VDC speed control input and integral automatic-resetting thermal overload protection,
 - .3 three phase: TEFC motor.
- .7 Electrical and controls:
 - .1 single-point power supply connection,
 - .2 integral contactors for heating elements,
 - .3 integral transformer with fused protection for fan-motor power (if required based on supply voltage),
 - .4 24 V control circuit with transformer,
 - .5 motor controller with overload,
 - .6 internal high-temperature limit control with automatic reset,
 - .7 fan-On delay for units 5 kW and smaller to pre-heat coils,
 - .8 fan-Off delay to cool heating element on unit shut-down,
 - .9 single-stage heating for heaters up to 10 kW, and 2-stage heating for heating capacities greater than 10 kW,

- .10 unit mounted fan switch,
- .11 24 V wall thermostat, with number of control output contacts to suit number of heating stages in the heater,.

3 EXECUTION

3.1 General

- .1 Attach heaters to building structure with angles, hanger rods and supplementary suspension steel before installation of piping.
- .2 Except for horizontal and vertical projection heaters, conceal electrical conduit runouts to heating equipment in wall furring or, where applicable, through pedestal feet.

3.2 Horizontal Projection Unit Heaters

- .1 Install horizontal unit heaters with the direction of discharge airflow as shown.
- .2 Adjust discharge louver blades to a 45° down angle.

3.3 Motor Controllers

- .1 Where heating equipment is not provided with a factory installed motor controller, provide a motor controller in accordance with Specification section 20 05 14.13 as follows:
 - .1 single-phase motors: Type K motor controller where remote control from the Building Automation System is not required,
 - .2 single-phase motors: Type L motor controller where equipment is remotely controlled by the BAS.
 - .3 three-phase motors: Type B motor controller.
- .2 Provide unfused disconnect switches adjacent to unit heaters and door curtain heaters.
- .3 Provide locks on power-distribution panel circuit-breakers feeding cabinet heaters.

3.4 Controls

- .1 Install remote thermostats, multi-speed controllers, motor starter switches and other controls and provide interconnecting power and control wiring.
- .2 Provide control wiring between door contact switch and door heater.
- .3 Wiring to conform to Specification section 20 05 12.

3.5 Completion

- .1 Clean coils and comb fins on finned elements.
- .2 Set dampers to 100% open.
- .3 Re-finish units damaged during installation.

END OF SECTION

BUILDING AUTOMATION COMMON WORK RESULTS

25 05 01

1 GENERAL

1.1 Scope

- .1 Provide a building automation system ("BAS") for control and supervisory management of facility mechanical and electrical equipment systems.
- .2 The BAS is to be a direct digital control ("DDC") system with digital/electric instrumentation and electric operation[.] along with pneumatic operators for select control devices].
- .3 The BAS is to integrate with:
 - .1 other building services subsystems including lighting control systems, access control systems and fire alarm systems,
 - .2 facility equipment other than equipment and systems under Divisions 20 to 28.

1.2 Dependent Sections

- .1 The BAS Work is further defined in the following specification sections:

25 05 06	Work on Existing Building Automation
25 05 11	Building Automation Control Panels and Wiring
25 30 13	Building Automation Actuators and Operators
25 90 01	Building Automation Control Sequences

1.3 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the BAS system is further described in the following the work under this section directly integrates with or refers to the following specification sections:

.1 20 05 12	Common Electrical Requirements for Mechanical Services
.2 20 05 49	Seismic Restraint
.3 20 08 11	Testing of Mechanical Life Safety and Fire Protection Requirements
.4 23 36 13	Terminal Units

1.4 Equipment Supplied for Installation under Other Sections

- .1 Supply the following equipment for installation under other Sections of Division 20;
 - .1 automatic control valves and pressure independent control valves,
 - .2 instrumentation including pressure sensors, flow meters and energy meters to be installed in piping systems,
 - .3 temperature wells for controllers and sensors provided under this Section, for installation in piping systems,
 - .4 instrumentation including air flow stations to be installed in ductwork systems,
 - .5 motorized dampers, except:
 - (a) where provided as part of factory built air handling units,
 - (b) motorized fire dampers, smoke dampers and/or combination fire/smoke dampers,

1.5 Equipment Provided under Other Divisions

- .1 The following equipment is provided under other Sections of Division 20;
 - .1 steam humidifiers with automatic control valves,
 - .2 unit heater and cabinet unit heater line voltage thermostats,
 - .3 manual dampers, non-motorized fire dampers, and gravity dampers,
 - .4 motorized fire dampers, smoke dampers and combination smoke/fire dampers, including damper actuators,

1.6 Definitions and Abbreviations

- .1 The following definitions, abbreviations, and acronyms apply to this Division of the Work:
 - .1 AI Analog Input: continuously variable value, usually a sensor, referenced to a controller
 - .2 AO Analog Output: continuously variable value, usually a control signal to an actuator device, referenced to a controller.
 - .3 ASC Application Specific Controller
 - .4 DI Digital Input: a two-state (On-Off) value, usually associated with a switch or state, referenced to a controller.
 - .5 DO Digital Output: a two-state (On-Off) value, usually associated with starting or stopping equipment or generating an alarm, referenced to a controller.
 - .6 FC Fail Close (valve or damper action on failure of the controller)
 - .7 FO Fail Open (valve or damper action on failure of the controller)
 - .8 FAS Fire Alarm System
 - .9 GUI Graphic User Interface: an LED, LCD or monitor display
 - .10 I/O Input/Output
 - .11 LAN Local Area Network
 - .12 NC Normally Closed: position of device in a de-energized state.
 - .13 NO Normally Open: position of device in a de-energized state.
 - .14 NSC Network Supervisory Controller
 - .15 OEM Original Equipment Manufacturer
 - .16 OWS Operator workstation: a PC based server or computer
 - .17 Tier 1 Building level network providing communication between NSCs and workstations.
 - .18 Tier 2 Field level network providing communications between ASCs and NSCs
 - .19 WAN Wide Area Network

1.7 Applicable Codes and Standards

- .1 Product standards:
 - .1 ANSI/ASHRAE 135 BACnet – A Data Communication Protocol for Building Automation and Control Networks
 - .2 ANSI/CEA 709.1 Control Network Protocol Specification (Lonworks)
- .2 Interfacing Standard:

- .1 Input/output devices to use ASCII (American Standard for Communication and Information Interchange) code and standard EI (Electronic Industry Association) interfaces.
 - (a) CSA T530 Commercial Building Standard for Telecommunications Pathways and Spaces
 - (b) IEEE 802.3 Ethernet

1.8 Qualified Tradesperson

- .1 Work to be performed by qualified, licensed and recognized firm with an established reputation in this field, using tradesperson holding applicable certificates of competency.
- .2 BAS to be provided by an organization that:
 - .1 specializes in design, installation, commissioning and service of BAS systems,
 - .2 has completed five (5) projects of similar size and complexity within the preceding five (5) years,
 - .3 employs licensed journeymen experienced in this type of work,
 - .4 is either:
 - (a) a controls manufacturing company listed under the following Standard of Acceptance to directly perform the Work, or
 - (b) provided by an authorized controls distributor-contractor of the listed manufacturer, to perform the Work.]

Standard of Acceptance

- Honeywell (WEBs)
- Johnson Controls (Metasys NAE)
- Siemens Building Technologies (Desigo)
- Delta Controls Inc
- Automated Logic (WebCTRL)

1.9 Design Services

- .1 Provide engineering services for the design of the BAS including product selection, wiring details, and all installation details to meet the prescribed and performance requirements described in the specifications sections of Division 25. Issued design documents are to be sealed by a professional engineer licensed in the province of the Work.
- .2 Prior to preparation of shop drawings for the BAS, provide a design assist to review Consultant's sequence of operation and provide feedback on any recommendation that may improve the installation or ease of operation, while remaining within the hardware scope as originally designed and specified herein.

1.10 Licences and Ownership

- .1 Ownership of, and licences for, hardware and software supplied or used for this project or for ongoing system operation, maintenance and modification to be registered, without restrictions, in Owner's name.
- .2 This is applicable to System Software, Workstation Application Editors, and Controller Software.
- .3 Licensing to permit an unlimited number of users to access system without additional fees.
- .4 At the time of substantial performance of the Work, upgrade the BAS software to the most current release version at that time, at no additional cost to the Owner.
- .5 Project-developed software and resulting documentation to be treated as part of system and subject to these same requirements for ownership and licensing. This material includes;
 - .1 project graphic images,
 - .2 CAD generated record drawings,

- .3 project database,
- .4 project-specific application programming code and documentation.

1.11 Seismic Qualification

- .1 Seismically qualify (certify) control panels for the BAS to remain operational after being subjected to the design seismic forces assuming a building height factor (NBCC) $A_x = 3.0$ with equipment rigidly mounted, by the shaker table method in accordance with Specification section 20 05 49.

1.12 Submittals

- .1 Submit one (1) completely engineered and coordinated shop drawing package. Partial or incomplete submission of data and/or drawings will be returned without review.
- .2 Submit shop drawings for designed elements;
 - .1 list of materials of equipment to be used indicating manufacturer, model number, and other relevant technical data,
 - .2 BAS riser diagram showing system controllers, operator workstations, network devices, and network wiring,
 - .3 control panel internal wiring diagrams, .
 - .4 single-line schematics and system flow diagrams showing location of control devices,
 - .5 wiring diagrams identifying interface hard-wire terminations to controlled equipment OEM control panels,
 - .6 points list for each system controller, including: Point Type, System Name, Object Name, Expanded ID, Display Units, Controller Type, Address, Cable Destination, Panel, Reference Drawing, and Cable Number,
 - (a) points to be named by function, and list to include software points such as programmable set-points, range limits, time delays, and so forth,
 - .7 detailed analysis of each Sequence of Operation from Consultant's design documents, ready for development of actual programming code,
 - .8 written Sequence of Operations to cover normal operation and operation under various alarm conditions applicable to that system.
- .3 Submit shop drawing schedules for;
 - .1 control dampers: spreadsheet type, to include separate line for each damper and columns for damper attributes.
 - .2 control valve: spreadsheet type, to include separate line for each valve and separate columns for valve attributes.
- .4 Submit catalogue cut-sheets for;
 - .1 manufacturer's description and technical data, such as performance curves, product specification sheets, and installation/maintenance instructions for equipment and hardware items as follows;
 - (a) controllers (NSC's and ASC's),
 - (b) instrumentation, including
 - i) accuracy data, range and scale information,
 - ii) one sheet for each device marked with applicable options. Where several devices of same type are to be used, submit one sheet for each device, individually marked.
 - (c) actuators,
 - (d) valves and dampers,

- (e) relays/switches,
 - (f) control panel enclosures,
 - (g) power supplies,
 - (h) batteries,
 - (i) GUI operator interfaces,
 - (j) wiring and wiring accessories.
- .5 Submit supporting documentation:
- .1 representative examples of graphics for GUI to include;
 - (a) BAS network schematics,
 - (b) typical terminal unit floor plan graphic that shows conditions on occupied floor,
 - (c) typical equipment room floor plan graphic,
 - (d) typical graphics for each system and terminal unit at least one sample graphic for each type of equipment,
 - (e) one sample graphic for chilled water system,
 - (f) one sample graphic for hot water system,
 - (g) description of techniques used for dynamic display of information on graphics and method of how building operator drills down to secondary information and affects control of equipment.
 - .2 Protocol Implementation Conformance (PIC) statement for BACnet devices,
 - .3 where interfaces occur with control or wiring diagrams of other sections, obtain reproducible copies of those diagrams and revise to show terminal numbers at interface and include diagrams as part of interconnection schematic shop drawings.

1.13 Quality Control

- .1 Continuity of staff and subcontractors:
- .1 Controls contractor's project manager is to be nominated at time of shop drawing submission and is to remain involved with the project, from shop drawing preparation through to project acceptance, unless a request for change of personnel is submitted to and approved by Owner.
 - .2 Subcontractors listed in preliminary design submission are to execute the Work defined as sublet in preliminary design document, unless request for change is submitted to and approved by Owner.
 - .3 Requests for changes in staff, subcontractors, or extent of work subcontracted are to be submitted for approval by Owner and such approval is not to be unreasonably withheld.
- .2 Identification of non-conforming materials and equipment:
- .1 Submit documentation at time of bid, identifying nature and extent of non-conformance and variances from specifications or referenced standards.
 - .2 Failure to submit this documentation at time of bid will be interpreted as confirmation that materials, workmanship, hardware and software will be in strict accordance with specifications and standards.
- .3 All products that are connected to a piping system that is subject to registration under applicable boiler and pressure vessel legislation are to have current Canadian Registration Numbers in accordance with CSA B51.
- .4 Site Acceptance Testing
- .1 Manufacturer to provide services of manufacturer's authorized service personnel in accordance with the requirements of Part 3 of this specification.

1.14 Warranty

- .1 At completion of Work, submit written guarantee undertaking to remedy defects in work for period of two (2) years from date of acceptance, which includes:
 - .1 rectification of control system failures attributable to defects in workmanship, materials, hardware, and software,
 - .2 service technician to arrive on site within 24 hours of warranty service request, to install and debug software patches, to replace defective parts, materials or equipment, and to provide incidental supplies, and labour for remedial work,
 - .3 technician to remain in attendance until system is returned to operating condition.
- .2 Submit similar guarantee for any part of the Work accepted by Owner, before completion of whole work.

2 PRODUCTS

2.1 General

- .1 Provide equipment which functions and meets detailed performance criteria when operating in following minimum ambient condition ranges unless otherwise specified in other specification sections of Division 25:
 - .1 temperature: 0°C to 40°C (32°F to 104°F)
 - .2 relative humidity 10% to 90% non-condensing
 - .3 electrical power service of single phase, 120 VAC +/- 10%, 60 Hz nominal.
- .2 Components installed within motor control devices to be designed to operate with transient electrical fields occurring within these devices.

2.2 Equipment Standard

- .1 Products and software: manufacturer/developer/supplier's catalogued current stock.
- .2 This installation is not to be used as test site for newly developed product or software, without explicit written approval by Owner.
- .3 Equipment and systems installed to meet;
 - .1 performance specifications when subjected to VHF, UHF, FM, AM or background RFI as generated by commercial or private, portable or fixed transmitters that meet regulatory codes,
 - .2 Federal Communication Commission (FCC) Rules and Regulations, Part 15, Subpart J for computing devices.

2.3 BAS General Functional Requirements

- .1 Control mechanical and electrical equipment as specified in control sequences, shown on control schematics, detailed in Points Lists, and described in equipment schedules.
- .2 Scalable system architecture to be modular, permitting stepped expansion of application software, system peripherals, and field hardware.
- .3 Control system:
 - .1 high-speed, peer-to-peer network of microprocessor based Direct Digital Control (DDC) controllers with web-based operator interface,
 - .2 each mechanical system, building floor plan, and control device to be displayed through point-and-click graphics,
 - .3 Web server with network interface card to gather data from this system and generate web pages that can be accessed through conventional web browser on any PC connected to network,

- .4 operators to access this system through web browser on connected PC's, wireless tablet PCs and smart phones to perform normal operator functions,
- .5 scalable, modular, automatic process and optimized workflows, with automatic data acquisition and energy performance analytics,
- .4 Each controller;
 - .1 operates with local closed loop programming, independent from server, able to continue functional control if peer-to-peer communication is interrupted;
 - .2 performs resident control routines;
 - (a) receiving information from field mounted sensors and switches and
 - (b) transmitting instructions to actuators to perform control sequences.
 - .3 manages local hardware and software alarms;
 - (a) to collect historical data,
 - (b) to facilitate operator input and output,
 - (c) to communicate with Central BAS web server and GUI.
- .5 Central BAS Web server;
 - .1 performs global application programs and data consolidation;
 - (a) communicating with controllers,
 - (b) obtaining data from field devices for central monitoring of building systems, and
 - (c) transmitting instructions to controllers.
 - .2 has software routines for;
 - (a) BAS Server operation,
 - (b) database creation and data storage,
 - (c) web based GUI with graphics generation and display,
 - (d) report formulation, printing, and presentation,
 - (e) alarm detection, management and reporting,
 - (f) event initiated programming.

2.4 Network Integration Functional Requirements

- .1 Open protocol:
 - .1 Provide an integrated, open protocol building automation system using BACnet to ANSI/ASHRAE Standard 135, with native integration with:
 - (a) Lonworks,
 - (b) Modbus,
 - (c) OPC (OLE for process control).
 - (d) ONVIF,
 - (e) DALI.
- .2 Integral systems integration functionality:
 - .1 provide hardware and software to allow bi-directional digital communications between BAS and facility control subsystems including:
 - (a) HVAC,
 - (b) fire safety including fire alarm systems,
 - (c) security systems,

- (d) power control and monitoring systems,
 - (e) lighting control systems,
 - (f) 3rd party integration with other facility systems.
- .3 OEM Controller integration:
- .1 provide hardware and software to allow bi-directional digital communications between BAS and 3rd party manufacturers' equipment control panels including but not limited to;
 - (a) boilers,
 - (b) chillers,
 - (c) variable frequency drives,
 - (d) packaged HVAC equipment,
 - (e) power monitoring equipment,
 - (f) medical gas equipment.
 - .2 integrate real-time data from these systems.

2.5 BMS Network Architecture

- .1 Refer to specification section 25 05 06 for work required on existing BAS networks.
- .2 BAS network architecture - Dedicated LAN for BAS:
 - .1 BAS communication architecture to consist of at least two tiers with each tier using local area networks.
 - .2 Tier 1: Network Supervisory Controller network;
 - (a) Ethernet communications (ISO 8802-3/IEEE 802-3), using high speed local area network communications. TCP/IP to be used as communication protocol on first tier network.
 - .3 Tier 2: Application Specific Controller network;
 - (a) open, peer-to-peer control networks to interconnect BAS controllers (NSC's and/or ASC's) on ring or star topology bus,
 - (b) peer-to-peer configuration means units exist and speak equally on same bus,
 - (c) controllers in peer-to-peer configuration can share data without assistance from GUI.
- .3 Bas network architecture - common structured LAN for IT and BAS:
 - .1 Tier 1: Building Control Network;
 - (a) structured Tier 1 network [provided under Division 27][supported on the existing facility IT network].
 - .2 Tier 2: Equipment Controller Network;
 - (a) open, peer-to-peer control networks to interconnect BAS controllers (BCU's and/or ECU's) on ring or star topology bus,
 - (b) peer-to-peer configuration means units exist and speak equally on same bus,
 - (c) controllers in peer-to-peer configuration can share data without assistance from Operator Interface.
- .4 BAS network architecture: no network
 - .1 no networking of controllers required.
 - .2 for greater clarity, all equipment controllers are stand-alone devices.

2.6 Performance

- .1 General:
 - .1 information transmission and display times are based upon network connections,
 - .2 test systems using manufacturer's recommended hardware and software for operator interface.
- .2 Performance criteria:
 - .1 Graphic Display;
 - (a) display graphic with 50 dynamic points with current data within 10 seconds.
 - .2 Graphic Refresh;
 - (a) update graphic with 50 dynamic points with current data within 10 seconds and
 - (b) automatically refresh every 15 seconds.
 - .3 Configuration and Tuning Screens;
 - (a) special screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic to refresh every 5 seconds.
 - .4 Object Command response;
 - (a) time between command of binary object at GUI and onset of reaction by device to be less than 5 seconds,
 - (b) time between command of analog object at GUI and start of adjustment to be less than 5 seconds.
 - .5 Alarm Response Time;
 - (a) time between when an object goes into alarm and when it is annunciated at GUI to be less than 15 seconds.
 - .6 Program Execution Frequency;
 - (a) execution repeat frequency to be selected in manner consistent with process under control,
 - (b) custom and standard applications to be capable of executing as often as once every 5 seconds.
 - (c) programmable controllers to be able to perform PID control loop routines at selectable frequency, adjustable at GUI down to once every second.
 - (d) workstations connected to network to receive alarms with not more than 5 seconds spread between first and last annunciation.

2.7 Capacity for Future Expansion

- .1 Tier 1 network;
 - .1 network backbone to have capacity for future 50 routers or building controller/routers in addition to connected devices at time of acceptance of the Work,
 - .2 each router or building controller/router on network backbone to have routing capacity for 50 controllers.

2.8 Wiring and Conduit

- .1 Wire and conduit for power wiring, control wiring, and communication wiring to conform to specification section 20 05 12.

3 EXECUTION

3.1 Examination

- .1 Inspect site and thoroughly examine documents to establish locations for control devices and equipment and report discrepancies, conflicts, or omissions for resolution before starting rough-in work.
- .2 Be responsible for correction of defects caused through neglect of inspections and examinations or failure to report and resolve discrepancies.

3.2 Protection

- .1 Protect work and material against damage during construction and be responsible for work and equipment until inspected, tested, and accepted.
- .2 Protect material not immediately installed and seal connector terminations with temporary covers or plugs during storage and construction to prevent entry of foreign objects.
- .3 Protect electronic equipment from elements during construction.

3.3 Coordination

- .1 Coordinate and schedule BAS work with other work in same area to ensure orderly progress.
- .2 Testing and balancing:
 - .1 Supply sets of tools of sufficient quantity for Testing and Balancing Technicians to interface to control system, train these technicians in use of tools, and provide qualified Control Technician to assist with testing and balancing the first 10 terminal units.
 - .2 Tools to be turned over to Owners on completion of testing and balancing.
- .3 Controls work by others:
 - .1 Integrate and coordinate this control work with controls and control devices provided or installed by others.
 - .2 Each supplier of control product to configure, program, start up, and test that product to satisfy requirements of Sequence of Operation regardless of where within contract documents product is specified or described.
 - .3 Resolve compatibility issues between control products provided under this Division and those provided under other Divisions of the Work.

3.4 General Workmanship

- .1 Installation to be performed by skilled and certified technicians.
- .2 Install equipment, piping, and wiring or raceways horizontally, vertically, and parallel to building lines.
- .3 Provide sufficient slack and flexibility in connections to allow for vibration isolation between conduit, raceways, piping and equipment.
- .4 Install instrumentation and devices in locations providing adequate ambient conditions.
- .5 Protect components placed in areas of potentially high humidity.

3.5 Wiring for Power, Control and Communications

- .1 Provide wire and raceways (conduit) for power wiring, control wiring, and communications wiring for BAS controllers and associated instrumentation and actuation devices, at voltages of 120 V and under, in accordance with specification section 20 05 12 and, for greater clarity, Schedule A appended to that specification section.
- .2 Verify wiring integrity to ensure continuity and freedom from shorts and ground faults.

Issued For

3.6 Cleaning

- .1 Clean up debris, remove packaging material, collect waste and place in designated location, on a daily basis.
- .2 Keep work areas free from dust, dirt, and debris.
- .3 On completion of work, check finish of equipment provided under this section for damage and repair damaged factory-finished paint, replace deformed cabinets and enclosures with new material, and repaint to match original.
- .4 Prior to hand-over to the Owner, clean the inside of control panels;
 - .1 remove debris and vacuum clean internal components,
 - .2 the use of low-pressure dry nitrogen or inert compressed gases may be used to blow dust and debris out of panels where the use of such pressurized gases will not damage equipment or loosen wiring terminations,
 - .3 after cleaning, apply a label to the exterior side of the panel to identify the date the panel was cleaned and the initial of the person who cleaned the panel.

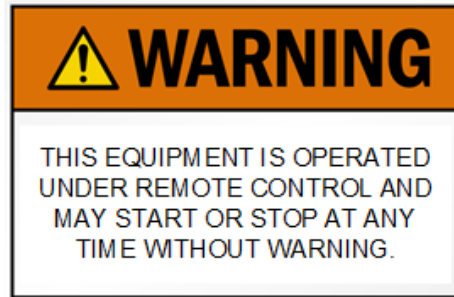
3.7 Field Quality Control

- .1 Ensure work, materials, and equipment comply with this specification and reviewed shop drawings.
- .2 Monitor field installation for applicable safety and building code compliance and workmanship quality.
- .3 Arrange and pay for inspections by local or provincial authorities having jurisdiction over the work.

3.8 Identification of Equipment

- .1 Manufacturers' nameplates and product certification labels to be visible and legible after equipment is installed.
- .2 Identify discrete items of equipment with plastic nameplates or plasticized labels, identifying equipment and function. Identification plates are in addition to manufacturers nameplates.
- .3 Identification plates:
 - .1 provided for equipment identified with number designations in schedules and equipment shop drawings.
 - .2 marked with equipment type, number and service following wording and numbering used in contract documents and shop drawings,
 - .3 plastic laminated labels,
 - .4 white face and black background field,
 - .5 minimum size 75 mm x 40 mm x 3 mm (3 in x 1½ in x 1/8 in),
 - .6 engraved or printed with 6.5 mm (1/4 in) high lettering.
 - .7 securely attached to equipment with brass chains.
- .4 Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 50 mm (2 in) of termination.
- .5 Label pneumatic tubing at each end within 50 mm (2 in) of termination with descriptive identifier.
- .6 Permanently label or code each point of field terminal strips to show instrument or item served.
- .7 Label each control component with permanent label. Label plug-in components so that label remains stationary during component replacement.
- .8 Label room sensors related to terminal boxes or valves with nameplates. Place labels on back of sensors.

- .9 Identify motor controllers that are remotely controlled by the BAS with self-adhesive labels, black letters on white background with a red border and electric shock warning icon, with wording as follows;



3.9 Checkout and Testing

- .1 Provide schedule for start-up and testing.
- .2 Calibrate and prepare for service equipment, instruments, controls, and accessories.
- .3 Start-up testing to verify completion of control system before system demonstrations begin;
 - .1 verify that control wiring is connected and free of shorts and ground faults. Verify that terminations are tight,
 - .2 enable control systems and verify input device calibration,
 - .3 verify that binary output devices operate and that normal positions are correct,
 - .4 verify failure positions of dampers and control valves are correct when power/compressed air is deenergized to the device,
 - .5 verify that analog output devices are functional, that start and span are correct, and that direction and normal positions are correct,
 - .6 check control valves and automatic dampers for proper action and closure and adjust valve stroke/rotation and damper blade travel,
 - .7 verify that damper and control valve feedback signals are correct when device is stroked fully open and closed (two position) and at any opening position between zero and fully open (modulating devices),
 - .8 verify that system operates according to Sequences of Operation. Simulate changes in variables by overriding and varying inputs and schedules and observe and record each operational mode response.,
 - .9 tune PID loops and control routines to provide stabile operation and to minimize valve and damper hunting,
 - .10 check each alarm with an appropriate signal at value that will trip alarm,
 - .11 trip interlocks using field contacts to check logic and to ensure that actuators fail in proper direction,
 - .12 test interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.
- .4 Prepare and submit test log documenting start-up testing of each input and output device and each control routine, with technician's initials certifying each device and each routine is functioning correctly and sensors have been calibrated. Include list of deficiencies and a workplan schedule setting out rectification program with time lines.

3.10 Testing of Integrated Life Safety and Fire Protection Systems

- .1 Comply with the requirements of specification section 20 08 11 for the testing of the integration of controls and communications between the BAS and life safety and fire protection systems.

3.11 Control System Demonstration

- .1 Obtain approval of start-up testing log and rectification program before scheduling demonstrations.
- .2 Provide notification to Owner and Consultant not less than 10 business days before system demonstration begins.
- .3 Demonstration to follow previously submitted and approved procedures;
 - .1 submit checklists and report forms for each system as part of demonstration,
 - .2 lists and forms to have initials of technicians conducting demonstrations,
 - .3 date of each demonstration and signatures of Owner's representatives witnessing each demonstration section.
- .4 Prior to acceptance, perform the following operating tests in the presence of the Owner or Owner's representative and Consultant to demonstrate system operation and compliance with specification after and in addition to tests specified above in article Checkout and Testing.
- .5 Demonstrate field operation of;
 - .1 each Sequence of Operation,
 - .2 Operator Interface,
 - .3 control loop response with graphical trend data output showing;
 - (a) each control loop response to set point change producing an actuator position change of at least 25% of full range.
 - (b) trend sampling rate to be from 10 seconds to 3 minutes, depending on loop speed,
 - (c) loop trend data to show set point, actuator position, and controlled variable values,
 - (d) documentation of further tuning of any loop that displays significantly under- or over-damped control
 - .4 demand limiting routine with trend data output showing demand-limiting algorithm action;
 - (a) trend data to document action sampled each minute over at least 30-minute period and to show building kW, demand-limiting set point, and status of set-points and other affected equipment parameters.
 - .5 control integration with life safety and fire protection systems,
 - .6 trend logs for system points as selected by the Owner with;
 - (a) trend data to indicate set-points, operating points, valve positions, and other data as specified in points list provided with each Sequence of Operation,
 - (b) each log to cover three 48-hour periods and to have sample frequency not less than 10 minutes, except where a Control Sequence specifies other time intervals,
 - (c) show that trend logs are accessible through operator interface and can be retrieved for use in other software programs.
 - .7 substantiate calibration and response of any input and output points requested,
 - .8 provide at least two technicians equipped with two-way communication,
 - .9 provide and operate test equipment to establish calibration and prove system operation.
- .6 Tests that fail to demonstrate system operation are to be repeated after repairs and/or revisions to hardware or software is completed.

3.12 Training

- .1 Materials:
 - .1 provide course outline and materials for each class at least four (4) weeks before first class,
 - .2 provide training through instructor-led sessions, with computer-based, or web-based techniques,
 - .3 instructors to be factory-trained and experienced in presenting this material,
 - .4 perform classroom training using network of working controllers representative of installed hardware.
- .2 Operating staff training:
 - .1 provide training for Owners operating staff using abovementioned training materials in self-paced mode, web-based or computer-based mode, classroom mode, or combination of these methods,
 - .2 allow for 1 repeat sessions for each category to cover operator shift rotation.
- .3 Training to enable students to accomplish following objectives:
 - .1 Group 1:
 - (a) proficiently operate system,
 - (b) understand control system architecture and configuration,
 - (c) understand BAS system components,
 - (d) understand system operation, including BAS system control and optimizing routines (algorithms),
 - (e) understand Sequence of Operations,
 - (f) operate workstation and peripherals,
 - (g) log on and off system,
 - (h) access graphics, point reports, and logs,
 - (i) adjust and change system set-points, time schedules, and holiday schedules,
 - (j) recognize common HVAC system malfunctions by observing system graphics, trend graphs, and other system tools,
 - (k) understand system drawings and Operation and Maintenance manual,
 - (l) understand project layout and location of control components,
 - (m) access data from BAS controllers,
 - (n) set-up trend logs,
 - (o) operate portable operator's terminals
 - .2 Group 2:
 - (a) create and change system graphics,
 - (b) create, delete, and modify alarms, including configuring alarm reactions,
 - (c) create, delete, and modify point trend logs (graphs) and multi-point trend graphs,
 - (d) configure and run reports,
 - (e) add, remove, and modify system's physical points,
 - (f) create, modify, and delete application programming,
 - (g) add and configure GUIs,
 - (h) add new controller to system,
 - (i) download firmware and advanced applications programming to controller,
 - (j) configure and calibrate I/O points.

- .3 Group 3:
 - (a) maintain software and prepare backups,
 - (b) interface with job-specific, third-party operator software,
 - (c) add new users and understand password security procedures.
- .4 Divide presentation of objectives into three sessions:
 - .1 Group 1: Day-to-day Operators,
 - .2 Group 2: Advanced Operators,
 - .3 Group 3: System Managers and Administrator,
 - .4 participants will attend one or more sessions, depending on knowledge and expertise level required,
 - .5 provide each student with one copy of training material.

3.13 Record Submittals

- .1 Submit record documents to the Owner.
- .2 Document language: English,
- .3 Submit three copies of project record documents and obtain approval during acceptance procedures.
- .4 Submit AHJ inspection certificates.
- .5 Provide as-built drawings;
 - .1 as-built interconnection wiring diagrams, or wire lists of field installed system with identified, ordering number of each system component and service,
 - .2 floor plans with accurate depiction of location of system devices, controllers, and trunk wiring. Drawings to be constructed using Architectural backgrounds provided,
 - .3 provide copies of as-built drawings on two (2) removable storage devices,
 - .4 provide five (5) full size hard copies of floor plan drawings.
- .6 Operation and Maintenance (O&M) Manuals:
 - .1 provide two (2) paper copies of material and copies on five (5) removable storage devices in portable document format.
 - .2 describe operation, maintenance and servicing requirements of system and associated equipment,
 - .3 provide the following information in separate sections, each with an index:
 - (a) Service and parts;
 - i) names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems,
 - ii) list of recommended spare parts with part numbers and suppliers.
 - (b) System description;
 - i) outline of BAS system and system architecture,
 - ii) as-built versions of shop drawing product data,
 - iii) reduced size (11 in x 17 in) copies of record drawings,
 - iv) graphic files, programs, and database on magnetic or optical media,
 - v) licenses, guarantees, and warranty documents for equipment and systems.
 - (c) Technical literature for equipment, including;
 - i) catalogue sheets,

- ii) calibration, adjustments and operation instructions,
- iii) installation instructions,
- iv) hardware and software manuals, with information supplied by original product developer, on application programs and on computers and controllers supplied,
- v) Operator's manual with procedures for operating control systems; logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing set-points and variables,
- vi) engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware,
- vii) original-issue documentation with installation and maintenance information for third-party hardware including computer equipment and sensors,
- viii) recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions,
- ix) programming manual or set of manuals with description of programming language and syntax, explanation of statements for algorithms and calculations used, procedures for point database creation and modification, documentation of techniques for program creation and modification, and instructions for use of editor,
- x) documentation of programs created using custom programming language including set-points, tuning parameters, and object database. Electronic copies of programs to modify and create control logic, set-points, tuning parameters, and objects that can be viewed using programming tools.

.7 Original Software:

- .1 Furnish one original set of application and system software on original media. Disks to bear manufacturer's label. Field copies are not acceptable.
- .2 Original-issue copies of software to include operating systems, custom programming language, application generation, graphic support, maintenance support, operator workstation or web server software, and other utilities provided in support of installed system. [

.8 On-line record documentation:

- .1 After completion of testing and adjustment, install the following additional information on the server OWS.
 - (a) as-built record drawing files,
 - (b) detailed catalog data on all installed system components, with supplier contact information for purchasing and factory authorized repair service.]]

3.14 Acceptance

- .1 Application for substantial performance of the Work requires as a prerequisite the completion of the BAS including testing, demonstration, and submittal of required documentation, except where the Owner agrees to differ any work to a later date.
- .2 In support of an application for substantial performance, submit a signed declaration to the Owner certifying that:
 - .1 the BAS is complete and operating in accordance with the contract documents,
 - .2 control system checkout and testing is completed,
 - .3 control system demonstration is completed,

- .4 training is completed,
- .5 as-built documentation is completed and turned-over to the owner.
- .3 Certification document may identify tests that cannot be performed due to extenuating circumstances such as weather conditions, where previously agreed to be deferred to a later date by the Owner. Append a program for completion of deferred work to the certification document for rectification and completing these tests during warranty period.

3.15 Correction After Completion

- .1 After start-up, testing, and commissioning phase has been completed and satisfactory and reliable operation of equipment and systems has been demonstrated, acceptance of the system is to be given by Owner. Warranty period to begin on date established on certificate of acceptance.
- .2 Provide updates and patches to resolve software deficiencies in operator workstation or web server software, project-specific software, graphic software, database software, and firmware during warranty period.
- .3 Provide upgrades that improve routines and procedures of operator workstation software, web server software, project-specific software, graphic software, or database software, free of charge, during warranty period.
- .4 Provide details of proposed changes and obtain written authorization from Owner before installation of updates, patches, or upgrades.
- .5 Include preventative maintenance, with allowance for spare parts, labour, and emergency (24 hour) service for system and equipment during warranty period.
- .6 Equipment manufacturers to submit written undertakings to make circuit board repairs and provide spare parts, software support and patches, and technical assistance for at least five years after acceptance is certified.

End of Section

WORK ON EXISTING BUILDING AUTOMATION

25 05 06

1 GENERAL

1.1 Scope

- .1 Modifications to existing building control systems including:
 - .1 connection to of new BAS networks to the existing building BAS networks,
 - .2 connection of new control devices to existing BAS networks,
 - .3 selective demolition of existing building controls,
 - .4 modifications and upgrades of existing BAS.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 26 Pipeline Hot-Tapping and Line Stopping
 - .2 25 05 01 Building Automation Common Work Results

1.3 Definitions and Abbreviations

- .1 Refer to specification section 25 05 01.

1.4 Designated Controls Contractor

- .1 BAS work shall be performed by [enter name of controls contractor] as the base building controls contractor authorised by the Owner to perform such Work.

1.5 Design Criteria

- .1 Existing BAS networks:
 - .1 Tier 1: dedicated [BACnet /IP][BACnet /Ethernet][Lonworks][control vendor proprietary].
 - .2 Tier 1: hosted on facility IT network.
 - .3 Tier 2: [BACnet MSTP][Lonworks][control vendor proprietary].

1.6 Submittals

- .1 Shop drawings:
 - .1 In addition to the requirements of section 25 05 01, submit the following information as a shop drawing:
 - (a) documentation of existing sequence of operations for applicable equipment and systems affected by the Work.

2 PRODUCTS

2.1 General

- .1 Conform to specification section 25 05 01 and other sections of Division 01 except as specified herein.
 - .1 [replace all ASCs,]
 - .2 replace all ASCs controlling existing equipment in the project work zone for the following equipment types:

- (a) terminal units (VAV boxes),
- (b) unit heaters,
- (c) fan coil units,
- (d) ●
- (e) ●.]

.3 replace the ASCs as listed in Schedule B at the end of this specification section.

2.2 Data and Graphic Upgrades

- .1 Upgrade existing data presentation and graphic displays on existing-to-remain NSC and ASC devices, by providing a new Web server with GUI graphics to comply with the requirements for new products in accordance with specification section 25 05 01 and reference specification sections.
- .2 Develop new graphics to display existing data tables and/or graphical display of control systems, along with additional features as shown.

2.3 GUI Upgrades

- .1 Replace existing GUI devices with new products in accordance with specification section 25 05 01 and reference specification sections. The existing devices and replacement types are to be in accordance with Schedule C at the end of this specification section.

3 EXECUTION

3.1 Existing Equipment

- .1 Reuse of control components:
 - .1 reuse existing equipment and components as listed below where condition and conformance with this specification permits;
 - (a) valves and operators,
 - (b) dampers and operators,
 - (c) compressed air system,
 - (d) thermocouple wells,
 - (e) freezestats,
 - (f) firestats,
 - (g) limit, end, or level switches and air or liquid flow switches,
 - (h) static pressure sensors and controllers,
 - (i) wiring and conduit for safety controls and I/O points,
 - (j) relays,
 - (k) cabinets,
 - (l) other items specifically noted as existing, to be re-used.
- .2 Remove and replace existing temperature and humidity sensors with new units, throughout the installation,
- .3 Check and re-calibrate existing indicator gauges,
 - .1 under no circumstances are existing gauges or thermometers be removed.
- .4 Re-calibrate valves and dampers as part of installation of this system.
- .5 Existing thermowells for conventional control system may be reused for new sensors,

- .1 repack temperature wells, both new and reused, with heat conductive grease.

3.2 Existing Programming and Configuration

- .1 Document existing control device programming, configuration, and setpoint values at the start of the work, prior to any demolition or other work on existing control equipment.
- .2 For each NSC or ASC being replaced, review the existing control programming and/or configuration settings, and prepare a written sequence of operation in laymen terms that describes the operating control of each control device. Where multiple control devices of the same type exist (e.g. terminal units), review at least three (3) randomly selected controllers to verify the same control functions; a single written control sequence for each type controller is sufficient.
- .3 Provide a copy of these documentation to the Owner.
- .4 Except where otherwise specified for new sequence of operations, program and/or configure software for replacement NSC and ASC to achieve the same control functionality and sequence of operation of the pre-existing NSC and ASC controllers, and configure setpoints to match pre-existing controller values.

3.3 Existing Condition Survey

- .1 Conduct a condition survey of existing control devices:
 - .1 test, inspect and report on existing devices which are to be incorporated into the BAS, for satisfactory operation within 30 days of award of contract and prior to installation of any new devices,
 - .2 for those items found in unacceptable condition, provide with report test data, original specification sheets or written functional requirements to confirm conclusion,
 - .3 Owner to arrange for repair or replacement of those existing items judged defective, but shown to be re-used in BAS and control system,
 - .4 items thus repaired or replaced by Owner will be returned to site and handed over to Contractor under this Section for storage, installation, testing, and commissioning.,
 - .5 warrant reused devices that have been rebuilt or repaired. Demonstrate satisfactory operating condition of reused devices at time of acceptance,
 - .6 responsibility for existing control devices that have been reused is to terminate at end of warranty period.

3.4 Demolition and Removals

- .1 Unless specifically noted or shown otherwise, remove existing control components made redundant:
 - .1 room thermostats, controllers, auxiliary electronic devices, pneumatic controllers and relays, control valves, electronic sensors, and transmitters: to be removed and placed in storage as directed by Owner.
 - .2 local control panels: removed and placed in storage as directed by Owner.
- .2 Remove and dispose of existing conduits, wiring and tubing in all areas (including above accessible ceilings) as they become redundant;
 - .1 remove existing control compressed air systems and, where applicable, connect to new control air system;
 - .2 existing hardwired interlocks to remain installed in systems.
- .3 In existing areas not otherwise involved in renovations, arrange and pay for holes and marks left by decommissioning and removal of control components, wiring, conduit, and tubing to be patched and refinished to match existing.

3.5 Maintaining Existing System Operation

- .1 Mechanical systems to remain in operation and to maintain space conditions between hours of 6 a.m. and 9 p.m., Monday through Friday.
- .2 In these periods mechanical control system shut downs of up to 15 minutes may be permitted, after obtaining written agreement from Owner.
- .3 When time required for cut-over of controls will not meet these constraints, perform work outside of operating hours after making application; outlining areas affected; and likely length of interruption, and obtain written agreement from Owner. .
- .4 Maintain fan scheduling using existing or temporary time clocks or control systems throughout period of control system installation.
- .5 Modify existing motor controllers to incorporate new local operator control switches for motors to be controlled through BAS system.

3.6 Installation of New Thermowells

- .1 Existing piping services to remain in service during installation of thermowells.
- .2 Coordinate with the trade contractor under Division 23 to install thermowells for new temperature sensors mounted on steel piping by hot-tapping in accordance with specification section 20 05 26.

3.7 Interfacing Between New and Existing Control Systems

- .1 Certain building systems are to operate in event of building power failure or fire alarm. Under no circumstances should interfacing of equipment or controls modify these existing sequences of operation.
- .2 Where tying new system into existing control equipment, show on shop drawings;
 - .1 signal levels,
 - .2 wire type,
 - .3 wire numbers, and
 - .4 terminal numbers.
- .3 Before attempting replacement of existing control systems, install new field panels, controllers and associated devices loose-ended ready for system changeover.
- .4 Submit written request to Owner setting out proposed starting time for changeover, duration of system down time, and establishing extent of interruption to operation of existing control system.
- .5 Do not proceed with work until Owner's written approval of time for, duration of, and extent of interruption is received.
- .6 Subsequent decommissioning and removal of control components to be carried out without interfering with normal operations or creating an interruption in service of any building systems except through an approval process similar to that noted above.

3.8 Schedules

- .1 The following schedules form part of this specification section.
 - .1 Schedule A NSC Replacement
 - .2 Schedule B ASC Replacement
 - .3 Schedule C

Schedule A – Network System Controller Replacement			
Building	Floor	Room Number	NSC Device Reference Number Or Equipment Name

Schedule B – Application Specific Controller Replacement			
Building	Floor	Room Number	ASC Device Reference Number Or Equipment Name

Schedule C – Operator Display Device (GUI) Replacement		
Location	Existing Operator Display Device	Replacement GUI Device
	Workstation PC	[Workstation PC] [Local Display Unit]
	Control panel display	Local Display Unit

End of Section

BUILDING AUTOMATION CONTROL PANELS AND WIRING

25 05 12

1 GENERAL

1.1 Scope

- .1 Provide building automation control panels for mounting and securing building automation control equipment and devices.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 05 12 Common Electrical Requirements for Mechanical Services
 - .2 25 30 16 Building Automation Instrumentation

1.3 Definitions and Abbreviations

- .1 The following definitions apply to this section.
 - .1 **Control wiring** – has the meaning as defined in specification section 20 05 12.
 - .2 **Extra-low voltage** – any voltage not exceeding 30 V (has the same meaning as per CSA C22.1)
 - .3 **GUI** means “graphic user interface”, to display system data to the user and to allow the user to enter operating commands and data selection.
 - .4 **Power wiring** - has the meaning as defined in specification section 20 05 12.

1.4 Applicable Codes and Standards

- .1 Product standards:
 - .1 CSA C22.2 No. 0.3 Test Methods for Electrical Wires and Cables
 - .2 CSA C22.2 No. 14 Industrial Control Equipment
CSA C33.3 No. 18.5/UL 1565
Positioning Devices
 - .3 CSA C22.2 No. 66.2 Low Voltage Transformers – Part 2: General Purpose Transformers
CSA C22.2 No. 66.3 / UL 5085-3
Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers
 - .4 CSA C22.2 No. 72 Heater Elements
 - .5 CSA C22.2 No. 94.1 Enclosures for Electrical Equipment, Non-Environmental Considerations
 - .6 CSA C22.2 No. 223 Power Supplies with Extra-Low-Voltage Class 2 Outputs.

1.5 Qualified Tradesperson

- .1 Work to be performed by qualified, licensed and recognized firm with an established reputation in this field, using tradesperson holding applicable certificates of competency.

1.6 Registration and Inspection

- .1 Where control panels are not listed in accordance with CSA C22.2 No. 14, arrange and pay for field inspection by the AHJ for electrical safety.

1.7 Submittals

- .1 Shop drawings:
 - .1 submit product data sheets for materials specified herein.
 - .2 submit shop drawings for control panels including wiring diagrams and panel layout details.

2 PRODUCTS

2.1 General

- .1 Provide custom factory-made building automation control panels including all factory-installed devices and equipment required for operation of associated building equipment or systems including but not limited to DDC controllers, GUI, power supplies, transducers, solenoid air valves, relays and accessories.
- .2 Comply with the requirements of specification section 20 05 12 for products not otherwise specified herein.
- .3 Provide equipment which functions and meets detailed performance criteria when operating under the following conditions:
 - .1 ambient temperature:
 - (a) indoors: 4°C to 40°C (39°F to 104°F)
 - (b) outdoors: -30°C to + 40°C (-22°F to 104°F)
 - .2 ambient relative humidity: 10% to 90% non -condensing,
 - .3 electrical power service: 120 VAC +/- 10%, 1 phase, 60 Hz nominal.

2.2 Control Panels

- .1 Panel enclosure:
 - .1 indoors: type 2 with sprinkler shield, 3R or 4 to CSA C22.2 No. 94.1 (NEMA 2, 3R, or 4),
 - .2 material: galvanized steel,
 - .3 with hinged door and lock,
 - .4 integral cooling fans and vents with power supplies, wiring and circuit protection,
 - .5 mounting backplate and/or DIN rails for mounting of wiring devices, controllers, sensors, transducers, and relays,
 - .6 conduit openings and adapters in sufficient quantities and sizes to accommodate wiring terminating within enclosure,
 - .7 document holder inside panel, to include one set of as built, plasticized control Shop Drawings for equipment served by that panel permanently affixed to cabinet frame,
 - .8 enclosure finish: vendors standard colour,
- .2 GUI display:
 - .1 surface mounted on or semi-recessed in panel front door where GUI is required by other specification sections of Division 25.
 - .2 where GUI is mounted on the controller inside the panel, provide panel door cut-out with viewing glass to allow viewing only of GUI with panel door closed.
- .3 Control panel layout and construction:
 - .1 enclosures to be of sufficient size to house control components including controllers and associated transformers, control relays, wiring, conduits and other auxiliary equipment, so as to

- allow access for maintenance and replacement of components without requiring removal of other components.
- .2 permanent engraved labels with black lettering on white background indicating;
 - (a) stating applicable building system name and reference number.
 - (b) function of each panel door mounted device.
- .3 mount air pressure gauges on front of panel door to allow viewing from outside the panel,
- .4 support wiring in cable ducts; arrange cable ducting and install wiring in a neat and workmanlike manner,
- .5 provide numbered terminal strips for field wiring terminations; do not terminate field wiring directly on control devices or controllers. Arrange terminal strips in a common location adjacent to minimize routing and quantity of field wiring inside of panel.
- .6 label both ends of internal wiring with label markers using name of cable function, or to identify wire number as shown on panel shop drawings,
- .7 layout circuit fuses to facilitate location and replacement; provide labels at each fuse holder identifying fuse number and replacement fuse type and size,
- .4 Control devices mounted on panel door-front:
 - .1 Key-lock operated main panel power ON-OFF switch,
 - .2 alarm buzzer silence pushbutton (where applicable),
 - .3 alarm reset pushbutton (where applicable),
 - .4 indicating lights:
 - (a) main panel power ON (white),
 - (b) summary alarm (red),
 - (c) other indicating lights as specified by control sequences.
- .5 Panel mounted alarm devices:
 - .1 alarm buzzer (where applicable).
- .6 Cable Ducts
 - .1 non-metallic cable ducting with removable cover, slotted access cable restraints,
 - .2 ambient temperature rating: -40 to +60°C (-40 to +140°F)
 - .3 listed to CSA C33.3 No. 18.5/UL 1565.
- .7 Terminal strips:
 - .1 NEMA finger-safe terminal blocks, spring-clamp or screw fastened,
 - .2 directly fastened to panel backplane or DIN rail mounted.

2.3 Power Supplies and Line Filtering

- .1 For control panels and for field installed devices.
- .2 Transformers and Power Supplies:
 - .1 industrial control transformers to be listed to CSA C22.2 No. 66-2, and temperature rated for 40°C,
 - .2 control transformers to be listed to CSA C22.2 No. 66-3,
 - .3 AC/DC power supplies to be listed to CSA C22.2 No. 223,
 - .4 provide over-current protection in primary and secondary circuits,
 - .5 limit connected loads to 80% of rated capacity.
- .3 DC power supplies:

- .1 output to match equipment current and voltage requirements,
 - .2 units to be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation to be 1.0% line and load combined, with 100-microsecond response time for 50% load changes,
 - .3 units to have built-in over-voltage and over-current protection and to be able to withstand 150% current overload for at least three seconds without trip-out or failure,
 - .4 units to operate between 0°C and 50°C (32°F and 120°F).
 - .5 EM/RF to meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.
- .4 Power Line Filtering:
- .1 provide internal or external transient voltage and surge suppression for workstations and control modules,
 - .2 surge protection:
 - (a) dielectric strength of 1000 V minimum,
 - (b) response time of 10 nanoseconds or less,
 - (c) transverse mode noise attenuation of 65 dB or greater,
 - (d) common mode noise attenuation of 150 dB or greater at 40-100 Hz.

2.4 Miscellaneous Electrical Control Devices

- .1 Control Relays:
- .1 plug-in type, UL listed, with dust cover and LED "energized" indicator.
 - .2 contact rating, configuration, and coil voltage suitable for application.
 - .3 NEMA 1 enclosure for relays not installed in local control panels.
- .2 Time Delay Relays:
- .1 solid-state plug-in type, UL listed, with adjustable time delay adjustable $\pm 100\%$ from set point shown.
 - .2 contact rating, configuration, and coil voltage suitable for application.
 - .3 NEMA 1 enclosure for relays not installed in local control panels.
- .3 Override Timers:
- .1 spring-wound line voltage, UL Listed, with contact rating and configuration by application unless implemented in control software.
 - .2 0-6 hour calibrated dial.
 - .3 flush mounted on local control panel face.
- .4 Electronic signal isolation transducers:
- .1 provided whenever;
 - (a) an analog output signal from BAS is connected to an external control system as an input (such as chiller control panel) or
 - (b) BAS is to receive an analog input signal from an external remote system.
 - .2 designed for ground plane isolation between systems.

2.5 Electro-Pneumatic (E/P) Transducers

- .1 To convert 4-20 mA, 0-5 Vdc, or 0-10 Vdc analog control input signal to a 20-100 kPa (3-15 psig) output signal;
- .1 separate span and zero adjustments,

- .2 manual output adjustments,
- .3 output pressure gauge assembly,
- .4 feedback loop control,
- .5 mid-range air consumption of 0.05 NL/s (0.1 SCFM).

2.6 Pressure-Electric (P/E) Switches

- .1 To convert pressure signal to activate electric switch;
 - .1 diaphragm operated SPDT. snap acting contacts with electrical rating suitable for application,
 - .2 designed to withstand up to 170 kPa (25 psi) input pressure,
 - .3 adjustable cut-in and cut-out settings between 25 and 140 kPa ([3 and 20 psi).

2.7 Additional Requirements for Outdoor Panels

- .1 The following additional requirements apply where control panels are installed outdoors, or indoors in unheated spaces.
- .2 Enclosure: type 4, 4X or 12 to CSA C22.2 No. 94.1 (NEMA 4, 4X or 12),
- .3 Thermally insulated on all interior surfaces
 - .1 minimum thickness: 25 mm (1 in) at a maximum thermal conductivity of 0.0365 W/mK (0.0211 Btuh/ft²F) , or equivalent minimum RSI= 0.68 m²K/W (R = 3.86 ft²F/BTUH).
- .4 Mount GUI and other front-mount devices on inner front panel behind main panel door.
- .5 Electric resistance panel heater:
 - .1 electric resistant heaters listed to CAN/CSA C22.2 No. 72,
 - .2 sized to maintain panel interior temperature at not less than 4.5°C (40°F), at the ambient design temperature.
 - .3 integral or line mounted thermostat control, set with a temperature deadband of ON at 4.5°C (50°F) and OFF at 12°C (55°F).

2.8 Wiring and Raceways

- .1 Electrical materials, equipment and installation procedures to conform to the electrical safety code applicable to the location of the Work, in accordance with the requirements of specification section 20 05 12, and as specified herein.
 - .1 conductors for digital functions: 18 AWG minimum, twisted and shielded,
 - .2 conductors for analog functions: 18 AWG minimum, twisted and shielded, 2 or 3 wire to match analog function hardware.
 - .3 conductors for transformer current wiring: 16 AWG minimum,
 - .4 conductors for sensor wiring: 22 AWG minimum, twisted and shielded, 2 or 3 wire to match analog function hardware. Provide additional conductors as to support supplemental features of sensor (i.e. set-point adjustment, override, etc.).
- .2 Non-continuous cable supports:
 - .1 Sling strap:
 - (a) Galvanized steel support bracket with adjustable polyethylene support sling.

Standard of Acceptance

- ° nVent – fig. Caddy Cable 425

3 EXECUTION

3.1 Control Panel Installation

- .1 Install transmitters, transducers, controllers, solenoid air valves and relays in control panels.
- .2 Mount control panels to poured concrete or concrete block walls on mounting channels; do not fasten directly to the wall.
- .3 Where control panels are located away from concrete walls, provide a fabricated floor-mounted galvanized-steel channel support frame to mount control panels. Design support frame to withstand applicable seismic loads.
- .4 Install control panels with user interface devices on the panel door so that the centerline of the principle interface device is between 1500 and 1600 mm (60 to 64 in) above floor level.
- .5 Install other panels so that the top of the panel is located between 1800 and 1900 mm (72 to 76 in) above the floor.
- .6 Trim-back or neatly collect excess field wiring inside of control panels.

3.2 Field Wiring Installation

- .1 Provide power wiring and control wiring as needed to support operation of the building automation system. Refer to Section 20 05 12 for description of division of work and responsibility.
- .2 Installation of field wiring for power wiring and control wiring to conform to specification section 20 05 12 except/and as specified herein.
- .3 During installation follow cable manufacturer's specified cable pulling tension, and recommended minimum bend radius.
- .4 Verify entire network's integrity following cable installation using appropriate tests for each cable.
- .5 Install lightning arrester according to manufacturer's recommendations between cable and ground wherever cable enters or exits the building.
- .6 Each run of communication wiring to be continuous length without splices.
- .7 Label communication wiring to indicate origin and destination.
- .8 Ground coaxial cable according to Division 26 requirements.
- .9 Fiber optic cable installation:
 - .1 do not exceed pulling tensions specified by cable manufacturer. Post-installation residual cable tension to be in accordance with cable manufacturer's specifications,
 - .2 do not exceed minimum cable and unfaceted fiber bend radii specified by cable manufacturer.[]]

3.3 Conduit and Raceways

- .1 Run power wiring and control wiring in conduit except where otherwise specified herein.
- .2 Extra-low voltage control wiring located in horizontal service spaces above dropped ceilings may be run exposed (without conduit) provided that wiring is;
 - .1 installed neatly and parallel to building lines,
 - .2 supported from J-hooks at intervals not exceeding 1200 mm (4 ft),
 - .3 have a FT6 rating in accordance with CSA C22.2 NO. 0.3 when installed in a supply or return air ceiling plenum

- .3 Low-voltage power and control wiring may be run in IT cable trays provided a metal barrier is installed in the cable tray system to prevent mixing and cross-over of cable types (communication, instrumentation, actuator control).
- .4 Run conduit and raceways parallel to building lines and be secured to building structure.
- .5 Where conduit leaves heated areas and enters unheated areas, seal conduit with weather-tight sealant at the first junction box in the unheated space.

3.4 Power Conversion and Control Relays

- .1 Provide interposing and motor control relays at local item of equipment or at associated MCC as applicable.
- .2 Provide control transformers and power supplies for system components requiring power supply that do not have integral control transformers.
- .3 Where point schematics and specifications indicate auxiliary contact provision, provide instrumentation, wiring, conduit, power supplies and services as to integrate these points into BAS.
- .4 Mount transformers in enclosures adjacent to equipment served.

3.5 Cleaning

- .1 Prior to handover to the Owner, remove all debris from and vacuum clean inside of control panels. Clean exterior surfaces of panels including GUI displays.

End of Section

BUILDING AUTOMATION ACTUATORS AND OPERATORS 25 30 13

1 GENERAL

1.1 Scope

- .1 Provide actuators and operators for building systems automation.
- .2 Provide actuators for operating control dampers provided as part of factory built air handling units.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 23 35 13 Terminal Units
 - .2 25 05 01 Building Automation Common Work Results
 - .3 25 30 23 Building Automation PICV and Energy Valves
 - .4 25 30 26 Building Automation Control Valves
 - .5 25 30 33 Building Automation Control Dampers
 - .6 25 35 26 Building Automation Compressed Air Supply

1.3 Definitions

- .1 The following definitions apply to this section.
 - .1 **Emergency equipment** means engine-driven electrical generators and diesel-engine driven fire pumps.
 - .2 **Terminal units** has the meaning in accordance with specification section 23 35 13.
 - .3 **Valves** means a water, glycol, or steam control valve in accordance with specification sections 25 30 23 or 25 30 26.

1.4 Applicable Codes and Standards

- .1 Product standards:
 - .1 CSA C22.2 No. 24 Temperature-Indicating and -Regulating Equipment
 - .2 CSA C22.2 No. 94.1 Enclosures for Electrical Equipment, Non-Environmental Considerations
 - .3 CAN/CSA-E60730-2-14 Automatic Electrical Controls - Part 2: Particular Requirements for Electric Actuators

2 PRODUCTS

2.1 General

- .1 Provide equipment which functions and meets detailed performance criteria when operating in the following minimum ambient condition ranges except where otherwise specified:
 - .1 ambient temperature:

Actuator Location	Service Temperature Range	Notes
Intake and exhaust air plenums (with enclosure heater)	-40°C to + 40°C (-40°F to 104°F)	(b)

Actuator Location	Service Temperature Range	Notes
Emergency equipment intake and exhaust air plenums	-40°C to + 50°C (-40°F to 122°F)	(b)

Notes:

- (a) *Unheated spaces to be treated as outdoor spaces.*
- (b) *Temperature ratings may be met by use of heated actuator enclosure.*

- .2 Ambient relative humidity 10% to 90% non -condensing
- .2 Components installed within motor controllers to be designed to operate with transient electrical fields occurring within these devices.

2.2 Damper Actuators - General Purpose Electric/Electronic

- .1 General purpose damper actuators for air handling unit dampers and plenum/duct mounted dampers.
- .2 Listed to CAN/CSA-E60730-2-14.
- .3 Control action:
 - .1 electric/electronic operation for two position (OPEN-CLOSE) and proportional-modulating operation as shown,
 - (a) floating-point modulation not acceptable.
- .4 Enclosure:
 - .1 Type 2 to CSA C22.2 No. 94.1, or NEMA 2, for indoor applications,
 - .2 Type 4 or 12 to CSA C22.2 No. 94.1 or NEMA 4 or 12, for outdoor use and where dampers are exposed to the airstream inside an air intake plenum.
 - .3 integral heating element for low temperature operation, 24 VAC.
- .5 Construction:
 - .1 gear type mechanism with spring-return to failed position, or electronically fail-safe,
 - .2 adjustable motor rotation direction,
 - .3 mechanical position indicator,
 - .4 directly mounted to damper shaft,
 - (a) remote mounted with connecting linkage and with fastening clamp assembly are permitted only where there is insufficient space for mounting actuator directly onto damper shaft.
 - .5 electronic overload or digital rotation sensing circuitry to protect damper operator through entire range of rotation,
 - .6 angle of rotation adjustable between 0° to 90°,
 - .7 input control signals:
 - (a) proportional-modulation service: 0 - 10V, 2-10 V, or 0 - 20mA,
 - (b) two position service: power On-Off
 - .8 feedback signals:
 - (a) proportional-modulating service: 2 - 10 V position feedback signal.
 - (b) two position service: two (2) x SPDT auxiliary switches for end stop position indication (open and closed), 3 A resistive @ 250 VAC
 - .9 power supply:
 - (a) modulating service: 24 VAC/VDC, 50/60 Hz.

(b) two position service: 120 VAC or 24 VAC.

.6 Selection:

- .1 sized and selected in accordance with manufacturer's instructions,
- .2 minimum torque rating for dampers: sufficient to operate damper to provide smooth response up to fan dead-head pressure plus 15%,

2.3 Damper Actuators - Specific Purpose Electric/Electronic for Emergency Equipment

- .1 Specific purpose damper actuators for ventilation dampers serving emergency equipment.
- .2 Type: as above for general purpose damper actuators and as follows.
- .3 Operating temperature: -40°C to + 50°C (-40°F to 122°F).
- .4 Control action:
 - .1 spring return to fail position on loss of power supply:
 - (a) combustion air dampers : fail-to-open
 - (b) ventilation inlet air dampers: fail-to-open
 - (c) recirculation air dampers: fail-to-close
 - (d) exhaust air dampers: fail-to-open.
 - .2 spring operating cycle time: <20 seconds at -20°C to 50°C (-4°F to 122°F)
- .5 Enclosure:
 - .1 integral heating element for low temperature operation, 24 VAC.
- .6 Operating control:
 - .1 combustion air dampers: two position open/closed
 - .2 all other dampers: proportional-modulating with 0-10VDC or 4-20 mA input signal

Standard of Acceptance

- Belimo - EFB24-S N4/EFB120-S N4 series for two position dampers
- Belimo - EFB24-SR-S N4 series for modulating dampers

2.4 Damper Actuators - Specific Purpose Electronic for Terminal Units

- .1 Specific purpose damper actuators for terminal units.
- .2 Listed to CAN/CSA-E60730-2-14.
- .3 Control action:
 - .1 proportional-modulating type control,
- .4 Enclosure:
 - .1 Type 2 to CSA C22.2 No. 94.1, or NEMA 2, for indoor applications,
- .5 Construction:
 - .1 gear drive, direct coupled type operators mounted to terminal box damper shaft with universal V-bolt clamp,
 - .2 selectable / reversible rotation direction,
 - .3 input type and range as suitable for interfacing to output of terminal unit controller,
 - .4 angle of rotation adjustable between 0 to 90° with adjustable mechanical limit stops,
 - .5 damper position indication visible without cover removal,

- .6 manual override to set damper position without power applied to actuator,
 - .7 electronic stall protection,
 - .8 actuator running time of not more than 100 seconds,
 - .9 failure mode on loss of power to the actuator:
 - (a) non-smoke control or smoke venting applications: fail in last position,
 - .10 power supply: 24 VAC/VDC, 50/60 Hz.
- .6 Selection:
- .1 sized and selected in accordance with terminal unit manufacturer's requirements.

2.5 Valve Actuators - General Purpose Electric/Electronic

- .1 General purpose valve actuators for liquid and steam control valves for ball valves and globe valves.
- .2 Listed to CAN/CSA-E60730-2-14 or CSA C22.2 No. 24.
- .3 Control action:
 - .1 electric/electronic operation for two position (OPEN-CLOSE) and proportional-modulating operation as shown,
 - (a) floating-point modulation not acceptable,
 - .2 rotary or linear acting to suit valve action.
- .4 Enclosure:
 - .1 Type 2 to CSA C22.2 No. 94.1, or NEMA 2, for indoor applications,
 - .2 Type 4 or 12 to CSA C22.2 No. 94.1 or NEMA 4 or 12, for outdoor use and where dampers are exposed to the airstream inside an air intake plenum.
- .5 Construction:
 - .1 high alloy gear type mechanism with spring-return to failed position, or electronically fail-safe,
 - .2 adjustable motor rotation direction,
 - .3 mechanical position indicator,
 - .4 directly mounted to valve shaft, or with linear linkage drive assembly,
 - .5 compatible for installation on ISO 5211 mounting pad,
 - .6 electronic overload or digital rotation sensing circuitry to protect actuator through entire range of rotation,
 - .7 running time: < 160 seconds, independent of load,
 - .8 input control signals:
 - (a) proportional-modulation service: 0 - 10V, 2-10 V, or 0 - 20mA,
 - (b) two position service: power On-Off
 - .9 feedback signals:
 - (a) proportional-modulating service: 2 - 10 V position feedback signal.
 - (b) two position service: two (2) x SPDT auxiliary switches for end stop position indication (open and closed), 3 A resistive @ 250 VAC
 - .10 power supply:
 - (a) modulating service: 24 VAC/VDC, 50/60 Hz.
 - (b) two position service: 120 VAC or 24 VAC.

- .6 Selection:
 - .1 sized and selected in accordance with valve manufacturer's instructions,
 - .2 minimum torque ratings for valves: sufficient to suit valve opening or closing requirements against a fluid differential pressure on:
 - (a) closed loop piping system of not less than 280 kPa (40 psig), plus 15%.
 - (b) open loop piping systems of not less than 700 kPa (100 psig), plus 15%.
 - .3 actuators may be supplied as multiple units to achieve required torque.

2.6 Valve Actuators - Specific Purpose Electric/Electronic for Large Valves

- .1 Specific purpose valve actuators for large rotary operation butterfly valves with high torque requirements.
- .2 Listed to CAN/CSA-E60730-2-14 or CSA C22.2 No. 24.
- .3 Ambient temperature: -40°C to + 40°C (-40°F to 104°F),
- .4 Control action:
 - .1 electric/electronic operation for two position (OPEN-CLOSE) and proportional-modulating operation as shown,
 - (a) floating-point modulation not acceptable,
- .5 Enclosure:
 - .1 die-cast aluminum alloy,
 - .2 Type 4X to CSA C22.2 No. 94.1 or NEMA 4 or 12.
 - .3 integral heating element for internal humidity control and low temperature operation, same voltage as actuator motor.
- .6 Construction:
 - .1 single or dual-winding bidirectional motor driven actuator,
 - .2 spring-return or electronically fail-safe to failed position,
 - .3 self-locking high alloy steel gear type mechanism,
 - .4 electronic interface control board, solid state drive,
 - .5 span and zero travel adjustment,
 - .6 adjustable motor rotation direction,
 - .7 mechanical position indicator,
 - .8 directly mounted to valve shaft,
 - .9 compatible for installation on ISO 5211 mounting pad,
 - .10 thermal or electronic overload to protect actuator through entire range of rotation,
 - .11 running time: < 60 seconds, independent of load,
 - .12 duty cycle:
 - (a) On/Off valves: minimum 30%
 - (b) Proportional valves: minimum 75%
 - .13 declutching handwheel override,
 - .14 valve position indicator,
 - .15 input control signals:
 - (a) 0 - 10VDC or 0 - 20mA for proportional-modulation control,

- (b) power On-Off for two position service,
- .16 feedback signals:
 - (a) proportional-modulating service: 2 - 10 V position feedback signal.
 - (b) two position service: two (2) x SPDT auxiliary switches for end stop position indication (open and closed), 3 A resistive @ 250 VAC
- .17 power supply:
 - (a) modulating service: 24 VAC/VDC or 120 VAC, 50/60 Hz.
 - (b) two position service: 120 VAC or 24 VAC, 50/60 Hz.
- .7 Selection:
 - .1 sized and selected in accordance with valve manufacturer's instructions,
 - .2 minimum torque ratings for valves: sufficient to suit valve opening or closing requirements against a fluid differential pressure on:
 - (a) closed loop piping system of not less than 280 kPa (40 psig), plus 15%.
 - (b) open loop piping systems of not less than 700 kPa (100 psig), plus 15%.

3 EXECUTION

3.1 Application

- .1 Use electric/electronic actuators for damper and actuators.

3.2 Installation

- .1 General:
 - .1 Mount actuators and provide adapters according to manufacturer's recommendations.
- .2 Electric and Electronic Damper Actuators:
 - .1 Mount damper actuators directly on damper shaft or jackshaft; linkages may be used only where there is insufficient space to install and remove the actuator directly on the damper shaft.
 - .2 Mount valve actuator directly on shaft or with linkages according to manufacturer's recommendations.
 - .3 For low-leakage dampers with seals, mount actuator with minimum 5° travel available for damper seal tightening.
 - .4 To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close damper, then tighten linkage.
 - .5 Provide mounting hardware and linkages for actuator installation.

3.3 Power and Control Wiring

- .1 Provide power and control wiring to each electric/electronic operator in accordance with the manufacturer requirements and in accordance with specification section 25 05 13.
- .2 Where required by actuator manufacturer instructions for parallel actuator installation, provide power isolation relays to isolate forward and reverse motor windings.

3.4 Compressed Air

- .1 Provide compressed air service to each pneumatic actuator in accordance with specification section 25 35 26.
- .2 Provide a manual isolation valve for each actuator.

3.5 Testing

- .1 Test each actuator by applying appropriate control signal and inspect for smooth operation while operating under normal load conditions.
- .2 Alternatively, where there are more than ten (10) actuators serving the same application, a timed cycle test may be used for all valves in each application:
 - .1 randomly select ten samples for each application, and measure open and closed timing of the sample valve set, and then estimate the average time of the set.
 - .2 Using the BAS, cycle open and then closed and record the time duration for each half cycle for each actuator. Test acceptance criteria is where each damper opens and closes within 90% of the tested average time.]

End of Section

BUILDING AUTOMATION INSTRUMENTATION

25 30 16.13

1 GENERAL

1.1 Scope

- .1 Provide measurement switches, sensors, and transmitter instrumentation for building automation.

1.2 Related Sections

- .1 Without limiting the scope of work or applicability of other specification sections, the work under this section directly integrates with or refers to the following specification sections:
 - .1 20 01 13 Definitions and Abbreviations – Mechanical
 - .2 20 05 26 Pipeline Hot-Tapping and Line Stopping
 - .3 23 11 33 Facility Fuel-oil Controls
 - .4 25 05 01 Building Automation Common Work Results

1.3 Definitions

- .1 The following definitions apply to this section.
 - .1 **Finished rooms/spaces** means a room or space that is not a service room.
 - .2 **Instrumentation** means products covered by this specification section.
 - .3 **Service rooms** has the meaning as defined in specification section 20 01 13.

1.4 Applicable Codes and Standards

- .1 Installation codes and standards:
 - .1 CSA B51 Boilers, Pressure Vessels, and Pressure Piping Code
- .2 Product standards:
 - .1 CSA C22.2 No. 94.1 Enclosures for Electrical Equipment, Non-Environmental Considerations.

1.5 Design Criteria

- .1 Pressure rating of instrumentation connected to pressure piping to be equal to or greater than the design pressure at the design temperature of the associated piping system.

1.6 Submittals

- .1 Submit manufacturer product data sheets in accordance with the requirements of Division 01.
- .2 Include Canadian Registration Numbers for applicable products.

1.7 Quality Control

- .1 Products that are in contact with the process fluid of a piping system that is subject to registration under applicable boiler and pressure vessel legislation are to have Canadian Registration Numbers in accordance with CSA B51.

2 PRODUCTS

2.1 General

- .1 Provide equipment which functions and meets detailed performance criteria when operating in the following minimum ambient condition ranges except where otherwise specified:

- .1 ambient temperature:

Instrument Location	Service Temperature Range	Notes
Intake and exhaust air plenums (with enclosure heater)	-40°C to + 40°C (-40°F to 104°F)]	(b)

Notes:

- (a) *Unheated spaces to be treated as outdoor spaces.*
(b) *Temperature ratings may be met by use of heated actuator enclosure.*

- .2 Ambient relative humidity 10% to 90% non -condensing
- .2 Components installed within motor controllers to be designed to operate with transient electrical fields occurring within these devices.

2.2 Temperature Switches

- .1 Low temperature limit temperature switch:
- .1 6m (20 ft) of sensing capillary sensitive to freezing air over any 400mm (15 in) section,
 - .2 automatic reset with fixed differential temperature,
 - .3 installed in multiples with one unit serving not more than 5 m² (40 sq. ft) of duct area.
 - .4 single pole double throw (SPDT) contacts,
 - .5 operating temperature range: 1.7°C to 7.2°C (35°F to 45°F),
 - .6 adjustable set point within specified range,
 - .7 protective enclosure.
- .2 Temperature switches:
- .1 sensing element of liquid, vapour or bimetallic type,
 - .2 adjustable set-point and differential of at least 0.22°C to 1.7°C (0.4°F to 3.0°F),
 - .3 snap action type rated at 120 volts, 15 amps or 24 volts DC,
 - .4 automatic in-operation and automatically reset when condition returns to normal,
 - .5 type:
 - (a) suitable for wall mounting on standard electrical box with protective guard, or suitable for insertion into air ducts with insertion length of 450 mm (18 in), or
 - (b) thermowell type with compression fitting for 20 mm (0.8 in) NPT well, mounting length of 100 mm (4 in), and immersion wells of type 316 stainless steel, or
- .3 Strap-on-type temperature switch with helical screw stainless steel clamps:
- .1 operating temperature range: 23°C to 57°C (75°F to 138°F) [38°C to 71°C (100°F to 160°F)],
 - .2 adjustable set point within specified range,
 - .3 single pole double throw (SPDT) contacts,
 - .4 protective enclosure.

2.3 Temperature Sensors – General Requirements

- .1 Sensor element types:
- .1 Resistance temperature device (RTD) of precision thin film platinum element type;
 - (a) linear characteristics over sensor range,

- (b) reference resistance: 1000 ohm, ± 20 ohms (2%) at 0°C (32°F),
- (c) temperature resistance coefficient: $0.0385 \text{ ohms/ohm/}^{\circ}\text{C}$ ($0.0212 \text{ ohms/ohm/}^{\circ}\text{F}$),
- (d) accuracy: $\pm 0.36^{\circ}\text{C}$ at 21°C ($\pm 0.65^{\circ}\text{F}$ at 70°F) accuracy to Din IEC 751
- .2 Resistance temperature device (RTD) of precision thin film nickel element type;
 - (a) linear characteristics over sensor range,
 - (b) reference resistance: 1000 ohm, ± 20 ohms (2%) at 21°C (70°F),
 - (c) temperature resistance coefficient: $5.4 \text{ ohm/}^{\circ}\text{C}$ ($3.0 \text{ ohm/}^{\circ}\text{F}$)
 - (d) accuracy: $\pm 0.18^{\circ}\text{C}$ at 21°C ($\pm 0.34^{\circ}\text{F}$ at 70°F)
- .3 Thermistor;
 - (a) non-linear negative temperature coefficient of resistance,
 - (b) reference resistance: 10,000 ohms at 25°C (77°F),
 - (c) accuracy: curve matched to $\pm 0.2^{\circ}\text{C}$ ($\pm 0.36^{\circ}\text{F}$) over 0°C to 70°C (32°F to 158°F),
 - (d) long term stability: 0.025°C (0.045°F) drift per year
- .2 Sensor construction general requirements:
 - .1 2 integral anchored lead wires,
 - .2 waterproof sensor to sheath seal,
 - .3 strain minimizing construction,
 - .4 standard conduit box termination with cover,
 - .5 pig-tail wire leads with wire nuts or screwed terminal connector block,
 - .6 factory calibrated and capable of end to end (sensing element to BAS) accuracy of $\pm 0.25^{\circ}\text{C}$ ($\pm 0.5^{\circ}\text{F}$) over full range of measured variable,
 - .7 transducing circuit to convert output to signal compatible with equipment controller.

2.4 Temperature Sensors – General Purpose Space Sensors

- .1 For general use space/room temperature measurement.
- .2 General purpose space temperature sensors – no display (type TS):
 - .1 hard-wired sensor only, no display,
 - .2 sensor operating temperature range: 4°C to 60°C (40°F to 140°F),
 - .3 enclosure: surface mounted, blank (no interface) plastic mono-chromatic guard with surface mounting plate and wall anchors,
 - .4 guard secured to mounting plate by screws or snaps.
- .3 Space temperature sensors with display (type TSD):
 - .1 BAS network sensor with user interface display,
 - .2 user interface:
 - (a) LCD display, for measured values and setpoint values,
 - (b) temperature display resolution: 0.1°C (0.2°F)
 - (c) physical or virtual buttons for user adjustment of setpoints and selection of measured values.
 - .3 Programmable user input selection (buttons):
 - (a) physical or touchscreen buttons,
 - (b) sensor reading selection,
 - (c) sensor setpoint adjustment (temperature only),

- .4 ambient relative humidity: 5 to 95% RH non condensing,
- .5 temperature sensor: 10 kOhm,
- .6 temperature sensor accuracy: $\pm 0.2^{\circ}\text{C}$ ($\pm 0.36^{\circ}\text{F}$)
- .7 adjustable setpoint range (programmed default is 20°C to 25°C (68°F to 78°F)),
- .8 BAS field-bus connector to allow local access to sensor and BAS controller and network,
- .9 temperature setpoint remotely resettable from BAS,
- .10 minimum/maximum limit set point values adjustable locally and remote from BAS,
- .11 surface mounted plastic mono-chromatic guard with surface mounting plate and wall anchors,
- .12 network connection: BACnet MSTP.
- .13 guard secured to mounting plate by screws or snaps.
- .4 Space temperature sensors with display and additional features (type TSD/x):
 - .1 Type TSD space temperature sensors with the following additional sensor elements, singly and in combination.
 - .2 Relative humidity sensor (type TSD/H)
 - (a) accuracy: $\pm 3\%$ RH of reading,
 - .3 Carbon Dioxide sensor (type TSD/C):
 - (a) dual beam, self-calibrating NDIR detection,
 - (b) range: 0 – 2000 ppm
 - (c) accuracy: ± 50 ppm + 2% of measured value at 25°C (77°F)
 - (d) stability: 20 ppm/year
 - .4 Occupancy sensor (type TSD/O):
 - (a) passive infrared motion sensor,
 - (b) range: 5 m (16 ft) minimum,
 - (c) sweep coverage: 100° horizontal.
- .5 Special purpose space temperature sensors - Secure Areas (type TSS):
 - .1 hard-wired sensor only, no display,
 - .2 sensor operating temperature range: 4°C to 60°C (40°F to 140°F),
 - .3 enclosure:
 - (a) stainless steel flat plate surface type with sensor epoxy-bonded to back of cover plate,
 - (b) secured to standard electrical junction box with Torx head fasteners with center-pin.

2.5 Fuel Oil Detection Devices

- .1 Refer to Specification section 23 11 33.

2.6 Electric Power Instrumentation

- .1 Current sensing relays:
 - .1 metering transformer ranged to match load being metered,
 - .2 plug in base and shorting shunt to protect current transformer when relay is removed from socket,
 - .3 current transformer for single or three phase metering connected into single relay,
 - .4 adjustable latch level, adjustable delay on latch and minimum differential of 10% of latch setting between latch level and release level,

- .5 discrimination between phases in three phase applications to allow worst case selection,
- .6 mounted in motor starter enclosure and fed from starter control transformer,
- .7 relay contacts capable of handling 10 amps at 240 volts.
- .2 Current switches:
 - .1 self-powered, solid-state type with adjustable trip current,
 - .2 integral current transformers and relays to indicate motor status,
 - .3 SPDT output relay suitable for use as digital input to the BAS,
 - .4 field adjustable output relay trip setting, over 0-100% of range. Deadband adjustment to maximum of 10% of range,
 - .5 integral zero-leakage LED's indicating sensor power and switch status,
 - .6 long term setting drift of current transformer and relay combination not more than 5% full range over 6 months,
 - .7 over current and over voltage protection for current transformer and relay,
 - .8 operating temperature range; -10°C to 50°C (14°F to 122°F),
 - .9 operating humidity range; 5% to 90% RH non condensing.
- .3 Current transducer:
 - .1 output signal proportional to measured line current,
 - .2 output signal in one of following ranges; 4-20 mA, 0-5 Vdc or 0-10 Vdc
- .4 AC Current Transmitters:
 - .1 self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two-wire output,
 - .2 full-scale unit ranges of 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment,
 - .3 accuracy: $\pm 1\%$ full-scale at 500 ohm maximum burden.
 - .4 UL/CSA listed and meet or exceed ANSI/ISSA 50.1 requirements.
- .5 AC Voltage Transmitters:
 - .1 self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.
 - .2 adjustable full-scale unit ranges; 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400-600 Vac.
 - .3 Accuracy: $\pm 1\%$ full-scale at 500 ohm maximum burden.
 - .4 UL/CSA listed, 600 Vac rated and conforming to ANSI/ISSA 50.1.
- .6 Power Monitors:
 - .1 three-phase type with three-phase disconnect and shorting switch assembly,
 - .2 UL listed voltage transformers, and
 - .3 UL listed split-core current transformers.
 - .4 selectable output either rate pulse for kWh reading or 4-20 mA for kW reading.
 - .5 maximum error of $\pm 2\%$ at 1.0 power factor or $\pm 2.5\%$ at 0.5 power factor.

3 EXECUTION

3.1 Instrumentation Installation – General Requirements

- .1 Mount instrumentation;

- .1 in clean areas wherever possible,
- .2 to be accessible to allow for replacement and servicing without interfering with access for adjacent equipment and personnel traffic in surrounding space,
- .2 Provide access doors where instrumentation is concealed behind solid surfaces.
- .3 In finished spaces and rooms, install room instrumentation on concealed junction boxes;
 - .1 fully recessed in gypsum board, wood, or similar construction,
 - .2 fully recessed in new concrete block construction, with conduit run block void spaces,
 - .3 fully recessed in new poured concrete construction, with conduit and outlet box roughed-in before concrete pour.
 - .4 surface mounted with exposed conduit on existing concrete block walls and existing poured concrete walls.
- .4 In service rooms, loading docks, and parking garages, install room instrumentation on surface mounted junction boxes with exposed surface-mounted conduit.
- .5 Rigidly support field mounted instrumentation on pipe stands or channel brackets.
- .6 Rigidly support duct mounted instrumentation to side of duct, in a location that will allow full removal of the instrumentation including duct probes.
- .7 Orient instrumentation sensing elements to correctly sense measured variable and to be isolated from vibrations and environmental conditions that could affect measurement or calibration.
- .8 Identify each cable and wire at every termination point.
- .9 Air seal wires attached to sensors at entry into junction box.

3.2 Power and Control Wiring

- .1 Provide power and control wiring to each instrument in accordance with the manufacturer requirements and in accordance with specification section 25 05 13.

3.3 Temperature and Humidity Instrumentation

- .1 Averaging duct temperature sensors:
 - .1 Use averaging sensors in the following locations:
 - (a) mixing plenums in front of the first downstream component,
 - (b) ducts with cross sectional area greater than 1.5 m² (16 sq. ft),
 - (c) downstream of the supply air leaving side of a thermal heat wheel, located approximately 200 mm (8 in) from leaving face of wheel.
 - .2 Install averaging sensors in serpentine manner vertically across duct. Support each bend with capillary clip. Provide sensor element length of 3 m per m² (1 ft per ft²) of plenum/duct cross sectional area.
- .2 Low-temperature switch:
 - .1 Install mixing plenum low-limit temperature switches in serpentine manner horizontally across duct. Support each bend with capillary clip. Provide sensor element length of 3 m per 1 m² (1 ft per 1 sq. ft) of coil area.
- .3 Pipe mounted temperature sensors:
 - .1 Thermowells to be installed by the trade contractor under the applicable Division of the Work for each piping system. Supply the thermowells to the trade contractor and coordinate with them as to installation location and orientation.

- .2 For existing steel piping systems, coordinate with the piping trade contractor to install the thermowells by hot-tapping in accordance with specification section 20 05 26 except where the Owner permits draining of the piping system.
- .3 Install pipe-mounted liquid temperature sensors in thermowells with heat-conducting material.
- .4 Orientate thermowells and transmitters to be located from the side of the pipe or top of pipe for horizontal piping.
- .5 Cut and recover piping insulation to 300 mm (12 in) either side for installation of strap-on temperature sensors. Provide removable insulation box over sensor and patch insulation to match existing.
- .4 Space temperature and humidity sensors:
 - .1 Mount space temperature or combination temperature/humidity sensors / transmitters at 1200 mm (4 ft) above finished floor.
- .5 Humidity sensors:
 - .1 Locate humidity sensors adjacent to temperature sensors except as follows.
 - .2 Locate humidity sensors in the supply air downstream of a thermal heat wheel in a location that represents the average relative humidity when hand-measured at the upstream face of the next component in the air handling unit.
- .6 Outdoor temperature and humidity transmitters:
 - .1 Install outdoor air combination humidity and temperature transmitters on north facing wall, in a location readily accessible for maintenance access.

3.4 Space Temperature Sensor Selection

- .1 Select general purpose space temperature sensor types in accordance with the following table unless otherwise shown on drawings or in control sequences:

Space Types	Temperature Sensor Type
Service rooms, corridors, data centers, distributed electrical and data rooms, janitorial rooms, loading docks, storage rooms	TS
All other spaces not identified above	TS [TSD]

3.5 Safety Controls

- .1 Unless otherwise shown, safety devices including smoke detectors, freezestats, low- and high-pressure cut-offs, and other safety switches and controls, are to be hard-wired to de-energize equipment as described in Sequence of Operation.
- .2 Provide contacts that allow BAS software to monitor safety control status.

End of Section

CS01 – Plant Space Heating

Reference: M-102

Applicable
Equipment: Detail 1: Unit Heater UH-1, Room Temperature Sensor T-1
Detail 2: Existing Unit Heater, Room Temperature Sensor T-1
Detail 3: Unit Heater UH-2, Room Temperature Sensor T-1

System
Start: Continuous 24/7 Operation.

Normal
Operation: If Room Temperature Sensors T-1 < 10°C(adjustable), enable applicable unit heater.
If Room Temperature Sensors T-1 > 20°C(adjustable), disable applicable unit heater.

System
Stop: Continuous 24/7 Operation.

Schedule: Continuous 24/7 Operation.

CS02 – Plant Space Cooling

Reference: M-102

Applicable
Equipment: Detail 1: Exhaust Fan EF-3, Motorized Fire Damper D-3, Room Temperature Sensor T-1
Detail 2: Exhaust Fan EF-2, Motorized Fire Damper D-2, Room Temperature Sensor T-1
Detail 3: Exhaust Fan EF-1, Motorized Fire Damper D-1, Room Temperature Sensor T-1

System
Start: Continuous 24/7 Operation.

Normal
Operation: If Room Temperature Sensor T-1 > 25°C(adjustable) or operator manually enables system, open applicable motorized fire damper, enable applicable exhaust fan and VFD to modulate and maintain room temperature of 25°C(adjustable).

If applicable exhaust fan VFD at 10% speed(adjustable) and Room Temperature T-1 < 20°C(adjustable) for 10 minutes, disable applicable exhaust fan and close applicable motorized damper.

System
Stop: Continuous 24/7 Operation.
Motorized Fire Dampers are equipped with electric resettable heat detection switches which will override operation in the case of applicable temperatures being reached.

Schedule: Continuous 24/7 Operation.