NAHANI WAY PS
AHU REPLACEMENT

MECHANICAL/ELECTRICAL SPECIFICATIONS

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PART 1 - GENERAL

1.1. **GENERAL**

1.1.1. This specification defines the general requirements and procedures for submittals. A submittal is information submitted for the Consultant's review to establish compliance with the contract documents.

1.1.2. Detailed submittal requirements are found in the technical sections of the contract specifications. The Consultant may request submittals in addition to those specified when deemed necessary to adequately describe the work covered in the respective technical specifications at no additional cost to the Client.

1.1.3. Consultant review of a submittal does not relieve the Contractor of the responsibility for compliance with the contract documents or any error which may exist. The Contractor is responsible for fully complying with all contract requirements and the satisfactory construction of all work, including the need to check, confirm, and coordinate the work of all subcontractors for the project. Non-compliant material incorporated in the work will be removed and replaced at the Contractor's expense.

1.2. **DEFINITIONS**

1.2.1. <u>Shop Drawings:</u> Drawings, diagrams, and schedules specifically prepared to illustrate some portion of the work. Drawings prepared by or for the Contractor to show how multiple systems and interdisciplinary work will be integrated and coordinated.

1.2.2. <u>Product Data:</u> Catalog cuts, illustrations, schedules, diagrams, performance charts, instructions, and brochures, which describe and illustrate size, physical appearance, and other characteristics of materials, systems, or equipment for some portion of the work. Samples of warranty language when the contract requires extended product warranties.

1.2.3. <u>Samples:</u> Physical examples of materials, equipment, or workmanship that illustrate functional and aesthetic characteristics of a material or product and establish standards by which the work can be judged. Color samples from the manufacturer's standard line (or custom color samples if specified) to be used in selecting or approving colors for the project. Field samples and mock-ups constructed to establish standards by which the ensuing work can be judged.

1.2.4. <u>Design Data:</u> Calculations, mix designs, analyses, or other data pertaining to a part of work.

1.2.5. <u>Test Reports:</u> Report which includes findings of a test required to be performed by the Contractor on an actual portion of the work. Report which includes finding of a test made at the job site or on sample taken from the job site, on portion of work during or after installation.

1.2.6. Certificates: Document required of Contractor, or of a manufacturer, supplier, installer, or subcontractor through Contractor. The purpose is to document procedures, acceptability of methods, or personnel qualifications for a portion of the work.

1.2.7. Manufacturer's Instructions: Pre-printed material describing installation of a product, system, or material, including special notices and MSDS concerning impedances, hazards, and safety precautions.

1.2.8. Manufacturer's Field Reports: Documentation of the testing and verification actions taken by manufacturer's representative at the job site on a portion of the work, during or after installation, to confirm compliance with manufacturer's standards or instructions. The documentation must indicate whether the material, product, or system has passed or failed the test.

1.2.9. Operation and Maintenance Data: Manufacturer data that is required to operate, maintain, troubleshoot, and repair equipment, including manufacturer's help, parts list, and product line documentation. This data shall be incorporated in an operations and maintenance manual.

1.2.10. Closeout Submittals: Documentation necessary to properly close out a construction contract. For example, Operation and Maintenance manuals, as-built drawings. Also, submittal requirements necessary to properly close out a phase of construction on a multi-phase contract.

1.3. **SUBMITTAL REGISTER**

1.3.1. The submittal registers prepared by the Contractor will list items of equipment and materials for which submittals are required by the specifications. This list may not be all inclusive and additional submittals may be required by the specifications. The Contractor is not relieved from supplying submittals required by the contract documents but which have been omitted from the submittal register.

1.3.2. The submittal register will serve as a scheduling document for submittals and will be used to control submittal actions throughout the contract period.

1.3.3. The Contractor shall provide the initial submittal register in electronic format. Thereafter, the Contractor shall track all submittals by maintaining a complete list, including completion of all data columns, including dates on which submittals are received and returned by the Consultant.

1.3.4. The Contractor shall update the submittal register as submittal actions occur and maintain the submittal register at the project site until final acceptance of all work by Client representative.

1.3.5. The Contractor shall submit formal monthly updates to the submittal register in electronic format. Each monthly update shall document actual submission and approval dates for each submittal.

1.4. **SUBMISSION PROCEDURES – SHOP DRAWINGS**

1.4.1. The Contractor shall review all shop drawings before submittal to the Consultant. This review implies that the Contractor has determined or will determine measurements and has verified or will verify on the site, the construction criteria, materials, catalog numbers and similar data, and that he has reviewed and coordinated each shop drawing with the Contractual Documents and Specifications.

1.4.2. Submit shop drawings to the Consultant within reasonable delays and in a logical sequence in compliance with the construction schedule.

1.4.3. Submit for approval, all of the items specifically mentioned under the separate sections of the specification, with information sufficient to evidence full compliance with contract requirements. Materials, fabricated articles and the like to be installed in permanent work shall equal those of approved submittals.

1.4.4. Submission Preparation

1.4.4.1. Each submittal is to be complete and in sufficient detail to allow ready determination of compliance with contract requirements.

1.4.4.2. Collect required data for each specific material, product, unit of work, or system into a single submittal. Prominently mark choices, options, and portions applicable to the submittal. Partial submittals will not be accepted for expedition of construction effort. Submittal will be returned without review if incomplete.

1.4.4.3. All irrelevant or unnecessary data shall be removed from the submittal to facilitate accuracy and timely processing. Submittals that contain the excessive amount of irrelevant or unnecessary data will be returned with review.

1.4.4.4. Forward submittals in sufficient time to permit proper consideration and approval action by the Consultant; minimum time required for Consultant's review shall be 10 business days or longer, if the submitted equipment does not match the standard of acceptance and additional time is required for the evaluation.

1.4.4.5. Schedule submission to assure adequate lead time for procurement of contract required items. Delays attributable to untimely and rejected submittals will not serve as a basis for extending contract time for completion.

1.4.4.6. The Consultant's review consists in reviewing the conformity of shop drawings with the contract documents for recommendation to the Client or Owner. The Consultant is not liable for any responsibility for dimensions, details nor quantities.

1.4.4.7. After an item has been reviewed by the Consultant no change in brand or make will be permitted unless:

1.4.4.7.1. Satisfactory written evidence is presented to, and positively reviewed by the Consultant, that manufacturer cannot make scheduled delivery of approved item or;

1.4.4.7.2. Item delivered has been rejected and substitution of a suitable item is an urgent necessity or;

1.4.4.7.3. Other conditions become apparent which indicates approval of such substitute item to be in best interest of the Client.

1.4.5. If the Contractor installs equipment or material for which he has not submitted shop drawings for verification, the Consultant may, if the equipment or material is not installed in accordance with plans and specifications, require the equipment or material to be removed and replaced by a compliant product at no additional cost to the Client.

1.4.6. Shop drawings relating to products, special design systems or installations, custom equipment or similar to, all of which are not standard or catalogued products, will be considered engineering documents and as such, shall be authenticated by their author engineer. Authentication shall be in conformity with current Province of Ontario Laws and By-Laws. As an example, not limited to, shop drawings of a custom air-handling unit are covered by the present article and as such, constitute engineering documents that will require an authentication by their author engineer.

1.4.7. When shop drawings are resubmitted, indicate in writing all revisions other than those required by the Consultant.

1.4.8. Submit for review by the Consultant, within reasonable delays of the contract award, the complete set of shop drawings required. Faxed shop drawings are not accepted.

1.4.9. Shop drawings shall be submitted in electronic format. The following rules must be followed entirely:

1.4.9.1. The identification form must be included;

1.4.9.2. A shop drawing identification sheet hereby mentioned shall be included;

1.4.9.3. A single file in PDF format for each shop drawing shall be submitted. In the case where more than one document constitutes the drawing, they must all be incorporated into a single file;

1.4.9.4. Printing parameters of the drawings must be incorporated in the file to assure a scaled printing on a commercial printer;

1.4.9.5. The file must be of an excellent graphical quality;

1.4.9.6. Transmission of the shop drawings must follow the path of communication established for the project;

1.4.9.7. A transmittal sheet shall be attached to submitted drawings.

1.4.10. Shop drawings not following these directives will be returned to the Contractor with a "Rejected" recommendation.

1.4.11. Each shop drawing shall be presented with an identification form. The shop drawing identification sheet shall include as a minimum the following information:

1.4.11.1. Client's name
1.4.11.2. Project's name
1.4.11.3. Consultant’s name
1.4.11.4. Contractor's name
1.4.11.5. Name of sender
1.4.11.6. Sub contractor's name
1.4.11.7. Supplier's name
1.4.11.8. Specialty
1.4.11.9. Description
1.4.11.10. Specifications section number and article number
1.4.11.11. Revision number
1.4.11.12. Blank space for stamp of Conformity Review.

1.4.12. Submit all shop drawings in English, certified for construction by the manufacturer.

1.4.13. Drawings for non-standard articles or materials shall be produced, especially for the project.

1.4.14. Shop drawings shall include:

1.4.14.1. Construction details, dimensions, weights and equipment or material characteristics together with supplementary information such as bulletins, illustrations and exploded views of constituting parts.
1.4.14.2. Graphs, curves, capacities, efficiency and other technical data submitted by the manufacturer or requested by the Engineer concerning the operation of the equipment.
1.4.14.3. Wiring diagrams, single line diagrams, principle diagrams, control diagrams, operating sequences and all interconnections with other systems when required.
1.4.14.4. Flow diagrams for air, water, oil, fuel, etc. if applicable.
1.4.14.5. Marketing folders or publicity brochures will not be accepted.

1.4.15. Shop drawings will be returned with one or two of the following mentions: "Reviewed", "Modify and resubmit", "Modify as noted", "Rejected".

1.4.16. Drawings stamped "Reviewed" will not be further commented. Drawings comply with contractual documents.

1.4.17. Drawings stamped "Rejected" shall be done over again and resubmitted for approval. Drawings do not comply with contractual documents.

1.4.18. Drawings stamped "Modify as noted" shall not be resubmitted. Conditionally to the corrections indicated, drawings comply with contractual documents.

1.4.19. Drawings stamped "Modify and resubmit" shall be resubmitted, in part or in whole, as indicated for further examination. Drawings do not comply with contractual documents.

1.4.20. Drawings stamped "Modify as noted" and "Modify and resubmit" shall be resubmitted in part or in whole, as indicated, for further examination. Conditionally to the corrections indicated, drawings comply with contractual documents.

1.4.21. The Consultant’s examination of the shop drawings does not relieve the Contractor from supplying equipment conforming to current standards and bylaws and to the requirements of this specification.

1.4.22. Any equipment, which is manufactured without the Engineer's prior examination, may be rejected. Assume all costs inherent to such a rejection.

1.5. **SUBMISSION SCHEDULING**

1.5.1. Submittals are to be scheduled, submitted, reviewed, and returned to the Contractor prior to the acquisition of the material or equipment. All comments marked by the Consultant shall be incorporated in the item for which a submission was made. No material or equipment shall be acquisitioned if the respective submissions was reviewed and rejected by the Consultant

1.5.2. Coordinate scheduling, sequencing, preparing, and processing of submittals with performance of work so that work will not be delayed by submittal processing. Allow time for potential re-submittal.

1.5.3. No delay costs or time extensions will be allowed for time lost in late submittals or re-submittals.

1.5.4. All submittals are required to be reviewed prior to the start of the specified work activity.

1.6. **AS-BUILT DOCUMENTATION**

1.6.1. During progress of the Work, Contractor shall maintain a set of Record Documents and Shop Drawings at the Site. Contractor must update these documents weekly, at a minimum, with mark-ups of actual installations that vary from the Work as originally shown. Contractor shall include all Drawings issued as addenda, clarifications, or Change Orders.

1.6.2. Contractor shall maintain and have available for review in conjunction with project progress meetings, a current set of the marked-up Record Documents and Shop Drawings. Availability for review and acceptability of both the format and content are prerequisites for certification and acceptance of the Application for Payment by the Client and Consultant.

1.6.3. Contractor must protect marked-up Record Documents from deterioration and loss in a secure location.

1.7. **RECORD DOCUMENTS EDIT LOG**

1.7.1. During progress of the Work, Contractor shall update the Record Documents Edit Log each time updates or edits are made, or information is added. The Record Documents Edit Log shall be submitted to the Consultant and Client prior to submitting each monthly Application for Payment.

1.7.2. The Record Documents Edit Log shall include the following information as a minimum:

1.7.2.1. Date Edited.
1.7.2.2. Name and Company of Person Making Edit.
1.7.2.3. Edit Type: RFI, Change Order/Request for Proposal, Field Change, Red Line,
1.7.2.4. Supplemental Document, and Revision/ASI.
1.7.2.5. Reference: name and number of the source document if applicable, such as Change Order or RFI number.
1.7.2.6. Sheet(s) Edited.

1.8. **AS-BUILT DRAWINGS**

1.8.1. Contractor must mark-up Drawings that are most compatible for showing actual physical condition, fully and accurately and must reference all other appearances of this Work to the updated sheet. Contractor must include cross-references to the Change Order number on the updated Drawing sheet and all additional sheets where the Work is shown.

1.8.2. Contractor must mark-up with erasable colored pencil, in a legible and professional manner using separate colors where feasible, to distinguish between changes for different categories of Work at the same general location.

1.8.3. Contractor must mark-up important additional information, which was either shown schematically only or omitted from the Construction Documents. Contractor must give particular attention to information on concealed work that would be difficult to identify or measure and record at a later date.

1.8.4. The Contractor shall receive from the Consultant a set of electronic files of the project, with the engineering seal, stamp, signature and Consultant's logo removed.

1.8.5. The Contractor shall use the files as backgrounds on which all the changes recorded during the construction phase shall be transcribed electronically.

1.8.6. Once all the changes have been transcribed on the backgrounds, the drawings shall be electronically stamped "AS BUILT DRAWINGS" and shall be converted to pdf format and submitted to the Consultant for review. The Contractor remains responsible for the accuracy of the recorded information.

1.8.7. In association with Contractor’s request for Substantial Completion inspection, Contractor must submit one (1) electronic copy of the marked-up as-built drawings to Client's representative.

1.9. **RECORD SPECIFICATIONS**

1.9.1. It is mandatory that all changes to specified materials, installation, warranty, etc. be clearly and fully marked within the applicable Specification section in a manner acceptable to the Consultant and Client. Contractor shall review with the Owner and document an acceptable procedure early in the construction phase.

1.9.2. Contractor must give particular attention to substitutions, selection of options, and similar information on work where the exact products used are not clearly identified or readily discernible in the original Specifications. When applicable, Contractor must cross-reference related Record Drawing information and product data.

1.9.3. Contractor must neatly transcribe and post all marked-up information to a "clean" copy of the Specifications, ensuring that similar types of information are annotated in like fashion throughout the Specifications. The Record Specifications shall then be converted to pdf format and submitted to the Consultant for review. The Contractor remains responsible for the accuracy of Record Specifications content.

1.9.4. In association with Contractor’s request for Substantial Completion inspection, Contractor must submit the electronic version (pdf) of the Record Specifications to the Client representative.

1.10. **OPERATION AND MAINTENANCE MANUALS**

1.10.1. Submit operations and maintenance and operation data for all required equipment min. 15 days before application for Substantial Completion of the work. Substantial Completion status for the work will not be granted in the absence of full Operations and maintenance Information.

1.10.2. Contractor shall furnish the following equipment data content to be Included in Operating and Maintenance Manuals:

1.10.2.1. *Description of Equipment.*

1.10.2.2. *Record Product Submittals.* Clearly identify all options and accessories of actual installed product and variations in the actual Work in comparison with submitted information.

1.10.2.3. *Parts List.* Clearly identify every part in the item of equipment with the proper manufacturer's name, part nomenclature and number, local source, and list price.

1.10.2.4. *Recommended Spare Parts List.* For each equipment item that Owner will likely need within a 12-month period to support and operate that item of equipment. The quantities of spare parts recommended must be based upon the quantity of like equipment items installed under the Contract Documents.

1.10.2.5. *Normal Operating Instructions.* Detailed information to permit a journeyman mechanic to adjust, start-up, operate, and shut down the equipment. Special start-up precautions shall be noted as well as other action items required before the equipment is put into service.

1.10.2.6. *Emergency Operating Procedures.* Detailed description of the sequence of action to be taken in the event of a malfunction of the unit, either to permit a short period of continued operation or emergency shutdown to prevent further damage to the unit and to the system in which it is installed.

1.10.2.7. *Preventive Maintenance.* Detailed information to cover routine and special inspection requirements, including but not limited to, field adjustments, inspections for wear, adjustment changes, packing wear, lubrication points, frequency and specific lubrication type required, cleaning of the unit and type solvent to use, and such other measures as are applicable to preventive maintenance program.

1.10.2.8. *Calibration.* Detailed data on what to calibrate, how to calibrate, when to calibrate and procedures to enable checking the equipment for reliability or indications as well as data for test equipment, special tools and the location of test points.

1.10.2.9. *Scale and Corrosion Control.* Detailed information covering the prevention of and removal of scale and corrosion.

1.10.2.10. *Trouble Shooting Procedures.* Detailed information and procedures for detecting and isolating malfunctions and detailed information concerning probable causes and applicable remedies.

1.10.2.11. *Removal and Installation Instructions.* Detailed information concerning the logical sequence of steps required to remove and install the item including instructions for the use of special tools and equipment.

1.10.2.12. *Disassembly and Assembly Instructions.* Detailed illustrations and text to show the logical procedure and provide the instructions necessary to disassemble and assemble the unit properly. The text shall include all checks and special precautions as well as the use of special tools and equipment required to perform the assembly or disassembly.

1.10.2.13. *Repair Instructions.* Detailed repair procedures to bring the equipment up to the required operating standard including instruction for examining equipment and parts for needed repairs and adjustments, and tests or inspections required to determine whether old parts may be reused or must be replaced.

1.10.2.14. *Special Tools and Test Equipment.* Detailed list of the special tools and test equipment needed to perform repair and maintenance for each equipment item. The list shall contain the special tool and test equipment part number, size, quantity, price, manufacturer’s name and address, and local supplier’s name and address.

1.10.2.15. *System Drawings.* Contractor shall furnish detailed drawings, where applicable, that clearly show wiring diagrams, utility service diagrams, control diagrams, system schematics, pneumatic and fluid flow diagrams, etc., which pertain to the unit function. System drawings must show major pieces of equipment, such as chillers, boilers, heat exchangers, pumps, air handlers, tanks, switchgear, etc., as meaningful to the Project. Fluid flow and direction and valves with their valve tag identification numbers must be clearly noted on drawings. Drawings must show modifications to another manufacturer's standard unit when it is incorporated into the assembly or package unit.

1.10.3. Warranties And Guarantees

1.10.3.1. Contractor shall include, within the Operating and Maintenance Manual organizational structure for each system, equipment item, or material, an executed copy of the specified warranty/guarantee with warranty effective dates covering that particular system, equipment item, or material. Contractor shall include the manufacturer’s warranty as specified and the installing subcontractor’s and supplier’s guarantee for workmanship and system operation.

1.10.4. Requirements For Close-Out Manual

1.10.4.1. The Commissioning and Close-Out Manual shall include, but is not limited to, the following:

1.10.4.1.1. Commissioning documentation, pre-functional and functional check lists and forms.

1.10.4.1.2. Final air balance reports produced by the Test, Adjust, and Balance Firm.

1.10.4.1.3. Completed Valve Schedule and Fire, Fire/Smoke and Smoke Damper Schedule.

1.10.4.1.4. Owner Demonstration / Training Reports: Contractor shall furnish Training Plan and Documentation of Owner’s personnel training regarding operation of systems. Contractor shall include identification of parties receiving training and date(s) of such training.

1.10.4.1.5. Electrical Test Reports (including factory tests and settings).

1.10.4.1.6. Miscellaneous Equipment Test Reports (including factory tests and settings).
1.10.4.1.7. HVAC Calibration Reports (including duct testing reports).
1.10.4.1.8. Fire Alarm Test Reports.
1.10.4.1.9. Piping Test Reports.
1.10.4.1.10. Sewer Video Log.
1.10.4.1.11. Code-required Certifications as described within Technical Specifications.
1.10.4.1.12. Material Safety Data Sheets (MSDS) for any and all products incorporated into the Project.

1.10.5. Miscellaneous Close-out Documents.

1.10.5.1. Contractor shall provide categories of requirements resulting in miscellaneous work records including, but not be limited to, the following:
1.10.5.1.1. Required field records on excavations, foundations, underground construction, wells and similar work.
1.10.5.1.2. Accurate survey showing locations and elevations of underground lines, including invert elevations of drainage piping. Surveys establishing lines and levels of building.
1.10.5.1.3. Certifications received in lieu of labels on products and similar record documentation.
1.10.5.1.4. Testing and qualification of tradesmen.
1.10.5.1.5. Documented qualification of installation firms.
1.10.5.1.6. Materials testing reports.
1.10.5.1.7. Final inspection Punch-list and deficiency corrections.
1.10.5.1.8. All original, signed Project warranties and guarantees.

1.11. **MAINTENANCE AND OPERATIONS MANUAL FORMATTING**

1.11.1. Provide minimum of two (2) hard copies and one electronic copy of Mechanical Maintenance Manuals, in accordance to the following:

1.11.2. Manuals to be bound in a hard cover neatly labeled: "OPERATING AND MAINTENANCE INSTRUCTIONS".

1.11.3. The Maintenance and Operations Manuals shall be divided into sections with neatly labeled and tabbed dividers between each section. The sections to be included in the manual are:

1.11.3.1. Section I - General.
1.11.3.2. Section II - Piping and Pump Systems, Ductwork and Accessories.
1.11.3.3. Section III - HVAC Equipment/Electrical Equipment
1.11.3.4. Section IV - Automatic Controls
1.11.3.5. Section V - Air and Water Balancing

1.11.4. The following information shall be contained within the sections:

1.11.4.1. SECTION I: A list giving name, address and telephone number of the Consultant, Engineers, General Contractor, Mechanical Trade and Controls Trade. Written warranties for the Mechanical Systems. A copy of the Valve directory giving number, valve location, normal valve position, and purpose of valve. Equipment lists and certificates shall be provided - certificates shall be signed and sealed by the appropriate suppliers.

1.11.4.2. SECTION II, III: A copy of all pressure tests and operational tests. A copy of Gas Operational Tests for gas fired equipment. A list giving name, address and telephone number of all suppliers. Details of chemical treatment equipment and substances. A copy of all reviewed Shop Drawings for all mechanical equipment and ancillary devices (valves, expansion tanks, pumps, strainers, plumbing, etc.). Copies of warranties.

1.11.4.3. SECTION IV: Complete Control Diagrams, Wiring Diagrams and description of Control system and the functioning sequence of the system.

1.11.4.4. SECTION V: Complete air and hydronic balancing reports.

1.12. **WITHHOLDING OF PAYMENT**

1.12.1. Payment for materials incorporated in the work will not be made if required approvals have not been obtained.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

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PART 1 - GENERAL

1.1. **REQUIREMENTS INCLUDED**

1.1.1. Procedures for on-site demonstration and testing of equipment and systems, including temporary facilities.

1.2. **INSTRUCTION OF CLIENT'S OPERATING PERSONNEL**

1.2.1. All demonstrations, instructions and testing must be completed prior to Board acceptance for beneficial use. All safety devices most pass 100 percent before the mechanical systems can be accepted for beneficial use.

1.2.2. Plumbing and emergency power systems are not included.

1.3. **DEFINITIONS**

1.3.1. Start Up: Initial inspection, cleaning, lubrication, adjustment, and operation of equipment and systems by the contractor with the assistance of the representatives of the equipment manufacturers.

1.3.2. Pre-Tests: The final stage of the startup procedure. This occurs after all adjustments have been made except for minor fine-tuning that can be done during the pre-test. Serves as verification that the systems are ready for the final test. Witnessing of pre-test by the Consultant is not required.

1.3.3. Final Tests: Tests, witnessed by the Commissioning Agent or their representative, which demonstrate that all equipment and systems are in compliance with requirements.

1.4. **QUALITY ASSURANCE**

1.4.1. Experienced, trained technical service personnel who are representatives of the equipment manufacturers and system designers shall demonstrate, provide instructions, pre-test and final test, as specified, the following equipment:

1.4.1.1. Air Handling Equipment and VFDs
1.4.1.2. Air Conditioning/Refrigeration Equipment
1.4.1.3. Control systems and Instrumentation.
1.4.1.4. Pumps and VFDs

1.4.2. The person responsible for programming the BAS shall demonstrate and provide instructions on hardware, software and programming.

1.4.3. The Board will provide a list of personnel to receive instructions and will coordinate their attendance at agreed upon times.

1.4.4. All safety devices shall comply with the TSSA requirements.

1.5. **SUBMITTALS**

1.5.1. Names and qualifications of personnel performing demonstrations, instructions and tests.

1.5.2. Certification that pre testing is complete.

1.5.3. Preliminary schedule of all demonstrations, instructions and final tests two weeks prior to proposed dates.

1.5.4. Provide reports within three weeks after satisfactory completion of demonstrations, instructions, and tests. List date, type of work, persons participating, amount of time, test results, calculations of test results, test data.

1.5.5. Completed System Readiness Checklists provided by the Commissioning Agent and completed by the contractor, signed by a qualified technician and dated on the date of completion,

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION

3.1. **PREPARATION FOR FINAL TESTS, DEMONSTRATIONS, AND INSTRUCTIONS**

3.1.1. Verify that equipment and systems are fully operational. Complete all start up and pre-test activities for all equipment and systems. Complete all construction and finish work.

3.1.2. Arrange for all test personnel for all equipment to be continuously present during one period of time so that all equipment and systems can be tested in their interrelated functions. For instance, the burner in a heating system shall be tested during the boiler testing, and instrumentation performance will be evaluated in conjunction with boiler testing.

3.1.3. Deliver maintenance and operating manuals four weeks prior to instruction period.

3.1.4. Furnish all special tools.

3.2. **FINAL TESTS**

3.2.1. Demonstrate proper operation of each equipment and system.

3.2.2. Provide tests on equipment as specified in the individual specification sections.

3.3. **STARTUP AND TESTING**

3.3.1. The Consultant will observe startup and contractor testing of selected equipment. Coordinate the startup and contactor testing schedules with the Consultant. Provide a minimum of 7 days prior notice.

3.4. **DEMONSTRATIONS AND TRAINING**

3.4.1. Demonstrate operation and maintenance of equipment and systems to Board personnel no more than two weeks prior to scheduled Board operation of the equipment.

3.4.2. Use operation and maintenance manuals as basis of instruction. Review contents of manuals with personnel in detail to explain all aspects of operation and maintenance.

3.4.3. Demonstrate start up, operation, control, adjustment, trouble shooting, servicing, maintenance, and shut down of each item of equipment. Allow Government personnel to practice operating the equipment under supervision of instructors.

3.4.4. Prepare and insert additional data in operations and maintenance manuals when need for additional data becomes apparent during instructions.

3.4.5. Submit training plans and instructor qualifications

3.5. **TIME ALLOCATED FOR DEMONSTRATIONS AND INSTRUCTIONS**

3.5.1. At least 16 total instructor hours to include all new building services installed under this project.

3.5.2. At least 4 total instructor hours to include BAS and computer workstation and programs.

3.5.3. Do not exceed three trainees per session, one four-hour session, per day, per trainee.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section specifies demolition and removal of utilities, services and equipment, as noted on the drawings and as required for the completion of the new work.

1.2. DEFINITIONS

1.2.1. Remove: Detach items from existing construction and dispose of them off-site unless indicated to be salvaged or reinstalled.

1.2.2. Remove and Salvage: Detach items from existing construction, in a manner to prevent damage, and deliver to Owner ready for reuse or store as noted on Drawings.

1.2.3. Remove and Reinstall: Detach items from existing construction, in a manner to prevent damage, prepare for reuse, and reinstall where indicated.

1.2.4. Existing to Remain: Leave existing items that are not to be removed and that are not otherwise indicated to be salvaged or reinstalled.

1.2.5. Dismantle: To remove by disassembling or detaching an item from a surface, using gentle methods and equipment to prevent damage to the item and surfaces; disposing of items unless indicated to be salvaged or reinstalled.

1.3. WARRANTY

1.3.1. Existing Warranties: Remove, replace, patch, and repair materials and surfaces cut or damaged during demolition, by methods and with materials and using approved contractors so as not to void existing warranties. Notify warrantor before proceeding. Existing Warranties include the following:

1.3.1.1. Roof system

1.3.1.1.1. Notify warrantor on completion of selective demolition, and obtain documentation verifying that existing system has been inspected and warranty remains in effect. Submit documentation at Project closeout.

1.4. PROTECTION

1.4.1. Perform demolition in such manner as to eliminate hazards to persons and property; to minimize interference with use of adjacent areas, utilities and structures or interruption of use of such utilities; and to provide free passage to and from such adjacent areas of structures.

1.4.2. Carry out all demolition work in a neat and orderly manner. Keep noise, dust, and similar nuisances to a minimum. Do not collapse walls. Do not throw or drop materials.

1.4.3. Provide safeguards, including warning signs, barricades, temporary fences, warning lights, and other similar items that are required for protection of all personnel during demolition and removal operations.

1.4.4. Where material indicated to be removed is suspected of containing asbestos, inform Client's Representative immediately. Do not disturb materials suspected of containing asbestos until asbestos content has been verified by Client.

1.4.5. Use extreme caution when cutting into shafts and chases. Shafts and chases may end above occupied areas within building. Take all necessary precautions to prevent debris from falling through openings between floors during demolition operations.

1.4.6. Maintain fences, barricades, lights, and other similar items around exposed excavations until such excavations have been completely filled.

1.4.7. Prevent debris from blocking drainage systems (floor drains) or affecting other mechanical and electrical systems that must remain in operation.

1.4.8. Protect building floors against damage from demolition work. Use ½" plywood covers over floor where lifting, moving, rolling of removed equipment is anticipated. Be responsible for repairing any damage to flooring caused by the work defined in this section. Execute repairs to the satisfaction of the Board at no cost to the Board.

1.4.9. Provide enclosed dust chutes with control gates from each floor to carry debris to truck beds and govern flow of material into truck. Provide overhead bridges of tight board or prefabricated metal construction at dust chutes to protect persons and property from falling debris.

1.4.10. Prevent spread of flying particles and dust. Sprinkle rubbish and debris with water to keep dust to a minimum. Do not use water if it results in hazardous or objectionable condition such as, but not limited to; ice, flooding, or pollution. Vacuum and dust the work area daily.

1.4.11. Maintain at least one stairway in each structure in usable condition to highest remaining floor. Keep stairway free of obstructions and debris until that level of structure has been removed.

1.4.12. Wherever a cutting torch or other equipment that might cause a fire is used, provide and maintain fire extinguishers nearby ready for immediate use. Instruct all possible users in use of fire extinguishers.

1.4.13. Keep hydrants clear and accessible at all times. Prohibit debris from accumulating within a radius of 4500 mm (15 feet) of fire hydrants.

1.4.14. Before beginning any demolition work, the Contractor shall survey the site and examine the drawings and specifications to determine the extent of the work. The contractor shall take necessary precautions to avoid damages to existing items to remain in place, to be reused, or to remain the property of the Client.

1.4.15. Any damaged items shall be repaired or replaced as approved by the Consultant. The Contractor shall coordinate the work of this section with all other work and shall construct and maintain shoring, bracing, and supports as required.

1.4.16. The Contractor shall ensure that structural elements are not overloaded and shall be responsible for increasing structural supports or adding new supports as may be required as a result of any cutting, removal, or demolition work performed under this contract. Do not overload structural elements. Provide new supports and reinforcement for existing construction weakened by demolition or removal works. Repairs, reinforcement, or structural replacement must have Resident Engineer's approval.

1.5. **QUALIFICATIONS**

1.5.1. Work of this section shall be executed by trades personnel having a minimum of 3 years' experience in the demolition field and capable to deploy adequate equipment as required to complete the work in an efficient and orderly manner.

1.6. **EXAMINATION**

1.6.1. Examine existing property. Determine the nature of materials to be removed.

1.6.2. When utilities or building services are encountered that are not indicated on the drawings, the Consultant shall be notified prior to further work in that area.

1.7. **SCHEDULING**

1.7.1. Coordinate the timing and duration of DCW, DHW. HW and power shut-down with the Board representatives.

1.8. **MAINTAINING TRAFFIC**

1.8.1. Maintain and preserve Board's access requirements within, to and from existing building in areas where demolition and removal work is being carried out.

1.8.2. Do not close, obstruct, place or store material in the building driveways and passageways. Conduct operations with minimum interference with roads, streets, driveways, user traffic and passageways.

1.9. **HAULING OPERATIONS**

1.9.1. Maintain roadways and paving in the hauling areas clean on a daily basis and as required by Municipal Authorities.

1.9.2. Parking is not ample or readily available in the area where the building is located. Coordinate delivery of equipment with the Board representatives.

1.9.3. Contractor is responsible for all craning & lifting operations. It is the Contractor’s responsibility to coordinate with the respective Municipality & pay/obtain all required permits.

1.9.4. Contractor is responsible for providing a craning plan for review & approval by the Client.

1.10. **INTERRUPTIONS TO CLIENT'S OPERATIONS**

1.10.1. There will be absolutely no interruptions to the building schedule during demolition work. Therefore, it is imperative that operations and machine and equipment movements, deliveries and removals are executed at time or times that will permit uninterrupted Board's operations in and around the building, including parking, receiving areas, deliveries and site and means of access and egress.

1.10.2. Where interruptions of domestic cold and hot water are necessary, coordinate with the School Representatives the timing and duration of such interruptions.

1.11. **SAFETY REQUIREMENTS**

1.11.1. Coordinate posting of danger signs conspicuously around property. Close doorways and thoroughfares giving access to area of demolition with barricades.

1.11.2. Provide a competent, experienced supervisor in charge of the Work and on Site while Work is in progress.

1.11.3. Should any suspect designated substance not already identified, be encountered, cease work in the immediate area and immediately report, to the Board. Board is responsible for removal of designated substances.

1.12. **WORK INCLUDED IN THIS SECTION**

1.12.1. Demolition work for this project includes but is not limited to the following:

1.12.1.1. Remove the existing air handling units and associated return fans as noted.
1.12.1.2. Remove existing ductwork associated with the demolished equipment.
1.12.1.3. Remove portion of the heating pipes and associated pumps as noted and as required to complete the work.
1.12.1.4. Remove existing louvers and portion of existing wall to allow for the removal of the units and installation of new ones.

1.12.1.5. Remove and disconnect from power and controls the existing UV filtration system (Snippers).

1.12.1.6. Remove portion of existing ceiling as required to perform the demolition of the ductwork for the office area and kindergarten. Temporary remove and disconnect any existing services attached to the ceiling to be removed.

1.12.1.7. Remove the rooftop unit serving the childcare. Disconnect from power, ductwork and controls.

1.12.1.8. Remove all redundant electrical wiring and conduits.

1.12.1.9. Remove existing concrete pads and provide new.

1.12.1.10. Remove all existing hangers and supports for the equipment to be demolished.

1.12.1.11. Remove existing condenser, DX coil and refrigerant pipes serving the Library unit. Collect the refrigerant and dispose in accordance with Authorities having jurisdiction.

1.12.2. All cutting and patching associated with the removal of the air handling equipment to be included.

1.12.3. The temporary removal of any other building services as required for the installation of the new equipment; upon completion of the work, the relocated equipment shall be relocated back to the original position or left in the new position, as warranted by the new layout.

1.12.4. Remove all the BAS controls associated with the equipment to be demolished. The removal of the controls shall be done by the controls Contractor. Contractor shall identify and label all controls before demolition, to ensure that all existing equipment that is to remain will not be affected by this work and to ensure proper connection of the new equipment to the school.

1.12.5. All existing building services not affected by this work shall be protected and where necessary, maintained operational during and after the demolition work is complete. Any accidental damage or interruption of existing building services not required by this project will be promptly repaired at no additional cost to the Owner.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION

3.1. GENERAL

3.1.1. At the end of each day's work, leave site in a safe condition and erect safety barriers and lights as required. Ensure that no parts of the existing building are in danger of collapsing.

3.1.2. Review the requirements of new equipment to be installed. Perform all demolition work required to allow for the new equipment to be installed, whether shown on the drawings or not.

3.1.3. Provide any additional labour, materials and services not specifically indicated on the drawings but required to complete the demolition work.

3.1.4. Do not disturb adjacent structures or equipment designated to remain in place.

3.1.5. Confine operations and workers to those parts of the building which are defined on the drawings and exercise great care not to damage existing construction beyond that necessary for the carrying out of new work. Make good any such damage in every respect, to the satisfaction of the Client.

3.2. **DUST CONTROL**

3.2.1. Prevent spread of flying particles and dust. Sprinkle rubbish and debris with water to keep dust to a minimum. Do not use water if it results in hazardous or objectionable condition such as, but not limited to; ice, flooding, or pollution. Vacuum and dust the work area daily

3.3. **DISPOSAL**

3.3.1. <u>Removed Items</u>

3.3.1.1. Unless otherwise instructed by the Client's representative, all materials from demolition including brick, concrete, stone, metals, insulation, wiring, tubing and similar materials shall be removed

3.3.1.2. Removed items become property of Contractor and shall be disposed of by him daily, off the site to avoid accumulation at the demolition site. Materials that cannot be removed daily shall be stored in areas specified by the Consultant. Contractor shall dispose debris in compliance with applicable federal, provincial or local permits, rules and/or regulations.

3.3.1.3. Dispose of demolished materials in accordance with the requirements of Authorities Having Jurisdiction. At the end of demolition work, leave site in broom-clean condition. Clean existing surfaces specified to receive new applied finishes to ensure proper adherence.

3.3.2. <u>Removed and Salvaged Items:</u>

3.3.2.1. The Board Representative will review the Site prior to commencement of demolition and instruct the Contractor, in writing, as to the items to be Removed and Salvaged. Perform the following:

3.3.2.1.1. Clean salvaged items.

3.3.2.1.2. Pack or crate items after cleaning. Identify contents of containers.

3.3.2.1.3. Store items in a secure area until delivery to Owner.
3.3.2.1.4. Transport items to Owner's storage area location in building.
3.3.2.1.5. Protect items from damage during transport and storage.

3.3.3. <u>Removed and Reinstalled Items:</u>

3.3.3.1. Clean and repair items to functional condition adequate for intended reuse.
3.3.3.2. Pack or crate items after cleaning and repairing. Identify contents of containers.
3.3.3.3. Protect items from damage during transport and storage.
3.3.3.4. Reinstall items in locations indicated. Comply with installation requirements for new materials and equipment. Provide connections, supports, and miscellaneous materials necessary to make item functional for use indicated.

3.3.4. <u>Existing Items to Remain:</u>

3.3.4.1. Protect construction indicated to remain against damage and soiling during selective demolition. When permitted by Owner's Representative, items may be removed to a suitable, protected storage location off-site during selective demolition and reinstalled in their original locations after selective demolition operations are complete.

3.4. **REFRIGERANTS**

3.4.1. Refrigerant handling requirements are specified in Section: 23 23 00 Refrigerant Piping.

3.5. **DEMOLITION OF ARCHITECTURAL FINISHES**

3.5.1. General: Demolish and remove existing construction only to the extent required by new construction and as indicated. Use methods required to complete the Work within limitations of governing regulations and as follows:

3.5.1.1. Neatly cut openings and holes plumb, square, and true to dimensions required. Use cutting methods least likely to damage construction to remain or adjoining construction. Use hand tools or small power tools designed for sawing or grinding, not hammering and chopping, to minimize disturbance of adjacent surfaces. Temporarily cover openings to remain.
3.5.1.2. Cut or drill from the exposed or finished side into concealed surfaces to avoid marring existing finished surfaces.
3.5.1.3. Do not use cutting torches without written permission from Client's Representative. Comply with Owner's rules and procedures.
3.5.1.4. Locate selective demolition equipment and remove debris and materials so as not to impose excessive loading on supporting walls, floors, or framing.
3.5.1.5. Dispose of demolished items and materials promptly.

3.5.1.6. Remove all loose material from partially demolished work leaving only sound and secure construction.

3.5.2. Plaster:

3.5.2.1. Remove loose plaster that will be exposed in finished construction. Loose plaster is defined as plaster material of at least 2 inches by 4 inches in size that can be moved by touch or that sounds hollow when lightly tapped with a hammer.

3.5.3. Flooring:

3.5.3.1. Where shown, scheduled or otherwise required for application or installation of new floor finishes or coverings, remove existing flooring tile, resilient sheet flooring as follows:

3.5.3.1.1. Remove all traces of existing flooring materials. Remove resilient sheet and tile flooring products

3.5.3.1.2. Remove adhesives, except those containing asbestos. Use chemical strippers approved by manufacturer of new flooring materials, or grind concrete floor surfaces to completely remove adhesive. Obtain Client's Representative's approval of removal method prior to beginning removal work.

3.5.3.1.3. Do not remove vinyl composition tile or adhesives suspected of containing asbestos. Client will verify asbestos content of questionable materials. Removal of asbestos-containing adhesives (if any) shall be undertaken separately by the Client

3.5.3.1.4. Clean floor slabs of dust and adhesive residue.

3.6. DEMOLITION OF CONCRETE OR ASPHALT

3.6.1. Water used during concrete and asphalt work (including sweeping and saw-cutting) must be contained and collected for proper disposal. Do not discharge water containing dust or debris from concrete or asphalt work into storm drains, catch basins or to the sanitary sewer system.

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PART 1 - GENERAL

1.1. SUMMARY

1.1.1. This Section includes the following:

1.1.1.1. Gypsum board assemblies, including non-load-bearing steel framing.
1.1.1.2. Water-resistant gypsum drywall backer units installed with gypsum board assemblies.
1.1.1.3. Cementitious backer units installed with gypsum board assemblies.
1.1.1.4. Gypsum board shaft-wall assemblies.
1.1.1.5. Framing

1.2. ASSEMBLY PERFORMANCE REQUIREMENTS

1.2.1. Sound Transmission Characteristics: Where STC ratings are indicated, provide assemblies with STC ratings determined and classified in accordance with ASTM E 90 and ASTM E 413, respectively.

1.2.2. Fire Resistance: Provide gypsum board assemblies with fire-resistance ratings indicated.

1.2.3. Shaft-Wall Performance Requirements: Provide gypsum board shaft-wall assemblies that are composed of proprietary gypsum board panels and metal components designed for erection from outside the shafts, and that comply with performance requirements specified as determined from testing manufacturers' standard assemblies representing those indicated for this Project.

1.3. SUBMITTALS

1.3.1. Product data for each type of product specified.

1.4. QUALITY ASSURANCE

1.4.1. Fire-Test-Response Characteristics: Provide assemblies identical to those specified by indicated GA File Numbers in GA-600 "Fire Resistance Design Manual" or design designations in UL "Fire Resistance Directory," and that have been tested for fire resistance according to ASTM E 119 by an independent testing and inspecting agency.

PART 2 - PRODUCTS

2.1. MANUFACTURERS

2.1.1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

2.1.1.1. Gypsum Board and Related Products:

2.1.1.1.1. CertainTeed Saint-Gobain
2.1.1.1.2. Georgia-Pacific Corp.
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2.1.1.5.2. Georgia-Pacific Corp.
2.1.1.5.3. National Gypsum Co.
2.1.1.5.4. United States Gypsum Co.

2.2. **STEEL FRAMING FOR SUSPENDED CEILINGS**

2.2.1. General: Provide components complying with ASTM C 754 for conditions indicated.

2.2.2. Steel Studs for Ceiling Furring Channels: ASTM C 645, complying with the following requirements:

2.2.2.1. Minimum Base (Uncoated) Metal Thickness: 0.027 inch, unless otherwise indicated.
2.2.2.2. Depth: 2-1/2 inches, unless otherwise indicated.
2.2.2.3. Protective Coating: ASTM A 653, G 40 hot-dip galvanized coating.

2.3. **STEEL FRAMING FOR WALLS AND PARTITIONS**

2.3.1. General: Provide framing shapes as indicated, and with the following finish:

2.3.1.1. Protective Coating: Manufacturer's standard corrosion-resistant coating.
2.3.1.2. Protective Coating: ASTM A 653, G 40 hot-dip galvanized coating.

2.3.2. Steel Studs and Runners: ASTM C 645, Manufacturer's standard profiles, and complying with the following requirements:

2.3.2.1. Minimum Base (Uncoated) Metal Thickness: As indicated on drawings, or if not indicted, 0.0329 inch.

2.3.2.2. Minimum Depth: 3-5/8 inches, unless otherwise indicated.

2.3.3. Deflection and Firestop Track: Top runner designed to allow partition heads to expand and contract with movement of structure above while maintaining continuity of the assembly. Comply with requirements of ASTM C 645 except configuration, of thickness indicated for studs and width to accommodate depth of studs indicated with flanges offset at midpoint to accommodate gypsum board thickness.

2.3.4. Offset Configuration: Shadow-line design with offset projecting out from depth of stud.

2.3.5. Product: Subject to compliance with requirements, a product that may be incorporated in the Work includes, but is not limited to, "Fire Trak" manufactured by Fire Trak Corp.

2.3.6. Prefinished Top Track: Proprietary, pre-finished stud receptor track mounted to suspended ceiling grid. ASTM C 645, 25 gage galvanized steel; and as follows:

2.3.7. Accessories: Manufacturer's standard applied trim accessories for outside corners, wall ends and similar conditions requiring additional trim for a complete, finished appearance.

2.3.8. Finish: Baked-on polyester paint in color to match suspended ceiling grid manufacturer's standard white.

2.3.9. Product: Eliminator Track; Pro Products Mfg.

2.3.10. Steel Rigid Furring Channels: ASTM C 645, hat shaped, depth and 0.0179-inch minimum thickness of base (uncoated) metal, unless otherwise indicated. Provide furring brackets if recommended by manufacturer for application indicated.

2.3.11. Depth: 7/8 inch.

2.3.12. Steel Flat Strap and Backing Plate: Steel sheet for blocking and bracing, length and width as indicated, complying with ASTM A 653 or ASTM A 568, as follows:

2.3.13. Base (Uncoated) Metal Thickness: 0.0598 inch unless otherwise indicated.

2.4. GYPSUM BOARD PRODUCTS

2.4.1. Provide gypsum board of types indicated in maximum lengths available that will minimize end-to-end butt joints.

2.4.2. Gypsum Wallboard: ASTM C1396 and regular type for vertical surfaces, sag resistant for horizontal surfaces, Type X where required for fire-resistance-rated assemblies.

2.4.3. Thickness: Unless otherwise indicated, provide units that are 5/8 inch thick for all applications except 1/2 inch thick for ceilings and soffits.

2.4.4. Gypsum Liner Panels: Proprietary liner panels as required for the specific fire-resistant-rated gypsum board shaft-wall assemblies indicated, with moisture-resistant paper facings.

2.4.5. Glass-Mat, Water-Resistant Gypsum Backing Board: ASTM C 1178, of type and thickness indicated below:

2.4.5.1. Type and Thickness: Regular, 1/2 inch (12.7 mm) thick, unless otherwise indicated.
2.4.5.2. Type and Thickness: Type X, 5/8 inch (15.9 mm) thick, where required for fire-resistance-rated assemblies and where indicated.
2.4.5.3. Products: Subject to compliance with requirements, provide "Dens-Shield Tile Backer" manufactured by Georgia-Pacific Corp.

2.5. CEMENTITIOUS BACKER UNITS

2.5.1. Provide cementitious backer units complying with ANSI A118.9 and in maximum lengths available to minimize end-to-end butt joints.

2.5.2. Thickness: Manufacturer's standard thickness, but not less than 7/16 inch, unless otherwise indicated.

2.5.3. Width: Manufacturer's standard width, but not less than 32 inches.

2.6. TRIM ACCESSORIES

2.6.1. Accessories: Formed steel sheet zinc coated by hot-dip process, or rolled zinc, complying with the requirements of ASTM C 1047 for cornerbead, L, LC, U shapes.

2.6.2. One-piece control joint formed from rolled zinc with V-shaped slot and removable strip covering slot opening.

2.7. JOINT TREATMENT MATERIALS

2.7.1. General: Provide joint treatment materials complying with ASTM C 475 and the recommendations of both the manufacturers of sheet products and of joint treatment materials.

2.7.2. Joint Treatment for Gypsum Board: Provide paper reinforcing tape; and factory-packaged, vinyl-based, jobsite- or factory-mixed products. At Contractor's option, provide either specifically formulated taping and topping compounds or all-purpose compounds.

2.7.3. Joint Treatment Cementitious Backer Units: Tape and compound as recommended by cementitious backer unit manufacturer.

2.8. MISCELLANEOUS MATERIALS

2.8.1. Acoustical Sealant for Exposed and Concealed Joints: Latex sealant complying with ASTM C 834; and subject to compliance with requirements, one of the following products:

2.8.1.1. PL Acoustical Sealant; ChemRex, Inc.; Contech Brands.
2.8.1.2. AC-20 FTR Acoust. and Insul. Sealant; Pecora Corp.

2.8.2. Laminating Adhesive: Special adhesive or joint compound recommended for laminating gypsum panels.

2.8.3. Spot Grout: ASTM C 475, setting-type joint compound recommended for spot-grouting hollow metal door frames.

2.8.4. Foam Gaskets: Closed-cell vinyl foam adhesive-backed strips, 1/8 inch thick, in width to suit metal stud size.

2.8.5. Sound-Attenuation Blankets: Unfaced mineral-fiber blanket insulation produced by combining glass fibers with thermosetting resins to comply with ASTM C 665 for Type I (blankets without membrane facing).

2.8.6. Fasteners: Provide size and type of screws recommended by manufacturer for application indicated, and as follows:

2.8.6.1. Metal and Gypsum Board: Steel drill screws complying with ASTM C 1002 and of size, corrosion resistance and holding power required to fasten steel framing and furring members securely to substrates involved.
2.8.6.2. Cementitious Backer Units: Corrosion-resistant screws recommended by panel manufacturer.
2.8.6.3. Powder-Actuated Fasteners in Concrete: Corrosion-resistant materials suitable for application and capable of sustaining, without failure, a load equal to 5 times that imposed by ceiling construction, as determined by testing according to ASTM E 1190.

2.9. SHAFT-WALL BASIC ASSEMBLY DESCRIPTION

2.9.1. Cavity Shaft-Wall Assemblies: Provide assemblies constructed of proprietary gypsum liner panels inserted between steel tracks at each end of studs; with specially shaped steel studs engaged in tracks and fitted between gypsum liner panels; and with gypsum board on finished side or sides applied to studs in the number of layers, thicknesses and arrangement indicated.

2.9.2. Gypsum Liner Panel Thickness: As standard with manufacturer for gypsum board shaft-wall assemblies indicated.

2.9.3. Stud Shape and Depth and Thickness: As standard with manufacturer for gypsum board shaft-wall assemblies indicated; but not less than 0.0284-inch minimum base metal thickness.

2.9.4. Room-Side Finish: As indicated.

PART 3 - EXECUTION

3.1. **INSTALLING STEEL FRAMING, GENERAL**

3.1.1. Steel Framing Installation Standard: Comply with ASTM C 754 and with ASTM C 840 requirements that apply to framing installation.

3.1.2. Install supplementary framing, blocking, and bracing at terminations to support fixtures, equipment services, heavy trim, grab bars, toilet accessories, furnishings, or similar construction. Comply with details shown or, if not shown, with USG Co.'s "Gypsum Construction Handbook."

3.1.3. Isolate steel framing from building structure at the following locations:

3.1.3.1. In ceilings where building structure abuts ceiling perimeter or penetrates ceiling.
3.1.3.2. Where partition framing and wall furring abut structure, except at floor.

3.1.4. Independently frame both sides of joints at building control and expansion joints.

3.2. **INSTALLING STEEL FRAMING FOR SUSPENDED CEILINGS**

3.2.1. Install suspended steel framing components in sizes and at spacings indicated, but not less than that required by the referenced steel framing installation standard.

3.2.2. Do not connect or suspend steel framing from ducts, pipes, or conduit, or attach to steel roof deck.

3.2.3. Spacing: as indicated on the drawings. Default:

3.2.3.1. Framing Channel Spacing: 16 inches o.c.
3.2.3.2. Framing Channel Spacing: 24 inches o.c.

3.2.4. Installation Tolerances: Install with cross-furring members level to within 1/8 inch in 12 feet as measured both lengthwise on each member and transversely between parallel members.

3.3. **INSTALLING STEEL FRAMING FOR WALLS AND PARTITIONS**

3.3.1. Install runners (tracks) at floors and ceilings, and structural walls and columns where gypsum board stud assemblies abut other construction.

3.3.2. Where studs are installed directly against exterior walls, install foam gaskets between studs and wall.

3.3.3. Installation Tolerances: Install each steel framing and furring member so that fastening surfaces do not vary more than 1/8 inch from the plane formed by the faces of adjacent framing.

3.3.4. Extend partition framing to height indicated. Continue framing over frames for doors and openings and frame around ducts penetrating partitions above ceiling to provide support for gypsum board.

3.3.5. Terminate partition framing as shown on Drawings; or if not shown, as follows:

3.3.5.1. At suspended ceilings.

3.3.6. Install proprietary prefinished top track.

3.3.7. 6-inches above exposed face of suspended acoustic ceiling panels.

3.3.8. Full height to structural supports or substrates above suspended ceilings, if any. Cut studs 1/2 inch short of full height to provide perimeter relief.

3.3.9. Install proprietary deflection and firestop track at fire-rated partitions, and as otherwise indicated.

3.3.10. For STC-rated and fire-resistance-rated partitions that extend to the underside of floor/roof slabs and decks or other continuous solid structural surfaces to obtain ratings, install framing around structural and other members extending below floor/roof slabs and decks, as needed, to support gypsum board closures needed to make partitions continuous from floor to underside of solid structure.

3.3.11. Install steel studs and furring in sizes and at spacings as follows:

3.3.11.1. Maximum spacing between studs: 16-inches o.c., unless otherwise indicated.
3.3.11.2. Maximum spacing between studs: 24-inches o.c., unless otherwise indicated.

3.3.12. Frame openings to comply with GA-219, and with applicable published recommendations of gypsum board manufacturer, unless otherwise indicated. Attach vertical studs at jambs with screws either directly to frames or to jamb anchor clips on door frames; install runner track section (for cripple studs) at head and secure to jamb studs.

3.3.13. Install 2 studs at each jamb, unless otherwise indicated.

3.4. **APPLYING AND FINISHING GYPSUM BOARD, GENERAL**

3.4.1. Gypsum Board Application and Finishing Standards: Install and finish gypsum panels to comply with ASTM C 840 and GA-216.

3.4.2. Install gypsum panels with face side out.

3.4.3. Locate both edge or end joints over supports, except in ceiling applications where intermediate supports or gypsum board back-blocking is provided behind end joints. Do not place tapered edges against cut edges or ends. Stagger vertical joints on opposite sides of partitions. Avoid joints other than control joints at corners of framed openings where possible.

3.4.4. Spot grout hollow metal door frames for solid-core wood doors, hollow metal doors, and doors over 32 inches wide. Apply spot grout at each jamb anchor clip and immediately insert gypsum panels into frames.

3.4.5. Form control and expansion joints at locations indicated and as detailed, with space between edges of adjoining gypsum panels, as well as supporting framing behind gypsum panels.

3.4.6. Isolate perimeter of gypsum board partitions at structural abutments, except floors, with 1/4- to 1/2-inch-wide spaces and trim edges with LC-bead edge trim where edges of gypsum panels are exposed. Seal joints between edges and abutting structural surfaces with acoustical sealant.

3.4.7. Where STC-rated gypsum board assemblies are indicated, seal construction at perimeters, behind control and expansion joints, openings, and penetrations with a continuous bead of acoustical sealant including a bead at both faces of the partitions. Comply with ASTM C 919 and manufacturer's recommendations for location of edge trim and closing off sound-flanking paths around or through gypsum board assemblies, including sealing partitions above acoustical ceilings.

3.4.8. Space fasteners in gypsum panels according to referenced gypsum board application and finishing standard and manufacturer's recommendations.

3.4.9. Space screws a maximum of 12 inches o.c. for vertical applications.

3.4.10. Space fasteners in tile substrate panels a maximum of 8 inches o.c.

3.5. **GYPSUM BOARD APPLICATION METHODS**

3.5.1. Install gypsum wallboard panels on ceilings prior to wall/partition board application and at right angles to framing.

3.5.2. On partitions/walls, apply gypsum panels horizontally (perpendicular to framing), unless parallel application is required for fire-resistance-rated assemblies. Use maximum-length panels to minimize end joints. Stagger abutting end joints not less than one framing member in alternate courses of board.

3.5.3. On Z-furring members, apply gypsum panels vertically (parallel to framing) with no end joints. Locate edge joints over furring members.

3.5.4. Wall Tile Substrates: For substrates indicated to receive thin-set ceramic tile and similar rigid applied wall finishes, comply with the following:

3.5.4.1. Install cementitious backer units to comply with ANSI A108.11 at showers, and where indicated.
3.5.4.2. Install water-resistant gypsum backing board panels at showers, tubs, and where indicated. Install with 1/4-inch open space where panels abut other construction or penetrations.
3.5.4.3. Install gypsum wallboard panels with tapered edges taped and finished to produce a flat surface except at showers, tubs, and other locations indicated to receive water-resistant panels.

3.5.5. Apply gypsum panels to supports with screws.

3.5.6. Direct-Bonding to Substrate: Where gypsum panels are indicated as directly adhered to a substrate (other than studs, joists, furring members, or base layer of gypsum board), comply with gypsum board manufacturer's recommendations, and temporarily brace or fasten gypsum panels until fastening adhesive has set.

3.6. INSTALLING TRIM ACCESSORIES

3.6.1. General: Fasten trim accessories according to accessory manufacturer's directions for type, length, and spacing of fasteners.

3.6.2. Install cornerbead at external corners.

3.6.3. Install edge trim where edge of gypsum panels would otherwise be exposed. Provide edge trim type with face flange formed to receive joint compound, except where other types are indicated.

3.6.4. Install control joints according to ASTM C 840 and manufacturer's recommendations and in specific locations approved by Architect for visual effect.

3.7. INSTALLATION OF GYPSUM BOARD SHAFT-WALL ASSEMBLIES

3.7.1. General: Install gypsum board shaft-wall assemblies to comply with performance and other requirements indicated as well as with manufacturer's installation instructions and ASTM C 754 for installing steel framing.

3.7.2. Do not bridge building expansion joints with shaft-wall assemblies; frame both sides of joints with furring and other support as indicated.

3.7.3. At penetrations in shaft wall, maintain fire-resistance rating of entire shaft-wall assembly by installing supplementary steel framing around perimeter of penetration and fire protection behind boxes containing wiring devices similar items.

3.8. **FINISHING GYPSUM BOARD ASSEMBLIES**

3.8.1. Levels of Gypsum Board Finish: Provide the following levels of gypsum board finish per GA-214.

3.8.2. Level 1 for ceiling plenum areas, concealed areas, and where indicated, unless a higher level of finish is required for fire-resistance-rated assemblies and sound-rated assemblies.

3.8.3. Level 4 for gypsum board surfaces, unless otherwise indicated.

3.8.4. Level 5 for gypsum board the following surfaces where wood, stone, or cast plastic trim or base are indicted:

3.8.4.1. At gypsum column enclosures.
3.8.4.2. Where wall segments are less than 48-inches wide.
3.8.4.3. Where indicated.

3.8.5. Where Level 1 gypsum board finish is indicated, embed tape in joint compound.

3.8.6. For Level 4 gypsum board finish, embed tape in joint compound and apply first, fill (second), and finish (third) coats of joint compound over joints, angles, fastener heads, and accessories. Touch up and sand between coats and after last coat as needed to produce a surface free of visual defects and ready for decoration.

3.8.7. Where Level 5 gypsum board finish is indicated, after application of embedding, fill and finish coats, apply a thin, uniform skim coat of joint compound over entire surface. Touch up and sand between coats and after last coat as needed to produce a surface free of visual defects, tool marks, and ridges and ready for decoration.

3.8.8. Finish cementitious backer units to comply with unit manufacturer's directions.

3.9. **IDENTIFICATION**

3.9.1. Provide permanent identification of all assemblies requiring opening protectives including fire walls, fire barriers, fire partitions, and smoke barriers.

3.9.2. Install in accordance with the requirements of Michigan Building Code chapter 7.

3.9.3. Location:

3.9.3.1. Locate in accessible concealed spaces above finished ceiling. In locations without accessible concealed location, coordinate location with architect.

3.9.3.2. Locate within 15 feet of the end of each wall and at intervals not exceeding 30 feet measured horizontally along the assembly.

3.9.4. Signage requirements:

3.9.4.1. Lettering:

3.9.4.1.1. 3-inch minimum; 3/8-inch stroke width.

3.9.4.1.2. Color: Red on white background

3.9.4.2. Verbiage incorporating project specific hourly rating. Refer to life safety plan for rating requirements:

3.9.4.2.1. FIRE RATED ASSEMBLY (__HR) - PROTECT ALL OPENING

3.9.4.2.2. SMOKE BARRIER - PROTECT ALL OPENINGS

3.9.4.2.3. CLEANING AND PROTECTION

3.9.4.3. Promptly remove any residual joint compound from adjacent surfaces.

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PART 1 - GENERAL

1.1. GENERAL

1.1.1. Extent of acoustical ceilings is indicated on Drawings and schedules.

1.1.2. Types of acoustical ceiling products include the following:

1.1.2.1. Acoustical lay-in panels of the following types:
1.1.2.1.1. Standard acoustic panels.
1.1.2.1.2. Suspended grid systems, specialty trim and accessories.

1.2. SUBMITTALS

1.2.1. Product Data: Submit manufacturer's literature, including certification by a recognized independent testing laboratory, indicating compliance with requirements.

1.2.2. Affidavits of Compliance to be included in final inspection manual:

1.2.3. Provide manufacturer's letter of certification showing compliance with finish testing and classification requirements referenced by current adopted NFPA 101 "Life Safety Code".

1.2.4. Letter shall include project number, project name, and building name.

1.3. QUALITY ASSURANCE

1.3.1. Standards: Comply with the following:

1.3.1.1. Acoustical Materials: ASTM E 1264.
1.3.1.2. Suspension Systems: ASTM C 635 for materials; ASTM C 636 for installation.
1.3.1.3. Surface Burning Characteristics: Flame spread: 25 or less; smoke developed: 50 or less; per ASTM E 84. UL listed and marked.

1.3.2. Source Limitations: Obtain each type of acoustic panel and related grid system from one source and by a single manufacturer.

1.4. PROJECT CONDITIONS

1.4.1. Do not install ceilings until ambient temperature and humidity conditions can be continuously maintained at values near those intended for final occupancy.

1.4.2. Building areas to receive ceiling shall be free of construction dust and debris.

PART 2 - PRODUCTS

2.1. STANDARD ACOUSTIC PANELS

2.1.1. Smooth surface, humidity-tolerant, mineral composition panels with washable surface; and as follows:

2.1.1.1. Surface: Perforated.
2.1.1.2. Edges: Rabbeted for 15/16-inch grid.
2.1.1.3. Edges: Square.
2.1.1.4. Size: 24 inches by 24 inches by 5/8 inch thick.
2.1.1.5. Size: 24 inches by 48 inches by 5/8 inch thick.
2.1.1.6. LR: Not less than .82.
2.1.1.7. NRC: Not less than .55.
2.1.1.8. CAC: Not less than 33.
2.1.1.9. Color: White.
2.1.1.10. Manufacturer/Style: Provide one of the following:
2.1.1.10.1. Armstrong World Industries, Inc.
2.1.1.10.2. U.S. Gypsum.

2.1.2. Related Suspension Grid: Standard 15/16-inch Panel Suspension System in compliance with requirements of "Suspension Systems" Article of this Section.

2.2. **SUSPENSION SYSTEMS**

2.2.1. Suspension Systems, General: As required to support acoustical units, electrical and mechanical fixtures and other components as indicated, including anchorages, hangers, runners, cross runners, splines, clips, moldings, fasteners and other members, devices and accessories. Comply with requirements of ASTM C 635.

2.2.2. Hanger Wire: Not less than 12 gage (0.106 inch) galvanized steel.

2.2.3. Type: Exposed Direct-Hung Steel Suspension System

2.2.4. Structural Class: Medium-Duty System.

2.2.5. Standard 15/16-inch Panel Suspension System: Suspension system with exposed faces painted.

2.2.6. Face Width: 15/16-inch wide.

2.2.7. Product/Manufacturer: Provide the following:

2.2.7.1. Armstrong World Industries, Inc.
2.2.7.2. U.S. Gypsum.

2.3. **SPECIALTY TRIM SYSTEMS**

2.3.1. Custom Exposed Edge and Perimeter Trim System: Manufacturer's custom designed, painted steel trim system for fully exposed edge conditions; integrated with manufacturer's suspension system to create a free-floating installed appearance. Provide units of depth with 9/16-inch horizontal legs and with hems for attachment to suspension system.

2.3.2. Depth: 4-inches unless otherwise indicated.

2.3.3. Product/Manufacturer: Provide the following:

2.3.3.1. Armstrong World Industries, Inc.
2.3.3.2. U.S. Gypsum

PART 3 - EXECUTION

3.1. **INSTALLATION**

3.1.1. Comply with ASTM C636 and seismic design requirements indicated, per manufacturer's written instructions and CISCA's "Ceiling Systems Handbook."

3.1.2. Layout: Balance ceiling borders on opposite sides, using more-than-half width acoustical units, except where otherwise dimensioned or indicated.

3.1.2.1. Tolerance: 1/8 inch in 12 feet level tolerance.
3.1.2.2. Pattern Direction: One-way, align joints.

3.1.3. Suspension System: Secure to building structure, free from contact with objects within the ceiling plenum, with hangers spaced 48 inches on center along supported members; provide hangers not more than 8 inches from ends of each member.

3.1.4. Where interference with ducts or suspended equipment prevents direct connection of suspension elements to building structure, provide steel channel members (Unistrut or equivalent) hung from structural members with threaded rods with appropriate fasteners; and adequately sized for suspension system capacity. Secure suspension system to steel channels. Connection to ductwork or equipment is not permitted.

3.1.5. Do not fasten ceiling suspension members to metal roof deck.

3.1.6. Rabbeted Panels: Rabbet panel edges that have been field cut to fit non-modular suspension grid shapes at room perimeter, columns, and similar obstructions. Use router or other factory-approved rabbeting method.

3.1.7. Edge Moldings: Secure to substrate with screw anchors spaced 16 inch on center. Set with concealed bead of acoustical sealant. Miter corner joints. Cope exposed flanges of intersecting suspension members for flush intersections.

3.2. **SPECIALTY TRIM INSTALLATION**

3.2.1. Exposed Edge and Perimeter Trim System: Install units in accordance with manufacturer's printed instructions for specific Project application.

3.3. **CLEANING AND REPAIR**

3.3.1. Clean suspension grid and panels. Remove and replace panels and grid that are defective, or that have been damaged.

3.3.2. Touch-up paint field-cut edges of factory painted tile that are exposed to view in finished installation, including horizontal and vertical surfaces at perimeter of ceilings where panels are cut for rabbeted edge molding.

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PART 1 - GENERAL

1.1. **GENERAL**

1.1.1. Qualifications of the HVAC System Cleaning Contractor

1.1.1.1. Certification: The HVAC system cleaning subtrade shall have staff certified by a nationally recognized certification program and organization dedicated to the cleaning of HVAC systems.

1.1.1.2. Supervisor Qualifications: A person maintaining a certification by a nationally recognized program and organization, shall be responsible for the total work herein specified.

1.1.1.3. Experience: The HVAC system cleaning subtrade shall submit a list of projects where they have performed HVAC system cleaning services. Bids shall only be considered from firms which are regularly engaged in HVAC system maintenance with an emphasis on HVAC system cleaning and decontamination.

1.1.1.4. Equipment, Materials and Labor: The HVAC system cleaning subtrade shall possess and furnish all necessary equipment, materials and labor to adequately perform the specified services.

1.1.2. Standards

1.1.2.1. NADCA Standards: The HVAC system cleaning subtrade shall perform the services specified here in accordance with the current published standards of the National Air Duct Cleaners Association (NADCA) or other recognized duct cleaning organization.

1.2. **APPLICABLE STANDARDS AND PUBLICATIONS**

1.2.1. The following current standards and publications of the issues currently in effect form a part of this specification to the extent indicated by any reference thereto:

1.2.1.1. National Air Duct Cleaners Association (NADCA): Assessment, Cleaning & Restoration of HVAC Systems (ACR 2005), 2004.

1.2.1.2. National Air Duct Cleaners Association (NADCA): Understanding Microbial Contamination in HVAC Systems, 1996.

1.2.1.3. National Air Duct Cleaners Association (NADCA): Introduction to HVAC System Cleaning Services, 2004.

1.2.1.4. National Air Duct Cleaners Association (NADCA): Standard 05 Requirements for the Installation of Service Openings in HVAC Systems, 2004.

1.2.1.5. Underwriters' Laboratories (UL): UL Standard 181.

1.2.1.6. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE): Standard 62 89, Ventilation for Acceptable Indoor Air Quality.

1.2.1.7. Environmental Protection Agency (EPA): Building Air Quality, December 1991.

1.2.1.8. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA): HVAC Duct Construction Standards Metal and Flexible, 1985.

1.3. **DOCUMENTS**

1.3.1. Mechanical Drawings

1.3.2. The Consultant will provide CAD drawings of the ductwork layout, based on the data available in the Owner's archives. The CADS layouts shall be verified against the actual conditions, since some discrepancies may exist. The final extent of ductwork to be cleaned shall be determined by review of available construction documents and field verification.

PART 2 - PRODUCTS

2.1. **SCOPE OF WORK**

2.1.1. The scope of work for this project will include cleaning of all HVAC ductwork system, including supply and exhaust/return air ductwork, dampers and accessories connected to the equipment to be replaced. Include the duct cleaning for the ductwork connected to the Library unit AHU-2 and associated return fan. (location of major equipment and terminal equipment is shown on the mechanical drawings).

2.1.2. The Contractor shall be responsible for the removal of visible surface contaminants and deposits from within the HVAC system in strict accordance with these specifications.

2.1.3. The HVAC ductwork system includes any interior surface of the facility’s air distribution system for conditioned spaces and/or occupied zones. This includes all heating, ventilating and air conditioning systems from the points where the air enters the system to the points where the air is discharged from the system. The supply air ducts, supply air diffusers and grilles, return air ductwork and grilles, elbow turning vanes, are all considered part of the HVAC ductwork system.

2.2. **HVAC SYSTEM INSPECTION AND SITE PREPARATIONS**

2.2.1. HVAC System Component Inspection

2.2.1.1. Prior to the commencement of any cleaning work, the HVAC system cleaning subtrade shall perform a visual inspection of the HVAC system to determine appropriate methods, tools, and equipment required to satisfactorily complete this project.

2.2.1.2. The cleanliness inspection shall be conducted without negatively impacting the indoor environment through excessive disruption of settled dust, microbial amplification or other debris. In cases where contamination is suspected, and/or in sensitive environments where even small amounts of contaminant may be of concern, environmental engineering control measures should be implemented

2.2.2. Pre-Existing System Damage

2.2.2.1. Contractor is not responsible for problems resulting from prior inappropriate or careless cleaning techniques of others. Damaged system components found during the inspection shall be documented and brought to the attention of the Owner.

2.2.3. Site Evaluation and Preparations

2.2.3.1. Contractor shall conduct a site evaluation, and establish a specific, coordinated plan which details how each area of the building will be protected during the various phases of the project.

2.3. **GENERAL SYSTEM CLEANING REQUIREMENTS**

2.3.1. Containment

2.3.1.1. Debris removed during cleaning shall be collected and precautions must be taken to ensure that debris is not otherwise dispersed outside the HVAC system during the cleaning process.

2.3.2. Particulate Collection

2.3.2.1. Where the Particulate Collection Equipment is exhausting inside the building, HEPA filtration with 99.97 percent collection efficiency for 0.3 micron size (or greater) particles shall be used. When the Particulate Collection Equipment is exhausting outside the building, Mechanical Cleaning operations shall be undertaken only with Particulate Collection Equipment in place, including adequate filtration to contain debris removed from the HVAC system. When the Particulate Collection Equipment is exhausting outside the building, precautions shall be taken to locate the equipment down wind and away from all air intakes and other points of entry into the building.

2.3.3. Controlling Odors

2.3.3.1. Measures shall be employed to control odors and/or mist vapors during the cleaning process.

2.3.4. Component Cleaning

2.3.4.1. Cleaning methods shall be employed such that all HVAC system components must be Visibly Clean as defined in applicable industry standards. Upon completion, all components must be returned to those settings recorded just prior to cleaning operations.

2.3.5. Air Volume Control Devices

2.3.5.1. Dampers and any air directional mechanical devices inside the HVAC system must have their position marked prior to cleaning and, upon completion, must be restored to their marked position.

2.3.6. Service Openings

2.3.6.1. The contractor shall utilize service openings, as required for proper cleaning, at various points of the HVAC system for physical and mechanical entry, and inspection.
2.3.6.2. Contractor shall utilize the existing service openings already installed in the HVAC system where possible.
2.3.6.3. Other openings shall be created where needed and they must be created so they can be sealed in accordance with industry codes and standards.
2.3.6.4. Closures must not significantly hinder, restrict, or alter the airflow within the system.
2.3.6.5. Closures must be properly insulated to prevent heat loss/gain or condensation on surfaces within the system.
2.3.6.6. Openings must not compromise the structural integrity of the system.
2.3.6.7. Construction techniques used in the creation of openings should conform to requirements of applicable building and fire codes, and applicable NFPA, SMACNA and industry standards.
2.3.6.8. Cutting service openings into flexible duct is not permitted. Flexible duct shall be disconnected at the ends as needed for proper cleaning and inspection.
2.3.6.9. All service openings capable of being re-opened for future inspection or remediation shall be clearly marked and shall have their location reported to the Owner in project report documents.

2.3.7. Ceiling Tile

2.3.7.1. The Contractor may remove and reinstall ceiling sections to gain access to HVAC systems during the cleaning process.

2.3.8. Air Distribution Devices (VAV, re-heat coils, registers, grilles and diffusers)

2.3.8.1. The Contractor and subtrade shall clean all air distribution devices.

2.3.9. Air Handling units

2.3.9.1. The Contractor and subtrade shall clean all the AHU units including, coils and fan sections.

2.3.10. Duct Systems

2.3.10.1. Contractor shall create service openings in the system as necessary in order to accommodate cleaning of otherwise inaccessible areas.

2.3.10.2. Contractor and subtrade shall mechanically clean all duct systems to remove all visible contaminants, such that the systems are capable of passing Cleaning Verification Tests (see NADCA Standards).

2.4. **OCCUPANT SAFETY**

2.4.1. No processes or materials shall be employed in such a manner that they will introduce additional hazards into occupied spaces.

2.4.2. Disposal of debris

2.4.2.1. All debris removed from the HVAC System shall be disposed of in accordance with applicable federal, state and local requirements.

PART 3 - EXECUTION

3.1. **SOURCE REMOVAL CLEANING METHODS**

3.1.1. The HVAC system shall be cleaned using source removal mechanical cleaning methods designed to extract contaminants from within the HVAC system and safely remove contaminants from the facility. It is the Contractor's responsibility to select Source Removal methods that will render the HVAC system visibly clean and capable of passing cleaning verification methods (See applicable industry standards) and other specified tests, in accordance with all general requirements. No cleaning method, or combination of methods, shall be used which could potentially damage components of the HVAC system or negatively alter the integrity of the system.

3.1.2. All methods used shall incorporate the use of vacuum collection devices that are operated continuously during cleaning. A vacuum device shall be connected to the downstream end of the section being cleaned through a predetermined opening. The vacuum collection device must be of sufficient power to render all areas being cleaned under negative pressure, such that containment of debris and the protection of the indoor environment are assured.

3.1.3. All vacuum devices exhausting air inside the building shall be equipped with HEPA filters (minimum efficiency), including hand held vacuums and wet vacuums.

3.1.4. All vacuum devices exhausting air outside the facility shall be equipped with particulate collection including adequate filtration to contain debris removed from the HVAC system. Such devices shall exhaust in a manner that will not allow contaminants to re-enter the facility. Release of debris outdoors must not violate any outdoor environmental standards, codes or regulations.

3.1.5. All methods require mechanical agitation devices to dislodge debris adhered to interior HVAC system surfaces, such that debris may be safely conveyed to vacuum collection devices. Acceptable methods will include those, which will not potentially damage the integrity of the ductwork, nor damage porous surface materials such as liners inside the ductwork or system components.

3.2. **CLEANLINESS VERIFICATION**

3.2.1. General

3.2.1.1. Verification of HVAC system cleanliness will be determined after mechanical cleaning

3.2.2. Visual Inspection

3.2.2.1. The HVAC system shall be inspected visually to ensure that no visible contaminants are present.

3.2.2.2. If no contaminants are evident through visual inspection, the HVAC system shall be considered clean; however, the Owner reserves the right to further verify system cleanliness through Surface Comparison Testing or the NADCA vacuum test specified in the NADCA standards.

3.2.2.3. If visible contaminants are evident through visual inspection, those portions of the system where contaminants are visible shall be re-cleaned and subjected to re-inspection for cleanliness.

3.2.3. Post Project Report

3.2.3.1. At the conclusion of the project, the Contractor shall provide a report to the Owner indicating the following:

3.2.3.1.1. Success of the cleaning project, as verified through visual inspection and/or gravimetric analysis.

3.2.3.1.2. Areas of the system found to be damaged and/or in need of repair.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. The requirements of this Section apply to all sections of Division 23.

1.2. DEFINITIONS

1.2.1. Exposed: Piping, ductwork, and equipment exposed to view in finished rooms.

1.2.2. Option or optional: Contractor's choice of an alternate material or method.

1.3. RELATED WORK

1.3.1. Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.3.2. Section: 23 05 13 Common Motor Requirements for HVAC Equipment.

1.3.3. Section: 23 05 48 Vibration and Seismic Controls for HVAC.

1.3.4. Section: 23 05 93 Testing, Adjusting and Balancing For HVAC.

1.3.5. Section: 23 07 00 HVAC Insulation.

1.4. QUALITY ASSURANCE

1.4.1. Mechanical, electrical and associated systems shall be safe, reliable, efficient, durable, easily and safely operable and maintainable, easily and safely accessible, and in compliance with applicable codes as specified. The systems shall be comprised of high quality institutional-class and industrial-class products of manufacturers that are experienced specialists in the required product lines. All construction firms and personnel shall be experienced and qualified specialists in industrial and institutional HVAC.

1.5. PRODUCTS CRITERIA

1.5.1. Standard Products: Material and equipment shall be the standard products of a manufacturer regularly engaged in the manufacture of the products for at least 3 years (or longer as specified elsewhere). The design, model and size of each item shall have been in satisfactory and efficient operation on at least three installations for approximately three years. However, digital electronics devices, software and systems such as controls, instruments, computer work station, shall be the current generation of technology and basic design that has a proven satisfactory service record of at least three years. See other specification sections for any exceptions and/or additional requirements.

1.5.2. All items furnished shall be free from defects that would adversely affect the performance, maintainability and appearance of individual components and overall assembly.

1.5.3. Conform to codes and standards as required by the specifications. Conform to local codes, if required by local authorities such as the natural gas supplier, if the local codes are more stringent than those specified. Refer any conflicts to the Consultant.

1.5.4. Multiple Units: When two or more units of materials or equipment of the same type or class are required, these units shall be products of one manufacturer.

1.5.5. Assembled Units: Manufacturers of equipment assemblies, which use components made by others, assume complete responsibility for the final assembled product.

1.5.6. Nameplates: Nameplate bearing manufacturer's name or identifiable trademark shall be securely affixed in a conspicuous place on equipment, or name or trademark cast integrally with equipment, stamped or otherwise permanently marked on each item of equipment.

1.5.7. Asbestos products or equipment or materials containing asbestos shall not be used.

1.6. **EQUIPMENT SERVICE ORGANIZATIONS**

1.6.1. HVAC: Products and systems shall be supported by service organizations that maintain a complete inventory of repair parts and are located within 50 miles to the site.

1.6.2. HVAC Mechanical Systems Welding: Before any welding is performed, contractor shall submit a certificate certifying that welders comply with the following requirements:

1.6.2.1. Qualify welding processes and operators for piping according to ASME "Boiler and Pressure Vessel Code", Section IX, "Welding and Brazing Qualifications".
1.6.2.2. Comply with provisions of ASME B31 series "Code for Pressure Piping".

1.7. **EXECUTION (INSTALLATION, CONSTRUCTION) QUALITY**

1.7.1. Apply and install all items in accordance with manufacturer's written instructions. Refer conflicts between the manufacturer's instructions and the contract drawings and specifications to the Consultant for resolution.

1.7.2. Provide complete layout drawings, schematics, diagrams, sections, notes and specifications as required to allow for competitive bidding and construction. Do not commence construction work on any system until the layout drawings have been approved.

1.8. **DUTIES OF MECHANICAL CONTRACTOR**

1.8.1. The mechanical contractor shall assume the responsibilities and duties of a general contractor including but not limited to the ones described below:

1.8.1.1. Superintendence

1.8.1.1.1. Provide full time on-site superintendent personnel and supporting staff with proven experience in project of similar value and complexity.

1.8.1.1.2. Site superintendent shall have over-all authority to speak for and represent the mechanical contractor.

1.8.1.2. Coordination

1.8.1.2.1. Coordinate the work with all the sub-trades involved to ensure that the work will be carried out on schedule and in proper sequence.

1.8.1.2.2. Take complete responsibility for all remedial work that results from failure to coordinate any aspect of the mechanical work prior to its fabrication and/or installation.

1.8.1.2.3. Take responsibility for the delivery of equipment necessary to complete the work in accordance with the approved schedule.

1.8.1.3. Staffing and Scheduling

1.8.1.3.1. Within seven days after the award of the contract, the Mechanical Contractor shall provide to the Board representative the following information:

- Appointment of official representatives in the project.
- Schedule of work.
- Delivery schedule for specified equipment.
- Requirements for temporary facilities, site signs, storage, etc.

1.8.1.4. Work Completion Meeting

1.8.1.4.1. Prior to application for Substantial Performance of the Work, the mechanical contractor shall participate in the take-over meeting. Agenda to include the following:

- Review of outstanding deficiencies.
- Submission of maintenance manuals, warranties and as-built drawings.
- Results of performance tests and described further in this section.
- Scheduling of training to Board’s personnel.

1.9. **COMMISSIONING**

1.9.1. The Board may at its discretion use a third party as a commissioning agent for the construction portion of the work. The requirement for commissioning shall be included in the front-end documents of the bidders’ package.

1.9.2. If commissioning is included, the contractor shall provide all manpower and will take into account all the hours required to participate in the commissioning process including meetings with the commissioning agent, completion of forms and check-lists, verifications, simulations, rectifications of deficiencies and other activities associated with the commissioning process.

1.10. **SCHEDULING OF WORK**

1.10.1. For all work to be performed under this contract, adhere to Construction Schedule agreed upon with the Board.

1.11. **INTENT**

1.11.1. Bidders for this work shall include for all labor, material, equipment and all other related cost including all applicable taxes (except HST) and fees to provide the work as indicated on the drawings.

1.11.2. Misinterpretation of any requirement of the drawings and specifications will not relieve the Mechanical Contractor of responsibility. If in any doubt, the Mechanical Contractor shall contact the Consultant for written clarification prior to submitting a bid for the Work.

1.11.3. The scope of work for this project includes but is not limited to:

1.11.3.1. <u>New Layout Work</u>

1.11.3.1.1. Supply and install new air handling equipment as noted on the drawings. Equipment to be delivered in sections to allow installation through the wall opening. Coordinate with the units manufacturer for the size of each section.
1.11.3.1.2. Supply and install new condensing units and all associated refrigerant pipes, supports, hangers, etc.
1.11.3.1.3. Provide new ductwork system for the new AHUs and connect to existing as noted.
1.11.3.1.4. All ductwork and piping in the mechanical room to be insulated (new and existing).
1.11.3.1.5. Provide new concrete pads to suit the layout of the new equipment.
1.11.3.1.6. Provide new louvers as noted and repair the existing wall opening under the louver to match existing.
1.11.3.1.7. Reinstall all the UV filtration system and connect to power and controls. Contractor to modify the UV installation or the number as required to suit the new ductwork layout.
1.11.3.1.8. Revise the ductwork for the office/ administration area as required to install the new VAV terminals. Provide all required controls.
1.11.3.1.9. Temporary remove and reinstate the existing ceiling.
1.11.3.1.10. Upgrade the existing BAS system to include for the operation of the new equipment.
1.11.3.1.11. Allow for the draining of the existing heating system and refill at the completion of the work.
1.11.3.1.12. Balance the entire hydronic and air system connected to the equipment to be replaced.

1.12. **INTERFERENCES**

1.12.1. The mechanical drawings do not show all the architectural and structural details, and any information involving accurate measuring of the building shall be taken from the building drawings or at the building. Make without additional change, any necessary changes or additions to the runs of drains, pipes, ducts, etc., to accommodate the above conditions. The location of equipment may be altered without charge providing the change is made before installation and does not necessitate major additional material.

1.12.2. Wherever differences occur between specifications, riser diagrams or schematics and drawings, the maximum conditions shall govern and the bid shall be based on whichever information indicates the greater cost.

1.12.3. Field verifications of dimensions on plans shall be made since actual locations, distances, and levels will be governed by actual field conditions.

1.12.4. Discrepancies between different plans, or between plans and actual field conditions, or between plans and specifications shall promptly be brought to the attention of the Consultant for a decision.

1.12.5. Install all mechanical services including but not exclusive to drains, pipes, and ducts, to conserve headroom and interfere as little as possible with the free use of the space through which they pass. All drains, pipes, ducts, etc., particularly those which may interfere with the inside treatment of the building, or conflicting with other trades, shall be installed only after the locations have been approved by the Consultant. Special care shall be taken in the installation of all mechanical services including, but not exclusive to drains, pipes, and ducts, which are to be concealed, to see that they come within the finished lines of floors, walls, and ceilings. Where such drains, pipes, ducts, etc., have been installed in such a manner as to cause interference, they shall be removed and re installed in suitable locations without extra cost to the Board.

1.12.6. Before commencing work, check and verify all grade and invert elevations, stacks, levels, and dimensions, to ensure proper and correct installation of the work.

1.12.7. In every place where there is space indicated as reserved for future or other equipment, leave such space clear, install blank offs, shut off valves with blind flanges and other work so that the necessary connections can be made without any stoppages to the system. Consult with the consultant whenever necessary for this purpose.

1.12.8. In addition to the work specifically mentioned in the Specifications and shown on the drawings, provide all other items that are obviously necessary to make a complete working installation, including those required by the Authorities Having Jurisdiction over the work.

1.12.9. The mechanical plans show approximate locations for wall mounted devices. Obtain Consultant's approval of mounting heights and locations before commencement of work.

1.13. **EXAMINE SITE**

1.13.1. Examine the site and the local conditions affecting the work <u>prior to submission of the tender price</u>. Examine carefully all drawings and the complete specifications to ensure that the work can be satisfactorily carried out as shown. No allowance will be made later for any expenses incurred through the failure to make these examinations or to report any such discrepancies in writing to the Consultant.

1.14. **INTERFERENCE AND SLEEVING DRAWINGS**

1.14.1. Submit complete consolidated and coordinated interference drawings for all new air handling systems, and for existing systems that are in the same areas.

1.14.2. The drawings shall include plan views, elevations and sections of all systems and shall be on a scale of not less than 1:200. Clearly identify and dimension the proposed locations of the principal items of equipment. The drawings shall clearly show locations and adequate clearance for all equipment, ductwork, piping, valves, control panels and other items. Show the access means for all items requiring access for operations and maintenance. Provide detailed layout drawings of all piping and duct systems.

1.14.3. Do not install equipment foundations, equipment, ductwork or piping until interference drawings have been approved.

1.15. **WARRANTY**

1.15.1. All work completed under this contract shall carry a min. 2 years' warranty (labour and material) from the date of substantial completion.

1.15.2. **All equipment supplied under this contract shall carry a 2 years' warranty**. Where certain equipment specifications call for a for a longer warranty on certain components, the longest period shall apply.

1.16. **SUBMITTALS**

1.16.1. Submit documentation in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples, and with requirements in the individual specification sections.

1.16.2. Contractor shall make all necessary field measurements and investigations to assure that the equipment and assemblies will meet contract requirements.

1.16.3. If equipment is submitted which differs in arrangement from that shown, provide drawings that show the rearrangement of all associated systems. Approval will be given only if all features of the equipment and associated systems, including accessibility, are equivalent to that required by the contract.

1.16.4. Prior to submitting shop drawings for approval, contractor shall certify in writing that manufacturers of all major items of equipment have each reviewed drawings and specifications, and have jointly coordinated and properly integrated their equipment and controls to provide a complete and efficient installation.

1.16.5. Submittals and shop drawings for interdependent items, containing applicable descriptive information, shall be furnished together and complete in a group. Coordinate and properly integrate materials and equipment in each group to provide a completely compatible and efficient.

1.16.6. Manufacturer's Literature and Data:

1.16.6.1. Submit all information pertaining to the performance and capacity of the equipment.
1.16.6.2. Submit all information pertaining to methods of connection to piping and ductwork, electrical wiring, controls and noise generated by the equipment (as applicable to the project).
1.16.6.3. Submit belt drive with the driven equipment. Submit selection data for specific drives when requested by the Consultant.
1.16.6.4. Submit electric motor data and variable speed drive data with the driven equipment.
1.16.6.5. Equipment and materials identification.
1.16.6.6. Fire-stopping materials.
1.16.6.7. Hangers, inserts, supports and bracing, for both indoor and outdoor installations. Where applicable, provide load ratings and deflection for spring supports and hangers.
1.16.6.8. Wall, floor, and ceiling plates.

1.16.7. HVAC Maintenance Data and Operating Instructions:

1.16.7.1. Provide a listing of recommended replacement parts for keeping in stock supply, including sources of supply, for equipment. Include in the listing belts for equipment: Belt manufacturer, model number, size and style, and distinguished whether of multiple belt sets.
1.16.7.2. Provide copies of approved HVAC equipment submittals to the Testing, Adjusting and Balancing Subcontractor.

1.17. **MATERIALS AND STANDARDS OF ACCEPTANCE**

1.17.1. Where materials, equipment, apparatus, or other products are specified by the manufacturer, brand name, type or catalogue number, such designation is to establish standards of desired quality style or dimensions and shall be the basis of the Bid. Materials so specified shall be furnished under this Contract.

1.17.2. Where two or more designations are listed, the contractor shall choose one of those listed and state the choice made on the Bid Form (where applicable). *Note that the basis of design equipment has specific physical characteristics in terms of footprint and clearances requirements. Inclusion of a manufacturer other than the one for the Basis of Design in the Standard of Acceptance is not an automatic approval for submission of equipment which cannot be installed due to specific site conditions.*

1.17.3. *Should the contractor select an approved alternate manufacturer, the contractor remains responsible for all structural, electrical, and mechanical adjustments necessary to install the new equipment.*

1.18. **MATERIAL SUBSTITUTIONS**

1.18.1. After execution of the Contract, requests for substitution of materials or makes other than those specifically named in the Contract Documents may be reviewed and approved by the Consultant, subject to Board's review and acceptance of the financial credits involved.

1.18.2. In the absence of such express approval by the Consultant, the Mechanical Contractor will be held to furnish specified items under the base bid as the standard of acceptance.

1.18.3. If equipment is submitted which differs in arrangement from that specified/shown on the documents, provide drawings that show the rearrangement of all associated systems. Approval will be given only if all features of the equipment and associated systems, including accessibility, are equivalent to that required by the contract.

1.18.4. Any additional changes to the contract documents (including ductwork, piping or electrical power supply, structural, etc) due to the selection of a different equipment other than the base Bid is the full responsibility of the Contractor. No additional fees will be paid for these changes

1.19. **CODES, PERMITS, FEES AND CONNECTIONS**

1.19.1. Conform to Federal, Provincial and Municipal regulations and perform work in accordance with requirements of By Laws and Regulations in force in area where the building is to be erected.

1.19.2. Apply for, obtain, and pay for all permits, fees and service connections for the work and the inspections required by Authorities Having Jurisdiction in the area where the work will take place

1.19.3. Where applicable, apply for, obtain, and pay for all permits, fees and service connections for the work and the inspections required by Authorities Having Jurisdiction in the area where the work will take place, including TSSA and ESA. Where applicable, have the work inspected and certified by PV [Boilers and Pressure Vessels Reg], OE [Operating Engineers

Reg.] and FS [Fuel Safety Reg.] branches of TSSA. At the end of the work, the new plant shall be fully TSSA certified.

1.19.4. For information, a specific code or standard might be mentioned. This information must not be taken as the only code or standard applicable.

1.19.5. When part of equipment does not bear the required CSA label, the contractor shall obtain from CSA or Hydro Electric Power Commission, when that part of the equipment is an electric component, a special approval and pay the applicable fees.

1.19.6. Furnish necessary certificates as evidence that the work installed conforms with laws and regulations of Authorities having jurisdiction. Changes in work requested by an Authority having jurisdiction shall be carried out without charge.

1.20. **CONSULTANT'S INSTRUCTIONS**

1.20.1. During construction the Consultant will issue such instructions as may be necessary for verification and correction of the work. These instructions shall be binding as part of the specification.

1.21. **ADDITIONAL WORK AND CHANGES**

1.21.1. Unless a written order, reviewed by the Consultant and countersigned or otherwise approved by the Board Representative, no additional work shall be undertaken by the Contractor.

1.22. **DELIVERY, STORAGE AND HANDLING**

1.22.1. Protection of Equipment:

1.22.1.1. Equipment and material placed on the job site shall remain in the custody of the Contractor until phased acceptance, whether or not the Board has reimbursed the Contractor for the equipment and material. The Contractor is solely responsible for the protection of such equipment and material against any damage.

1.22.1.2. Place damaged equipment in first class, new operating condition; or, replace same as determined and directed by the Consultant. Such repair or replacement shall be at no additional cost to the Board.

1.22.1.3. Protect interiors of new equipment and piping systems against entry of foreign matter. Clean both inside and outside before painting or placing equipment in operation.

1.22.1.4. Existing equipment and piping being worked on by the Contractor shall be under the custody and responsibility of the Contractor and shall be protected as required for new work.

1.22.2. Cleanliness of Piping and Equipment Systems:

1.22.2.1. Exercise care in storage and handling of equipment and piping material to be incorporated in the work. Remove debris arising from cutting, threading and welding of piping.

1.22.2.2. Piping systems shall be flushed, blown or pigged as necessary to deliver clean systems.

1.22.2.3. Clean interior of all tanks prior to delivery for beneficial use by the Board.

1.22.2.4. Boilers shall be left clean following final internal inspection by Board insurance representative or inspector.

1.22.2.5. Contractor shall be fully responsible for all costs, damage, and delay arising from failure to provide clean systems.

1.23. **HAULING OPERATIONS**

1.23.1. Maintain roadways and paving in the hauling areas clean on a daily basis and as required by Municipal Authorities.

1.23.2. Parking is not ample or readily available in the area where the building is located. Coordinate delivery of equipment with the Board representatives.

1.23.3. Contractor is responsible for all craning & lifting operations. It is the Contractor's responsibility to coordinate with the respective Municipality & pay/obtain all required permits.

1.23.4. Contractor is responsible for providing a craning plan for review & approval by the Client.

1.24. **JOB CONDITIONS – WORK IN EXISTING BUILDING**

1.24.1. Building Operation: Board employees will be continuously operating and managing all facilities, including temporary facilities, that serve the building.

1.24.2. Maintenance of Service: Schedule all work to permit continuous service as required by the Board.

1.24.3. Services Interruptions: Limited service interruptions, as required for interconnections of new and existing systems, will be coordinated with the Board and permitted by the Board during the agreed-upon schedule of interruption. Provide at least one week advance notice to the Board representatives.

1.24.4. Phasing of Work: Comply with all requirements shown on drawings or specified.

1.24.5. Building Working Environment: Maintain the architectural and structural integrity of the building and the working environment at all times. Maintain the interior of building at 18 degrees C (65 degrees F) minimum. Limit the opening of doors, windows or other access openings to brief periods as necessary for rigging purposes. No storm water or ground water leakage permitted. Provide daily clean up of construction and demolition debris on all floor surfaces and on all equipment being operated by the Board.

1.24.6. Acceptance of Work for Board Operation: As new facilities are made available for operation and these facilities are of beneficial use to the Board, inspections will be made and tests will be performed. Based on the inspections, a list of contract deficiencies will be issued to the Contractor. After correction of deficiencies as necessary for beneficial use, the Consultant will process necessary acceptance and the equipment will then be under the control and operation of Board personnel.

PART 2 - PRODUCTS

2.1. FACTORY-ASSEMBLED PRODUCTS

2.1.1. Provide maximum standardization of components to reduce spare part requirements.

2.1.2. Manufacturers of equipment assemblies that include components made by others shall assume complete responsibility for final assembled unit.

2.1.3. All components of an assembled unit need not be products of same manufacturer.

2.1.4. Constituent parts that are alike shall be products of a single manufacturer.

2.1.5. Components shall be compatible with each other and with the total assembly for intended service.

2.1.6. Contractor shall guarantee performance of assemblies of components, and shall repair or replace elements of the assemblies as required to deliver specified performance of the complete assembly.

2.1.7. Components of equipment shall bear manufacturer's name and trademark, model number, serial number and performance data on a name plate securely affixed in a conspicuous place, or cast integral with, stamped or otherwise permanently marked upon the components of the equipment.

2.1.8. Major items of equipment, which serve the same function, must be the same make and model. Exceptions will be permitted if performance requirements cannot be met.

2.2. COMPATIBILITY OF RELATED EQUIPMENT

2.2.1. Equipment and materials installed shall be compatible in all respects with other items being furnished and with existing items so that the result will be a complete and fully operational plant that conforms to contract requirements.

2.3. BELT DRIVES

2.3.1. Type: ANSI/RMA standard V belts with proper motor pulley and driven sheave. Belts shall be constructed of reinforced cord and rubber.

2.3.2. Dimensions, rating and selection standards: ANSI/RMA IP 20 and IP 21.

2.3.3. Minimum Horsepower Rating: Motor horsepower plus recommended ANSI/RMA service factor (not less than 20 percent) in addition to the ANSI/RMA allowances for pitch diameter, center distance, and arc of contact.

2.3.4. Maximum Speed: 25 m/s (5000 feet per minute).

2.3.5. Adjustment Provisions: For alignment and ANSI/RMA standard allowances for installation and take up.

2.3.6. Drives may utilize a single V Belt (any cross section) when it is the manufacturer's standard.

2.3.7. Multiple Belts: Matched to ANSI/RMA specified limits by measurement on a belt measuring fixture. Seal matched sets together to prevent mixing or partial loss of sets. Replacement, when necessary, shall be an entire set of new matched belts.

2.3.8. Sheaves and Pulleys:

2.3.8.1. Material: Pressed steel, or close grained cast iron.
2.3.8.2. Bore: Fixed or bushing type for securing to shaft with keys.
2.3.8.3. Balanced: Statically and dynamically.
2.3.8.4. roove spacing for driving and driven pulleys shall be the same.
2.3.8.5. Drive Types, Based on ARI 435.

2.3.9. Provide adjustable pitch or fixed pitch drive as follows:

2.3.9.1. Fan speeds up to 1800 RPM: 7.5 kW (10 horsepower) and smaller.
2.3.9.2. Fan speeds over 1800 RPM: 2.2 kW (3 horsepower) and smaller.
2.3.9.3. Provide fixed pitch drives for drives larger than those listed above.

2.3.10. The final fan speeds required to just meet the system CFM and pressure requirements, without throttling, shall be determined by adjustment of a temporary adjustable pitch motor sheave or by fan law calculation if a fixed pitch drive is used initially.

2.4. **DRIVE GUARDS**

2.4.1. For machinery and equipment, provide guards as shown in AMCA 410 for belts, chains, couplings, pulleys, sheaves, shafts, gears and other moving parts regardless of height above the floor to prevent damage to equipment and injury to personnel. Drive guards may be excluded where motors and drives are inside factory fabricated air handling unit casings.

2.4.2. Pump shafts and couplings shall be fully guarded by a sheet steel guard, covering coupling and shaft but not bearings. Material shall be minimum 16-gage sheet steel; ends shall be braked and drilled and attached to pump base with minimum of four 6 mm (1/4-inch) bolts. Reinforce guard as necessary to prevent side play forcing guard onto couplings.

2.4.3. V-belt and sheave assemblies shall be totally enclosed, firmly mounted, non-resonant. Guard shall be an assembly of minimum 22-gage sheet steel and expanded or perforated metal to permit observation of belts. 25 mm (one-inch) diameter hole shall be provided at each shaft centerline to permit speed measurement.

2.4.4. Materials: Sheet steel, cast iron, expanded metal or wire mesh rigidly secured so as to be removable without disassembling pipe, duct, or electrical connections to equipment.

2.4.5. Access for Speed Measurement: 25 mm (One inch) diameter hole at each shaft center.

2.5. **LIFTING ATTACHMENTS**

2.5.1. Provide equipment with suitable lifting attachments to enable equipment to be lifted in its normal position. Lifting attachments shall withstand any handling conditions that might be encountered, without bending or distortion of shape, such as rapid lowering and braking of load.

2.6. **EQUIPMENT REQUIREMENTS AND INSTALLATION**

2.6.1. Permit equipment maintenance and disassembly by use of unions or flanges to minimize disturbance to connecting piping and duct systems and without interference from building structure or other equipment.

2.6.2. Provide accessible means for lubricating equipment including permanent lubricated bearings.

2.6.3. For all base mounted boilers, pumps, compressors, air handling units, fans and other rotating equipment, provide chamfered edge housekeeping pads a minimum of 4" high and 4" larger than equipment dimensions all around. Work shall be performed by the trades specializing in this work.

2.6.4. Pipe drain lines, overflows and safety relief vents to drains. If the horizontal drains present a tripping hazard, use aluminum checkered plate covers.

2.6.5. Line up equipment, rectangular cleanouts and similar items with building walls wherever possible.

2.7. **ELECTRIC MOTORS**

2.7.1. All material and equipment furnished and installation methods shall conform to the requirements of Section: 23 05 13 Common Motor Requirements for HVAC Equipment, and Section: 26 05 19 Low-Voltage Electrical Power Conductors and Cables, Provide all electrical wiring, conduit, and devices necessary for the proper connection, protection and operation of the systems. Provide special energy efficient premium efficiency type motors as scheduled.

2.8. **VARIABLE SPEED MOTOR CONTROLLERS**

2.8.1. Refer to Section: 26 05 00 Common Work Results for Electrical, and Section: 26 29 23 Variable-Frequency Motor Controllers for specifications.

2.8.2. The combination of controller and motor shall be provided by the manufacturer of the driven equipment, such as pumps and fans, and shall be rated for 100 percent output performance. Multiple units of the same class of equipment, i.e. air handlers, fans, pumps, shall be product of a single manufacturer.

2.8.3. Motors shall be premium efficiency type and be approved by the motor controller manufacturer. The controller-motor combination shall be guaranteed to provide full motor nameplate horsepower in variable frequency operation. Both driving and driven motor/fan sheaves shall be fixed pitch.

2.8.4. Controller shall not add any current or voltage transients to the input AC power distribution system, DDC controls, sensitive medical equipment, etc., nor shall be affected from other devices on the AC power system.

2.8.5. Controller shall be provided with the following operating features and accessories:

2.8.5.1. Suitable for variable torque load.

2.8.5.2. Provide thermal magnetic circuit breaker or fused switch with external operator and incoming line fuses. Provide output line reactors on line between drive and motor for motors over 50 HP or where the distance between the breaker and motor exceeds 50 feet.

2.9. **EQUIPMENT AND MATERIALS IDENTIFICATION**

2.9.1. Refer to Section: 23 05 53 Identification for HVAC Piping and Equipment.

2.10. **FIRESTOPPING**

2.10.1. Provide either factory built (Firestop Devices) or field installed (through-Penetration Firestop Systems) to form a specific building system maintaining required integrity of the fire barrier and stop the passage of gases or smoke. Firestop systems to accommodate building movements without impairing their integrity.

2.10.2. Through-penetration firestop systems and firestop devices tested in accordance with ASTM E814 or UL 1479 using the "F" or "T" rating to maintain the same rating and integrity as the fire barrier being sealed. "T" ratings are not required for penetrations smaller than or equal to 101 mm (4 inches) nominal pipe or 0.01 square meter (16 square inches) in overall cross sectional area.

2.10.3. Firestop sealants used for firestopping or smoke sealing to have the following properties:

2.10.3.1. Contain no flammable or toxic solvents.
2.10.3.2. Release no dangerous or flammable out gassing during the drying or curing of products.
2.10.3.3. Water-resistant after drying or curing and unaffected by high humidity, condensation or transient water exposure.
2.10.3.4. When installed in exposed areas, capable of being sanded and finished with similar surface treatments as used on the surrounding wall or floor surface.

2.10.4. Firestopping system or devices used for penetrations by glass pipe, plastic pipe or conduits, unenclosed cables, or other non-metallic materials to have following properties:

2.10.4.1. Classified for use with the particular type of penetrating material used.
2.10.4.2. Penetrations containing loose electrical cables, computer data cables, and communications cables protected using firestopping systems that allow unrestricted cable changes without damage to the seal.

2.10.5. Maximum flame spread of 25 and smoke development of 50 when tested in accordance with ASTM E84 or UL 723. Material to be an approved firestopping material as listed in UL Fire Resistance Directory or by a nationally recognized testing laboratory.

2.10.6. FM, UL, or WH rated or tested by an approved laboratory in accordance with ASTM E814.

2.10.7. Materials to be nontoxic and noncarcinogen at all stages of application or during fire conditions and to not contain hazardous chemicals. Provide firestop material that is free from Ethylene Glycol, PCB, MEK, and asbestos.

2.10.8. For firestopping exposed to view, traffic, moisture, and physical damage, provide products that do not deteriorate when exposed to these conditions.

2.10.8.1. For piping penetrations for plumbing and wet-pipe sprinkler systems, provide moisture-resistant through-penetration firestop systems.
2.10.8.2. For floor penetrations with annular spaces exceeding 101 mm (4 inches) or more in width and exposed to possible loading and traffic, provide firestop systems capable of supporting the floor loads involved either by installing floor plates or by other means acceptable to the firestop manufacturer.
2.10.8.3. For penetrations involving insulated piping, provide through-penetration firestop systems not requiring removal of insulation.

2.11. **GALVANIZED REPAIR COMPOUND**

2.11.1. Mil. Spec. DOD P 21035B, paint form.

2.12. **HVAC PIPE AND EQUIPMENT SUPPORTS AND RESTRAINTS**

2.12.1. Vibration Isolators: Refer to Section: 23 05 48 Vibration and Seismic Controls for HVAC.

2.12.2. Supports for Roof Mounted Items:

2.12.2.1. Equipment: Refer to details on mechanical and structural drawings.
2.12.2.2. Pipe Supports: Refer to details on the drawings.
2.12.2.3. Supports for Indoor Mounted Items
2.12.2.3.1. Attachment to Concrete Building Construction:

- Concrete insert: MSS SP-58, Type 18.
- Self drilling expansion shields and machine bolt expansion anchors: Permitted in concrete not less than 102 mm (four inches) thick when approved by the Consultant for each job condition.
- Power driven fasteners: Permitted in existing concrete or masonry not less than 102 mm (four inches) thick when approved by the Consultant for each job condition.

2.12.2.3.2. Attachment to Steel Building Construction:

- Welded attachment: MSS SP 58, Type 22.
- Beam clamps: MSS SP-58, Types 20, 21, 28 or 29. Type 23 C clamp may be used for individual copper tubing up to 23mm (7/8 inch) outside diameter.

2.12.2.3.3. Attachment to existing structure: Support from existing floor/roof frame

- Attachment to Wood Construction: Wood screws or lag bolts.
- Hanger Rods: Hot rolled steel, ASTM A36 or A575 for allowable load listed in MSS SP 58. For piping, provide adjustment means for controlling level or slope. Types 13 or 15 turn buckles shall provide 38 mm (1 1/2 inches) minimum of adjustment and incorporate locknuts. All thread rods are acceptable.

2.12.2.3.4. Hangers Supporting Multiple Pipes (Trapeze Hangers): Galvanized, cold formed, lipped steel channel horizontal member, not less than 41 mm by 41 mm (1 5/8 inches by 1 5/8 inches), 2.7 mm (No. 12 gage), designed to accept special spring held, hardened steel nuts. Not permitted for steam supply and condensate piping.
2.12.2.3.5. Allowable hanger load: Manufacturers rating less 91kg (200 pounds).
2.12.2.3.6. Guide individual pipes on the horizontal member of every other trapeze hanger with 6 mm (1/4 inch) U bolt fabricated from steel rod. Provide Type 40 insulation shield, secured by two 13mm (1/2 inch) galvanized steel bands, or preinsulated calcium silicate shield for insulated piping at each hanger.

2.12.3. Supports for Piping Systems:

2.12.3.1. Select hangers sized to encircle insulation on insulated piping. Refer to Section 23 07 11 for insulation thickness. To protect insulation, provide Type 39 saddles for roller type supports or pre-insulated calcium silicate shields. Provide Type 40 insulation shield or pre-insulated calcium silicate shield at all other types of supports and hangers including those for pre-insulated piping.

2.12.4. Piping Systems (MSS SP 58):

2.12.4.1. Standard clevis hanger: Type 1; provide locknut.
2.12.4.2. Riser clamps: Type 8.
2.12.4.3. Wall brackets: Types 31, 32 or 33.
2.12.4.4. Roller supports: Type 41, 43, 44 and 46.
2.12.4.5. Saddle support: Type 36, 37 or 38.
2.12.4.6. Turnbuckle: Types 13 or 15. Preinsulate.
2.12.4.7. U bolt clamp: Type 24.

2.12.5. Copper Tube:

2.12.5.1. Hangers, clamps and other support material in contact with tubing shall be painted with copper colored epoxy paint, plastic coated or taped with non-adhesive isolation tape to prevent electrolysis.
2.12.5.2. For vertical runs use epoxy painted or plastic coated riser clamps.
2.12.5.3. For supporting tube to strut: Provide epoxy painted pipe straps for copper tube or plastic inserted vibration isolation clamps.

2.12.6. Insulated Lines: Provide pre-insulated calcium silicate shields sized for copper tube.

2.12.7. Supports for plastic or glass piping: As recommended by the pipe manufacturer with black rubber tape extending one inch beyond steel support or clamp.

2.12.8. Piping with Vertical Expansion and Contraction:

2.12.8.1. Movement up to 20 mm (3/4 inch): Type 51 or 52 variable spring unit with integral turn buckle and load indicator.
2.12.8.2. Movement more than 20 mm (3/4 inch): Type 54 or 55 constant support unit with integral adjusting nut, turn buckle and travel position indicator.
2.12.8.3. Convertor and Expansion Tank Hangers: May be Type 1 sized for the shell diameter. Insulation where required will cover the hangers.

2.12.9. For pipe sizes larger than (50 mm) 2-inches:

2.12.9.1. Pre-insulated Calcium Silicate Shields:
2.12.9.1.1. Provide 360 degree water resistant high density 965 kPa (140 psi) compressive strength calcium silicate shields encased in galvanized metal.

2.12.9.1.2. Pre-insulated calcium silicate shields to be installed at the point of support during erection.

2.12.9.1.3. Shield thickness shall match the pipe insulation.

2.12.9.1.4. The type of shield is selected by the temperature of the pipe, the load it must carry, and the type of support it will be used with.

2.12.9.1.5. Shields for supporting chilled or cold water shall have insulation that extends a minimum of 1 inch past the sheet metal. Provide for an adequate vapor barrier in chilled lines.

2.12.9.1.6. The pre-insulated calcium silicate shield shall support the maximum allowable water filled span as indicated in MSS-SP 69. To support the load, the shields may have one or more of the following features: structural inserts 4138 kPa (600 psi) compressive strength, an extra bottom metal shield, or formed structural steel (ASTM A36) wear plates welded to the bottom sheet metal jacket.

2.12.9.1.7. Shields may be used on steel clevis hanger type supports, roller supports or flat surfaces

2.13. **PIPE PENETRATIONS – ROOFS**

2.13.1. Refer to details on the drawings

2.14. **PIPE PENETRATIONS THROUGH INTERIOR BUILDING ELEMENTS**

2.14.1. Install sleeves during construction for other than blocked out floor openings for risers in mechanical bays.

2.14.2. To prevent accidental liquid spills from passing to a lower level, provide the following:

2.14.2.1. For sleeves: Extend sleeve 25 mm (one inch) above finished floor and provide sealant for watertight joint.

2.14.2.2. For blocked out floor openings: Provide 40 mm (1½ inch) angle set in silicone adhesive around opening.

2.14.2.3. For drilled penetrations: Provide 40 mm (1½ inch) angle ring or square set in silicone adhesive around penetration.

2.14.3. Penetrations are not allowed through beams or ribs, but may be installed in concrete beam flanges. Any deviation from these requirements must receive prior approval of Consultant.

2.14.4. Sheet Metal, Plastic, or Moisture resistant Fiber Sleeves: Provide for pipe passing through floors, interior walls, and partitions, unless brass or steel pipe sleeves are specifically called for below.

2.14.5. Cast Iron or Zinc Coated Pipe Sleeves: Provide for pipe passing through exterior walls below grade. Make space between sleeve and pipe watertight with a modular or link rubber seal. Seal shall be applied at both ends of sleeve.

2.14.6. Galvanized Steel or an alternate Black Iron Pipe with asphalt coating Sleeves: Provide for pipe passing through concrete beam flanges, except where brass pipe sleeves are called for. Provide sleeve for pipe passing through floor of mechanical rooms, laundry work rooms, and animal rooms above basement. Except in mechanical rooms, connect sleeve with floor plate.

2.14.7. Brass Pipe Sleeves: Provide for pipe passing through quarry tile, terrazzo or ceramic tile floors. Connect sleeve with floor plate.

2.14.8. Sleeves are not required for wall hydrants for fire department connections or in drywall construction.

2.14.9. Sleeve Clearance: Sleeve through floors, walls, partitions, and beam flanges shall be one inch greater in diameter than external diameter of pipe. Sleeve for pipe with insulation shall be large enough to accommodate the insulation. Interior openings shall be caulked tight with fire stopping material and sealant to prevent the spread of fire, smoke, and gases.

2.15. **DUCT PENETRATIONS - ROOFS**

2.15.1. Provide curbs for roof mounted piping, ductwork and equipment. Curbs shall be 18 inches high with continuously welded seams, built-in cant strip, interior baffle with acoustic insulation, curb bottom, hinged curb adapter.

2.15.2. Refer to details on mechanical and structural drawings.

2.16. **DUCT PENETRATIONS – INTERIOR BUILDING ELEMENTS**

2.16.1. Provide sheet metal sleeves min 150 mm (6”) raised above the penetrated floors. Seal space between sleeves and ducts.

2.16.2. For penetrations through fire rated building elements, refer to details on the drawings.

2.16.3. Provide firestopping for openings through fire and smoke barriers, maintaining minimum required rating of floor, ceiling or wall assembly.

2.17. **SPECIAL TOOLS AND LUBRICANTS**

2.17.1. Furnish, and turn over to the Board, tools not readily available commercially, that are required for disassembly or adjustment of equipment and machinery furnished.

2.17.2. Grease Guns with Attachments for Applicable Fittings: One for each type of grease required for each motor or other equipment.

2.17.3. Refrigerant Tools: Provide system charging/Evacuation equipment, gauges, fittings, and tools required for maintenance of furnished equipment.

2.17.4. Tool Containers: Hardwood or metal, permanently identified for intended service and mounted, or located, where directed by the Consultant.

2.17.5. Lubricants: A minimum of 0.95 L (one quart) of oil, and 0.45 kg (one pound) of grease, of equipment manufacturer's recommended grade and type, in unopened containers and properly identified as to use for each different application.

2.18. **WALL, FLOOR AND CEILING PLATES**

2.18.1. Material and Type: Chrome plated brass or chrome plated steel, one piece or split type with concealed hinge, with set screw for fastening to pipe, or sleeve. Use plates that fit tight around pipes, cover openings around pipes and cover the entire pipe sleeve projection.

2.18.2. Thickness: Not less than 2.4 mm (3/32 inch) for floor plates. For wall and ceiling plates, not less than 0.64 mm (0.025-inch) for up to 80 mm (3 inch pipe), 0.89 mm (0.035-inch) for larger pipe.

2.18.3. Locations: Use where pipe penetrates floors, walls and ceilings in exposed locations, in finished areas only. Provide a watertight joint in spaces where brass or steel pipe sleeves are specified.

PART 3 - EXECUTION

3.1. **ARRANGEMENT AND INSTALLATION OF EQUIPMENT AND PIPING**

3.1.1. Coordinate location of piping, sleeves, inserts, hangers, ductwork and equipment. Locate piping, sleeves, inserts, hangers, ductwork and equipment clear of windows, doors, openings, light outlets, and other services and utilities. Prepare equipment layout drawings to coordinate proper location and personnel access of all facilities. Submit the interference drawings for review as required by Part 1. Follow manufacturer's published recommendations for installation methods not otherwise specified.

3.1.2. Operating Personnel Access and Observation Provisions: Select and arrange all equipment and systems to provide clear view and easy access, without use of portable ladders, for maintenance and operation of all devices including, temperature but not limited to: all equipment items, valves, filters, strainers, transmitters, sensors, control devices. All gages and indicators shall be clearly visible by personnel standing on the floor or on permanent platforms. Do not reduce or change maintenance and operating space and access provisions that are shown on the drawings.

3.2. **THERMOMETERS AND PRESSURE GAUGES**

3.2.1. General:

3.2.1.1. Locate direct reading thermometers and gauges for reading from floor or platform.
3.2.1.2. Provide remote reading thermometers and gauges where direct reading instruments cannot be satisfactorily located.
3.2.1.3. Locate engraved lamacoid nameplate as specified in Section Identification, identifying medium adjacent to thermometers and gauges.

3.2.2. Thermometers:

3.2.2.1. Industrial, 9" adjustable angle cast aluminum case, CGSB standard CAN/CGSB-14.4-M88 red reading mercury, lens front tube, white scale black embossed figures, clear glass or acrylic window, tapered aluminum stem.
3.2.2.2. Scale shall be suitable for 2 times the temperature range of service. Scale shall be combined Celsius and Fahrenheit.
3.2.2.3. Standard of Acceptance: Weiss, Ashcroft, Trerice.

3.2.3. Pressure Gauges:

3.2.3.1. 5" dial, solid front blow out back, fibreglass reinforced polypropylene case, phosphor bronze bourdon tube and brass 1/4" N.P.T. socket, bottom connection, stainless steel rotary type movement, gauge to be registered with the Provincial Boiler and Pressure Vessel Safety Branch with a registration number and conform to ANSI B40.1. Accuracy to be grade "A".
3.2.3.2. On pumps liquid filled gauges shall be utilized.
3.2.3.3. Standard of Acceptance: Weiss, Ashcroft, Trerice.
3.2.3.4. Provide bronze stop cock, bronze bar stock ¼" N.P.T. bronze porous core pressure snubber for pulsating operation and diaphragm for corrosive service.
3.2.3.5. Use materials compatible with system requirements.

3.2.4. Gauges shall have combined kilopascal and psi scales.

3.3. **EQUIPMENT AND PIPING SUPPORT**

3.3.1. Coordinate structural systems necessary for pipe and equipment support with pipe and equipment locations to permit proper installation.

3.3.2. Location of pipe sleeves, trenches and chases shall be accurately coordinated with equipment and piping locations.

3.3.3. Cutting Holes:

3.3.3.1. Cut holes through concrete and masonry by rotary core drill. Pneumatic hammer, impact electric, and hand or manual hammer type drill will not be allowed, except as permitted by Consultant where working area space is limited.

3.3.3.2. Locate holes to avoid interference with structural members such as beams or grade beams. Holes shall be laid out in advance and drilling done only after approval by Consultant. If the Contractor considers it necessary to drill through structural members, this matter shall be referred to Consultant for approval.

3.3.3.3. Do not penetrate membrane waterproofing.

3.4. **ITEMS NOT SHOWN BUT REQUIRED**

3.4.1. Interconnection of Instrumentation or Control Devices: Generally, electrical and pneumatic interconnections are not shown but must be provided.

3.4.2. Minor Piping: Generally, small diameter pipe runs from drips and drains, water cooling, and other service are not shown but must be provided.

3.4.3. Electrical and Pneumatic Interconnection of Controls and Instruments: This generally not shown but must be provided. This includes interconnections of sensors, transmitters, transducers, control devices, control and instrumentation panels, instruments and computer workstations. Comply with NFPA-70.

3.5. **PROTECTION AND CLEANING**

3.5.1. Equipment and materials shall be carefully handled, properly stored, and adequately protected to prevent damage before and during installation, in accordance with the manufacturer's recommendations and as approved by the Consultant. Damaged or defective items in the opinion of the Consultant, shall be replaced.

3.5.2. Protect all finished parts of equipment, such as shafts and bearings where accessible, from rust prior to operation by means of protective grease coating and wrapping. Close pipe openings with caps or plugs during installation. Tightly cover and protect fixtures and equipment against dirt, water chemical, or mechanical injury. At completion of all work thoroughly clean fixtures, exposed materials and equipment.

3.6. **WORK IN EXISTING BUILDING**

3.6.1. Make alterations to existing service piping at times that will least interfere with normal operation of the facility.

3.6.2. Cut required openings through existing masonry and reinforced concrete using diamond core drills. Use of pneumatic hammer type drills, impact type electric drills, and hand or manual hammer type drills, will be permitted only with approval of the Board. Locate openings that will least effect structural slabs, columns, ribs or beams. Refer to the Consultant for determination of proper design for openings through structural sections and opening layouts approval, prior to cutting or drilling into structure. After Consultant's approval, carefully cut opening through construction no larger than absolutely necessary for the required installation.

3.6.3. Switchgear/Electrical Equipment Drip Protection: Every effort shall be made to eliminate the installation of pipe above electrical and telephone switchgear. If this is not possible, encase pipe in a second pipe with a minimum of joints. Installation of piping, ductwork, leak protection apparatus or other installations foreign to the electrical installation shall be located in the space equal to the width and depth of the equipment and extending from to a height of 1.8 m (6 ft.) above the equipment to ceiling structure, whichever is lower (NFPA 70).

3.6.4. Inaccessible Equipment:

3.6.4.1. Where the Board determines that the Contractor has installed equipment not conveniently accessible for operation and maintenance, equipment shall be removed and reinstalled or remedial action performed as directed at no additional cost to the Board.

3.6.4.2. The term "conveniently accessible" is defined as capable of being reached without climbing or crawling under or over obstacles such as motors, fans, pumps, belt guards, transformers, high voltage lines, piping, and ductwork.

3.7. TEMPORARY PIPING AND EQUIPMENT

3.7.1. Continuity of operation of existing facilities will generally require temporary installation or relocation of equipment and piping.

3.7.2. The Contractor shall provide all required facilities in accordance with the requirements of phased construction and maintenance of service. All piping and equipment shall be properly supported, sloped to drain, operate without excessive stress, and shall be insulated where injury can occur to personnel by contact with operating facilities.

3.7.3. Temporary facilities and piping shall be completely removed and any openings in structures sealed. Provide necessary blind flanges and caps to seal open piping remaining in service.

3.8. RIGGING

3.8.1. Design is based on application of available equipment. Openings in building structures are planned to accommodate design scheme.

3.8.2. Alternative methods of equipment delivery may be offered by Contractor and will be considered by Board under specified restrictions of phasing and maintenance of service as well as structural integrity of the building.

3.8.3. Close all openings in the building when not required for rigging operations to maintain proper environment in the facility for Board operation and maintenance of service.

3.8.4. Contractor shall provide all facilities required to deliver specified equipment and place on foundations. Attachments to structures for rigging purposes and support of equipment on structures shall be Contractor's full responsibility. Upon request, the Board will check structure adequacy and advise Contractor of recommended restrictions.

3.8.5. Contractor shall check all clearances, weight limitations and shall offer a rigging plan designed by a Registered Professional Engineer. All modifications to structures, including reinforcement thereof, shall be at Contractor's cost, time and responsibility.

3.8.6. Rigging plan and methods shall be referred to Consultant for evaluation prior to actual work.

3.8.7. Restore building to original condition upon completion of rigging work.

3.9. **PIPE AND EQUIPMENT SUPPORTS**

3.9.1. Where hanger spacing does not correspond with joist or rib spacing, use structural steel channels secured directly to joist and rib structure that will correspond to the required hanger spacing, and then suspend the equipment and piping from the channels. Drill or burn holes in structural steel only with the prior approval of the Consultant.

3.9.2. Use of chain, wire or strap hangers; wood for blocking, stays and bracing; or, hangers suspended from piping above will not be permitted. Replace or thoroughly clean rusty products and paint with zinc primer.

3.9.3. Use hanger rods that are straight and vertical. Turnbuckles for vertical adjustments may be omitted where limited space prevents use. Provide a minimum of 15 mm (1/2 inch) clearance between pipe or piping covering and adjacent work.

3.9.4. HVAC Horizontal Pipe Support Spacing: Refer to MSS SP 69. Provide additional supports at valves, strainers, in line pumps and other heavy components. Provide a support within one foot of each elbow.

3.9.5. HVAC Vertical Pipe Supports:

3.9.5.1. Up to 150 mm (6 inch pipe), 9 m (30 feet) long, bolt riser clamps to the pipe below couplings, or welded to the pipe and rests supports securely on the building structure.

3.9.5.2. Vertical pipe larger than the foregoing, support on base elbows or tees, or substantial pipe legs extending to the building structure.

3.9.6. Overhead Supports:

3.9.6.1. The basic structural system of the building is designed to sustain the loads imposed by equipment and piping to be supported overhead.

3.9.6.2. Provide steel structural members, in addition to those shown, of adequate capability to support the imposed loads, located in accordance with the final approved layout of equipment and piping.

3.9.7. Tubing and capillary systems shall be supported in channel troughs.

3.9.8. Floor Supports:

3.9.8.1. Provide concrete bases, concrete anchor blocks and pedestals, and structural steel systems for support of equipment and piping. Anchor and dowel concrete bases and structural systems to resist forces under operating and seismic conditions (if applicable) without excessive displacement or structural failure.

3.9.8.2. Do not locate or install bases and supports until equipment mounted thereon has been approved. Size bases to match equipment mounted thereon plus 50 mm (2 inch) excess on all edges. Boiler foundations shall have horizontal dimensions that exceed boiler base frame dimensions by at least 150 mm (6 inches) on all sides. Refer to structural drawings. Bases shall be neatly finished and smoothed, shall have chamfered edges at the top, and shall be suitable for painting.

3.9.9. All equipment shall be shimmed, leveled, firmly anchored, and grouted with epoxy grout. Anchor bolts shall be placed in sleeves, anchored to the bases. Fill the annular space between sleeves and bolts with a granular material to permit alignment and realignment.

3.10. **CLEANING AND PAINTING**

3.10.1. Prior to final inspection and acceptance of the plant and facilities for beneficial use by the Board, the plant facilities, equipment and systems shall be thoroughly cleaned and painted.

3.10.2. At the completion of the project, clean and prepare all floors in the fan rooms for painting. Cover the entire floors for the mechanical room (in the area of work) with two coats of urethane-based paint (colour: battleship gray). Refer to Section 09 91 00.

3.10.3. In addition, the following special conditions apply:

3.10.3.1. Cleaning shall be thorough. Use solvents, cleaning materials and methods recommended by the manufacturers for the specific tasks. Remove all rust prior to painting and from surfaces to remain unpainted. Repair scratches, scuffs, and abrasions prior to applying prime and finish coats.

3.10.4. Material And Equipment Not To Be Painted Includes:

3.10.4.1. Motors, controllers, control switches, and safety switches.
3.10.4.2. Control and interlock devices.
3.10.4.3. Regulators.
3.10.4.4. Pressure reducing valves.
3.10.4.5. Control valves and thermostatic elements.
3.10.4.6. Lubrication devices and grease fittings.
3.10.4.7. Copper, brass, aluminum, stainless steel and bronze surfaces.
3.10.4.8. Valve stems and rotating shafts.
3.10.4.9. Pressure gauges and thermometers.
3.10.4.10. Glass.
3.10.4.11. Name plates.

3.10.5. Control and instrument panels shall be cleaned, damaged surfaces repaired, and shall be touched-up with matching paint obtained from panel manufacturer.

3.10.6. Pumps, motors, steel and cast iron bases, and coupling guards shall be cleaned, and shall be touched-up with the same color as utilized by the pump manufacturer

3.10.7. Temporary Facilities: Apply paint to surfaces that do not have existing finish coats.

3.10.8. Final result shall be smooth, even-colored, even-textured factory finish on all items. Completely repaint the entire piece of equipment if necessary to achieve this.

3.11. **IDENTIFICATION SIGNS**

3.11.1. Refer to Section: 23 05 53 Identification for HVAC Piping and Equipment.

3.12. **MOTOR AND DRIVE ALIGNMENT**

3.12.1. Belt Drive: Set driving and driven shafts parallel and align so that the corresponding grooves are in the same plane.

3.12.2. Direct connect Drive: Securely mount motor in accurate alignment so that shafts are free from both angular and parallel misalignment when both motor and driven machine are operating at normal temperatures.

3.13. **LUBRICATION**

3.13.1. Lubricate all devices requiring lubrication prior to initial operation. Field-check all devices for proper lubrication.

3.13.2. Equip all devices with required lubrication fittings or devices. Provide a minimum of one liter (one quart) of oil and 0.5 kg (one pound) of grease of manufacturer's recommended grade and type for each different application; also provide 12 grease sticks for lubricated plug valves. Deliver all materials to Consultant in unopened containers that are properly identified as to application.

3.13.3. Provide a separate grease gun with attachments for applicable fittings for each type of grease applied.

3.13.4. All lubrication points shall be accessible without disassembling equipment, except to remove access plates.

3.14. **CONCRETE**

3.14.1. All concrete work required to complete this project, whether shown on the drawings or not, shall be the Contractor's responsibility.

3.14.2. Refer to this specification section for requirements for housekeeping pad.

3.15. **METALS**

3.15.1. All steel construction required for the completion of this project, whether shown on the drawings or not, shall be the Contractor's responsibility.

3.16. **CUTTING, PATCHING, ROOFING, AND X-RAY**

3.16.1. All cutting, patching, roofing and X-Rays required for the completion of this project whether shown on the drawings or not, shall be the Contractor's responsibility. The cutting and patching work shall be performed in accordance with the following:

3.16.1.1. All cutting and patching shall be done by the trades specializing in the materials to be cut.

3.16.1.2. All flashing and equipment supports on the roof shall be done in strict accordance with the Board standards by Board-approved roofing contractors only.

3.16.1.3. Should any cutting, roofing and/or repairing of finished surfaces be required, the Sub-trade contractor for the Contractor shall employ the particular trades engaged on the site for this type of work.

3.16.1.4. None of the roofing work shall affect any current roof warranty. Coordinate with the Board representative the status of the roof, and if under warranty, coordinate all the work with the warranty holder.

3.16.1.5. Supporting members of any floor, wall or the building structure shall be cut only in such a location and manner as approved by the Consultant.

3.16.1.6. Where slabs in the portions of the building which are existing must be saw-cut or core drilled, all locations shall be x-rayed prior to saw-cutting or core-drilling. All x-raying shall be done by personnel qualified in the use of the type of equipment required to x-ray the saw-cuts shall be permitted to perform this work on the site. No allowance will be made later for expenses incurred through the failure of performing these x-rays.

3.17. **OPERATING AND MAINTENANCE MANUALS**

3.17.1. Refer to Section: 01 33 23 Shop Drawings, Product Data, and Samples.

3.18. **CLOSE-OUT DOCUMENTATION**

3.18.1. 10 (ten) days prior to substantial performance of work obtain documentation and/or prepare certification of the following items and submit them to the Board representative:

3.18.1.1. All inspection certificates.
3.18.1.2. Guarantee certificates as called for under "Warranty".
3.18.1.3. Record drawings.
3.18.1.4. Operating and Maintenance Manuals.
3.18.1.5. Test certifications as called for under "Testing".
3.18.1.6. Provide a signed statement to the effect that all tests for mechanical systems and equipment have been completely carried out in the Trade Sections of these Specifications and to the manufacturer's recommendations, and in accordance with the requirements of all authorities having jurisdiction.

3.19. **COMMISSIONING**

3.19.1. Where applicable and the commissioning process is part of the project, provide commissioning documentation and all the manpower required for all inspection, start up, and contractor testing required above and required by the Checklists provided by the Commissioning Agent.

3.19.2. Coordinate with the Commissioning Agent if the start up and operation of the installed equipment is part of larger systems which require additional testing and verification.

3.20. **STARTUP AND TEMPORARY OPERATION**

3.20.1. Startup equipment as described in equipment specifications. Verify that vibration is within specified tolerance prior to extended operation.

3.21. **FIRE ALARM SUB-CONTRACTOR**

3.21.1. The Mechanical contractor is do carry a Fire Alarm Subcontractor for all associated fire alarm work. The Fire Alarm Subcontractor must be one of the following:

3.21.2. Magnum Fire Protection Inc, Ruban Ratnasingam, 905-660-9111

3.21.3. EPI Fire Protection and Security, Jonathan Zafrani, 416-746-2225 (x226

3.22. **OPERATING AND PERFORMANCE TESTS**

3.22.1. Prior to the final inspection, perform required tests as specified and submit the test reports and records to the Consultant. The timing of the tests shall be arranged to suit the convenience of the Consultant, and the manner and duration shall be as the Consultant deems necessary. Record the daily start and stop times, operating hours and functions performed. Ensure that the performance tests are witnessed by the Consultant.

3.22.2. Should evidence of malfunction in any tested system, or piece of equipment or component part thereof, occur during or as a result of tests, make proper corrections, repairs or replacements, and repeat tests at no additional cost to the Board.

3.22.3. At the successful completion of Performance Tests and all testing and balancing, make the systems ready for final inspection and subsequent acceptance of the Board. Replace and clean filters, flush out lines and equipment, remove and clean strainers, fill liquid systems and purge air. Provide water treatment to pipes and report in accordance to current by-laws. Disinfect all domestic water as required by current by-laws and Authorities Having Jurisdiction.

3.22.4. When completion of certain work or system occurs at a time when final control settings and adjustments cannot be properly made to make performance tests, then make performance tests for heating systems and for cooling systems respectively during first actual seasonal use of respective systems following completion of work.

3.23. **INSTRUCTIONS TO BOARD PERSONNEL**

3.23.1. Provide in accordance with Section: 01 79 00 Demonstration and Training.

TABLE OF CONTENTS

PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section specifies the furnishing, installation and connection of motors for HVAC equipment.

1.2. RELATED WORK

1.2.1. Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.2.2. Section: 23 05 00 Common Work Results for HVAC.

1.2.3. Section: 26 05 00 Common Work Results for Electrical.

1.2.4. Section: 26 05 19 Low-Voltage Electrical Power Conductors and Cables.

1.3. SUBMITTALS

1.3.1. Submit in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples, and Section: 26 05 00 Common Work Results for Electrical.

1.3.2. Shop Drawings:

1.3.2.1. Provide documentation to demonstrate compliance with drawings and specifications.

1.3.2.2. Include electrical ratings, efficiency, bearing data, power factor, frame size, dimensions, mounting details, materials, horsepower, voltage, phase, speed (RPM), enclosure, starting characteristics, torque characteristics, code letter, full load and locked rotor current, service factor, and lubrication method.

1.3.3. Manuals:

1.3.3.1. Submit simultaneously with the shop drawings, companion copies of complete installation, maintenance and operating manuals, including technical data sheets and application data.

1.3.3.2. Certification: Two weeks prior to final inspection, unless otherwise noted, submit four copies of the following certification to the Resident Engineer:

1.3.3.3. Certification that the motors have been applied, installed, adjusted, lubricated, and tested according to manufacturer published recommendations.

1.4. APPLICABLE PUBLICATIONS

1.4.1. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.

1.4.2. National Electrical Manufacturers Association (NEMA):

1.4.2.1. MG 1-2006 Rev. 1 2009 Motors and Generators

1.4.2.2. MG 2–2001Rev. 1 2007 Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators

1.4.3. National Fire Protection Association (NFPA):

1.4.3.1. 70-latest National Electrical Code (NEC)

1.4.4. Institute of Electrical and Electronics Engineers (IEEE):

1.4.4.1. 112-04 Standard Test Procedure for Polyphase Induction Motors and Generators

1.4.5. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE):

1.4.5.1. 90.1-latest Energy Standard for Buildings Except Low-Rise Residential Buildings

1.5. **STANDARDS OF ACCEPTANCE**

1.5.1. Baldor Electric Company

1.5.2. Leeson Electric

1.5.3. General Electric

1.5.4. Dayton

PART 2 - PRODUCTS

2.1. **MOTORS**

2.1.1. All material and equipment furnished and installation methods shall conform to the requirements of Section: 26 29 10 Motor Starters to 600 V and Section: 26 05 19 Low-Voltage Electrical Power Conductors and Cables (600 VOLTS AND BELOW). Provide all electrical wiring, conduit, and devices necessary for the proper connection, protection and operation of the systems. Provide premium efficiency type motors as scheduled. Unless otherwise specified for a particular application, use electric motors with the following requirements.

2.1.2. Single phase Motors: Motors for centrifugal fans and pumps may be split phase or permanent split capacitor (PSC) type. Provide capacitor-start type for hard starting applications.

2.1.3. Electrically Commutated motor (EC Type): Motor shall be brushless DC type specifically designed for applications with heavy duty ball bearings and electronic commutation. The motor shall be speed controllable down to 20% of full speed and 85% efficient at all speeds.

2.1.4. Poly-phase Motors: NEMA Design B, Squirrel cage, induction type.

2.1.5. Two Speed Motors: Each two-speed motor shall have two separate windings. Provide a time- delay (20 seconds minimum) relay for switching from high to low speed.

2.1.6. Number of phases shall be as follows:

2.1.6.1. Motors, less than 373 W (1/2 HP): Single phase.
2.1.6.2. Motors, 373 W (1/2 HP) and larger: 3 phase.
2.1.6.3. Exceptions:
2.1.6.3.1. Hermetically sealed motors.
2.1.6.3.2. Where specified otherwise on the equipment schedules
2.1.6.3.3. Motors for equipment assemblies, less than 746 W (one HP), may be single phase provided the manufacturer of the proposed assemblies cannot supply the assemblies with three phase motors.

2.1.7. Motors shall be designed for operating the connected loads continuously in a 40°C (104°F) environment, where the motors are installed, without exceeding the NEMA standard temperature rises for the motor insulation. If the motors exceed 40°C (104°F), the motors shall be rated for the actual ambient temperatures.

2.1.8. Motor designs, as indicated by the NEMA code letters, shall be coordinated with the connected loads to assure adequate starting and running torque.

2.2. **MOTOR ENCLOSURES**

2.2.1. Shall be the NEMA types as specified and/or shown on the drawings.

2.2.2. Where the types of motor enclosures are not shown on the drawings, they shall be the NEMA types, which are most suitable for the environmental conditions where the motors are being installed.

2.2.3. Enclosure requirements for certain conditions are as follows:

2.2.3.1. Motors located outdoors, indoors in wet or high humidity locations, or in unfiltered airstreams shall be totally enclosed type.
2.2.3.2. Where motors are located in an NEC 511 classified area, provide TEFC explosion proof motor enclosures.
2.2.3.3. Where motors are located in a corrosive environment, provide TEFC enclosures with corrosion resistant finish.
2.2.3.4. Enclosures shall be primed and finish coated at the factory with manufacturer's prime coat and standard finish.

2.2.4. Special Requirements:

2.2.4.1. Where motor power requirements of equipment furnished deviate from power shown on plans, provide electrical service designed under the requirements of NFPA 70 without additional time or cost to the Client.

2.2.4.2. Assemblies of motors, starters, controls and interlocks on factory assembled and wired devices shall be in accordance with the requirements of this specification.

2.2.5. Wire and cable materials specified in the electrical division of the specifications shall be modified as follows:

2.2.5.1. Wiring material located where temperatures can exceed 71 degrees C (160 degrees F) shall be stranded copper with Teflon FEP insulation with jacket. This includes wiring on the boilers.

2.2.5.2. Other wiring at boilers and to control panels shall be NFPA 70 designation THWN.

2.2.5.3. Provide shielded conductors or wiring in separate conduits for all instrumentation and control systems where recommended by manufacturer of equipment.

2.2.6. Select motor sizes so that the motors do not operate into the service factor at maximum required loads on the driven equipment. Motors on pumps shall be sized for non-overloading at all points on the pump performance curves.

2.2.7. Motors less than 3 HP:

2.2.7.1. Steel or cast iron motor frames, cast aluminum, cast iron, or steel end plates, steel or cast iron terminal box, copper windings. Motor nameplates shall be steel, engraved-type, riveted to motor.

2.2.7.2. Bearings: Regreasable with relief plugs, pre-lubricated ball bearings suitable for radial and thrust loading of the application, with grease fittings, selected for a minimum L-10bearing life of 26,280 hours, for belted and direct drive.

2.2.8. Motors 3 HP and above:

2.2.8.1. Cast iron motor frame and mounting feet, cast iron end plates (bells), steel or cast iron terminal box, copper windings. Motor nameplates shall be stainless steel engraved type, riveted to the motor.

2.2.8.2. Bearings shall be regreasable with relief plugs, pre-lubricated ball bearings suitable for radial and thrust loading of the application, with grease fittings. Rated for an L-10 life of 40,000 hours (belted) or 130,000 hours (direct connected).

2.2.9. Bearing life calculations shall be per ABMA 9, and for belted applications shall be based on the maximum external side load limits for belted applications per NEMA MG-1 Table 14-1A. L-10 life calculations for vertical motors and horizontal motors mounted in the vertical position shall consider the application's thrust loading.

2.2.10. TEFC motors shall also include an external shaft slinger on drive end.

2.2.11. Motors shall not exceed dBA levels listed in NEMA MG-1 54 PART 9 Tables 9-1 and 9-3, at all speeds.

2.2.12. Motors utilized with variable frequency drives shall be rated “inverter-duty” per NEMA Standard, MG1, Part 31.4.4.2. Provide motor shaft grounding apparatus that will protect bearings from damage from stray currents.

2.3. **ENERGY EFFICIENT MOTORS (MOTOR EFFICIENCIES):**

2.3.1. All permanently wired polyphase motors of 746 Watts (1 HP) or more shall meet the minimum full-load efficiencies as indicated in the following table.

2.3.2. Motors of 746 Watts or more with open, drip-proof or totally enclosed fan-cooled enclosures shall be NEMA premium efficiency type, unless otherwise indicated.

2.3.3. Motors provided as an integral part of motor driven equipment are excluded from this requirement if a minimum seasonal or overall efficiency requirement is indicated for that equipment by the provisions of another section.

Minimum Premium Efficiencies Open Drip-Proof				**Minimum Premium Efficiencies Totally Enclosed Fan-Cooled**			
Rating kW (HP)	**1200 RPM**	**1800 RPM**	**3600 RPM**	**Rating kW (HP)**	**1200 RPM**	**1800 RPM**	**3600 RPM**
0.746 (1)	82.5%	85.5%	77.0%	0.746 (1)	82.5%	85.5%	77.0%
1.12 (1.5)	86.5%	86.5%	84.0%	1.12 (1.5)	87.5%	86.5%	84.0%
1.49 (2)	87.5%	86.5%	85.5%	1.49 (2)	88.5%	86.5%	85.5%
2.24 (3)	88.5%	89.5%	85.5%	2.24 (3)	89.5%	89.5%	86.5%
3.73 (5)	89.5%	89.5%	86.5%	3.73 (5)	89.5%	89.5%	88.5%
5.60 (7.5)	90.2%	91.0%	88.5%	5.60 (7.5)	91.0%	91.7%	89.5%
7.46 (10)	91.7%	91.7%	89.5%	7.46 (10)	91.0%	91.7%	90.2%
11.2 (15)	91.7%	93.0%	90.2%	11.2 (15)	91.7%	92.4%	91.0%
14.9 (20)	92.4%	93.0%	91.0%	14.9 (20)	91.7%	93.0%	91.0%
18.7 (25)	93.0%	93.6%	91.7%	18.7 (25)	93.0%	93.6%	91.7%

22.4 (30)	93.6%	94.1%	91.7%	22.4 (30)	93.0%	93.6%	91.7%
29.8 (40)	94.1%	94.1%	92.4%	29.8 (40)	94.1%	94.1%	92.4%
37.3 (50)	94.1%	94.5%	93.0%	37.3 (50)	94.1%	94.5%	93.0%
44.8 (60)	94.5%	95.0%	93.6%	44.8 (60)	94.5%	95.0%	93.6%
56.9 (75)	94.5%	95.0%	93.6%	56.9 (75)	94.5%	95.4%	93.6%
74.6 (100)	95.0%	95.4%	93.6%	74.6 (100)	95.0%	95.4%	94.1%
93.3 (125)	95.0%	95.4%	94.1%	93.3 (125)	95.0%	95.4%	95.0%
112 (150)	95.4%	95.8%	94.1%	112 (150)	95.8%	95.8%	95.0%

2.3.4. Minimum Power Factor at Full Load and Rated Voltage: 90 percent at 1200 RPM, 1800 RPM and 3600 RPM.

PART 3 - EXECUTION

3.1. INSTALLATION

Install motors in accordance with manufacturer’s recommendations, the NEC, NEMA, as shown on the drawings and/or as required by other sections of these specifications.

3.2. FIELD TESTS

3.2.1. Perform an electric insulation resistance Test using a megohmmeter on all motors after installation, before start-up. All shall test free from grounds.

3.2.2. Perform Load test in accordance with ANSI/IEEE 112, Test Method B, to determine freedom from electrical or mechanical defects and compliance with performance data.

3.2.3. Insulation Resistance: Not less than one half meg-ohm between stator conductors and frame, to be determined at the time of final inspection.

3.2.4. All test data shall be complied into a report form for each motor and provided to the contracting officer or their representative.

3.3. STARTUP AND TESTING

3.3.1. The Commissioning Agent will observe startup and contractor testing of all equipment. Coordinate the startup and contractor testing schedules with Resident Engineer and Commissioning Agent. Provide a minimum of 7 days prior notice.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section specifies the application of noise and vibration control techniques to AHU equipment, fans, compressors and motors.

1.2. **RELATED WORK**

1.2.1. Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.3. **SUBMITTALS**

1.3.1. Submit in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.3.1.1. Noise and Vibration Control Devices; include with the equipment submittals.
1.3.1.2. Provide separate shop drawings for each isolated system complete with performance and product data.
1.3.1.3. Submit type of isolator, size, height when uncompressed and maximum allowable static deflection weight of all isolated equipment, loads on each isolator and static deflection of each isolator under the specific design load.
1.3.1.4. Submit marked up plans indicating all locations where pipes are to be isolated in mechanical rooms and as specified.

1.4. **APPLICABLE PUBLICATIONS**

1.4.1. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by basic designation only.

1.4.2. ASHRAE - 1995 - HVAC Applications, Chapter 43 - "Sound and Vibration Control".

1.5. **SCOPE OF WORK**

1.5.1. Provide vibration control items for isolating vibration of mechanical equipment, piping and ductwork.

1.5.2. Provide all hangers, isolators, bases, pads, sleeves and other devices specified, required, or detailed for the project. Include all vibration isolation system elements as recommended by the equipment manufacturer's representative to make a complete, correct and safe installation. Supply and install all incidental materials needed.

1.6. **QUALITY ASSURANCE**

1.6.1. Work of this section shall be performed by skilled workers who are experienced in the necessary crafts to meet the requirements of this Section.

1.6.2. Provide field supervision and inspection to assure proper installation, adjustment and performance. Replace any isolators that are found to resonate with the supported equipment.

1.6.3. As a minimum provide vibration control per ASHRAE - 1995 - HVAC Applications, Chapter 43 - "Sound and Vibration Control".

1.6.4. Isolators shall be selected, installed and adjusted to prevent the transmission of objectionable vibration and noise to the building structure.

1.6.5. The size and number of mounts and hangers shall be chosen to meet these specifications, even if not specifically shown on the plans. Brackets, rails, bases, braces, etc., shall be provided as needed for a complete and correct installation.

1.7. **ACCEPTABLE MANUFACTURERS**

1.7.1. Subject to compliance with the Contract Documents, manufacturers for products specified in this Section shall be one of the following:

1.7.1.1. Kinetics Noise Controls.
1.7.1.2. Mason Industries, Inc.
1.7.1.3. Vibron Ltd.

PART 2 - PRODUCTS

2.1. **SUSPENDED VIBRATION ISOLATION**

2.1.1. <u>Combination isolation hanger assembly with neoprene insert</u>

2.1.1.1. Vibration isolators for suspended equipment with minimum static deflection requirement exceeding 0.4" (10 mm), and where both high and low frequency vibrations are to be isolated, shall be hangers consisting of a laterally stable spring in series with an elastomer-in-shear insert complete with load transfer plates and assembled in a stamped or welded steel bracket.
2.1.1.2. The bracket shall be finished with an polyester powder coating. The manufacturer shall provide independent laboratory testing showing that the bracket with this finish has endured a minimum of 1,000 hours of exposure to salt spray fog testing per ASTM B117 without signs of corrosion.
2.1.1.3. The elastomer insert shall be molded from oil-resistant compounds and shall be color coded to indicate load capacity and selected to operate within its published load range.
2.1.1.4. The spring element shall have a minimum lateral stiffness of 1.0 times the rated vertical stiffness.
2.1.1.5. Springs shall be color coded or otherwise identified to indicate load capacity.
2.1.1.6. The hanger bracket shall be designed to carry a 500% overload without failure and to allow a support rod misalignment through a 30° arc without metal-to-metal contact or other short circuit.
2.1.1.7. The 1" and 2" hanger brackets shall incorporate spring caps with indexed steps which correspond to the washer diameter of appropriately sized hanger rod to keep the rod centered in the spring cap and reduce rod misalignment. The spring caps are protected under U.S. patent number 5,653,426.

2.1.1.8. Isolation hangers shall be selected by the manufacturer for each specific application to comply with deflection requirements as shown on the Vibration Isolation Schedule or as indicated on the project documents.

2.1.1.9. *Applications: Suspended mechanical equipment such as in-line fans, cabinet fans, and piping and ductwork in close proximity to mechanical equipment.*

2.1.1.10. Standard of Acceptance: Kinetics Noise Control SRH series.

2.1.2. <u>Neoprene Isolation Hangers</u>

2.1.2.1. Vibration isolators with maximum static deflection requirements under operating load conditions not exceeding 0.57" (15 mm) shall be hangers consisting of an elastomer-in-shear insert encased in a welded steel bracket and provided with a stamped load transfer cap.

2.1.2.2. The elastomer insert shall be molded from oil resistant compounds, shall be color coded to indicate load capacity and selected to operate within its published load range.

2.1.2.3. The hanger bracket shall be designed to carry a 500% overload without failure and to allow support rod misalignment through a 30° arc without metal-to-metal contact or other short circuit.

2.1.2.4. Isolation hangers shall be selected by the manufacturer for each specific application to comply with deflection requirements as shown on the Vibration Isolation Schedule or as indicated on the project documents.

2.1.2.5. *Applications: isolation of vibration produced by suspended mechanical equipment, in-line and exhaust fans, ductwork, piping.*

2.1.2.6. Standard of Acceptance: Kinetics Noise Control SRH series.

2.1.3. <u>Piping Hangers Spring Vibration isolators</u>

2.1.3.1. Vibration isolators for suspended equipment with minimum static deflection requirement exceeding 0.4" (10 mm), and where both high and low frequency vibrations are to be isolated, shall be hangers consisting of a laterally stable spring in series with an elastomer-in-shear insert complete with load transfer plates and assembled in a stamped or welded steel bracket.

2.1.3.2. The bracket shall be finished with a polyester powder coating. The manufacturer shall provide independent laboratory testing showing that the bracket with this finish has endured a minimum of 1,000 hours of exposure to salt spray fog testing per ASTM B117 without signs of corrosion.

2.1.3.3. The elastomer insert shall be molded from oil-resistant compounds and shall be color coded to indicate load capacity and selected to operate within its published load range.

2.1.3.4. The spring element shall have a minimum lateral stiffness of 1.0 times the rated vertical stiffness.

2.1.3.5. Springs shall be color coded or otherwise identified to indicate load capacity.

2.1.3.6. The hanger bracket shall be designed to carry a 500% overload without failure and to allow a support rod misalignment through a 30° arc without metal-to-metal contact or other short circuit.

2.1.3.7. The 1" and 2" hanger brackets shall incorporate spring caps with indexed steps which correspond to the washer diameter of appropriately sized hanger rod to keep the rod centered in the spring cap and reduce rod misalignment. The spring caps are protected under U.S. patent number 5,653,426.

2.1.3.8. Isolation hangers shall be selected by the manufacturer for each specific application to comply with deflection requirements as shown on the Vibration Isolation Schedule or as indicated on the project documents.

2.1.3.9. *Application: first three pipe hangers upstream/downstream of pumping equipment.*

2.1.3.10. The combination isolation hanger assembly with neoprene insert shall be Model SRH, as manufactured by Kinetics Noise Control, Inc.

2.2. FLOOR MOUNTED VIBRATION ISOLATION

2.2.1. Restrained Spring Isolators

2.2.1.1. Vibration isolators for equipment which is subject to load variations and large external or torquing forces shall consist of large diameter laterally stabile steel springs assembled into welded steel housing assemblies designed to limit vertical movement of the supported equipment.

2.2.1.2. Housing assemblies shall be fabricated steel members and shall consist of a top load plate complete with adjusting and leveling bolts, vertical restraints, isolation washers and a bottom plate with internal non-skid noise isolation pads. Housing shall be electrozinc plated or hot dip galvanized for corrosion resistance. Housing should be designed to provide a constant free and operating height within 1/8" (0.06 mm).

2.2.1.3. Spring elements shall have a lateral stiffness greater than 1.2 times the rated vertical stiffness and shall be designed to provide a minimum of 50% overload capacity. Non-welded spring elements shall be polyester powder coated, and shall have a 1000 hr rating when tested in accordance with ASTM B-117.

2.2.1.4. All springs shall have a minimum additional travel to solid equal to 50% of the rated deflection. All springs except internal nested springs shall have an outside diameter not less than 0.8 of the compressed height of the spring. Ends of springs shall be square and ground for stability. Laterally stable springs shall have kx/ky ratios of at least 0.9. All springs shall be fully color-coded to indicate capacity – color striping is not considered adequate.

2.2.1.5. Corrosion Protection: All springs shall be powder-coated enamel. Housings shall be galvanized, powder-coated enamel, or painted with rust-resistant paint. Hot-dipped galvanized housings shall be provided as indicated on the Schedule

2.2.1.6. Operating static deflections are available up to 4" (102 mm) to compensate for long span flexible floor structures and maintain a high degree of noise and vibration isolation.

2.2.1.7. Springs shall be selected to provide maximum deflections; select from manufacturer's literature based on supported equipment weight. Springs shall be color coded or otherwise identified to indicate load capacity.

2.2.1.8. *Vertically restrained spring isolation mounts are recommended as a noise and vibration isolator for heavy mechanical equipment, or when the equipment to be isolated has significant changes of weight during maintenance operations, and for equipment subjected to moderate external forces or wind loads, such as such as chillers, cooling towers, condensing units larger than 50 ton capacity, air handlers and utility type exhaust fans larger than 10,000 cfm capacity, and similar.*

2.2.1.9. Standards of Acceptance: Kinetics Nose Controls FRS (supported weight up to 1,500 kg) or FLS series (supported equipment weight above 1,500 kg).

2.2.2. <u>Neoprene Isolation Pads</u>

2.2.2.1. Isolation pads shall be single ribbed or crossed, double ribbed elastomer-in-shear pads, in combination with steel shims when required, having maximum deflections between 0.08" to 0.14"

2.2.2.2. All pads shall be true elastomer-in-shear using alternately higher and lower ribs to provide effective vibration isolation, and shall be molded using 2500 PSI (176 kg/cm2) tensile strength, oil resistant compounds with no color additives.

2.2.2.3. Pads shall be 45 to 65 durometer and designed to permit 60 or 120 PSI (4.2 or 8.4 kg/cm2) loading at maximum rated deflections.

2.2.2.4. When two isolation pads are laminated, they shall be separated by, and bonded to, a galvanized steel shim plate.

2.2.2.5. *Application: floor/concrete curb/sleeper mounted equipment such as boilers pumps, utility type exhaust fans of less than 10,000 cfm capacity, condensing units of less than 50 ton capacity, condensers/fluid coolers, and similar*

2.2.2.6. Standard of Acceptance: Kinetics Noise Control models NPS, NPD, NGS or NGD to suit weight of equipment and max. deflection rates.

2.2.3. <u>Elastomeric Isolation Mounts</u>

2.2.3.1. One-piece molded neoprene mounts with encapsulated metal inserts, color coded to identify capacity, with non-skid ribs on the bottom load surfaces. Each isolator incorporates two bolt-down holes on the bottom load surface and a tapped steel load top plate for attachment to the supported equipment. The neoprene is highly oil resistant and has been designed to operate within the strain limits of the isolator to provide maximum isolation and longest life expectancy possible using neoprene compounds.

2.2.3.2. *Isolation mounts are designed for up to 0.5" (13 mm) deflection, available in four sizes and eleven capacities from 55 lbs. to 4,000 lbs. (25 kg to 1814 kg).*

2.2.3.3. Standard of Acceptance: Kinetics Noise Control model RDS.

2.2.4. <u>Inertia Base Pads</u>

2.2.4.1. Isolation bases shall be constructed of concrete cast into fabricated inertia base frames, the steel members of which are designed and supplied by the isolator manufacturer. The concrete shall be poured into a welded steel frame, incorporating prelocated equipment anchor bolts, 1/2-in (13 mm) diameter reinforcing bars on nominal 8-in (203 mm) centers each way, and recessed isolator mounting brackets to reduce the mounting height of the equipment, and reduce the footprint of the base. The thickness of the base shall be a minimum of 8% of the longest span between isolators, at least 6 in (152 mm), or as indicated on the drawings. Where inertia bases are used to mount pumps, the bases shall be sized to support piping elbows.

2.2.4.2. Applications: Support of heavy equipment where preventing noise transmission to adjacent spaces is critical. Inertia bases are used to support mechanical equipment, reduce equipment vibration, provide for attachment of vibration isolators, prevent differential movement between driving and driven members, reduce rocking by lowering equipment center of gravity, reduce motion of equipment during start-up and shut-down, act to reduce reaction movement due to operating loads on equipment, and act as a noise barrier.

2.2.4.3. *Typical uses for inertia base frames, with poured concrete and supported by noise and vibration isolators, include use with open-type centrifugal chillers, reciprocating air and refrigeration compressors, chillers, and heat pumps, close-coupled and base-mounted pumps, centrifugal fans, internal combustion engines, and similar types of equipment.*

2.2.4.4. Standard of Acceptance: Kinetics Noise Control model CIB-L

2.2.5. <u>Vibration isolator Rails</u>

2.2.5.1. Spring components shall be 1"/25 mm for air handling equipment/condensing units and 2"/50 mm deflection for cooling towers/chillers, free-standing, un-housed, laterally stable steel springs. Springs shall have a lateral stiffness greater than 1.0 times the rated vertical stiffness and shall be designed for 50% overload to solid.

2.2.5.2. Springs shall be color coded to indicate load capacity.

2.2.5.3. Rails shall provide continuous support for the rooftop equipment and shall be designed to provide isolation against casing-radiated vibration in the rooftop equipment housing and structure borne vibration from rotating and mechanical equipment in the rooftop package.

2.2.5.4. Rail assembly shall consist of extruded aluminum top and bottom members connected by spring isolators and a continuous air- and water-tight seal. The seal shall be a beaded elastomeric material retained in a keyway along the top extrusion. The weather strip shall be sealed along the bottom with an aluminum fascia strip.

2.2.5.5. Rail assemblies shall incorporate means for attachment to the building and the supported equipment and shall incorporate additional stiffening members if necessary to assure stability.

2.2.5.6. Vibration isolators shall be selected by the manufacturer for each specific application to comply with deflection requirements as shown on the Vibration Isolation Schedule or as indicated on the project documents.

2.2.5.7. *Application: designed and engineered to isolate packaged roof mounted equipment from the roof structure. Typical applications: cooling tower, condensing units, roof mounted air handling equipment and similar*

2.2.5.8. Where specified, the vibration isolation rails shall have a positive elastomeric air and weather seal permitting the inside of the unit to be used as a return air plenum. The KSR mates with the inside of the manufacturers' curb eliminating any internal interference.

2.2.5.9. Standard of Acceptance: Kinetics Noise Control Model KSR

2.3. PIPING CONNECTIONS

2.3.1. Flexible Piping Connectors

2.3.1.1. Flexible Braided Hose Connectors – HVAC Systems

2.3.1.1.1. Type 321 Stainless Steel Hose with type 304 Stainless Steel Outer Braid and 150# Carbon Steel Flat Faced Drilled Bolting Flanges

2.3.1.1.2. Length: 229 mm (9") to 356" (14") depending on diameter. max. lateral offset: 10 mm (0.125")

2.3.1.1.3. Application: piping connected to rotating equipment to reduce the transmission of noise and vibration, and to eliminate stresses in piping systems due to misalignment and thermal movement of the piping, where fluid temperature may exceed 90^{O}C.

2.3.1.1.4. Standard of Acceptance: Kinetics Noise Control model BFMC-FFF

2.3.1.2. Refrigerant Piping Flexible Hose Connectors

2.3.1.2.1. Bronze flexible bellows with bronze braided outer cover and shall have bronze female copper sweat ends.

2.3.1.2.2. Standards of Acceptance: Kinetics Nose Control model BFMC-CFE

2.3.2. Twin Sphere Neoprene Connector

2.3.2.1. Made of molded EPDM reinforced with nylon tire cord and shall have mild steel floating flanges. Use control rods to limit deflections and movements to within the prescribed values indicated by the manufacturer.
2.3.2.2. Axial compression: 50 mm (2"). Axial elongation: 30 mm (1.25"). Transverse movement: 40 mm (1.5")
2.3.2.3. Application: piping connected to rotating equipment piping connected to rotating equipment to reduce the transmission of noise and vibration, and to eliminate stresses in piping systems due to misalignment and thermal movement of the piping, where fluid temperatures remain in the -10 deg. C to 90 deg. C (14 deg. F to 190 deg. F).
2.3.2.4. Standard of Acceptance: Kinetics Noise Control model FTC

2.4. **DUCTWORK CONNECTIONS**

2.4.1. Ductwork Flexible Connector

2.4.1.1. Fully welded match drilled carbon steel flanges equipped with backing bars fastened in place with zinc plated hardware and EPDM flex membrane material. Acoustically rated design shall be used where called for on the design documentation, with an absorptive acoustic fill and EPDM outer barrier.
2.4.1.2. EPDM Flexible material: 1/8" thick layered EPDM flex membrane with internal nylon scrim for superior tear strength. Resistant to ozone and UV exposure and cold cracking (suitable for outdoor use).
2.4.1.3. Aerodynamic protective metal flow liner for air streams in excess of 6,000 cfm.
2.4.1.4. Construction: flange to flange distance: 200 mm (8") static mode. Lateral and axial movement: +/- 12.5 mm (1/2 inch). Operating temperature: up to 100 deg. C (212 deg. F)
2.4.1.5. Application: between fans (intake and discharge) and ductwork.
2.4.1.6. *Exception: not required for air handling units where fans are internally isolated*
2.4.1.7. Standard of Acceptance: Kinetics Noise Control model Kineflex

PART 3 - EXECUTION

3.1. **GENERAL**

3.1.1. Statically and dynamically balance all pumps, fans, compressors and drivers. Align shafts of pumps, fans, and drivers to limit noise and vibration to specified values. Level and anchor equipment as necessary to achieve and maintain alignment.

3.1.2. All equipment mounted on vibration isolators springs shall have a minimum operating clearance of 2 inches between the bottom of the equipment or inertia base (and height saving bracket) and the concrete housekeeping pad (or bolt heads) beneath the equipment.

3.1.3. Check the clearance to ensure that no scraps have been left to short circuit the vibration isolators.

3.1.4. Provide a minimum of 4 inches between isolated equipment and the walls, ceiling, floors, columns and any other equipment not installed on vibration isolators.

3.1.5. Piping, ductwork, conduit or mechanical equipment shall not be hung from or supported on other equipment, pipes, or ductwork installed on vibration isolators.

3.1.6. Equipment connected to water or other fluid piping shall be erected on isolators or isolated foundations at correct operating heights prior to connection of piping. Equipment should be blocked-up with temporary shims to final operating height. When the system is assembled and fluid is added, the isolators shall be adjusted to allow removal of the shims.

3.1.7. All mechanical equipment not specifically identified in this specification that contains rotating or vibration elements shall be installed on neoprene isolators as appropriate. Provide supporting steel structure between isolators and equipment if isolator does not readily connect to equipment.

3.2. **FLOOR MOUNTED FANS AND AIR HANDLING EQUIPMENT**

3.2.1. Neoprene isolation pads (less than 10,000 cfm), restrained springs (above 10,000 cfm) with or without inertia concrete pads, as specified or shown on the drawings. Secure springs to equipment and pads.

3.3. **PIPING ISOLATION**

3.3.1. Use flexible hoses or neoprene vibration isolators at all connections between piping and equipment containing rotating parts (pumps, air handlers, chillers, cooling towers, etc). Applicable to refrigerant piping as well. Do not use neoprene isolators outdoors or where fluid temperatures temperature not suitable.

3.3.2. Use restrained spring isolators for the first three piping supports upstream and downstream of each pump.

3.4. **CEILING SUSPENDED EQUIPMENT**

3.4.1. Restrained spring isolators or neoprene isolation pads, as indicated on the drawings

3.5. **AIR COOLED CONDENSING UNITS**

3.5.1. Neoprene pad or elastomeric mounts secured to the support structure and equipment base rails (less than 50 ton capacity). Select based on equipment weight.

3.5.2. Restrained springs or vibration isolator rails secured to the support structure and equipment base rails (over 50 ton capacity). Select based on equipment weight.

3.6. **AIR COOLED CONDENSING UNITS**

3.6.1. Neoprene pad or elastomeric mounts secured to the support structure and equipment base rails

3.7. **ROOFTOP AIR HANDLING UNITS AND UTILITY TYPE EXHAUST FANS**

3.7.1. Vibration isolation rails (where specified)

3.8. **DUCT CONNECTORS**

3.8.1. At all connections between fans and ductwork, where not provided by the manufacturer.

3.8.2. Exception: kitchen grease exhaust ductwork connection to exhaust fan.

3.9. **ELECTRICAL CONNECTIONS**

3.9.1. All wiring connections to mechanical equipment on vibration isolators (either spring or neoprene type) shall be made with a minimum 36 inch long flexible liquid-tight conduit in a 360^{o} loop. Coordinate wiring connections with the electrical sub-trade.

3.10. **INSPECTION**

3.10.1. Supplier shall inspect and approve the installation of the vibration isolators and shall submit a report to the Client which verifies that all of the isolation equipment has been properly installed and that the installation is in full conformance with the specification. The report shall record the vibration isolator identification and model or type.

3.10.2. For isolators containing steel springs the report shall also record the size and uncompressed height, design static deflection and measured static deflection of the isolators provided.

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PART 1 - GENERAL

1.1. RELATED DOCUMENTS

1.1.1. Drawings and general provisions of the Contract apply to this Section.

1.1.1.1. Section: 23 21 13 Hydronic Piping.
1.1.1.2. Section: 23 31 13 Metal Ducts.

1.2. SUMMARY

1.2.1. Section Includes:

1.2.1.1. Equipment labels.
1.2.1.2. Warning signs and labels.
1.2.1.3. Pipe labels.
1.2.1.4. Valve tags.
1.2.1.5. Duct labels.

1.2.2. For BAS identification, also refer to requirements of Section: 23 09 00 Instrumentation and Control for HVAC.

1.3. SUBMITTAL

1.3.1. Product Data: For each type of product indicated.

PART 2 - PRODUCTS

2.1. STANDARDS OF ACCEPTANCE

2.1.1.1. Brady, Kolbi, or Panduit.

2.2. EQUIPMENT LABELS

2.2.1.1. Metal Labels for Equipment:
2.2.1.1.1. Material and Thickness: Brass, 0.032-inch minimum thickness, and having pre-drilled or stamped holes for attachment hardware.
2.2.1.1.2. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
2.2.1.1.3. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

2.2.2. Fasteners: Stainless-steel rivets or self-tapping screws.

2.2.3. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

2.2.4. Plastic Labels for Equipment:

2.2.4.1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.
2.2.4.2. Letter Color: White.
2.2.4.3. Background Color: Black.
2.2.4.4. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
2.2.4.5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
2.2.4.6. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

2.2.5. Fasteners: Stainless-steel rivets or self-tapping screws.

2.2.6. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

2.2.7. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified.

2.2.8. Label is to also indicate area and type of service being provided.

2.2.8.1. For Example AHU - 3 - floors 1-4
2.2.8.2. P3 HW Hot Water Pump - building perimeter

2.2.9. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2-by-11-inch bond paper. Tabulate equipment identification number and identify Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

2.3. **WARNING SIGNS AND LABELS**

2.3.1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.

2.3.2. Letter Color: White.

2.3.3. Background Color: Red.

2.3.4. Maximum Temperature: Able to withstand temperatures up to 160 deg F.

2.3.5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

2.3.6. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

2.3.7. Fasteners: Stainless-steel rivets or self-tapping screws.

2.3.8. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

2.3.9. Label Content: Include caution and warning information, plus emergency notification instructions.

2.4. **PIPE LABELS**

2.4.1. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, showing flow direction, and area served (i.e. perimeter heating hot water).

2.4.2. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.

2.4.3. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings, pipe size, and an arrow indicating flow direction.

2.4.4. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions, or as separate unit on each pipe label to indicate flow direction, and visible all around pipe.

2.4.5. Lettering Size: At least 1-1/2 inches high.

2.4.6. All piping, except that piping which is within inaccessible chases, shall be identified.

2.4.7. Each marker background shall be appropriately color coded with a clearly printed legend to identify the contents of the pipe in conformance with the “Scheme for the Identification of Piping Systems” (ASME A13.1-1981).

2.4.8. Set mark snap-around markers shall be used for overall diameters up to 6” and strap around markers shall be used above 6” overall diameters.

2.4.9. Markers shall be located:

2.4.9.1. Adjacent to each valve
2.4.9.2. At each branch
2.4.9.3. At each cap for future
2.4.9.4. At each riser takeoff,
2.4.9.5. At each pipe passage through wall (each side)

2.4.9.6. At each pipe passage at 20’ – 0” intervals maximum.
2.4.9.7. At each piece of equipment.
2.4.9.8. At all access doors.
2.4.9.9. A minimum of one (1) marker shall be provided at each room.

2.5. **VALVE TAGS**

2.5.1. Valve tags shall be according to project valve specification section(s). Unless required differently in project valve specification section(s), valve tags to be minimum 1.5" round brass, attached with metallic chains.

2.6. **DUCT LABELS**

2.6.1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.

2.6.1.1. Letter Color: White.
2.6.1.2. Background Color: Red.
2.6.1.3. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
2.6.1.4. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
2.6.1.5. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

2.6.2. Fasteners: Stainless-steel rivets or self-tapping screws.

2.6.3. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

2.6.4. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings, duct size, and an arrow indicating flow direction.

2.6.5. Flow-Direction Arrows: Integral with duct system service lettering to accommodate both directions, or as separate unit on each duct label to indicate flow direction.

2.6.6. Lettering Size: At least 1-1/2 inches high.

2.6.7. Markers shall be located:

2.6.7.1. Adjacent to each air handling equipment
2.6.7.2. At each branch
2.6.7.3. At each cap for future
2.6.7.4. At each riser takeoff,
2.6.7.5. At each duct passage through wall (each side)

2.6.7.6. On each duct straight run at 20' – 0" intervals maximum.

2.6.7.7. At all access doors.

2.6.7.8. A minimum of one (1) marker shall be provided at each room.

2.7. **OTHER SPECIALIZED LABELING AND REQUIREMENTS**

2.7.1. Fire damper access panels shall be permanently identified on the exterior by labels not less than 2" in height reading "FIRE DAMPER".

2.7.2. Smoke damper access panels shall be permanently identified on the exterior by labels not less than 2" in height reading "SMOKE DAMPER".

2.7.3. Combination fire/smoke damper access panels shall be permanently identified on the exterior by labels not less than 2" in height reading "RESETTABLE FIRE/SMOKE DAMPER". Mark the other access panels "FIRE/SMOKE DAMPER."

2.7.4. Items listed in items 1-3 above, will also be listed on a full size, laminated print and left in the main mechanical room as indicated above.

2.7.5. Duct static pressure sensors shall be permanently identified on the exterior by labels not less than 2" in height reading "STATIC PRESSURE SENSOR".

2.7.6. Humidity sensors in ductwork shall be permanently identified on the exterior by labels not less than 2" in height reading "HUMIDITY SENSOR".

2.7.7. Abbreviations: No abbreviations to be used.

2.7.8. All smoke and fire damper locations are to be posted as a pdf on the DDC system per fan system. This information is also to be located in the fire command center for the building. Coordinate with other trades to make sure this happens, and support as required via that coordination.

2.8. **STENCILING**

2.8.1. Not allowed.

PART 3 - EXECUTION

3.1. **PREPARATION**

3.1.1. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

3.2. **EQUIPMENT LABEL INSTALLATION**

3.2.1. Install or permanently fasten labels on each major item of mechanical equipment.

3.2.2. Locate equipment labels where accessible and visible.

3.3. **VALVE TAG INSTALLATION AND DOCUMENTATION**

3.3.1. Tag valves according to project valve specification section(s), and provide typed list (loose and framed under glass) per same specification section(s).

3.3.2. A valve tag schedule is to be mounted in each mechanical room and on every floor (for that respective floor) in a location to be determined by the Consultant

3.3.3. Each valve tag schedule will have an associated architectural print showing each valve location.

3.3.4. At project completion two additional hard copies are to be provided in addition to an electronic copy.

3.3.5. Two copies of the mechanical piping flow diagram will be supplied. All prints that are supplied that are located in mechanical rooms are to be laminated.

3.3.6. Pipe tags that are the first isolation for a utility in a mechanical room or building need to have indicated where the next upstream valve is located and the associated valve number indicated on the valve tag.

3.3.7. This is applicable for all utility isolation valves for each mechanical room space.

3.4. **DUCT LABEL INSTALLATION**

3.4.1. Install self-adhesive duct labels with permanent adhesive on air ducts in the following color codes:

3.4.1.1. Blue: For cold-air supply ducts.
3.4.1.2. Yellow: For hot-air supply ducts.
3.4.1.3. Green: For exhaust-, outside-, relief-, return-, and mixed-air ducts.
3.4.1.4. ASME A13.1 Colors and Designs: For hazardous material exhaust.

3.4.2. Locate labels at maximum intervals of 10 feet, at every change in direction, and within 3' of wall and floor penetrations on both sides of same.

3.4.3. Along with all other ducting on the job, label toxic exhaust.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. Testing, adjusting, and balancing (TAB) of heating, ventilating and air conditioning (HVAC) systems. TAB includes the following:

1.1.1.1. Planning systematic TAB procedures.
1.1.1.2. Design Review Report.
1.1.1.3. Systems Inspection report.
1.1.1.4. Duct Air Leakage test report.
1.1.1.5. Systems Readiness Report.
1.1.1.6. Balancing air and water distribution systems; adjustment of total system to provide design performance; and testing performance of equipment and automatic controls.
1.1.1.7. Recording and reporting results.

1.1.2. Definitions:

1.1.2.1. TAB: Testing, Adjusting and Balancing; the process of checking and adjusting HVAC systems to meet design objectives.
1.1.2.2. AABC: Associated Air Balance Council.
1.1.2.3. NEBB: National Environmental Balancing Bureau.

1.1.3. Hydronic Systems: Includes chilled water, condenser water, heating hot water and glycol water systems as applicable to the project.

1.1.4. Air Systems: Includes all outside air, supply air, return air, exhaust air and relief air systems, as applicable to the project.

1.1.5. Flow rate tolerance: The allowable percentage variation, minus to plus, of actual flow rate from values (design) in the contract documents.

1.2. RELATED WORK

1.2.1. Section: 23 05 00 Common Work Results for HVAC.

1.2.2. Section: 23 31 13 Metal Ducts.

1.2.3. Section: 23 21 23 Hydronic Pumps.

1.2.4. Section: 23 37 00 Air Outlets and Inlets.

1.2.5. Section: 23 21 13 Hydronic Piping.

1.2.6. Section 23 73 13 Modular Indoor Central Station Air Handling Units

1.2.7. Section 23 74 00 Packaged Outdoor HVAC Equipment

1.3. **QUALITY ASSURANCE**

1.3.1. Qualifications:

1.3.1.1. TAB Agency: The TAB agency shall be a subcontractor of the General Contractor and shall report to and be paid by the General Contractor.

1.3.1.2. The TAB agency shall be either a certified member of AABC or certified by the NEBB to perform TAB service for HVAC, water balancing and vibrations and sound testing of equipment. The certification shall be maintained for the entire duration of duties specified herein. If, for any reason, the agency loses subject certification during this period, the General Contractor shall immediately notify the Consultant and submit another TAB firm for approval.

1.3.2. TAB Specialist: The TAB specialist shall be either a member of AABC or an experienced technician of the Agency certified by NEBB. The certification shall be maintained for the entire duration of duties specified herein.

1.3.3. TAB Specialist shall be identified by the General Contractor within 10 days after the notice to proceed. The TAB specialist will be coordinating, scheduling and reporting all TAB work and related activities and will provide necessary information as required by the Consultant. The responsibilities would specifically include:

1.3.3.1. Shall directly supervise all TAB work.

1.3.3.2. Shall sign the TAB reports that bear the seal of the TAB standard. The reports shall be accompanied by report forms and schematic drawings required by the TAB standard, AABC or NEBB.

1.3.3.3. Would follow all TAB work through its satisfactory completion.

1.3.3.4. Shall provide final markings of settings of all HVAC adjustment devices.

1.3.3.5. Permanently mark location of duct test ports.

1.3.4. All TAB technicians performing actual TAB work shall be experienced and must have done satisfactory work on a minimum of 3 projects comparable in size and complexity to this project. Consultant is to ensure that the Tab Technicians are qualified before work is performed. The lead technician shall be certified by AABC or NEBB

1.3.5. Test Equipment Criteria: The instrumentation shall meet the accuracy/calibration requirements established by AABC National Standards or by NEBB Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems and instrument manufacturer. Provide calibration history of the instruments to be used for test and balance purpose.

1.3.6. Tab Criteria:

1.3.6.1. Flow rate tolerance: Following tolerances are allowed. For tolerances not mentioned herein follow ASHRAE Handbook "HVAC Applications", Chapter 36, as a guideline. Air Filter resistance during tests, artificially imposed if necessary, shall be at least 100 percent of manufacturer recommended change over pressure drop values for pre-filters and after-filters.

1.3.6.2. Tolerances:

1.3.6.2.1. Air handling unit and all other fans, cubic meters/min (cubic feet per minute): +/-5% of design values noted in the equipment schedules.

1.3.6.2.2. Air terminal units (maximum values): +/-5% of the design values noted on the equipment schedules.

1.3.6.2.3. Exhaust hoods/cabinets: 0% to +10% of the design values noted on the equipment schedules

1.3.6.2.4. Minimum outside air: 0% to +10% of the design values noted on the equipment schedules

1.3.6.2.5. Individual room air outlets and inlets, and air flow rates not mentioned above: +/-5% of the design values noted on the equipment schedules.

1.3.6.2.6. Heating hot water pumps and hot water coils: +/-5% of the design values noted on the equipment schedules.

1.3.6.2.7. Chilled water and condenser water pumps: 0% to +5% of the design values noted on the equipment schedules

1.3.6.2.8. Chilled water coils: 0% to +5% of the design values noted on the equipment schedules.

1.3.6.2.9. Heat output capacities: 0% to +10% of the design values noted on the equipment schedules

1.3.6.2.10. Cooling output capacities: +/-5% of the design values noted on the equipment schedules

1.3.7. Typical TAB procedures and results shall be demonstrated to the Consultant for one air distribution system (including all fans, three terminal units, three rooms randomly selected by the Consultant) and one hydronic system (pumps and three coils) as follows:

1.3.7.1. When field TAB work begins.

1.3.7.2. During each partial final inspection and the final inspection for the project if requested by the Board

1.4. **SUBMITTALS**

1.4.1. Submit in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.4.2. Submit names and qualifications of TAB agency and TAB specialists within 10 days after the notice to proceed. Submit information on three recently completed projects and a list of proposed test equipment.

1.4.3. Submit Following for Review and Approval:

1.4.3.1. Design Review Report within 10 days after the award of contract from the General Contractor.
1.4.3.2. Systems inspection report on equipment and installation for conformance with design.
1.4.3.3. Duct Air Leakage Test Report.
1.4.3.4. Systems Readiness Report.

1.4.4. Intermediate and Final TAB reports covering flow balance and adjustments, performance tests, vibration tests and sound tests.

1.4.5. Include in final reports uncorrected installation deficiencies noted during TAB and applicable explanatory comments on test results that differ from design requirements.

1.4.6. Prior to request for Final or Partial Final inspection, submit completed Test and Balance report for the area.

1.5. **APPLICABLE PUBLICATIONS**

1.5.1. The following publications form a part of this specification to the extent indicated by the reference thereto. In text the publications are referenced to by the acronym of the organization.

1.5.1.1. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE):
1.5.1.2. 2007 HVAC Applications ASHRAE Handbook, Chapter 37, Testing, Adjusting, and Balancing and Chapter 47, Sound and Vibration Control
1.5.1.3. Associated Air Balance Council (AABC):
1.5.1.3.1. AABC National Standards for Total System Balance
1.5.1.3.2. National Environmental Balancing Bureau (NEBB):
1.5.1.3.3. 7th Edition 2005 Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems
1.5.1.3.4. 2nd Edition 2006 Procedural Standards for the Measurement of Sound and Vibration
1.5.1.3.5. 3rd Edition 2009 Procedural Standards for Whole Building Systems Commissioning of New Construction
1.5.1.4. Sheet Metal and Air Conditioning Contractors National Association (SMACNA):
1.5.1.4.1. 3rd Edition 2002 HVAC SYSTEMS Testing, Adjusting and Balancing

PART 2 - PRODUCTS

2.1. PLUGS

2.1.1. Provide plastic plugs to seal holes drilled in ductwork for test purposes.

2.2. INSULATION REPAIR MATERIAL

2.2.1. See Section: 23 07 00 HVAC Insulation.

2.2.2. Provide for repair of insulation removed or damaged for TAB work.

PART 3 - EXECUTION

3.1. GENERAL

3.1.1. Obtain applicable contract documents and copies of approved submittals for HVAC equipment and automatic control systems.

3.1.2. *Coordinate all balancing work with the BAS vendor. Where balancing variable flow systems, fine tune the pressure differential sensor settings to ensure that all end users receive adequate water and air flows.*

3.2. DESIGN REVIEW REPORT

3.2.1. The TAB Specialist shall review the Contract Plans and specifications and advise the Consultant of any design deficiencies that would prevent the HVAC systems from effectively operating in accordance with the sequence of operation specified or prevent the effective and accurate TAB of the system. The TAB Specialist shall provide a report individually listing each deficiency and the corresponding proposed corrective action necessary for proper system operation.

3.3. SYSTEMS INSPECTION REPORT

3.3.1. Inspect equipment and installation for conformance with design.

3.3.2. The inspection and report are to be done after piping and air distribution equipment is on site and piping/duct installation has begun, but well in advance of performance testing and balancing work. The purpose of the inspection is to identify and report deviations from design and ensure that systems will be ready for TAB at the appropriate time.

3.3.3. Reports: Follow check list format developed by AABC, NEBB or SMACNA, supplemented by narrative comments, with emphasis on air handling units and fans. Check for conformance with submittals. Verify that diffuser and register sizes are correct. Check air terminal unit installation including their duct sizes and routing.

3.4. DUCT AIR LEAKAGE TEST REPORT

3.4.1. TAB Agency shall perform the leakage test as outlined in "Duct leakage Tests and Repairs" in Section: 23 31 13 Metal Ducts.

3.5. **SYSTEM READINESS REPORT**

3.5.1. The TAB Contractor shall measure existing air and water flow rates associated with existing systems utilized to serve renovated areas as indicated on drawings. Submit report of findings to Consultant.

3.5.2. Inspect each System to ensure that it is complete including installation and operation of controls. Submit report to Consultant in standard format and forms prepared and or approved by the Commissioning Agent, as applicable to the project.

3.5.3. Verify that all items such as ductwork piping, ports, terminals, connectors, etc., that is required for TAB are installed. Provide a report to the Consultant.

3.6. **TAB REPORTS**

3.6.1. The TAB contractor shall provide raw data immediately in writing to the Consultant if there is a problem in achieving intended results before submitting a formal report.

3.6.2. If over 20 percent of readings in the intermediate report fall outside the acceptable range, the TAB report shall be considered invalid and all contract TAB work shall be repeated and re-submitted for approval at no additional cost to the Board.

3.6.3. Do not proceed with the remaining systems until intermediate reports are reviewed by the Consultant.

3.7. **TAB PROCEDURES**

3.7.1. Tab shall be performed in accordance with the requirement of the Standard under which TAB agency is certified by either AABC or NEBB.

3.7.2. General: During TAB all related system components shall be in full operation. Fan and pump rotation, motor loads and equipment vibration shall be checked and corrected as necessary before proceeding with TAB. Set controls and/or block off parts of distribution systems to simulate design operation of variable volume air or water systems for test and balance work.

3.7.3. For air handling systems, perform balancing work when the building envelope is substantially completed (windows and doors installed, ceilings completed, transfer grilles installed)

3.7.4. For air handling systems equipped with hydronic components, make air and hydronic balancing at the same time.

3.7.5. Air Balance and Equipment Test: Include air handling units, fans, terminal units, fan coil units, room diffusers/outlets/inlets, computer room AC units, and laboratory fume hoods and biological safety cabinets.

3.7.6. Artificially load air filters by partial blanking to produce air pressure drop of manufacturer's recommended pressure drop.

3.7.7. Adjust fan speeds to provide design air flow.

3.7.8. Test and balance systems in all specified modes of operation, including variable volume, economizer, and fire emergency modes. Verify that dampers and other controls function properly.

3.7.9. Variable air volume (VAV) systems:

3.7.9.1. Not applicable to this project

3.7.10. Water Balance and Equipment Test: Include circulating pumps, convertors, heat exchangers, boilers, coils, coolers and condensers

3.7.10.1. Adjust flow rates for equipment.
3.7.10.2. Primary secondary (variable volume) systems: Balance systems at design water flow and then verify that variable flow controls function as designed.
3.7.10.3. Record final measurements for hydronic equipment on performance data sheets. Include entering and leaving water temperatures for heating and cooling coils, and for convertors. Include entering and leaving air temperatures (DB/WB for cooling coils) for air handling units and reheat coils. Make air and water temperature measurements at the same time.

3.8. **LOCATION OF MEASUREMENTS AND MEASURED PARAMETERS**

3.8.1. Perform hydronic measurements at each:

3.8.1.1. Boiler
3.8.1.2. Coil
3.8.1.3. Heat Exchanger
3.8.1.4. Control Valve
3.8.1.5. Balancing Valve

3.8.2. Perform air measurements at each:

3.8.2.1. Fan/Air Handling System discharge
3.8.2.2. Exhaust fan
3.8.2.3. Coil
3.8.2.4. Fresh air/Exhaust damper

3.8.2.5. Terminal unit

3.8.2.6. Air distribution equipment

3.8.3. Measured parameters

3.8.3.1. Air flows

3.8.3.2. Hydronic flows

3.8.3.3. Temperatures entering/leaving coils (hydronic and air)

3.8.3.4. Pressure drops at each measured equipment/device (hydronic and air)

3.8.3.5. Electric Power drawn by electrical equipment

3.9. **MARKING OF SETTINGS**

3.9.1. Following approval of Tab final Report, the setting of all HVAC adjustment devices including valves, splitters and dampers shall be permanently marked by the TAB Specialist so that adjustment can be restored if disturbed at any time. Style and colors used for markings shall be coordinated with the Consultant.

3.10. **IDENTIFICATION OF TEST PORTS**

3.10.1. The TAB Specialist shall permanently and legibly identify the location points of duct test ports. If the ductwork has exterior insulation, the identification shall be made on the exterior side of the insulation. All penetrations through ductwork and ductwork insulation shall be sealed to prevent air leaks and maintain integrity of vapor barrier.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. Field applied insulation for thermal efficiency and condensation control for HVAC piping, ductwork and equipment.

1.1.2. Re-insulation of HVAC piping, ductwork and equipment after asbestos abatement.

1.1.3. Apply insulation for all ducts and piping in the mechanical room, new and existing.

1.1.4. Definitions

1.1.4.1. ASJ: All service jacket, white finish facing or jacket.
1.1.4.2. Air conditioned space: Space having air temperature and/or humidity controlled by mechanical equipment.
1.1.4.3. Cold: Equipment or piping handling media at design temperature of 16 degrees C (60 degrees F) or below.
1.1.4.4. Concealed: Piping above ceilings and in chases, interstitial space, and pipe chases.
1.1.4.5. Exposed: Piping and equipment exposed to view in finished areas including mechanical equipment rooms or exposed to outdoor weather. Shafts, chases, interstitial spaces, unfinished attics, crawl spaces and pipe basements are not considered finished areas.
1.1.4.6. Hot: Hot water equipment or piping handling media above 41 degrees C (105 degrees F).
1.1.4.7. Thermal conductance: Heat flow rate through materials.
1.1.4.8. Thermal Conductivity (k): Watt per meter, per degree C (BTU per inch thickness, per hour, per square foot, per degree F temperature difference).
1.1.4.9. Vapor Retarder (Vapor Barrier): A material which retards the transmission (migration) of water vapor. Performance of the vapor retarder is rated in terms of permeance (perms). or the purpose of this specification, vapor retarders shall have a maximum published permeance of 0.1 perms and vapor barriers shall have a maximum published permeance of 0.001 perms.

1.2. RELATED WORK

1.2.1. Section: 23 05 00 Common Work Results for HVAC.

1.2.2. Section: 23 31 13 Metal Ducts.

1.2.3. Section: 23 21 13 Hydronic Piping.

1.3. QUALITY ASSURANCE

1.3.1. Comply with OBC requirements for flame spread and smoke development rates.

1.3.2. Specified k factors are at 24 degrees C (75 degrees F) mean temperature unless stated otherwise. For pipe, use insulation manufacturer's published heat flow tables. For domestic hot water supply and return, run out insulation and condensation control insulation, no thickness adjustment need be made.

1.3.3. All materials shall be compatible and suitable for service temperature, and shall not contribute to corrosion or otherwise attack surface to which applied in either the wet or dry state.

1.3.4. Every package or standard container of insulation or accessories delivered to the job site for use must have a manufacturer's stamp or label giving the name of the manufacturer and description of the material

1.4. **SUBMITTALS**

1.4.1. Submit in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.4.2. Shop Drawings:

1.4.2.1. All information, clearly presented, shall be included to determine compliance with drawings and specifications and ASTM, federal and military specifications.
1.4.2.2. Insulation materials: Specify each type used and state surface burning characteristics.
1.4.2.3. Insulation facings and jackets: Each type used.
1.4.2.4. Insulation accessory materials: Each type used.
1.4.2.5. Manufacturer's installation and fitting fabrication instructions for flexible unicellular insulation.
1.4.2.6. Make reference to applicable specification paragraph numbers for coordination.

1.5. **STORAGE AND HANDLING OF MATERIAL**

1.5.1. Store materials in clean and dry environment, pipe covering jackets shall be clean and unmarred. Place adhesives in original containers. Maintain ambient temperatures and conditions as required by printed instructions of manufacturers of adhesives, mastics and finishing cements.

1.6. **APPLICABLE PUBLICATIONS**

1.6.1. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by basic designation only.

1.6.2. National Fire Protection Association (NFPA):

1.6.2.1. 101-09 Life Safety Code

1.6.2.2. 251-06 Standard methods of Tests of Fire Endurance of Building Construction Materials

1.6.2.3. 255-06 Standard Method of tests of Surface Burning Characteristics of Building Materials

1.6.3. Underwriters Laboratories, Inc (UL):

1.6.3.1. 723 UL Standard for Safety Test for Surface Burning Characteristics of Building Materials with Revision of 08/03

1.6.4. Manufacturer's Standardization Society of the Valve and Fitting Industry (MSS):

1.6.4.1. SP58-2002 Pipe Hangers and Supports Materials, Design, and Manufacture

1.7. **STANDARDS OF ACCEPTANCE**

1.7.1. Owens/Corning, Knauf, Johns Mansville

PART 2 - PRODUCTS

2.1. **HVAC PIPING INSULATION**

2.1.1. Application (as applicable to the project)

2.1.1.1. All hot water heating/glycol

2.1.1.2. All chilled water/glycol

2.1.1.3. All steam piping

2.1.1.4. All condensate piping

2.1.1.5. All piping conveying water and located in spaces where the temperature can drop below freezing. Also refer to heat tracing specifications

2.1.1.6. All other piping conveying fluids warmer than 30^{O}C or colder than 18^{O}C

2.1.2. <u>Mineral Fiber Or Fiber Glass</u>

2.1.2.1. ASTM C547 (Pipe Fitting Insulation and Preformed Pipe Insulation), class 1, k = 0.037 (0.26) at 24 degrees C (75 deg. F), for use at temperatures from -20 deg. C (-4 deg.F) and up to 230 deg.C (450 deg. F)with an all service vapor retarder jacket with polyvinyl chloride premolded fitting covering.

2.1.2.2. Thickness:

2.1.2.2.1. Piping larger than 75mm (3”): 38 mm thickness

2.1.2.2.2. Piping nominal 25mm-75mm (1-3”): 25 mm thickness

2.1.2.2.3. Piping nominal 19mm (3/4”) and less: 12 mm thickness

2.1.2.2.4. Outdoor insulation (any size): increase insulation thickness by 12 mm (½”)

2.1.2.3. At fittings and flanges (including water meter and body of roof drains), insulate with wrapped fiberglass insulation of same thickness as adjacent pipe, and cover with pre-molded PVC jackets. Seal edge of jacket with self-sealing vapor barrier tape.

2.1.3. Insulation Facings And Jackets

2.1.3.1. Vapor Retarder, higher strength with low water permeance = 0.02 or less perm rating, Beach puncture 50 units for insulation facing on pipe insulation jackets.

2.1.3.2. Facings and jackets

2.1.3.2.1. Concealed indoor areas:

- Shall be all service type (ASJ) in concealed spaces and PVC Vapor Retarder jacketing in all exposed areas, including mechanical rooms and service areas.
- All service Jacket (ASJ) shall be white kraft bonded to 0.025 mm (1 mil) thick aluminum foil, fiberglass reinforced, with pressure sensitive adhesive closure. Comply with ASTM C1136. Beach puncture 50 units, Suitable for painting without sizing. Jackets shall have minimum 40 mm (1-1/2 inch) lap on longitudinal joints and minimum 75mm (3 inch) butt strip on end joints. Butt strip material shall be same as the jacket. Lap and butt strips shall be self-sealing type with factory-applied pressure sensitive adhesive.
- Standard of Acceptance: Zeston, Ceeco, Proto

2.1.3.2.2. Exposed indoor areas:

- Shall be heavy PVC fitting covers (0.75 mm thickness. Overlap PVC covers on pipe insulation jackets as least 1 inch (25 mm) at each end. Secure fitting covers with manufacturer's attachments and accessories. Seal seams with tape and vapor-retarder mastic.

2.1.3.2.3. Indoor Fittings Jackets

- Pipe fitting insulation covering (jackets): Fitting covering shall be premolded to match shape of fitting and shall be polyvinyl chloride (PVC) minimum thickness 0.7 mm (0.03 inches). Provide color matching vapor retarder pressure sensitive tape.
- Adhesive: Compatible with PVC jacket, and recommended by insulation material manufacturer.
- Standard of Acceptance: Zeston, Ceeco, Proto

2.1.3.2.4. Aluminum Jackets – Outdoor Piping and Fittings

- Aluminum Jacket-Piping systems: ASTM B209, 3003 alloy, H-14 temper, 0.6 mm (0.023 inch) minimum thickness with locking longitudinal joints. Jackets for elbows, tees and other fittings shall be factory-fabricated to match shape of fitting and of 0.6 mm (0.024) inch minimum thickness aluminum. Fittings shall be of same construction as straight run jackets but need not be of the same alloy. Factory-fabricated stainless steel bands shall be installed on all circumferential joints. Bands shall be 13 mm (0.5 inch) wide on 450 mm (18 inch) centers. System shall be weatherproof if utilized for outside service.

- Field applied vapor barrier jackets shall be provided, in addition to the specified facings and jackets, on all exterior piping as well as on interior piping exposed to outdoor air (i.e.; in ventilated attics, piping in ventilated (not air conditioned) spaces, etc.) The vapor barrier jacket shall consist of a multi-layer laminated cladding with a maximum water vapor permeance of 0.001 perms. The minimum puncture resistance shall be 35 cm-kg (30 inch-pounds) for interior locations and 92 cm-kg (80 inch-pounds) for exterior or exposed locations or where the insulation is subject to damage.
- Neither rivets, screws, staples nor any other fastener capable of penetrating the underlying vapor retarder shall be used to secure the aluminum jacketing.
- Standards of Acceptance: Childers-Lock-on and Pabco-Surfeit.

2.1.4. Pipe Covering Protection Saddles

2.1.4.1. Cold pipe support - indoors: Premolded pipe insulation 180 degrees (half-shells) on bottom half of pipe at supports. Material shall be cellular glass or high density Polyisocyanurate insulation of the same thickness as adjacent insulation. Density of Polyisocyanurate insulation shall be a minimum of 48 kg/m3 (3.0 pcf).

2.1.4.2. Warm or hot pipe supports - indoors: Premolded pipe insulation (180 degree half-shells) on bottom half of pipe at supports. Material shall be high density Polyisocyanurate (for temperatures up to 149 degrees C [300 degrees F]), cellular glass or calcium silicate. Insulation at supports shall have same thickness as adjacent insulation. Density of Polyisocyanurate insulation shall be a minimum of 48 kg/m^3 (3.0 pcf).

2.1.4.3. All piping – outdoors: Metallic shield shall be made of galvanized steel painted on both sides with a minimum two coats of aluminum paint. 180 degree for clevises and roller type hangers and 360 degree for clamp type hangers and supports. Shield and insert length and gauge shall be 400 mm (16") long and min. 2.75 mm (12ga) thickness.

2.1.5. Adhesive, Mastic, Cement

2.1.5.1. Insulation manufacturers' published recommendations.

2.1.6. Mechanical Fasteners

2.1.6.1. Wire: 1.3 mm thick (18 gage) soft annealed galvanized or 1.9 mm (14 gage) copper clad steel or nickel copper alloy.

2.1.6.2. Bands: 13 mm (1/2 inch) nominal width, brass, galvanized steel, aluminum or stainless steel.

2.1.7. Flame And Smoke

2.1.7.1. Unless shown otherwise all assembled systems shall meet flame spread 25 and smoke developed 50 rating as developed under ASTM, NFPA and UL standards and specifications. See paragraph 1.3 "Quality Assurance".

2.2. **FITTINGS, FLANGE AND VALVE INSULATION – HOT AND COLD PIPING**

2.2.1. Factory molded, ASTM C547 or field mitered sections, joined with adhesive or wired in place.

2.2.2. For hot piping finish with a smoothing coat of finishing cement.

2.2.3. For cold fittings, 16 degrees C (60 degrees F) or less, vapor seal with a layer of glass fitting tape imbedded between two 2 mm (1/16 inch) coats of vapor barrier mastic.

2.2.4. Fitting tape shall extend over the adjacent pipe insulation and overlap on itself at least 50 mm (2 inches).

2.2.5. Nominal thickness: same as piping of same size.

2.3. **EQUIPMENT INSULATION**

2.3.1. Applications: all heat exchangers, chilled water pumps, chilled water expansion tanks, chiller headers or evaporator vessels

2.3.2. Flexible Elastomeric Cellular Thermal insulation, ASTM C177, C518, k = 0.039 (0.27) at 24 degrees C (75 degrees F), flame spread not over 25, smoke developed not over 50, for temperatures from minus 4 degrees C (40 degrees F) to 93 degrees C (200 degrees F). No jacket required.

2.4. **DUCTWORK INSULATION**

2.4.1. Application

2.4.1.1. All concealed ductwork, or exposed in mechanical rooms conveying air at temperatures above 30^{O}C or below 18^{O}C and running through heated spaces.
2.4.1.2. All ductwork running through unheated spaces (attics)
2.4.1.3. All exhaust air ductwork 3m upstream of the point of discharge to the outdoors
2.4.1.4. All fresh air supply ductwork
2.4.1.5. All ductwork mounted outdoors
2.4.1.6. All combustion air ductwork

2.4.2. Round Ductwork or Rectangular Ductwork – any side less than 750 mm (30”)

2.4.2.1. Insulate ductwork with 40 mm (1½") thick, blanket-type, fiberglass insulation with factory-applied vapor barrier, and 2" stapling and taping flange along one edge. Insulation: ASTM C553, density of 0.75, conductivity of 0.32. Vapor barrier: aluminum foil, permeance of 0.02, and puncture resistance of 50 units. Composite flame spread/ smoke density of 25/50.

2.4.2.2. Apply insulation from outlet of air handling equipment to air distribution equipment

2.4.2.3. Jacket

2.4.2.3.1. Apply for exposed ductwork a zero permeability, all weather, multi-layered laminate coated with a cold weather acrylic adhesive, superior resistance to weathering, mold, UV and extreme environmental conditions. Designed for use as a vapour barrier for insulation cladding and jacketing applications.

2.4.2.3.2. Zero permeability vapour barrier for insulation cladding and jacketing applications

2.4.2.3.3. Cold weather acrylic adhesive applies easily at temperatures as cold as -23°C (-10°F)

2.4.2.3.4. Puncture and Tear resistant

2.4.2.3.5. Self-Adhesive material installs easily with no offsite fabrication required

2.4.2.3.6. Cuts and installs easily on-site, no special tools required

2.4.2.3.7. Flexible, strong, reinforced insulation cladding

2.4.2.3.8. Standard Acceptance: 3M™ VentureClad™ Insulation Jacketing

2.4.3. Rectangular Ductwork – any side larger than 750 mm (30”)

2.4.3.1. In mechanical equipment rooms and all other areas where visible without removing ceilings or opening access panels, insulate ductwork with 40 mm (1 ½” thick) rigid, fiberglass insulation board ASTM C612 Class 2, conductivity of 0.26, density of 3.0. with factory-applied vapor barrier. Vapor barrier: laminated white kraft paper, aluminum foil, glass fiber reinforcement, permeance of 0.02, and puncture resistance of 50 units. Composite flame spread/ smoke density of 25/50.

2.4.3.2. In ceiling spaces, building shafts, and other locations where not visible, insulate ductwork with 1-1/2" thick, blanket-type, fiberglass insulation with factory-applied vapor barrier, and 2" stapling and taping flange along one edge. Insulation: ASTM C553, density of 0.75, conductivity of 0.23 @75F. Vapor barrier: laminated white kraft paper, aluminum foil, glass fiber reinforcement, permeance of 0.02, and puncture resistance of 50 units. Composite flame spread/ smoke density of 25/50.

2.4.3.3. Jacket

2.4.3.3.1. Apply on exposed ductwork a zero permeability, all weather, multi-layered laminate coated with a cold weather acrylic adhesive, superior resistance to weathering, mold, UV and extreme environmental conditions. Designed for use as a vapour barrier for insulation cladding and jacketing applications.

2.4.3.3.2. Zero permeability vapour barrier for insulation cladding and jacketing applications

2.4.3.3.3. Cold weather acrylic adhesive applies easily at temperatures as cold as -23°C (-10°F)

2.4.3.3.4. Puncture and Tear resistant

2.4.3.3.5. Self Adhesive material installs easily with no offsite fabrication required

2.4.3.3.6. Cuts and installs easily on-site, no special tools required

2.4.3.3.7. Flexible, strong, reinforced insulation cladding

2.4.3.3.8. Standard Acceptance: 3M™ VentureClad™ Insulation Jacketing

2.4.4. <u>Outdoor Rectangular Ductwork – any size</u>

2.4.4.1. Insulate ductwork with 50 mm (2" thick) rigid, fiberglass insulation board with factory-applied vapor barrier. Insulation: ASTM C612 Class 2, conductivity of 0.26, density of 3.0.

2.4.4.2. Vapor barrier: laminated white kraft paper, aluminum foil, glass fiber reinforcement, permeance of 0.02, and puncture resistance of 50 units. Composite flame spread/ smoke density of 25/50.

2.4.4.3. Jacket

2.4.4.3.1. A zero permeability, all weather, multi-layered laminate coated with a cold weather acrylic adhesive, superior resistance to weathering, mold, UV and extreme environmental conditions. Designed for use as a vapour barrier for insulation cladding and jacketing applications.

2.4.4.3.2. Zero permeability vapour barrier for insulation cladding and jacketing applications

2.4.4.3.3. Cold weather acrylic adhesive applies easily at temperatures as cold as -23°C (-10°F)

2.4.4.3.4. Puncture and Tear resistant

2.4.4.3.5. Self Adhesive material installs easily with no offsite fabrication required

2.4.4.3.6. Cuts and installs easily on-site, no special tools required

2.4.4.3.7. Flexible, strong, reinforced insulation cladding

2.4.4.3.8. Standard Acceptance: 3M™ VentureClad™ Insulation Jacketing

2.4.5. <u>Accessories</u>

2.4.5.1. Closure Materials: Butt strips, bands, wires, staples, mastics, adhesives; pressure-sensitive tapes.

2.4.5.2. Support Materials: Hanger straps, hanger rods, saddles, support rings.

2.4.5.3. Contact adhesive: quick-setting, non-flammable fire resistive adhesive to adhere fibrous glass to ducts. Flame spread 15 smoke development 0.

PART 3 - EXECUTION

3.1. GENERAL REQUIREMENTS

3.1.1. Required pressure tests of piping and ductwork joints and connections shall be completed and the work approved by the Consultant for application of insulation. Surface shall be clean and dry with all foreign materials, such as dirt, oil, loose scale and rust removed.

3.1.2. Except for specific exceptions, insulate all specified equipment, and piping (pipe, fittings, valves, accessories). Insulate each pipe individually. Do not use scrap pieces of insulation where a full length section will fit.

3.1.3. Insulation materials shall be installed in a first class manner with smooth and even surfaces, with jackets and facings drawn tight and smoothly cemented down at all laps. Insulation shall be continuous through all sleeves and openings, except at fire dampers and duct heaters (NFPA 90A). Vapor retarders shall be continuous and uninterrupted throughout systems with operating temperature 16 degrees C (60 degrees F) and below. Lap and seal vapor barrier over ends and exposed edges of insulation. Anchors, supports and other metal projections through insulation on cold surfaces shall be insulated and vapor sealed for a minimum length of 150 mm (6 inches).

3.1.4. Install vapor stops at all insulation terminations on either side of valves, pumps and equipment and particularly in straight lengths of pipe insulation.

3.1.5. Construct insulation on parts of equipment such as chilled water pumps and heads of chillers, convertors and heat exchangers that must be opened periodically for maintenance or repair, so insulation can be removed and replaced without damage. Install insulation with bolted 1 mm thick (20 gage) galvanized steel or aluminum covers as complete units, or in sections, with all necessary supports, and split to coincide with flange/split of the equipment.

3.1.6. Insulation on hot piping and equipment shall be terminated square at items not to be insulated, access openings and nameplates. Cover all exposed raw insulation with white sealer or jacket material.

3.1.7. Protect all insulations outside of buildings with aluminum jacket using lock joint or other approved system for a continuous weather tight system. Access doors and other items requiring maintenance or access shall be removable and sealable.

3.1.8. Elbows, flanges and other fittings shall be insulated with the same material as is used on the pipe straights.

3.1.9. Hot piping work not to be insulated:

3.1.9.1. Factory pre-insulated components.

3.1.9.2. Over equipment nameplates.
3.1.9.3. Vibration control devices
3.1.9.4. Air chambers, unions, strainers, check valves, flow regulators.
3.1.9.5. Pot feeders, filtration cartridges

3.1.10. Ductwork not to be insulated:

3.1.10.1. Indoor return ductwork
3.1.10.2. Exhaust air ductwork up to 3 m (10 ft) prior to existing the building

3.1.11. Firestop Pipe insulation:

3.1.11.1. Provide firestopping insulation at fire and smoke barriers through penetrations. Fire stopping insulation shall be UL listed.
3.1.11.2. Pipe penetrations requiring fire stop insulation including, but not limited to the following:
3.1.11.2.1. Pipe risers through floors
3.1.11.2.2. Pipe chase walls and floors
3.1.11.2.3. Smoke partitions
3.1.11.2.4. Fire partitions
3.1.11.2.5. Freeze protection of above grade outdoor piping (over heat tracing tape): 20 mm (0.75) thick insulation, for all pipe sizes 75 mm(3 inches) and smaller and 25 mm(1inch) thick insulation for larger pipes. Provide metal jackets for all pipes. Provide where indicated on the drawings

3.1.12. Provide vapor barrier jackets over insulation as follows:

3.1.12.1. All piping and ductwork exposed to outdoor weather.
3.1.12.2. All interior piping and ductwork conveying fluids exposed to outdoor air (i.e. in attics, ventilated (not air conditioned) spaces, etc.

3.1.13. Provide metal jackets over insulation as follows:

3.1.13.1. All HVAC piping and ductwork exposed to outdoor weather.

3.2. **INSULATION INSTALLATION**

3.2.1. <u>Molded Mineral Fiber Pipe and Tubing Covering:</u>

3.2.1.1. Fit insulation to pipe, aligning longitudinal joints. Seal longitudinal joint laps and circumferential butt strips by rubbing hard with a nylon sealing tool to assure a positive seal. Staples may be used to assist in securing insulation. Seal all vapor retarder penetrations on cold piping with a generous application of vapor barrier mastic. Provide inserts and install with metal insulation shields at outside pipe supports. Install freeze protection insulation over heating cable.

3.2.2. Flexible Mineral Fiber Blanket - Ductwork:

3.2.2.1. Adhere insulation to metal with 75 mm (3 inch) wide strips of insulation bonding adhesive at 200 mm (8 inches) on center all around duct. Additionally secure insulation to bottom of ducts exceeding 600 mm (24 inches) in width with pins welded or adhered on 450 mm (18 inch) centers. Secure washers on pins. Butt insulation edges and seal joints with laps and butt strips. Staples may be used to assist in securing insulation. Seal all vapor retarder penetrations with mastic. Sagging duct insulation will not be acceptable. Install firestop duct insulation where required.

3.2.2.2. Blanket insulation shall be tightly sealed at all joints and seams. Insulation shall be cut longer than ductwork perimeter to allow maximum thickness on all areas and avoid excessive compression. All joints shall be over lapped at least 2" and stapled in place. The stapled seams shall be sealed with a minimum 3" wide pressure sensitive tape designed for use with the duct insulation. All breaks in the vapor barrier facing shall also be sealed with the tape. The underside of ductwork 18" or greater in width, and vertical surfaces 48" or greater shall have the insulation additionally secured with mechanical fasteners and speed clips spaced approximately 12" on center. The protruding ends of the fasteners shall be cut off flush after the speed clips are installed, and then sealed with the same tape as specified above.

3.2.2.3. Finished installation shall provide a continuous and effective vapor barrier.

3.2.2.4. Supply air ductwork to be insulated includes main and branch ducts from AHU discharge to room supply outlets, and the bodies of ceiling outlets to prevent condensation. Insulate sound attenuator units, coil casings and damper frames. To prevent condensation, insulate trapeze type supports and angle iron hangers for flat oval ducts that are in direct contact with metal duct.

3.2.3. Rigid Board Mineral Fiber Insulation - Ductwork

3.2.3.1. Apply board on pins spaced not more than 300 mm (12 inches) on center each way, and not less than 75 mm (3 inches) from each edge of board. In addition to pins, apply insulation bonding adhesive to entire underside of horizontal metal surfaces. Butt insulation edges tightly and seal all joints with laps and butt strips. After applying speed clips cut pins off flush and apply vapor seal patches over clips.

3.2.3.2. Insulation shall be scored, beveled or mitered to provide tight joints and be secured to equipment with bands spaced 225 mm (9 inches) on center for irregular surfaces or with pins and clips on flat surfaces. Use corner beads to protect edges of insulation.

3.2.3.3. For hot equipment: Stretch 25 mm (1 inch) mesh wire, with edges wire laced together, over insulation and finish with insulating and finishing cement applied in one coat, 6 mm (1/4 inch) thick, trowel led to a smooth finish.

3.2.3.4. For cold equipment: Apply meshed glass fabric in a tack coat 1.5 to 1.7 square meter per liter (60 to 70 square feet per gallon) of vapor mastic and finish with mastic at 0.3 to 0.4 square meter per liter (12 to 15 square feet per gallon) over the entire fabric surface.

3.2.4. <u>Duct Wrap for Kitchen Hood Grease Ducts:</u>

3.2.4.1. Not Applicable.

3.3. **INSULATION JOINTS**

3.3.1. All insulation joints should be sealed with pressure-sensitive joint sealing tape to match the insulation facing. Rub hard with a plastic sealing tool to affect a tight bond.

3.3.2. Recommended practice: 3" (76mm) wide tape on flat surfaces or where edges are ship-lapped and stapled. Use 5" (102mm) wide tape in lieu of ship-lapping.

3.3.3. All sheet metal joints must be sealed prior to insulating.

3.4. **INSULATION AT DUCT SUPPORTS**

3.4.1. Refer to and conform strictly to insulation and protection jacket manufacturers' instructions.

3.4.2. To properly insulate through a roof top duct support; lift duct off of support, insulate duct through the support, install protection jacket through the support and add an additional layer of protection jacket 6" wide on the bottom and both sides at the point of contact with the support system.

3.4.3. When it is not possible to lift a duct off the rooftop supports, it is necessary to incorporate the support system into the insulation system by encapsulating the supports with insulation. This same system must be used if duct supports are screwed onto the ductwork

3.5. **FIELD-APPLIED JACKET APPLICATION**

3.5.1. Apply PVC jacket on piping insulation where indicated, with 1 inch (25 mm) overlap at longitudinal seams and end joints. Seal with manufacturer's recommended adhesive.

3.5.2. Apply aluminum jacket where indicated (piping and ductwork) and on all piping/ductwork located outdoors, with 2-inch (50 mm) overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel band 12 inches (300 mm) o.c. and at end joints. Provide vapor-barrier jackets. Aluminum jackets shall have seams located below the horizontal plane of the horizontal piping route. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe, and cover with aluminum jackets.

3.6. OUTDOOR DUCTWORK – RECTANGULAR

3.6.1. All roof-top ductwork to must be designed and built with adequate slope (watershed) to prevent ponding water. Ponding water is defined as water that stays in place for greater than 24 hours.

Table of Contents

PART 1 - GENERAL

1.1. GENERAL

1.1.1. This section of the specification shall be read in conjunction with and shall be governed by the requirements outlined in Section: 23 05 00 Common Work Results for HVAC.

1.1.2. The Building Automation System (BAS) shall be capable of integrating multiple building functions, including equipment supervision and control, alarm management, energy management, and trend data collection. The BAS shall be the latest generation system available from the installation contractor that has been previously reviewed and accepted by the Board.

1.1.3. Perform an in-depth review of all existing control components associated with the work scope (e.g. controllers, control valves, control dampers, linkages, actuators, pipe and duct sensors, flow switches, etc.).

1.1.4. Immediately report any defective or inoperative components to the Consultant.

1.1.5. Co-ordinate and supervise the work of all sub-contractors required to complete the scope of work as specified in the contract documents.

1.1.6. The Controls Contractor and all sub-contractors shall employ only certified trades persons to carry out all applicable work.

1.1.7. Provide all necessary control wiring and hardware to complete the entire project, including but not limited to, wiring, fittings, connectors, conduits, hangers/supports, box covers, and all other accessories required to ensure complete, safe and fully operational systems.

1.1.8. The BAS at minimum, shall incorporate the following integrated features, functions, and services:

1.1.8.1. Operator information, alarm management and control function.
1.1.8.2. As-built drawings in a separate PDF file, to be retrievable by the Operator at any given time using the BAS interface.
1.1.8.3. Control access
1.1.8.4. Information management, including monitoring, transmission, archiving, retrieval and reporting functions
1.1.8.5. Diagnostic monitoring and reporting of BAS functions
1.1.8.6. Offsite monitoring and management access
1.1.8.7. Energy Management

1.2. APPROVED CONTROL SYSTEMS

1.2.1. JBS

1.3. **SCOPE OF WORK**

1.3.1. The general outline of the scope of work includes but is not limited to the following:

1.3.1.1. Remove all electric control devices, sensors, valves, operators and controllers serving the existing air handling equipment (refer to drawings for scope). Work includes removal of all redundant control panels, and wiring. Demolition of the existing controls is part of the control contractor scope of work.

1.3.1.2. Supply and install all the new BAS components (sensors, actuators, valves, operators, wiring, relays, controllers, panels, etc) required to make the new air handling systems operate in accordance with the sequences indicated on the drawings.

1.3.1.3. Remove any redundant timers and associated wiring and devices controlling the demolished equipment.

1.3.1.4. The temporary removal of the Air Sniper sanitizing equipment controls and reinstatement.

1.3.1.5. Update existing programming and user interface as required to match the sequence of operation indicated on the drawings; c/w graphical displays on the Board main server to match the new equipment layout and configuration.

1.3.1.6. Provide all necessary power wiring and hardware to complete the entire project, including but not limited to, wiring, fittings, connectors, conduits, hangers/supports, box covers, BAS control panels, and all other accessories required to ensure complete, safe and fully operational systems. This shall include the power wiring for all the equipment.

1.3.1.7. Make good all surfaces affected by the work.

1.3.1.8. All removed control valves to be returned to the Board. Coordinate with the Board for confirmation.

1.3.1.9. Arrange for Electrical Authority inspection of all electrical work done by the Control Sub- Contractor. Submit the Certificate of Inspection and Product Approval Certificate with the as built documentation.

1.3.1.10. Provide new wiring.

1.3.1.11. Update software and graphical interface as required.

1.3.1.12. All line and low voltage wiring shall be run in EMT metal conduit.

1.3.1.13. Control wiring installed in exposed areas (common areas, mechanical rooms, outdoors) shall be run in IMC rigid metal conduit

1.3.1.14. Control wiring installed in the ceiling space shall be plenum rated and does not require rigid conduit. Any controls wiring in ceiling spaces is to be run in a cable management tray, and transitions from the tray shall neatly follow the building structure and any wall penetrations must be sleeved in conduit with nylon bushings.

1.3.1.15. Include all wiring, conduit, piping, installation, materials, supervision and labor including calibration, commissioning software programming and data base generation, and additional work necessary to provide a complete and fully operating system to the approval of the Consultant.

1.3.1.16. Controls sub-contractor shall coordinate with the electrical sub-contractor for the location of breakers and junction boxes from which power to the control's equipment will be provided. The over-all responsibility for providing and coordinating power supply to the controls equipment rests with the mechanical contractor in his capacity as general contractor.

1.3.1.17. The BAS shall be completed in all details not necessarily defined or shown on the drawings but as may be reasonably inferred as necessary to complete each system and provide operating service in an acceptable manner.

1.3.1.18. Upon completion of the installation, all control equipment supplied under this control shall be adjusted to place the system in complete operating condition subject to the Owner's approval. All adjustments shall be made in co-ordination with the TAB sub-contractor responsible for balancing the air and water systems where required.

1.3.1.19. For variable flow systems (air or hydronic), coordinate the final settings of VFDs and pressure differential setpoints with the TAB contractor, to achieve the design flows noted in the equipment schedules.

1.3.1.20. When removing existing equipment, it is the responsibility of the contractor to ensure the integrity of the BAS communication line that must remain intact to ensure the proper function of the remainder of the school BAS system.

1.4. **QUALITY ASSURANCE**

1.4.1. Base bid basis of design products referenced under this Section establish the minimum acceptable standards of product quality, features and performance.

1.4.2. Work of this Section shall be provided by a recognized contractor regularly employed in the installation and wiring of BAS and temperature control system and equipment. The Board will provide a list of acceptable Contractors to bid the work (see Boards list of Pre-Qualified contractors).

1.5. **CODES AND STANDARDS**

1.5.1. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with current editions in effect 30 days prior to receipt of bids of the following codes:

1.5.1.1. National Electric Code (NEC)
1.5.1.2. International Building Code (IBC)

1.5.1.2.1. Section 719 Ducts and Air Transfer Openings
1.5.1.2.2. Section 907 Fire Alarm and Detection Systems
1.5.1.2.3. Section 909 Smoke Control Systems
1.5.1.3. Division 23 Mechanical
1.5.1.4. International Mechanical Code (IMC)
1.5.1.5. ANSI/ASHRAE 135-2004: Data Communication Protocol for Building Automation and Control Systems (BACNET)

1.6. **APPROVED CONTROL SYSTEM MANUFACTURERS**

1.6.1. Only approved building automation systems will be accepted.

1.7. **EQUIPMENT INSTALLED BY OTHERS (WHERE APPLICABLE TO PROJECT)**

1.7.1. As required, the following equipment shall be supplied as noted and installed by qualified sub trades as part of this contract:

1.7.2. Supply by Mechanical Contractor/Power wiring by Electrical Contractor/Controls wiring by Controls Contractor:

1.7.2.1. Variable Speed Drives, where not integral part of mechanical equipment

1.7.3. Supply Mechanical Contractor / Install – Mechanical Contractor

1.7.3.1. Automatic control dampers (not supplied with packaged equipment)

1.7.4. Supply Mech. Contractor/ install Control Contractor / wired by Control Contractor (not supplied with packaged equipment)

1.7.4.1. Damper Actuators

1.7.5. Supply by Control Contractor / install by Mech. Contractor/ wired by Control Contractor

1.7.5.1. Automatic Controls Valves & Actuators
1.7.5.2. Space temperature sensors

1.7.6. Supply and wired by Control Contractor/ installed by Mechanical Contractor

1.7.6.1. Temperature Sensing Wells

1.7.7. Supply by Mech. Contractor/ installed by Mech. Contractor/ wired by Control, Contractor

1.7.7.1. Air and Hydronic Flow and Pressure sensors

1.7.8. The final completeness of all required components to make equipment operational as indicated on the sequences of operation including wiring, setting and adjustment remains as the final the responsibility of the mechanical contractor acting as the general contractor.

1.8. **SUBMITTALS**

1.8.1. Provide three copies of shop drawings and other submittals on hardware, software, and equipment to be installed or furnished. Drawings should be 11” x 17” prints.

1.8.2. Provide submittals within 6 weeks of contract award.

1.8.3. Begin no work until submittals have been approved for conformity with design intent.

1.8.4. Provide drawings using AutoCAD 2007 (or newer) in following formats: original, pdf and print.

1.8.5. Submittal approval does not relieve Contractor of responsibility to supply sufficient materials to complete work.

1.8.6. Provide submittals on the following:

1.8.6.1. Product Submittals. Clearly indicate applicable data on manufacturer's cut sheets by highlighting or by other means. General catalogs shall not be accepted as cut sheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work.

1.8.6.2. Network Architecture. Riser diagrams showing control network layout, connections to all network devices, communication protocols, network speeds and wire types. Include schematic diagrams of control, communication, and power wiring for central system installation. Show interface wiring to control system.

1.8.6.3. Schematics. Schematic diagram of each controlled system. Label all control points with point names.

1.8.6.4. Wiring diagrams including complete power system, interlocks, control and data communications.

1.8.6.5. Programming code listing for all controllers

1.8.6.6. Manufacturers’ data/specification sheets and catalogue cuts for all material and equipment supplied.

1.8.6.7. Floor plan schematic diagrams indicating field sensor and controller locations.

1.8.6.8. Valve Schedule. Indicate system and device designation, product name, manufacturer, and model numbers (both valve and actuator), quantities, sizes, Cv (design and actual), pressure drop, close-off pressure, configuration, ports, and line sizes of each supplied valve and existing control valve.

1.8.6.9. Damper Schedule. Indicate system and device designation, product name, manufacturer, size, and model numbers (both damper and actuator) of each supplied damper/actuator and existing control damper/actuator.

1.8.6.10. Room and Equipment Schedules. Indicate controller type, address, model number, object names, setpoints, and room location.

1.8.6.11. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.

1.8.6.12. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:

1.8.6.12.1. Direct digital controllers (controller panels)
1.8.6.12.2. Transducers and transmitters
1.8.6.12.3. Sensors (include accuracy data)
1.8.6.12.4. Actuators
1.8.6.12.5. Valves
1.8.6.12.6. Dampers
1.8.6.12.7. Relays and switches
1.8.6.12.8. Control panels
1.8.6.12.9. Power supplies
1.8.6.12.10. Batteries
1.8.6.12.11. Operator interface equipment
1.8.6.12.12. Wiring

1.8.6.13. Complete description of control system operation including sequences of operation and points-lists for each control system. Include and reference schematic diagram of controlled system. List I/O points and software points specified in this section. Indicate alarmed and trended points.

1.8.6.14. Wiring diagrams and layouts for each control panel. Show termination numbers.

1.8.6.15. Schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.

1.8.6.16. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

1.8.7. Schedules

1.8.7.1. Construction Schedule of work provided within one month of contract award, indicating:

1.8.7.1.1. Intended sequence of work items
1.8.7.1.2. Start date of each work item
1.8.7.1.3. Duration of each work item
1.8.7.1.4. Planned delivery dates for ordered material and equipment and expected lead times.
1.8.7.1.5. Milestones indicating possible restraints on work by other trades or situations.

1.8.8. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.

1.9. PROJECT RECORD DOCUMENTS

1.9.1. Submit three copies of record (as-built) documents upon completion of installation for approval prior to final completion. Submittal shall consist of:

1.9.1.1. As-built versions of submittal shop drawings should be 11” x 17” prints. Provide drawings using AutoCAD 2007 (or newer) in following formats: original, pdf and print.

1.9.1.2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of this section (Control System Demonstration and Acceptance).

1.9.1.3. An Information sheet that contains:

1.9.1.3.1. School name and address

1.9.1.3.2. A brief description of the control details. i.e. total # of points, list of equipment controls and which panels they a connected to.

1.9.1.3.3. Panel’s information i.e. part numbers for panels used and their serial numbers and revision # (if applicable)

1.9.1.3.4. Software version

1.9.1.3.5. Modem telephone number

1.9.1.3.6. Warranty start date and duration

1.9.1.3.7. BAS contractor Name, address, and Phone number

1.9.1.4. Detailed sequence of operation for each controlled system.

1.9.1.5. Control schematics for each system. Including a System Architecture indicating the type and model number for all BAS components, the proposed interconnection and location of all panels, network connection and key peripheral devices (workstations, modems, printers, repeaters, etc)

1.9.1.6. BAS Points List indicating the panel ID, panel location, hardware address, point acronym, point description, field device type, point type (i.e. AO/DO/AI/DI), end device fail position, end device manufacture and model number and wire tag ID.

1.9.1.7. Floor plan with the location of all field mounted control devices.

1.9.1.8. Programming code for all DDC controllers.

1.9.1.9. Wiring diagrams including complete power system, interlocks, control and data communications.

1.9.1.10. Manufacturers’ data/specification sheets and catalogue cuts for all material and equipment supplied. This section shall include a summary sheet that indicates all BAS Device, Manufacturers’, model number, and quantity of each used on this job.

1.9.1.11. Automatic control valves and dampers where required.

1.9.1.12. Commissioning list including the name of the commissioning agent of the BAS Contractor, his signature and the date of commissioning.
1.9.1.13. Licensed BAS workstation software.
1.9.1.14. BAS programming database stored on a USB memory stick.

1.10. **WARRANTY**

1.10.1. Warrant work as follows:

1.10.1.1. All labour and material (hardware and software) supplied under this contract shall be warranted free from defects for a period of two (2) years after final completion and acceptance. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost to the Board. The Contractor shall respond to Board request for warranty service within one (1) business day.
1.10.1.2. The final completion and substantial performance date shall be the date of the project turnover meeting.
1.10.1.3. All work shall have a single warranty date, even when the Board has received beneficial use of part of the system in advance of the final completion date.
1.10.1.4. The contractor shall be responsible for correcting any deficiencies, errors or omissions in operating strategies, programming code, system functionality or parameters and operator workstation graphics during the warranty period.

1.11. **BOARD OWNERSHIP OF PROPRIETARY MATERIAL**

1.11.1. Project-specific software and documentation shall become Board's property. This includes, but is not limited to:

1.11.1.1. Record drawings / Documentation
1.11.1.2. Database
1.11.1.3. Application programming code (Two copies and two licenses of Engineering (Program) Tool)
1.11.1.4. All documentation.

1.12. **FACILITIES WITH EXISTING BUILDING AUTOMATION SYSTEM**

1.12.1. Where a facility has an existing BAS that is to be replaced, modified or upgraded, the Controls Contractor shall be responsible for ensuring that the entire system (hardware, programming and system graphics) and all integral parts (new and re-used) are in conformance with all requirements of the specifications outlined herein.

1.12.2. Ensure complete interoperability and compatibility between new and existing DDC systems and components. Provide system firmware and/or hardware upgrades to existing DDC panels/modules where required to ensure a complete working system to the satisfaction of the Consultant.

1.12.3. Where an existing DDC panel is re-used, ensure that sufficient controller memory is present to provide for all specified control functions. Provide memory and/or panel upgrades where required to meet system memory requirements.

1.12.4. Provide new network communication wiring for interconnection between all DDC panels and interfaces.

1.12.5. Existing control wiring and conduits may be re-used only where they comply with the requirements of these specifications and where approved by the Consultant.

1.12.6. Ensure that all re-used DDC panels/modules are upgraded to the latest version of system firmware and system operating software.

1.12.7. Provide complete commissioning and verification of all re-used automation input/output points, end devices and components.

1.12.8. Provide new labeling for wiring, devices and equipment where existing labelling does not meet the requirements of these specifications.

1.13. **CRITICAL ALARM CONTROL SEQUENCES**

1.13.1. Critical alarms are displayed on the plant operator’s PC. Critical alarms warn the building operators about critical control problems that require immediate attention.

1.13.2. Critical alarms shall be activated for the following reasons:

1.13.2.1. a boiler or air handler status has not responded to control by the FMS for more than 5 minutes
1.13.2.2. a VFD status has not responded to control by the FMS for more than 5 minutes
1.13.2.3. a heating pump or boiler pump status has not responded to control by the FMS for more than 10 minutes
1.13.2.4. a boiler flame ignition failed
1.13.2.5. a boiler low water cut off has shut the boiler
1.13.2.6. a boiler high limit temperature has shut the boiler
1.13.2.7. FMS low limit temperature controller has tripped
1.13.2.8. FMS supply fan and return fan status has been OFF
1.13.2.9. a space temperature has read below 16OC for more than 10 minutes
1.13.2.10. the radiation supply water temperature is more than 10OC below the supply water low limit for 1 hour during heating season (as determined by OAT)
1.13.2.11. return water temperature in the radiation and glycol loops has dropped 10OC below the low limit.

1.13.3. The remote alarm shall remain in effect until all of the critical alarm conditions are cleared.

1.13.4. The remote alarm shall be disabled when the outside air temperature is above 10OC.

PART 2 - PRODUCTS

2.1. **CONTROLLERS**

2.1.1. General.

2.1.1.1. Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified herein.

2.1.1.2. Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of BACnet Smart Actuators and Smart Sensors.

2.1.2. BACNET.

2.1.2.1. Building Controllers (BCs): Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-BC in the BACnet Testing Laboratories (BTL) Product Listing.

2.1.2.2. Advanced Application Controllers (AACs). Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.

2.1.2.3. Application Specific Controllers (ASCs). Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.

2.1.2.4. Smart Actuators (SAs). Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.

2.1.2.5. Smart Sensors (SSs). Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.

2.1.3. BACNET Communication.

2.1.3.1. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.

2.1.3.2. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.

2.1.3.3. Each AAC shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.

2.1.3.4. Each ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.

2.1.3.5. Each SA shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.

2.1.3.6. Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using ARCNET or MS/TP Data Link/Physical layer protocol.

2.2. **COMMUNICATION**

2.2.1. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135-2004, BACnet.

2.2.2. Install new wiring and network devices as required to provide a complete and workable control network.

2.2.3. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

2.2.4. Internetwork operator interface and value passing shall be transparent to internetwork architecture.

2.2.5. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.

2.2.6. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in this section. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

2.2.7. Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated controller via the internetwork. If applicable, system shall automatically adjust for daylight saving and standard time.

2.2.8. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

2.3. **CONNECTION TO THE BOARD SERVER**

2.3.1. Advise the Board representative of the proposed location of the system router/gateway panel within the facility The controls vendor shall Provide a communication cable (RJ45) between the BAS Controller and the schools HUB under the Board supervision and comply with the Board standard and he shall connect the BAS to the Board server and WAN and confirm that network access to the BAS has been established.

2.4. **BOARD CENTRAL SERVER**

2.4.1. New site databases shall be installed on the designated central PDSB central server.

2.4.2. Provide written notification to the PDSB representative prior to installing new site databases to the PDSB server. Do not install software or make any changes to the server without the written consent of the PDSB representative.

2.4.3. Set up and configure the server software and area routers (where required) to allow for seamless access to the site BAS via the PDSB WAN.

2.4.4. Coordinate all activities related to the central server with the PDSB representatives. Provide the PDSB with detailed documentation related to any changes made to the server software, settings or protocols

2.5. **LOCAL SERVICE PORTS**

2.5.1. Every DDC panel shall be provided with a local network access port to connect to laptop computer. A user connected to the local access port shall have the same level of system access and functionality as being connected to the site workstation PC.

2.5.2. Where BAS points (4 or more) are located in a mechanical room that does not have a local BAS panel installed, a remote network access port shall be provided. The access port shall be installed in a hinged metal enclosure with key-lock set and lamacoid ID label.

2.6. **COMMUNICATION**

2.6.1. Service Port

2.6.1.1. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on drawings.

2.6.2. Signal Management

2.6.2.1. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.

2.6.3. Data Sharing

2.6.3.1. Each BC and AAC shall share data as required with each networked BC and AAC.

2.6.4. Stand-Alone Operation

2.6.4.1. Each piece of equipment specified in this section Appendix A shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network.

2.6.5. Environment

2.6.5.1. Controller hardware shall be suitable for anticipated ambient conditions.

2.6.5.2. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29°C to 60°C (-20°F to 140°F).

2.6.5.3. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).

2.6.6. Keypad

2.6.6.1. Provide a local keypad and display for each BC and AAC. Operator shall be able to use keypad to view and edit data. Keypad and display shall require password to prevent unauthorized use. If the manufacturer does not normally provide a keypad and display for each BC and AAC, provide the software and any interface cabling needed to use a laptop computer as a Portable Operator's Terminal for the system.

2.6.7. Real-Time Clock

2.6.7.1. Controllers that perform scheduling shall have a real-time clock

2.6.8. Serviceability

2.6.8.1. Controllers shall have diagnostic LEDs for power, communication, and processor.

2.6.8.2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.

2.6.8.3. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.

2.6.9. Memory

2.6.9.1. Controller memory shall support operating system, database, and programming requirements.
2.6.9.2. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.
2.6.9.3. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.
2.6.9.4. Each controller shall have a min. 25% spare memory to allow for future expansion.
2.6.9.5. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

2.6.10. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

2.7. **INPUT AND OUTPUT INTERFACE**

2.7.1. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.

2.7.2. Protection. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.

2.7.3. Digital Inputs. Digital inputs shall monitor the on and off signal from a remote device. Digital inputs shall provide a wetting current of at least 12 mA and shall be protected against contact bounce and noise. Digital inputs shall sense dry contact closure without application of power external to the controller.

2.7.4. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall accumulate up to 10 pulses per second.

2.7.5. Analog Inputs. Analog inputs shall monitor low-voltage (0-10 Vdc), current (4-20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.

2.7.6. Digital Outputs. Digital outputs shall send an on-or-off signal for on and off control. Building Controller Digital outputs shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

2.7.7. Analog Outputs. Analog outputs shall send a modulating 0-10 Vdc or 4-20 mA signal as required to properly control output devices. Analog outputs shall not drift more than 0.4% of range annually.

2.7.8. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.

2.7.9. Universal Inputs and Outputs. Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

2.8. **POWER SUPPLIES AND LINE FILTERING**

2.8.1. All electronic equipment shall be complete with all necessary devices to safeguard against voltage spikes, fluctuations, or any other power line anomalies, which might damage the equipment.

2.8.2. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

2.8.3. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.

2.8.4. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.

2.8.5. Line voltage units shall be UL recognized and CSA listed.

2.8.6. Power Line Filtering.

2.8.6.1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:

2.8.6.1.1. Dielectric strength of 1000 V minimum
2.8.6.1.2. Response time of 10 nanoseconds or less
2.8.6.1.3. Transverse mode noise attenuation of 65 dB or greater
2.8.6.1.4. Common mode noise attenuation of 150 dB or greater at 40-100 Hz

2.9. AUXILIARY CONTROL DEVICES

2.9.1. Automatic Control Valves

2.9.1.1. Automatic control valves, shall be globe type valves. Valves and actuators shall be ordered as one factory-assembled and tested unit. Control ball valves will not be accepted.

2.9.1.2. Submit to the Consultant for review the following information for each valve:

- 2.9.1.2.1. Valve type and size
- 2.9.1.2.2. Connection type
- 2.9.1.2.3. Line size
- 2.9.1.2.4. Valve manufacturer and model number
- 2.9.1.2.5. Valve flow coefficient
- 2.9.1.2.6. Design flow
- 2.9.1.2.7. Pressure drop across valve.
- 2.9.1.2.8. Maximum close-off pressure
- 2.9.1.2.9. Actuator manufacturer and model number
- 2.9.1.2.10. Actuator maximum torque

2.9.1.3. Valves 2” (50mm) and smaller shall be constructed of bronze. Valves 2½” (65mm) and larger shall have iron bodies and bronze mountings.

2.9.1.4. All control valves shall have stainless steel stems. The bronze in bodies and bonnets of all bronze valves shall conform to ASTM B62 for valves rated up to 150psig (1035 Kpa) working pressure and to ASTM B61 for valves rated at 200 psig (1380 Kpa) working pressure. The bodies and bonnets of iron body valves shall conform to ASTM A126, Class B.

2.9.1.5. Control valve discs and seats shall be of bronze for 100 °C or less fluid temperature and of stainless steel for fluid temperatures above 100 °C.

2.9.1.6. The control valves shall have tight shut-off. Flat disk valves are not acceptable.

2.9.1.7. Control valves 2” (50mm) and smaller shall be complete with screwed ends type, except for bronze valves installed in soldered copper piping which shall be complete with soldering ends. Control valves larger than 2” (50mm) shall be complete with flanged end type and proper flanged adapters to copper shall be provided where flanged valves are installed in copper piping.

2.9.1.8. The water control valves shall be sized for a pressure drop of 6 ft. water column or as indicated on mechanical drawings.

2.9.1.9. Each automatic control valve must provide the design output and flow rates at pressure drops compatible with equipment selected.

2.9.1.10. Each automatic control valve must be suitable for the particular system working pressure.

2.9.1.11. Each automatic control valve shall be fitted with a position indicator.

2.9.1.12. All the same type control valves shall be the products of a single manufacturer and have the manufacturer's name, pressure rating and size clearly marked on the outside of the body.

2.9.1.13. All heating valves: default position shall be fully open to the coil.

2.9.1.14. Valves providing two-position service shall be quick opening. Two-way valves shall have replaceable disc or ball.

2.9.1.15. Close-off (Differential) Pressure Rating. Valve actuator and trim shall provide the following minimum close-off pressure ratings.

2.9.1.16. Two-way: 150% of total system (pump) head.

2.9.1.17. Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.

2.9.1.18. Ports. Valves providing modulating service shall have equal percentage ports.

2.9.1.19. Sizing.

2.9.1.19.1. Two-position service: line size.

2.9.1.19.2. Two-way modulating service: select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 35 kPa (5 psi).

2.9.1.19.3. Three-way modulating service: select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 35 kPa (5 psi).

2.9.1.20. Standard of Acceptance: Belimo

2.9.2. Electric Damper and Valve Actuators.

2.9.2.1. Stall Protection. Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator's rotation.

2.9.2.2. Spring-return Mechanism. Actuators used for power-failure, heating and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS), unless otherwise specified

2.9.2.3. Signal and Range. Proportional actuators shall accept a 0-10 Vdc or a 0-20 mA control signal and shall have a 2-10 Vdc or 4-20 mA operating range. (Floating motor actuators may be substituted for proportional actuators in terminal unit applications as described in paragraph 2.6H.)

2.9.2.4. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.

2.9.2.5. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 7 N•m (60 in.-lb) torque capacity shall have a manual crank.

2.9.2.6. Standard of Acceptance: Belimo

2.9.3. Positive positioning Relays.

2.9.3.1. Whenever a controller has to proportion more than one motor on a single damper, a positive positioning relay must be used. Whenever a controller has to sequence two or more devices, such as valves or dampers, and for all damper operators on modulating dampers, positive positioning relays must be used. Sequencing by spring ranges alone will not be acceptable. Positive positioning relays have positive mechanical feedback of the controlled device, ratio relays are not acceptable.

2.9.4. Switches

2.9.4.1. Pressure electric switches have diaphragm operated D.P.D.T. snap acting contacts with electrical rating suitable for applications as specified. Pressure electric switches withstand up to 25 psig. And are provided with adjustable cut-in and cutout settings between 3 and 20 psig.

2.9.4.2. Water flow switches are general purpose with a paddle actuated snap acting D.P.D.T. switch rated at 16 amp 120/1/60 A.C.

2.9.4.3. Air proving (differential pressure) switches utilize a differential pressure activated, diaphragm actuated, snap acting D.P.D.T. switch rated at 9.8 amp 120/1/60 A.C. full load. Select differential pressure range to suit the application and setpoint is adjustable. Mount switches with diaphragm in a vertical plane. Switches are CSA approved.

2.9.4.4. Install minimum positioning switches inside local cabinets and lock switches after system balancing.

2.9.4.5. Damper end switches are DPDT, lever operated, activated by damper blade movement and mounted securely on damper frame. Switches have contact ratings of 5A at 120 VAC and are CSA approved.

2.9.5. Electronic Temperature Sensors

2.9.5.1. All mixed air sensors are 1000 ohm nickel, resistance temperature detector (RTD) type with a twenty-five foot averaging element. Accuracy of the RTD sensor shall be +/-0.6°C over a range of –7°C to 49°C (19°F to 120°F).

2.9.5.2. All supply and return air sensors are 1000 ohm nickel RTD type temperature detectors. The sensor probe has a minimum length of 450mm (18"). The accuracy of the sensor is +/-0.6°C over a range of 4°C to 66°C (39°F to 151°F).

2.9.5.3. All space sensors (unless noted differently on drawings) are 1000 ohm nickel RTD type temperature detectors. All space sensors are provided with vented protective covers, local temperature adjustment of +/-1°C from setpoint, built in occupancy sensor. There shall be no temperature display.

2.9.5.4. Local temperature adjustment is by two cap touch buttons and LED scale (no actual temperature gradients will be accepted). The accuracy of the sensor is +/-0.6°C over a range of 4°C to 49°C (39°F to 120°F).

2.9.5.5. All space sensors for vestibules, corridors and other high traffic areas shall be nickel RTD stainless steel plate temperature sensor 100 ohm. Equal to Enercorp.

2.9.5.6. All liquid immersed sensors are 1000 ohm nickel RTD type temperature detectors. Each sensor is provided with a stainless steel well, suitable for the working temperature and pressure of the fluid. The accuracy of the sensor is +/- 0.6°C over a range of –7°C to 49°C (19°F to 120°F).

2.9.5.7. Outdoor air sensor is the 1000 ohm nickel RTD type temperature detector. The RTD sensor is mounted in a weatherproof enclosure. The accuracy of the sensor is +/- 0.6°C over a range of –40°C to 40°C (-40°F to 120°F).

2.9.5.8. All sensor elements other than those for space sensors shall be housed in a factory-made stainless-steel sheath.

2.9.5.9. All sensors shall be calibrated and linearized. Include a written documentation of individual sensors for records.

2.9.6. Duct Averaging Temperature Sensors

2.9.6.1. Provide plenum mounted mixed air temperature averaging type sensors with the following minimum characteristics:

2.9.6.1.1. Constructed of FT6 plenum rated cable incorporating a minimum of 9 temperature sensors encapsulated at equal distances along the 24 foot length of the element. The assembly acts as a single sensor reporting the average temperature from all individual sensors.

2.9.6.1.2. End-to-end accuracy +/- 0.3 °C.

2.9.6.1.3. Mount in a zigzag manner to provide continuous coverage of the entire duct cross-sectional area.

2.9.6.1.4. The use of thermistor type sensors is required.

2.9.6.2. Standard of Acceptance: Greystone

2.9.7. Outdoor Air Temperature Sensors

2.9.7.1. Provide outdoor air temperature sensors with the following minimum characteristics:

2.9.7.1.1. Each sensor shall be 10Kohm thermistor probe

2.9.7.1.2. Provide two sensors for each site.

2.9.7.1.3. Both sensors shall be mounted inside a heavy-duty (blow-proof) solar shield.

2.9.7.1.4. Provide a heavy-duty, metal, wire guard.

2.9.7.2. Standard of Acceptance: Greystone

2.9.8. CO_2 Sensor

2.9.8.1. Provide CO_2 sensors for either wall or duct mounting applications as specified. Provide a heavy duty metal guard to protect the sensor when mounted on walls. Provide the factory-supplied duct mounting kit for all duct mount applications.

2.9.8.2. The sensor shall be microprocessor controlled, fully digital, non-dispersive dual wavelength infrared technology with temperature compensation. The device output shall be 4 to 20mA.

2.9.8.3. The sensor shall have a measurement range of 0 to 3000ppm with an accuracy of +/-25ppm in the 15-30C range. Long term stability shall be no greater than 20 ppm per year. The user selectable range shall be 0 to 1500ppm.

2.9.8.4. Install the sensor in accordance with all manufacturer’s instructions. Wall mounted sensors shall be installed at a minimum height of 72” above the finished floor. Sensors shall not be mounted on an outside wall, close to a window, door or in draft areas with direct airflow.

2.9.8.5. The standard of acceptance shall be Greystone

2.9.9. Air Differential Pressure Transmitters

2.9.9.1. Provide differential pressure transmitters to sense differential pressure and convert to a proportional electrical output in applications such as pressure independent Variable Air Volume terminals, S/A duct static pressure, etc. The differential pressure range is selected to match the applications. Select materials suitable for the measured variable, i.e. water and air, and to withstand a minimum of twice the normal working pressure.

2.9.9.2. Each sensor is provided with an industry standard 4-20 mA transmitter, mounted at the sensor not the SCU or panel unless in a finished area. The transmitter and sensor have a combined accuracy of 0.5% of the differential pressure range.

2.9.9.3. Static pressure pickups within finished areas are in blank thermostat cases. Outside static pressure reference heads are complete with a wind baffle cap to eliminate wind pressure effects. The static pressure controller is of the slack diaphragm type with a minimum setpoint range of .01 inches to 6.0 inches W.G.

2.9.10. Liquid Pressure Differential Transmitters

2.9.10.1. The differential pressure transmitter is designed with dual remote sensors that enable it to accept high pressure in ranges up to 500 PSI. All models are rated for overload pressure 2X the maximum fully scale range and burst pressure is 5X the maximum full scaled range. Features include field selectable pressure ranges and output signal types, output reversal and slow damping, port swapping and bidirectional measurements for the most flexible applications. The output signal is factory calibrated and temperature compensated for the highest start-up accuracy.

2.9.10.2. Provide a 3-valve manifold assembly (optional kit to be ordered with sensor) to facilitate sensor servicing and maintenance.

2.9.10.3. Coordinate with the mechanical contractor to provide a pressure tap complete with shut-off valve and “pig tail” tubing (primed with water) for each sensor used to monitor steam pressure.

2.9.10.4. Specifications:

2.9.10.4.1. Power Supply: 24 Vac/dc ± 10% (non-isolated half-wave rectified)

2.9.10.4.2. Output Signal: 4-20 mA sourcing, 0-5/0-10 Vdc (switch selectable)

2.9.10.4.3. LCD: 35 x 15 mm (1.4 x 0.6"), 2-line x 8-character

2.9.10.4.4. Accuracy: ± 1% full scale of selected range (range 4 is ± 2%)

2.9.10.4.5. Stability: ± 0.25% FS typical (1 year)

2.9.10.4.6. Pressure Ranges: 4 per model (menu selectable)

2.9.10.4.7. Media Compatibility: 17-4 PH stainless steel

2.9.10.4.8. Proof Pressure: 2X highest range per model

2.9.10.4.9. Burst Pressure: 20X highest range per model

2.9.10.4.10. Pressure Cycles: > 100 million

2.9.10.4.11. Sensor Operating Range: -40 to 105°C (-40 to 221°F)

2.9.10.4.12. Operating Environment: 0 to 50°C (32 to 122°F), 10 to 90 %RH non-condensing

2.9.10.4.13. Pressure Connection: 1/4" NPT male

2.9.10.4.14. Sensor Housing: IP67

2.9.10.4.15. Remote Sensor Cable: S: FT-6 plenum rated, A: Armored Flexible S/S

2.9.10.4.16. Wiring Connection: 14-22 AWG screw terminal block

2.9.10.4.17. Enclosure: Polycarbonate, UL94-V0, IP65 (NEMA 4X)

2.9.10.5. Standard of Acceptance: Greystone DP series

2.9.11. Control Relays

2.9.11.1. Control relays are DPDT for control of electrical starters and equipment where shown on the Point Schedule.

2.9.11.2. Coil voltage matches the Unit Controller. Contacts are rated at 5A at 120 VAC.

2.9.12. Time Delay Relays

2.9.12.1. Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

2.9.12.2. Standard of Acceptance: Enercorp

2.9.13. Override Timers

2.9.13.1. Unless implemented in control software, override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration required by application. Provide 0-6 hour calibrated dial unless otherwise specified. Flush mount timer on local control panel face or where shown.

2.9.14. Current Transmitters

2.9.14.1. AC current transmitters shall be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two-wire output. Full-scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.

2.9.14.2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.

2.9.14.3. Unit shall be split-core type for clamp-on installation on existing wiring.

2.9.15. Current Transformers

2.9.15.1. AC current transformers shall be UL/CSA recognized and shall be completely encased (except for terminals) in approved plastic material.

2.9.15.2. Transformers shall be available in various current ratios and shall be selected for ±1% accuracy at 5 A full-scale output.

2.9.15.3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.

2.9.16. Voltage Transmitters

2.9.16.1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.

2.9.16.2. Adjustable full-scale unit ranges shall be 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400-600 Vac. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.

2.9.16.3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized at 600 Vac rating.

2.9.17. Voltage Transformers

2.9.17.1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.

2.9.17.2. Transformers shall be suitable for ambient temperatures of 4°C-55°C (40°F-130°F) and shall provide ±0.5% accuracy at 24 Vac and 5 VA load.

2.9.17.3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

2.9.18. Power Monitors

2.9.18.1. Power monitors shall be three-phase type and shall have three-phase disconnect and shorting switch assembly, UL listed voltage transformers, and UL listed split-core current transformers.

2.9.18.2. Power monitors shall provide selectable output: rate pulse for kWh reading or 4-20 mA for kW reading. Power monitors shall operate with 5 A current inputs and maximum error of ±2% at 1.0 power factor or ±2.5% at 0.5 power factor.

2.9.19. Current Switches

2.9.19.1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.

2.9.20. Current Sensors (Analog)

2.9.20.1. Current sensors (CT) shall be used for status monitoring of all motor-driven equipment, where specified.

2.9.20.2. Technical Performance – Output should be only 4-20mA only. Voltage output will not be accepted. End-to-end accuracy +/- 1% of full scale at each range.

2.9.20.3. The current sensors shall be mounted inside the starter cabinets whenever possible. If this is not possible due to space limitation, provide an enclosure to house the sensor.

2.9.20.4. Standard of Acceptance: Enercorp

2.9.21. Status Relays (Solid State)

2.9.21.1. The status relays shall be mounted inside newly provided enclosures mounted near the respective equipment starter cabinets.

2.9.21.2. Standard of Acceptance: Omron Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.

2.9.22. Variable Speed Drives

2.9.22.1. Refer to Section: 26 29 23 Variable-Frequency Motor Controllers.

2.9.23. Fire stopping and Smoke Seal Materials

2.9.23.1. Asbestos-free elastomeric materials tested, listed and labelled by ULC in accordance with CAN4-S115-M85, for installation in U.L.C. designated firestopping and smoke seal Systems. These Systems shall provide a positive fire, water and smoke seal and a fire- resistance rating (flame, smoke hose stream and temperature) not less than the fire resistance rating of surrounding construction.

2.9.23.2. Materials shall form ULC listed or UL classified assemblies and be compatible with abutting dissimilar materials and finishes.

2.9.23.3. Standard of Acceptance:

2.9.23.3.1. 3M Canada Limited

2.9.23.3.2. A/D Fire Protection System Ltd.

2.9.23.3.3. Fire Stop System

2.9.24. Wall Opening Covering Plates

2.9.24.1. All hole covering plates used on this project shall be stainless steel 18-8 chrome metal alloy, type 302, non-magnetic type for finished areas and pressed steel for unfinished areas. Finish brush marks shall be run in a vertical direction.

2.9.25. Access Doors

2.9.25.1. Access doors installed in unfinished areas shall be constructed of 12 ga prime coated steel and of stainless steel for all areas finished with tile or marble surfaces.

2.9.25.2. Access doors shall be complete with 180? opening door, round safety corners, concealed hinges, screwdriver latches, plaster lock and anchor straps.

2.9.25.3. Access doors shall be 24’x 24’ or 12’x 18’ as per site condition.

2.9.25.4. Access doors in fire rated construction shall be ULC listed and labeled and of a rating to maintain the fire separation integrity.

2.9.25.5. Standard of Acceptance:

2.9.25.5.1. Zurn Industries Canada Limited

2.9.25.5.2. LeHage Industries Limited

2.9.25.5.3. Acudor Acorn Limited.

2.9.26. Local Control Panels

2.9.26.1. Indoor control panels shall be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key shall open each control panel and sub-panel.

2.9.26.2. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be UL listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.

2.9.26.3. Each local panel shall have a control power source power switch (on-off) with over current protection.

2.10. **FAIL STATE POSITION OF OUTPUTS**

2.10.1. Unless specified otherwise, configure BAS output points for the following fail state (e.g. device position upon panel failure):

2.10.1.1.	All Fans	OFF
2.10.1.2.	Heating Valves	Full heat to terminal device
2.10.1.3.	Mixing Dampers	Full recirculation air
2.10.1.4.	Face/Bypass Dampers	Full to face
2.10.1.5.	Zone Dampers	Full heat
2.10.1.6.	Heating Pumps	ON (except boiler belly pumps)
2.10.1.7.	Boiler Belly Pumps	OFF
2.10.1.8.	Variable Frequency Drives	ON, minimum programmed speed
2.10.1.9.	Lighting Relays	Last State
2.10.1.10.	Boilers (1 stage)	ON
2.10.1.11.	Boilers (Multi-stage)	LOW ON, HIGH OFF
2.10.1.12.	Cooling Equipment	OFF
2.10.1.13.	Electric Heating	OFF
2.10.1.14.	Domestic Hot Water Pumps	OFF
2.10.1.15.	Roof-top Gas Burners	OFF

2.11. **LAN CABLING**

2.11.1. All LAN cabling shall be Category V as defined by EIA/TIA 568A. The contractor shall test all cabling to verify that 100Mb bandwidth is supported. See commissioning requirements.

2.11.2. Cabling shall be 4 pair, 100 ohm UTP, #24 AWG solid copper conductor PVC insulated, with blue or grey colour coded jacket. FT6 rated cable shall be used unless otherwise required to meet building codes or by-laws.

2.11.3. Data outlets shall be RJ45, 8 pin connectors, with 50 microns of hard gold over nickel, minimum durability of 750 mating cycles and contact pressure of 100 grams per contact. Transmission characteristics shall meet TSB-40 Category V.

2.11.4. Provide one RJ45 data outlet adjacent to each device to be terminated (e.g. workstation PC, DDC panel, hub, etc.) Use a flexible patch cable to connect from the data outlet to the end device. For Delta Controls installations, provide a duplex data outlet at the workstation PC to accommodate the remote security key wiring. LAN cabling shall not be directly terminated to any device.

2.11.5. Provide protection from EMI sources in accordance with CSA-T530 article 4

2.11.6. The contractor shall test all cabling to verify conformance with TIA /EIA TSB-67 - Basic Link Test using a Level 2, bi-directional tester. See commissioning requirements.

2.11.7. Where there are more than 2-90 degree in a conduit run, provide a pull box between sections so that there are two bends or less in any one section.

2.11.8. Where a conduit run requires a reverse bend, between 100 degrees and 180 degrees, insert a pull box at each bend having an angle from 100 degrees to 180 degrees.

2.11.9. Ream all conduit ends and install insulated bushings on each end.

2.11.10. Terminate all conduits that protrude through the structural floor 2" above the concrete base.

2.11.11. Do not use a pull box in lieu of a conduit bend. Align conduits that enter a pull box from opposite ends with each other.

2.11.12. FIBER OPTIC CABLE SYSTEM

2.11.13. Optical Cable. Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm.

2.11.14. Connectors. Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

2.12. **WIRING AND RACEWAYS**

2.12.1. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.

2.12.2. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

PART 3 - EXECUTION

3.1. **EXAMINATION**

3.1.1. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Consultant for resolution before starting rough-in work.

3.1.2. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Consultant for resolution before starting rough-in work.

3.1.3. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to Consultant and obtain written instructions for changes necessary to accommodate this Section's work with work of others. Controls Contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.2. **PROTECTION**

3.2.1. Controls Contractor shall protect against and be liable for damage to work and to material caused by Contractor's work or employees.

3.2.2. Controls Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3. **COORDINATION**

3.3.1. Site.

3.3.1.1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades. If installation without coordination causes interference with work of other trades, Contractor shall correct conditions without extra charge.

3.3.1.2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

3.3.2. Life Safety.

3.3.2.1. Duct smoke detectors required for air handler shutdown are provided under Division 16 and/or are existing. Interlock smoke detectors to air handlers for shutdown.

3.3.2.2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 23 and/or are existing. Interlock smoke dampers to air handlers

3.3.2.3. Coordination with Other Controls. Integrate with and coordinate controls and control devices furnished or installed by others as follows.

3.3.2.4. Communication media and equipment shall be provided as specified herein

3.3.2.5. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation described herein regardless of where within the contract documents those products are described.

3.3.2.6. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.

3.3.2.7. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.

3.3.2.8. Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

3.4. GENERAL WORKMANSHIP

3.4.1. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible.

3.4.2. Provide sufficient slack and flexible connections to allow for piping and equipment vibration isolation.

3.4.3. Install equipment in readily accessible locations as defined by National Electrical Code (NEC) Chapter 1 Article 100 Part A.

3.4.4. Verify wiring integrity to ensure continuity and freedom from shorts and ground faults.

3.4.5. Equipment, installation, and wiring shall comply with industry specifications and standards and local codes for performance, reliability, and compatibility.

3.5. FIELD QUALITY CONTROL

3.5.1. Work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in this section (Codes and Standards).

3.5.2. Continually monitor field installation for code compliance and workmanship quality.

3.5.3. Contractor shall arrange for work inspection by local or state authorities having jurisdiction over the work.

3.6. EXISTING EQUIPMENT

3.6.1. Wiring. Interconnecting control wiring shall be removed and shall become Contractor's property unless specifically noted or shown to be reused.

3.6.2. Local Control Panels. Remove and deliver existing control panels to Board.

3.6.3. Repair. Unless otherwise directed, Contractor is not responsible for repair or replacement of existing energy equipment and systems, valves, dampers, or actuators. Notify Consultant in writing immediately of existing equipment that requires maintenance.

3.6.4. Indicator Gauges. Ensure operation of and recalibrate for reasonable accuracy or replace existing gauges.

3.6.5. Room Thermostats. Remove and deliver existing room thermostats to Board unless otherwise noted. Patch and finish holes and marks left by removal to match existing walls.

3.6.6. Electronic Sensors and Transmitters. Remove and deliver existing sensors and transmitters to Board.

3.6.7. Controllers and Auxiliary Electronic Devices. Remove and deliver existing controllers and auxiliary electronic devices to Board.

3.6.8. Damper Actuators, Linkages, and Appurtenances: Remove and deliver existing damper actuators, linkages and appurtenances to Board.

3.6.9. Control Valves. Replace existing control valves with new. Deliver removed control valves to Board.

3.6.10. Existing System Operating Schedule. Existing mechanical system may be disabled during this work.

3.6.11. Maintain fan scheduling using existing or temporary time clocks or control systems throughout the control system installation.

3.6.12. Modify existing starter control circuits if necessary to provide hand-off-auto control of each controlled starter. Furnish new starters or starter control packages as required.

3.6.13. Patch holes and finish to match existing walls.

3.6.14. At Board's request, items to be delivered to Board shall instead be properly disposed of. Hazardous materials shall be disposed in accordance with current regulations and applicable by-laws.

3.7. WIRING

3.7.1. Control and interlock wiring and installation shall comply with national and local electrical codes, and manufacturer's recommendations.

3.7.2. NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway as specified by NEC.

3.7.3. All wiring shall be installed in EMT conduit unless specified otherwise. Exposed wiring in finished areas (e.g. corridors, classrooms, gymnasiums, etc.) shall be installed in wiremold (colour to match surrounding area)

3.7.4. Wiring from DDC controllers to sensors and actuators and control system network and low voltage wiring running in accessible ceilings may be installed using LVT cable. Where the ceiling is used as a return air plenum, plenum rated cable shall be used in lieu of LVT cable.

3.7.5. Install EMT and cable at right angles to building lines, securely fastened, and in accordance with current electrical codes and standards.

3.7.6. Power and control wiring shall be copper conductor (RW90). For power wiring, provide #12 AWG (minimum) with a 3% maximum voltage drop in accordance with CEC requirements. Control wiring shall be a minimum of #14 AWG, unless otherwise specified.

3.7.7. The wires smaller than 18 gauge shall not be used and will not be accepted on the project except for: wiring between terminal computer devices, wire in standard communication cables, such as printers and short haul modems, wire used in communication networks, i.e. any cable transferring digital data, using twisted shielded pairs.

3.7.8. The wiring from panels to devices shall be installed without splices. The use of crimp connectors is not allowed when connecting field wiring to sensor or device leads. The use of wire nuts is acceptable in this application.

3.7.9. Power for control system shall not be obtained by tapping into miscellaneous circuits that could be inadvertently switched off. Only dedicated circuit(s) shall power the control system. Provide additional breakers or electrical panels as required.

3.7.10. Mount transformers and other peripheral equipment in panels located in serviceable areas. Provide line-side breakers/fuses for each transformer.

3.7.11. All 120 VAC power for any controls equipment shall be from dedicated circuits. Provide a breaker lock for each breaker used to supply the control system. Update the panel circuit directory.

3.7.12. A dedicated power circuit may be used to power DDC panels and equipment within the same or adjoining mechanical rooms. The use of one power circuit to power DDC panels distributed throughout the building is not acceptable.

3.7.13. The controller may be powered from the equipment that it is directly controlling (i.e. heat pump, rooftop unit) only if the controller controls no other equipment and the power supply to the controller remains energized independently of unit operation or status.

3.7.14. Provide all required code gauge boxes, connectors and other wiring accessories.

3.7.15. For all DC wiring, positive conductors shall be WHITE or RED in colour while negative conductors shall be BLACK in colour.

3.8. **COMMUNICATION WIRING**

3.8.1. Communication wiring shall be low-voltage Class 2 wiring and shall comply with Article 3.7 (Wiring).

3.8.2. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.

3.8.3. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.

3.8.4. Verify entire network's integrity following cable installation using appropriate tests for each cable.

3.8.5. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.

3.8.6. Each run of communication wiring shall be a continuous length without splices when that length is commercially available. Runs longer than commercially available lengths shall have as few splices as possible using commercially available lengths.

3.8.7. Label communication wiring to indicate origination and destination.

3.8.8. Ground coaxial cable according to NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

3.8.9. BACnet MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:

3.8.9.1. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot.)

3.8.9.2. The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.

3.8.9.3. The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.

3.8.9.4. An MS/TP EIA-485 network shall have no T connections.

3.9. **FIBER OPTIC CABLE**

3.9.1. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension shall be within cable manufacturer's specifications.

3.9.2. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

3.10. **INSTALLATION OF SENSORS**

3.10.1. Install sensors according to manufacturer's recommendations.

3.10.2. Mount sensors rigidly and adequately for operating environment.

3.10.3. Install room temperature sensors on concealed junction boxes properly supported by wall framing.

3.10.4. Air seal wires attached to sensors in their raceways or in the wall to prevent sensor readings from being affected by air transmitted from other areas.

3.10.5. Use averaging sensors in mixing plenums and hot and cold decks. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.

3.10.6. Install mixing plenum low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 3 m (1 ft) of sensing element for each 1 m2 (1 ft2) of coil area.

3.10.7. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.

3.10.8. Install outdoor air temperature sensors on north wall at designated location with sun shield complete with metal cover cage.

3.10.9. Differential Air Static Pressure.

3.10.9.1. Supply Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.

3.10.9.2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.

3.10.9.3. Building Static Pressure. Pipe pressure sensor's low-pressure port to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe high-pressure port to a location behind a thermostat cover.

3.10.9.4. Piping to pressure transducer pressure ports shall contain a capped test port adjacent to transducer.

3.10.9.5. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ductwork. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.

3.10.9.6. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.

3.10.9.7. Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.

3.10.9.8. Install humidity sensors for duct mounted humidifiers at least 3 m (10 ft) downstream of the humidifier. Do not install filters between the humidifier and the sensor.

3.11. **FLOW SWITCH INSTALLATION**

3.11.1. Use correct paddle for pipe diameter.

3.11.2. Adjust flow switch according to manufacturer's instructions.

3.12. **ACTUATORS**

3.12.1. General. Mount actuators and adapters according to manufacturer's recommendations.

3.12.2. Electric and Electronic

3.12.2.1. Damper Actuators. Mount actuators directly on damper shaft or jackshaft unless shown as a linkage installation. Link actuators according to manufacturer's recommendations.
3.12.2.2. For low-leakage dampers with seals, mount actuator with a minimum 5° travel available for damper seal tightening.
3.12.2.3. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, then tighten linkage.
3.12.2.4. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
3.12.2.5. Provide necessary mounting hardware and linkages for actuator installation.
3.12.2.6. Valve Actuators. Connect actuators to valves with adapters approved by actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

3.13. **WARNING LABELS**

3.13.1. Affix permanent warning labels to equipment that can be automatically started by the control system.

3.13.2. Labels shall use white lettering (12-point type or larger) on a red background.

3.13.2.1. Warning labels shall read as follows.

CAUTION
This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to "Off" position before servicing.

3.13.2.2. Affix permanent warning labels to motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
3.13.2.3. Labels shall use white lettering (12-point type or larger) on a red background.
3.13.2.4. Warning labels shall read as follows.

CAUTION
This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

3.14. **IDENTIFICATION OF HARDWARE AND WIRING**

3.14.1. Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 5 cm (2 in.) of termination.

3.14.2. Label pneumatic tubing at each end within 5 cm (2 in.) of termination with a descriptive identifier.

3.14.3. Permanently label or code each point of field terminal strips to show instrument or item served.

3.14.4. Label control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.

3.14.5. Label each control component with a permanent label. Label plug-in components such that label remains stationary during component replacement.

3.14.6. Label room sensors related to terminal boxes or valves with nameplates.

3.14.7. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

3.14.8. Label identifiers shall match record documents.

3.14.9. Controllers

3.14.9.1. Provide a separate controller for each AHU or other HVAC system. A DDC controller may control more than one system provided that all points associated with the system are assigned to the same DDC controller. Points used for control loop reset, such as outside air or space temperature, are exempt from this requirement.

3.14.9.2. Building Controllers and Custom Application Controllers shall be selected to provide the required I/O point capacity required to monitor all of the hardware points listed in Appendix A (Sequences of Operation).

3.15. **PROGRAMMING**

3.15.1. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See drawings. If character limitations or space restrictions make it advisable to shorten the name, the abbreviations given in Appendix C may be used. Where multiple points with the same name reside in the same controller, each point name may be customized with its associated Program Object number. For example, "Zone Temp 1" for Zone 1, "Zone Temp 2" for Zone 2.

3.15.2. Software Programming. Programming shall provide actions for each possible situation. Graphic- or parameter-based programs shall be documented. Text-based programs shall be modular, structured, and commented to clearly describe each section of the program.

3.15.3. Application Programming. Provide application programming that adheres to sequences of operation specified in in this section. Program documentation or comment statements shall reflect language used in sequences of operation.

3.15.4. System Programming. Provide system programming necessary for system operation.

3.15.5. Operator Interface.

3.15.5.1. Standard Graphics. Provide graphics as specified in this section. Show on each equipment graphic input and output points and relevant calculated points such as indicated on the applicable Points List in this section and on the drawings. Point information on graphics shall dynamically update.

3.15.5.2. Install, initialize, start up, and troubleshoot operator interface software and functions (including operating system software, operator interface database, and third-party software installation and integration required for successful operator interface operation) as described in this section.

3.16. **SEQUENCES OF OPERATION**

3.16.1. As noted on the drawings, together with the list of control points.

3.17. **EQUIPMENT ENCLOSURES AND LOCATIONS**

3.17.1. Provide new enclosures for all field equipment (e.g. DDC panels, transducers, relays, etc.). Enclosures shall be equipped with a hinged door and latch. Provide a BOARD-standard key/lock set for each enclosure.

3.17.2. Mount all enclosures in serviceable areas of mechanical rooms, storage rooms or janitor closets. Obtain written approval of the Consultant prior to mounting any enclosure in ceiling spaces or more than 5’-6” above the finished floor.

3.17.3. All transformers and power supplies for control equipment shall be installed in new dedicated metal cabinets with hinged, lockable covers located in the proximity of their dedicated controller cabinets.

3.17.4. Include within a DDC panel enclosure one 120 VAC duplex receptacle for portable PC power, if the controller cabinet is located further than 5’-0” from the nearest wall receptacle.

3.17.5. Ensure that enclosures are sized to allow for ease of servicing of all equipment contained within. Enclosures containing DDC panels shall be sized to allow for the installation of the maximum allowable number of expansion panels/boards. Do not mount other equipment in a manner that may interfere with the future installation of expansion panels/boards.

3.17.6. For enclosures containing pneumatic transducers or devices, provide one pressure gauge (1½” dial, 0-30psi) for the main air line supply.

3.18. **IDENTIFICATION AND LABELING OF CONTROL EQUIPMENT**

3.18.1. All panels must have a lamicoid tag (min. 3”x1”) affixed to the front face indicating panel designation and function (i.e. “BAS Panel 1” or “Relay Panel 3”).

3.18.2. All field sensors or devices must have a lamicoid tag (min. 3”x1”) attached with tie-wrap or adhesive indicating the point software name and hardware address (i.e. AHU1-MAT, 2.IP4). Tags must be secured by screws where mounted outside of the building, in un-heated spaces, in high humidity areas or where subject to vibration.

3.18.3. Room sensors or other sensors in finished areas must have a lamicoid tag affixed to the front cover. This tag shall be minimum 1”x ½” and indicate the point software name and hardware address.

3.18.4. All devices within a field enclosure shall be identified via a label or tag.

3.18.5. All BAS panel power sources must be identified by a label (min. 3”x1”) indicating the source power panel designation and circuit number (i.e. “120vac fed from LP-2A cct #1).

3.18.6. All field control equipment panels fed from more than one power source must have a warning label on the front cover.

3.18.7. All wires shall be identified with the hardware address with a band-type self-adhesive strips or clip-on plastic wire markers at both ends.

3.18.8. All rotating equipment controlled by the BAS shall have a tag or label affixed indicating that the equipment may start without warning.

3.18.9. The location of the phone line manager shall be indicated via a label affixed to the inside cover of the modem enclosure or BAS panel.

3.18.10. All BAS panels will be supplied with a point’s list sheet (within a plastic sleeve) attached to the inside door.

3.18.11. The points list shall identify the following for each point:

3.18.11.1. Panel number.

3.18.11.2. Panel location.
3.18.11.3. Hardware address.
3.18.11.4. Software name.
3.18.11.5. Point description.
3.18.11.6. Field device type.
3.18.11.7. Point type (i.e. AI or DO).
3.18.11.8. Device fail position.
3.18.11.9. Device manufacturer.
3.18.11.10. Model number or reference.
3.18.11.11. Wire tag reference.

3.18.12. Provide laminated wiring diagrams for all field mounted relay enclosures. Securely attach to the inside door. Identify power panels and circuit numbers of the equipment being controlled.

3.18.13. Provide laminated wiring diagrams or modify existing equipment wiring diagrams wherever the BAS interfaces to other equipment. (e.g. boilers, chillers, etc.). Securely attach to the inside of the respective control cabinet.

3.18.14. Provide lamacoid labels indicating the required operating sequences, on the boilers and valves, where the boiler plants have manual or automatic isolating valves. Submit actual wording to the Consultant for approval prior to fabrication and installation.

3.18.15. Provide lamacoid or machine labels (as outlined above) for all interposing relays or contactors used in control circuits. The labels shall include the related point software name and hardware address

3.18.16. Provide a lamacoid label to identify the location of concealed devices above the ceiling space. Mount the label on the ceiling grid T-bar or a permanent surface adjacent to the devices. The label shall contain the wording “BAS Devices Above”.

3.18.17. Provide lamacoid labels for all auxiliary HVAC equipment (e.g. force flow cabinets, unit ventilators, unit heater, window AC units, etc.) controlled by the BAS. Mount the labels in the vicinity of the existing thermostat or power switch for the unit. The label shall contain the wording “Under BAS Control”.

3.18.18. Where directed by the Consultant, provide any and all additional labelling, diagrams. schematics or instructions as may be required to facilitate the correct operation and maintenance of controlled building systems.

3.19. **SYSTEM HARDWARE COMMISSIONING**

3.19.1. This contractor shall be responsible for the “end to end” commissioning, testing, verification and start-up of the complete control system hardware including panels, sensors, transducers, end devices, relays and wiring. Where applicable, this shall include any points from an existing and/or re-used automation system in the building.

3.19.2. The contractor shall conduct the hardware commissioning at the facility.

3.19.3. When the site hardware installation is 100% completed (including all labeling and documentation), the contractor shall provide written notification to the Board to schedule the hardware commissioning dates for each facility.

3.19.4. Board reserves the right, at its sole discretion, to discontinue site commissioning at any time if any part of the site hardware installation is found to be incomplete on the date of commissioning. If this occurs, the Contractor shall assume responsibility for any additional costs related to rescheduling of the site commissioning.

3.19.5. The Contractor shall prepare a hardware commissioning report containing the following information and test results:

3.19.5.1. Analog inputs (i.e. temperatures, pressure, etc.) shall be verified with an approved calibration device. All actual temperature readings should be with +/-1C of the readings observed at the workstation. Record calibration adjustments and settings.

3.19.5.2. Analog outputs shall be verified by manually commanding the output channel from the operator workstation to two or more positions within the 0-100% range and verifying the actual position of the actuator or device. All devices shall operate over their entire 0-100% range from a minimum control range of 10-90%. Record the actual output scale range (channel output voltage versus controller command) for each analogue end device

3.19.5.3. Digital outputs shall be verified by witnessing the actual start/stop operation of the equipment under control.

3.19.5.4. Digital inputs shall be verified by witnessing the status of the input point as the equipment is manually cycled on and off.

3.19.5.5. Identify any existing equipment (valves, dampers, fan starters, etc..) that are inoperative or require maintenance or repair.

3.19.5.6. The BAS field panel power source shall be toggled on and off to ensure reboot functionality and power down memory retention of all parameters. During the power down test, all controlled system outputs shall go to their fail-safe position.

3.19.5.7. The hardware commissioning report must be signed and dated by the Contractor’s technician performing the tests and participating Board representative.

3.19.5.8. Include with the hardware commissioning report a site floor plan indicating the location of all equipment installed in concealed or recessed locations (e.g. interposing relays in ceiling spaces).

3.19.5.9. Provide testing of all LAN cabling to ensure that 100Mb bandwidth is supported.

3.19.5.10. Verify conformance with TIA /EIA TSB-67 - Basic Link Test using a Level 2, bi-directional tester. Provide all equipment necessary to carry out the required tests.

3.19.5.11. The Contractor shall prepare a software commissioning report containing the following information and test results:

3.19.6. Alarms and Interlocks.

3.19.6.1. Check each alarm with an appropriate signal at a value that will trip the alarm.

3.19.6.2. Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.

3.19.6.3. Tests interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.

3.19.7. Record all out-of-season or unverified points in the commissioning report as “non-commissioned”.

3.19.8. Verify PID loop tuning parameters by applying a step change to the current setpoint and observing the response of the controlled device. Setpoint should be reached in an acceptable period of time without excessive cycling or hunting of the controlled device. Provide a graph of the trend response to setpoint change for important controlled devices (e.g. valves 1-inch or larger, dampers on major air handlers, etc.)

3.19.9. Provide confirmation that a series of test alarms has been successfully received at a designated remote monitoring workstations.

3.19.10. The software commissioning report must be signed and dated by the Contractor’s technician performing the tests and participating Board representative.

3.19.11. At the completion of site commissioning, submit four (4) copies of each the hardware and software commissioning reports to the Board.

3.20. **SUBSTANTIAL COMPLETION INSPECTION**

3.20.1.1. At the completion of the site hardware inspection, the Contractor shall test and verify that the system programming, graphics and alarm software is operating correctly and is in compliance all requirements of the specifications.

3.20.1.2. The Contractor shall provide written notification to the Board that the site is ready for the Substantial Completion Inspection by the Consultant.

3.20.1.3. At the conclusion of the Substantial Completion Inspection, the Consultant shall issue a comprehensive site deficiency report to the Contractor for his immediate action.

3.20.1.4. The Contractor shall correct all items noted in the site deficiency report within ten (10) business days of receipt.

3.20.1.5. The Contractor shall provide written notification to the Board that all items on the Consultant's site deficiency report have been corrected.

3.21. **CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE**

3.21.1. Demonstration. Prior to acceptance, perform the following performance tests to demonstrate system operation and compliance with specification after and in addition to tests specified above. Provide Consultant with log documenting completion of Substantial Completion Inspection.

3.21.2. Consultant and Board Representative will be present to observe and review system demonstration. Notify Consultant and Board Representative at least 10 days before system demonstration begins.

3.21.3. Demonstration shall follow process submitted and approved. Complete approved checklists and forms for each system as part of system demonstration.

3.21.4. Demonstrate actual field operation of each sequence of operation as specified herein. Provide at least two persons equipped with two-way communication. Demonstrate calibration and response of any input and output points requested by Consultant. Provide and operate test equipment required to prove proper system operation.

3.21.5. Demonstrate compliance with sequences of operation through each operational mode.

3.21.6. Demonstrate complete operation of operator interface.

3.21.7. Demonstrate each of the following.

3.21.7.1. DDC loop response. Supply graphical trend data output showing each DDC loop's response to a setpoint change representing an actuator position change of at least 25% of full range. Trend sampling rate shall be from 10 seconds to 3 minutes, depending on loop speed. Each sample's trend data shall show setpoint, actuator position, and controlled variable values. Consultant will require further tuning of each loop that displays unreasonably under- or over-damped control.

3.21.7.2. Building fire alarm system interface.

3.21.7.3. Trend logs for each system. Trend data shall indicate setpoints, operating points, valve positions, and other data as specified in the points list provided with each sequence of operation. Each log shall cover three 48-hour periods and shall have a sample frequency not less than 10 minutes or as specified on its points list. Logs shall be accessible through system's operator interface and shall be retrievable for use in other software programs.

3.21.8. Tests that fail to demonstrate proper system operation shall be repeated after Contractor makes necessary repairs or revisions to hardware or software to successfully complete each test.

3.21.9. Acceptance.

3.21.9.1. After tests described in this specification are performed to the satisfaction of both Consultant and Board, Consultant will accept control system as meeting completion requirements. Consultant may exempt tests from completion requirements that cannot be performed due to circumstances beyond Contractor's control. Consultant will provide written statement of each exempted test. Exempted tests shall be performed as part of warranty.

3.21.10. System shall not be accepted until completed demonstration forms and checklists are submitted and approved as required.

3.22. **CLEANING**

3.22.1. Each day clean up debris resulting from work. Remove packaging material as soon as its contents have been removed. Collect waste and place in designated location.

3.22.2. On completion of work in each area, clean work debris and equipment. Keep areas free from dust, dirt, and debris.

3.22.3. On completion of work, check equipment furnished under this section for paint damage. Repair damaged factory-finished paint to match adjacent areas. Replace deformed cabinets and enclosures with new material and repaint to match adjacent areas.

3.23. **TRAINING**

3.23.1. Provide training for a designated staff of Board's representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.

3.23.2. Training shall enable students to accomplish the following objectives.

3.23.2.1. Proficiently operate system.
3.23.2.2. Understand control system architecture and configuration.
3.23.2.3. Understand DDC system components.
3.23.2.4. Understand system operation, including DDC system control and optimizing routines (algorithms)
3.23.2.5. Operate workstation and peripherals
3.23.2.6. Log on and off system
3.23.2.7. Access graphics, point reports, and logs
3.23.2.8. Adjust and change system set-points, time schedules, and holiday schedules
3.23.2.9. Recognize common HVAC system malfunctions by observing system graphics, trend graphs, and other system tools
3.23.2.10. Understand system drawings and Operation and Maintenance manual
3.23.2.11. Understand job layout and location of control components

3.23.2.12. Access data from DDC controllers
3.23.2.13. Operate portable operator's terminals
3.23.2.14. Create and change system graphics
3.23.2.15. Create, delete, and modify alarms, including configuring alarm reactions
3.23.2.16. Create, delete, and modify point trend logs (graphs) and multi-point trend graphs
3.23.2.17. Configure and run reports
3.23.2.18. Add, remove, and modify system's physical points
3.23.2.19. Create, modify, and delete application programming
3.23.2.20. Add operator interface stations
3.23.2.21. Add a new controller to system
3.23.2.22. Download firmware and advanced applications programming to a controller
3.23.2.23. Configure and calibrate I/O points
3.23.2.24. Maintain software and prepare backups
3.23.2.25. Interface with job-specific, third-party operator software
3.23.2.26. Add new users and understand password security procedures

3.23.3. Divide presentation of objectives into three sessions (1-13, 14-23, and 24-26). Participants will attend one or more of sessions, depending on knowledge level required.

3.23.3.1. Day-to-day Operators (objectives 1-13)
3.23.3.2. Advanced Operators (objectives 1-13 and 14-23)
3.23.3.3. System Managers and Administrators (objectives 1-13 and 14-26)
3.23.3.4. Provide course outline and materials Provide one copy of training material per student.
3.23.3.5. Instructors shall be factory-trained and experienced in presenting this material.
3.23.3.6. Perform classroom training using a network of working controllers representative of installed hardware.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. Water piping to connect HVAC equipment, including the following:

1.1.1.1. Chilled water, condenser water, heating hot water and drain piping.
1.1.1.2. Extension of domestic water make up piping.
1.1.1.3. Glycol water piping.

1.2. RELATED WORK

1.2.1. Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.2.2. Section: 23 05 00 Common Work Results for HVAC.

1.2.3. Section: 23 21 23 Hydronic Pumps.

1.3. QUALITY ASSURANCE

1.3.1. Section: 23 05 00 Common Work Results for HVAC, which includes welding qualifications.

1.3.2. Submit prior to welding of steel piping a certificate of Welder’s certification. The certificate shall be current and not more than one year old.

1.3.3. All joint couplings, fittings, valves, and specialties shall be the products of a single manufacturer.

1.3.4. All castings used for coupling housings, fittings, valve bodies, etc., shall be date stamped for quality assurance and traceability.

1.4. SUBMITTALS

1.4.1. Submit in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.4.2. Manufacturer's Literature and Data:

1.4.2.1. Pipe and equipment supports.
1.4.2.2. Pipe and tubing, with specification, class or type, and schedule.
1.4.2.3. Pipe fittings, including miscellaneous adapters and special fittings.
1.4.2.4. Flanges, gaskets and bolting.
1.4.2.5. Valves of all types.
1.4.2.6. Heat Exchangers.
1.4.2.7. Strainers.
1.4.2.8. Flexible connectors for water service.
1.4.2.9. Pipe alignment guides.
1.4.2.10. Expansion joints.

1.4.2.11. Expansion compensators.
1.4.2.12. All specified hydronic system components.
1.4.2.13. Water flow measuring devices.
1.4.2.14. Gages.
1.4.2.15. Thermometers and test wells.
1.4.2.16. Electric heat tracing systems.
1.4.2.17. Air separators.
1.4.2.18. Expansion tanks.
1.4.2.19. Submit the welder's qualifications in the form of a current (less than one year old) and formal certificate.
1.4.2.20. As Built Piping Diagrams: Provide drawing as follows for chilled water/glycol, condenser water, and heating hot water/glycol system and other piping systems and equipment in electronic Autocad and pdf format.

1.5. **APPLICABLE PUBLICATIONS**

1.5.1. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only. American National Standards Institute, Inc.

1.5.2. American Society of Mechanical Engineers/American National Standards Institute, Inc. (ASME/ANSI):

1.5.2.1. B1.20.1-83(R2006) Pipe Threads, General Purpose (Inch)
1.5.2.2. B16.4 06 Gray Iron Threaded Fittings
1.5.2.3. B16.18-01 Cast Copper Alloy Solder joint Pressure fittings
1.5.2.4. B16.23-02 Cast Copper Alloy Solder joint Drainage fittings
1.5.2.5. B40.100-05 Pressure Gauges and Gauge Attachments

1.5.3. American National Standards Institute, Inc./Fluid Controls Institute (ANSI/FCI):

1.5.3.1. 70-2-2006 Control Valve Seat Leakage

1.5.4. American Society of Mechanical Engineers (ASME):

1.5.4.1. B16.1-98 Cast Iron Pipe Flanges and Flanged Fittings
1.5.4.2. B16.3-2006 Malleable Iron Threaded Fittings: Class 150 and 300
1.5.4.3. B16.4 2006 Gray Iron Threaded Fittings: (Class 125 and 250)
1.5.4.4. B16.5-2003 Pipe Flanges and Flanged Fittings: NPS ½ through NPS 24 Metric/Inch Standard
1.5.4.5. B16.9-07 Factory Made Wrought Butt Welding Fittings
1.5.4.6. B16.11-05 Forged Fittings, Socket Welding and Threaded
1.5.4.7. B16.18-01 Cast Copper Alloy Solder Joint Pressure Fittings
1.5.4.8. B16.22-01 Wrought Copper and Bronze Solder Joint Pressure Fittings.

1.5.4.9. B16.24 06 Cast Copper Alloy Pipe Flanges and Flanged Fittings
1.5.4.10. B16.39 06 Malleable Iron Threaded Pipe Unions
1.5.4.11. B16.42-06 Ductile Iron Pipe Flanges and Flanged Fittings
1.5.4.12. B31.1 08 Power Piping

1.5.5. American Society for Testing and Materials (ASTM):

1.5.5.1. A47/A47M-99 (2004) Ferritic Malleable Iron Castings
1.5.5.2. A53/A53M-07 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
1.5.5.3. A106/A106M-08 Standard Specification for Seamless Carbon Steel Pipe for High Temperature Service
1.5.5.4. A126 04 Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
1.5.5.5. A183 03 Standard Specification for Carbon Steel Track Bolts and Nuts
1.5.5.6. A216/A216M-08 Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High Temperature Service
1.5.5.7. A234/A234M-07 Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
1.5.5.8. A307 07 Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength
1.5.5.9. A536 84 (2004) Standard Specification for Ductile Iron Castings
1.5.5.10. A615/A615M-08 Deformed and Plain Carbon Steel Bars for Concrete Reinforcement
1.5.5.11. B32 08 Standard Specification for Solder Metal
1.5.5.12. B62 02 Standard Specification for Composition Bronze or Ounce Metal Castings
1.5.5.13. B88 03 Standard Specification for Seamless Copper Water Tube

1.5.6. American Water Works Association (AWWA):

1.5.6.1. C110-08 Ductile Iron and Grey Iron Fittings for Water
1.5.6.2. C203-02 Coal Tar Protective Coatings and Linings for Steel Water Pipe Lines Enamel and Tape Hot Applied

1.6. **SPARE PARTS**

1.6.1. For mechanical pressed sealed fittings provide tools required for each pipe size used at the facility.

PART 2 - PRODUCTS

2.1. **PIPE AND TUBING**

2.1.1. Chilled Water/Glycol Piping, Condenser Water Piping, Heating Hot Water/Glycol Piping as applicable to the project:

2.1.1.1. <u>50 mm (2") diam and smaller:</u>

2.1.1.1.1. Schedule 40 continuous weld or electric resistance welded black carbon steel conforming to ASTM A53 84a Grade B, with threaded ends.

2.1.1.1.2. Type "L" hard drawn copper tubing conforming to ASTM B88. Type "L" soft annealed copper tubing may be used within convector enclosures.

2.1.1.2. <u>65 mm (2½") diam and larger</u>

2.1.1.2.1. Schedule 40 continuous weld or electric resistance welded black carbon steel conforming to ASTM A53 84a Grade B, with beveled ends.

2.1.2. Cooling Coil Condensate Drain Piping:

2.1.2.1. From air handling units: Copper water tube, ASTM B88, Type M

2.1.2.2. From fan coil or other terminal units: Copper water tube, ASTM B88, Type L for runouts and Type M for mains.

2.1.3. Chemical Feed Piping for Cooling Tower Water Treatment: Chlorinated polyvinyl chloride (CPVC), Schedule 80, ASTM F441.

2.1.4. Pipe supports, including insulation shields, for above ground piping: Section 23 05 11, COMMON WORK RESULTS FOR HVAC.

2.2. FITTINGS FOR COPPER TUBING

2.2.1. Joints 50 mm (2") and smaller:

2.2.1.1. *Solder Joints:* Joints shall be made up in accordance with recommended practices of the materials applied. Apply 95/5 tin and antimony on all copper piping.

2.2.1.2. *Screwed Joints:* Pipe Thread: ANSI B1.20. Lubricant or Sealant: Oil and graphite or other compound approved for the intended service.

2.2.2. Joints 65 mm (2½") and larger:

2.2.2.1. Bronze Flanges and Flanged Fittings: ASME B16.24.

2.2.2.2. Fittings: ASME B16.18 cast copper or ASME B16.22 solder wrought copper.

2.3. FITTINGS FOR STEEL PIPE

2.3.1. 50 mm (2 inches) and Smaller: Screwed or welded joints.

2.3.1.1. Butt welding: ASME B16.9 with same wall thickness as connecting piping.

2.3.1.2. Forged steel, socket welding or threaded: ASME B16.11.

2.3.1.3. Screwed: 150 pound malleable iron, ASME B16.3. 125 pound cast iron, ASME B16.4, may be used in lieu of malleable iron. Bushing reduction of a single pipe size, or use of close nipples, is not acceptable.

2.3.2. 65 mm (2 1/2 inches) and Larger: Welded or flanged joints.

2.3.2.1. Butt welding fittings: ASME B16.9 with same wall thickness as connecting piping. Elbows shall be long radius type, unless otherwise noted.

2.3.2.2. Welding flanges and bolting: ASME B16.5:

2.3.2.3. Weld neck or slip on, plain face, with 6 mm (1/8 inch) thick full face neoprene gasket suitable for 104 degrees C (220 degrees F).

2.3.2.4. Flange bolting: Carbon steel machine bolts or studs and nuts, ASTM A307, Grade B.

2.4. **FITTINGS FOR PLASTIC PIPING**

2.4.1. Chemical feed piping for condenser water treatment: Chlorinated polyvinyl chloride (CPVC), Schedule 80, ASTM F439.

2.5. **DIELECTRIC FITTINGS**

2.5.1. Provide where copper tubing and ferrous metal pipe are joined.

2.5.2. 50 mm (2 inches) and Smaller: Threaded dielectric union, ASME B16.39.

2.5.3. 65 mm (2 1/2 inches) and Larger: Flange union with dielectric gasket and bolt sleeves, ASME B16.42.

2.5.4. Temperature Rating, 99 degrees C (210 degrees F).

2.6. **UNION**

2.6.1. 50 mm (2") diam and smaller:

2.6.1.1. All brass construction with ground joint and either solder joint or screwed ends as required.

2.6.1.2. Class 150 black malleable iron construction with brass to iron ground joint and screwed ends, conforming to ASTM A197 and ANSI/ASME B1.20.1.

2.6.1.3. Provide dielectric unions or couplings at all connections between copper tubing and ferrous piping or equipment.

2.7. **FLANGES**

2.7.1. Class 150 forged steel slip-on or weld-neck raised face type conforming to ASTM A181 Grade 1 and ANSI/ASME B16.5. Remove raised face where flanges connect to Class 125 cast iron valves.

2.7.2. Hinged, two piece, shouldered or keyed cast malleable iron

2.7.3. Conforming to ASTM A47 Grade 32510 with elastomeric gasket suitable for service and lock bolt.

2.8. **GASKETS AND BOLTS**

2.8.1. Gaskets

2.8.1.1. 1.6 mm (1/16") Garlock 3200 with SBR binder or equivalent asbestos free material.

2.8.2. Bolts

2.8.2.1. Semi finished hex head machine bolts and semi finished hex nuts, both of carbon steel conforming. to ASTM A307 Class A.

2.9. **PLUGS**

2.9.1. 50 mm (2") diam and smaller

2.9.2. Class 3000 screwed, square head, machined from solid steel or forging to ASTM A105 Grade 2.

2.10. **SCREWED JOINTS**

2.10.1. Pipe Thread: ANSI B1.20.

2.10.2. Lubricant or Sealant: Oil and graphite or other compound approved for the intended service.

2.11. **VALVES**

2.11.1. Asbestos packing is not acceptable.

2.11.2. All valves of the same type shall be products of a single manufacturer.

2.11.3. Provide chain operators for valves 150 mm (6 inches) and larger when the centerline is located 2400 mm (8 feet) or more above the floor or operating platform.

2.11.4. Standard of Acceptance: Crane, Toyo, Kitz, RWV

2.11.5. Shut-Off Valves

2.11.5.1. <u>Ball Valves</u> (Pipe sizes 50 mm [2”] and smaller): MSS-SP 110, screwed or solder connections, brass or bronze body with chrome-plated ball with full port and Teflon seat at 2760 kPa (400 psig) working pressure rating. Provide stem extension to allow operation without interfering with pipe insulation.

2.11.5.2. Butterfly Valves (Pipe Sizes 65 mm [2-1/2”] and larger): Provide stem extension to allow 50 mm (2 inches) of pipe insulation without interfering with valve operation. MSS SP 67, flange lug type end rated 1205 kPa (175 psig) working pressure at 93 degrees C (200 degrees F). Valves shall be ANSI Leakage Class VI and rated for bubble tight shut-off to full valve pressure rating. Valve shall be rated for dead end service and bi-directional flow capability to full rated pressure. Not permitted for direct buried pipe applications.

2.11.5.2.1. Body: Cast iron, ASTM A126, Class B. Malleable iron, ASTM A47 electro-plated, or ductile iron, ASTM A536, Grade 65 45 12 electro-plated.

2.11.5.2.2. Trim: Bronze, aluminum bronze, or 300 series stainless steel disc, bronze bearings, 316 stainless steel shaft and manufacturer's recommended resilient seat. Resilient seat shall be field replaceable, and fully line the body to completely isolate the body from the product. A phosphate coated steel shaft or stem is acceptable, if the stem is completely isolated from the product.

2.11.5.2.3. Actuators: Field interchangeable. Valves for balancing service shall have adjustable memory stop to limit open position.

2.11.5.2.4. Valves 150 mm (6 inches) and smaller: Lever actuator with minimum of seven locking positions, except where chain wheel is required.

2.11.5.2.5. Valves 200 mm (8 inches) and larger: Enclosed worm gear with handwheel, and where required, chain wheel operator.

2.11.5.3. Globe and Angle Valves

2.11.5.3.1. Globe Valves

- 50 mm (2 inches) and smaller: MSS SP 80, bronze, 1034 kPa (150 lb.) Globe valves shall be union bonnet with metal plug type disc.
- 65 mm (2 1/2 inches) and larger: 861 kPa (125 psig), flanged, iron body, bronze trim, MSS SP 85 for globe valves.

2.11.5.3.2. Angle Valves:

- 50 mm (2 inches) and smaller: MSS SP 80, bronze, 1034 kPa (150 lb.) Angle valves shall be union bonnet with metal plug type disc.
- 65 mm (2 1/2 inches) and larger: 861 kPa (125 psig), flanged, iron body, bronze trim, MSS SP 85 for angle.

2.11.5.3.3. Check Valves

- Swing Check Valves:
- 50 mm (2 inches) and smaller: MSS SP 80, bronze, 1034 kPa (150 lb.), 45 degree swing disc.
- 65 mm (2 1/2 inches) and larger: 861 kPa (125 psig), flanged, iron body, bronze trim, MSS SP 71 for check valves.
- Non Slam or Silent Check Valve: Spring loaded double disc swing check or internally guided flat disc lift type check for bubble tight shut off. Provide where check valves are shown in chilled water and hot water piping. Check valves incorporating a balancing feature may be used.

- Body: MSS-SP 125 cast iron, ASTM A126, Class B, or steel, ASTM A216, Class WCB, or ductile iron, ASTM 536, flanged, grooved, or wafer type.
- Seat, disc and spring: 18 8 stainless steel, or bronze, ASTM B62. Seats may be elastomer material.

2.11.5.3.4. Water Flow Balancing Valves: For flow regulation and shut off. Valves shall be line size rather than reduced to control valve size.

- Standard of Acceptance: Crane, Toyo, Kitz, RWV, Amstrong
- General

  Globe style valve.
  Provide a readout kit including flow meter, readout probes, hoses, flow charts or calculator, and carrying case.
  Standard of Acceptance: Armstrong CBV series, Taco, Tour and Anderson

- Valves ½” to 2” diam:

  Valves are to be of the ‘Y’ pattern, equal percentage globe-style and provide three functions: 1) Precise flow measurement, 2) Precision flow balancing, 3) Positive drip-tight shut-off.
  Valve shall provide multi-turn, 360° adjustment with micrometer type indicators located on the valve handwheel. Valves shall have a minimum of five full 360° handwheel turns. 90° ‘circuit-setter’ style ball valves are not acceptable. Valve handle shall have hidden memory feature, which will provide a means for locking the valve position after the system is balanced.
  Valves shall be furnished with precision machined venturi built into the valve body to provide highly accurate flow measurement and flow balancing. The venturi shall have two, ¼" threaded brass metering ports with check valves and gasketed caps located on the inlet side of the valve. Valves shall be furnished with flow smoothing fins downstream of the valve seat and integral to the forged valve body to make the flow more laminar. The valve body, stem and plug shall be brass. The handwheel shall be high-strength resin.

- Valves 2-1/2” to 12” diam:

  Valves are to be of the ‘Y’ pattern, equal percentage globe-style and provide three functions: 1) Precise flow measurement, 2) Precision flow balancing, 3) Positive drip-tight shut-off.
  Valve shall provide multi-turn, 360° adjustment with micrometer type indicators located on the valve handwheel. Valves shall have a minimum of five full 360° handwheel turns. 90° ‘circuit-setter’ style ball valves are not acceptable. Valve handle shall have hidden memory feature, which will provide a means for locking the valve position after the system is balanced.

Valves shall be furnished with precision machined venturi built into the valve body to provide highly accurate flow measurement and flow balancing. The venturi shall have two, ¼" threaded brass metering ports with check valves and gasketted caps located on the inlet side of the valve. Valves shall be furnished with flow smoothing fins downstream of the valve seat and integral to the forged valve body to make the flow more laminar. The valve body, stem and plug shall be brass. The handwheel shall be high-strength resin.

2.11.5.3.5. Automatic Balancing Control Valves:

- Use only where specifically approved by the consultant
- Factory calibrated to maintain constant flow (plus or minus five percent) over system pressure fluctuations of at least 10 times the minimum required for control. Provide standard pressure taps and four sets of capacity charts. Valves shall be line size and be one of the following designs:
- Gray iron (ASTM A126) or brass body rated 1205 kPa (175 psig) at 93 degrees C (200 degrees F), with stainless steel piston and spring.
- Brass or ferrous body designed for 2067 kPa (300 psig) service at 121 degrees C (250 degrees F), with corrosion resistant, tamper proof, self cleaning piston/spring assembly that is easily removable for inspection or replacement.
- Provide a readout kit including flow meter, probes, hoses, flow charts and carrying case.
- Standard of Acceptance: Kitz, RWV

2.11.5.3.6. Manual Radiator/Convector Valves: Brass, packless, with position indicator.

2.12. **WATER FLOW MEASURING DEVICES**

2.12.1. Minimum overall accuracy plus or minus three percent over a range of 70 to 110 percent of design flow. Select devices for not less than 110 percent of design flow rate.

2.12.2. Venturi Type: Bronze, steel, or cast iron with bronze throat, with valved pressure sensing taps upstream and at the throat.

2.12.3. Wafer Type Circuit Sensor: Cast iron wafer type flow meter equipped with readout valves to facilitate the connecting of a differential pressure meter. Each readout valve shall be fitted with an integral check valve designed to minimize system fluid loss during the monitoring process.

2.12.4. Self Averaging Annular Sensor Type: Brass or stainless steel metering tube, shutoff valves and quick coupling pressure connections. Metering tube shall be rotatable so all sensing ports may be pointed down stream when unit is not in use.

2.12.5. Flow Measuring Device Identification:

2.12.5.1. Metal tag attached by chain to the device.
2.12.5.2. Include meter or equipment number, manufacturer's name, meter model, flow rate factor and design flow rate in l/m (gpm).
2.12.5.3. Permanently Mounted Water Flow Indicating Meters: Minimum 150 mm (6 inch) diameter, or 450 mm (18 inch) long scale, for 120 percent of design flow rate, direct reading in lps (gpm), with three valve manifold and two shut off valves.

2.13. **STRAINERS**

2.13.1. Basket or Y Type.

2.13.1.1. Screens: Bronze, monel metal or 18 8 stainless steel, free area not less than 2 1/2 times pipe area, with perforations as follows: 1.1 mm (0.045 inch) diameter perforations for 100 mm (4 inches) and larger: 3.2 mm (0.125 inch) diameter perforations.
2.13.1.2. Suction Diffusers: Specified in Section: 23 21 23 Hydronic Pumps.

2.14. **FLEXIBLE CONNECTORS FOR WATER SERVICE**

2.14.1. Refer to Section: 23 05 48 Vibration and Seismic Controls for HVAC.

2.15. **EXPANSION JOINTS**

2.15.1. Factory built devices, inserted in the pipe lines, designed to absorb axial cyclical pipe movement which results from thermal expansion and contraction. This includes factory-built or field-fabricated guides located along the pipe lines to restrain lateral pipe motion and direct the axial pipe movement into the expansion joints.

2.15.2. Manufacturing Quality Assurance: Conform to Expansion Joints Manufacturers Association Standards.

2.15.3. Bellows Internally Pressurized Type:

2.15.3.1. Multiple corrugations of Type 304 or Type A240-321 stainless steel.
2.15.3.2. Internal stainless steel sleeve entire length of bellows.
2.15.3.3. External cast iron equalizing rings for services exceeding 340 kPa (50 psig).
2.15.3.4. Welded ends.
2.15.3.5. Design shall conform to standards of EJMA and ASME B31.1.
2.15.3.6. External tie rods designed to withstand pressure thrust force upon anchor failure if one or both anchors for the joint are at change in direction of pipeline.
2.15.3.7. Integral external cover.

2.15.4. Bellows Externally Pressurized Type:

2.15.4.1. Multiple corrugations of Type 304 stainless steel.
2.15.4.2. Internal and external guide integral with joint.
2.15.4.3. Design for external pressurization of bellows to eliminate squirm.
2.15.4.4. Welded ends.
2.15.4.5. Conform to the standards of EJMA and ASME B31.1.
2.15.4.6. Threaded connection at bottom, 25 mm (one inch) minimum, for drain or drip point.
2.15.4.7. Integral external cover and internal sleeve.

2.15.5. Expansion Compensators:

2.15.5.1. Corrugated bellows, externally pressurized, stainless steel or bronze.
2.15.5.2. Internal guides and anti torque devices.
2.15.5.3. Threaded ends.
2.15.5.4. External shroud.
2.15.5.5. Conform to standards of EJMA.

2.15.6. Expansion Joint Identification: Provide stamped brass or stainless steel nameplate on each expansion joint listing the manufacturer, the allowable movement, flow direction, design pressure and temperature, date of manufacture, and identifying the expansion joint by the identification number on the contract drawings.

2.15.7. Guides: Provide factory-built guides along the pipe line to permit axial movement only and to restrain lateral and angular movement. Guides must be designed to withstand a minimum of 15 percent of the axial force which will be imposed on the expansion joints and anchors. Field-built guides may be used if detailed on the contract drawings.

2.15.8. Supports: Provide saddle supports and frame or hangers for heat exchanger. Mounting height shall be adjusted to facilitate gravity return of steam condensate. Construct supports from steel, weld joints.

2.16. **HYDRONIC SYSTEM COMPONENTS**

2.16.1. Air Purger: Cast iron or fabricated steel, 861 kPa (125 psig) water working pressure, for in line installation.

2.16.2. Pressure Relief Valve: Bronze or iron body and bronze or stainless steel trim, with testing lever. Comply with ASME Code for Pressure Vessels, Section 8, and bear ASME stamp.

2.16.3. Automatic Air Vent Valves: Automatic air vent should be used only on air separators and similar applications in mechanical rooms. When used, pipe outlet to floor drain to prevent damage from leaks. Cast iron or semi steel body, 1034 kPa (150 psig) working pressure, stainless steel float, valve, valve seat and mechanism, minimum 15 mm (1/2 inch) water connection and 6 mm (1/4 inch) air outlet. Air outlet shall be piped to the nearest floor drain.

2.17. **GAGES, TEMPERATURE, PRESSURE AND COMPOUND**

2.17.1. See Section: 23 05 00 Common Work Results for HVAC.

2.17.2. Provide brass lever handle union cock. Provide brass/bronze pressure snubber for gages in water service.

2.17.3. Range of Gages: Provide range equal to at least 150 percent of normal operating range.

2.18. **PRESSURE/TEMPERATURE TEST PROVISIONS**

2.18.1. Pete's Plug: 6 mm (1/4 inch) MPT by 75 mm (3 inches) long, brass body and cap, with retained safety cap, model self closing valve cores, permanently installed in piping where shown, or in lieu of pressure gage test connections shown on the drawings.

2.19. **FIRESTOPPING MATERIAL**

2.19.1. Refer to Section: 23 05 00 Common Work Results for HVAC.

PART 3 - EXECUTION

3.1. **GENERAL**

3.1.1. The drawings show the general arrangement of pipe and equipment but do not show all required fittings and offsets that may be necessary to connect pipes to equipment, fan-coils, coils, radiators, etc., and to coordinate with other trades. Provide all necessary fittings, offsets and pipe runs based on field measurements and at no additional cost to the government. Coordinate with other trades for space available and relative location of HVAC equipment and accessories to be connected on ceiling grid. Pipe location on the drawings shall be altered by contractor where necessary to avoid interferences and clearance difficulties.

3.1.2. Store materials to avoid excessive exposure to weather or foreign materials. Keep inside of piping relatively clean during installation and protect open ends when work is not in progress.

3.1.3. Support piping securely. Refer to Section 23 05 11, COMMON WORK RESULTS FOR HVAC.

3.1.4. Install piping generally parallel to walls and column center lines, unless shown otherwise on the drawings. Space piping, including insulation, to provide 25 mm (one inch) minimum clearance between adjacent piping or other surface. Unless shown otherwise, slope drain piping down in the direction of flow not less than 25 mm (one inch) in 12 m (40 feet). Provide eccentric reducers to keep bottom of sloped piping flat.

3.1.5. Locate and orient valves to permit proper operation and access for maintenance of packing, seat and disc. Generally locate valve stems in overhead piping in horizontal position. Provide a union adjacent to one end of all threaded end valves. Control valves usually require reducers to connect to pipe sizes shown on the drawing. Install butterfly valves with the valve open as recommended by the manufacturer to prevent binding of the disc in the seat.

3.1.6. Offset equipment connections to allow valving off for maintenance and repair with minimal removal of piping. Provide flexibility in equipment connections and branch line take offs with 3 elbow swing joints where noted on the drawings.

3.1.7. Tee water piping runouts or branches into the side of mains or other branches. Avoid bull-head tees, which are two return lines entering opposite ends of a tee and exiting out the common side.

3.1.8. Provide manual or automatic air vent at all piping system high points and drain valves at all low points. Install piping to floor drains from all automatic air vents.

3.1.9. Connect piping to equipment as shown on the drawings and as recommended by the manufacturer.

3.1.10. Install components furnished by others such as:

3.1.10.1. Water treatment pot feeders and condenser water treatment systems.
3.1.10.2. Flow elements (orifice unions), control valve bodies, flow switches, pressure taps with valve, and wells for sensors.
3.1.10.3. Thermometer Wells: In pipes 65 mm (2 1/2 inches) and smaller increase the pipe size to provide free area equal to the upstream pipe area.

3.1.11. Firestopping: Fill openings around uninsulated piping penetrating floors or fire walls, with firestop material. For firestopping insulated piping refer to Section: 23 07 00 HVAC Insulation.

3.1.12. Where copper piping is connected to steel piping, provide dielectric connections.

3.2. PIPE JOINTS

3.2.1. Welded: Beveling, spacing and other details shall conform to ASME B31.1 and AWS B2.1. See Welder’s qualification requirements under "Quality Assurance" in Section 23 05 11, COMMON WORK RESULTS FOR HVAC and STEAM GENERATION.

3.2.2. Screwed: Threads shall conform to ASME B1.20; joint compound shall be applied to male threads only and joints made up so no more than three threads show. Coat exposed threads on steel pipe with joint compound, or red lead paint for corrosion protection.

3.2.3. 125 Pound Cast Iron Flange (Plain Face): Mating flange shall have raised face, if any, removed to avoid overstressing the cast iron flange.

3.2.4. Solvent Welded Joints: As recommended by the manufacturer.

3.3. **EXPANSION JOINTS (BELLOWS AND SLIP TYPE)**

3.3.1. Anchors and Guides: Provide type, quantity and spacing as recommended by manufacturer of expansion joint and as shown. A professional engineer shall verify in writing that anchors and guides are properly designed for forces and moments which will be imposed.

3.3.2. Cold Set: Provide setting of joint travel at installation as recommended by the manufacturer for the ambient temperature during the installation.

3.3.3. Preparation for Service: Remove all apparatus provided to restrain joint during shipping or installation. Representative of manufacturer shall visit the site and verify that installation is proper.

3.3.4. Access: Expansion joints must be located in readily accessible space. Locate joints to permit access without removing piping or other devices. Allow clear space to permit replacement of joints and to permit access to devices for inspection of all surfaces and for adding.

3.4. **BRAZING**

3.4.1. Flux shall not be allowed to penetrate to the inside of the pipe. The outside of the tube and fittings shall be cleaned by washing with hot water in order to remove any residual flux.

3.4.2. During the brazing of the pipe connections, except when performing final connections and emergency repairs, the interior of the pipe shall be maintained with a nitrogen atmosphere. This shall be done by purging the pipe a sufficient number of times to remove all air and oxygen and by maintaining a small purge flow to prevent reentry of

3.5. **LEAK TESTING ABOVEGROUND PIPING**

3.5.1. Inspect all joints and connections for leaks and workmanship and make corrections as necessary, to the satisfaction of the Resident Engineer. Tests may be either of those below, or a combination, as approved by the Resident Engineer.

3.5.2. An operating test at design pressure, and for hot systems, design maximum temperature.

3.5.3. A hydrostatic test at 1.5 times design pressure. For water systems the design maximum pressure would usually be the static head, or expansion tank maximum pressure, plus pump head. Factory tested equipment (convertors, exchangers, coils, etc.) need not be field tested. Isolate equipment where necessary to avoid excessive pressure on mechanical seals and safety devices.

3.6. **FLUSHING AND CLEANING PIPING SYSTEMS**

3.6.1. Water Piping: Clean systems as recommended by the suppliers of chemicals for the school

3.6.2. Initial flushing: Remove loose dirt, mill scale, metal chips, weld beads, rust, and like deleterious substances without damage to any system component. Provide temporary piping or hose to bypass coils, control valves, exchangers and other factory cleaned equipment unless acceptable means of protection are provided and subsequent inspection of hide out areas takes place. Isolate or protect clean system components, including pumps and pressure vessels, and remove any component which may be damaged. Open all valves, drains, vents and strainers at all system levels. Remove plugs, caps, spool pieces, and components to facilitate early debris discharge from system. Sectionalize system to obtain debris carrying velocity of 1.8 m/S (6 feet per second), if possible. Connect dead end supply and return headers as necessary. Flush bottoms of risers. Install temporary strainers where necessary to protect down stream equipment. Supply and remove flushing water and drainage by various type hose, temporary and permanent piping and Contractor's booster pumps. Flush until clean as approved by the Resident Engineer.

3.6.3. Cleaning: Using products supplied in Section 23 25 00, HVAC WATER TREATMENT, circulate systems at normal temperature to remove adherent organic soil, hydrocarbons, flux, pipe mill varnish, pipe joint compounds, iron oxide, and like deleterious substances not removed by flushing, without chemical or mechanical damage to any system component. Removal of tightly adherent mill scale is not required. Keep isolated equipment which is "clean" and where dead end debris accumulation cannot occur. Sectionalize system if possible, to circulate at velocities not less than 1.8 m/S (6 feet per second). Circulate each section for not less than four hours. Blow down all strainers, or remove and clean as frequently as necessary. Drain and prepare for final flushing.

3.6.4. Final Flushing: Return systems to conditions required by initial flushing after all cleaning solution has been displaced by clean make up. Flush all dead ends and isolated clean equipment. Gently operate all valves to dislodge any debris in valve body by throttling velocity. Flush for not less than one hour.

3.7. **WATER TREATMENT**

3.7.1. Install water treatment equipment and provide water treatment system piping.

3.7.2. Close and fill system as soon as possible after final flushing to minimize corrosion.

3.7.3. Utilize this activity, by arrangement with the Resident Engineer, for instructing VA operating personnel.

3.8. **OPERATING AND PERFORMANCE TEST AND INSTRUCTION**

3.8.1. Refer to PART 3 of Section: 23 05 00 Common Work Results for HVAC.

3.8.2. Adjust red set hand on pressure gages to normal working pressure.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. Hydronic pumps for Heating, Ventilating and Air Conditioning.

1.1.2. Includes pumps for hydronic heating and cooling service, including condensers. Includes process pumps except those covered in other specification sections.

1.1.3. Does not include steam condensate, domestic booster package, domestic hot water recirculation pumps, sump, or fire pumps.

1.2. RELATED WORK

1.2.1. Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.2.2. Section: 23 05 00 Common Work Results for HVAC.

1.2.3. Section: 23 05 13 Common Motor Requirements for HVAC Equipment.

1.2.4. Section: 23 05 48 Vibration and Seismic Controls for HVAC.

1.2.5. Section: 23 21 13 Hydronic Piping.

1.2.6. Section: 26 29 10 Motor Starters to 600 V.

1.3. QUALITY ASSURANCE

1.3.1. Refer to Paragraph, QUALITY ASSURANCE, in Section: 23 05 00 Common Work Results for HVAC.

1.4. QUALITY CONTROL

1.4.1. The pump control package shall be fully assembled by the manufacturer. The manufacturer shall be responsible for the complete pump control package.

1.4.2. Where applicable, the pump control package shall include the system interface with pumps and VFDs, as well as the successful operation of all components supplied by the pump control system manufacturer.

1.5. DESIGN CRITERIA

1.5.1. Pumps design and manufacturer shall conform to Hydraulic Institute Standards.

1.5.2. Pump sizes, capacities, pressures, operating characteristics and efficiency shall be as scheduled.

1.5.3. Head capacity curves shall slope up to maximum head at shut off. Curves shall be relatively flat for closed systems. Select pumps near the midrange of the curve, so the design capacity falls to the left of the best efficiency point, to allow a cushion for the usual drift to the right in operation, without approaching the pump curve end point and possible cavitation and unstable operation. Select pumps for open systems so that required net positive suction head (NPSHR) does not exceed the net positive head available (NPSHA).

1.5.4. Pump Driver: Furnish with pump. Size shall be non overloading at any point on the head capacity curve, including in a parallel or series pumping installation with one pump in operation.

1.5.5. Provide all pumps with motors, impellers, drive assemblies, bearings, coupling guard and other accessories specified. Statically and dynamically balance all rotating parts.

1.5.6. Furnish each pump and motor with a nameplate giving the manufacturers name, serial number of pump, capacity in GPM and head in feet at design condition, horsepower, voltage, frequency, speed and full load current and motor efficiency.

1.5.7. Test all pumps before shipment. The manufacturer shall certify all pump ratings.

1.5.8. After completion of balancing, provide replacement of impellers or trim impellers to provide specified flow at actual pumping head, as installed.

1.5.9. Allowable Vibration Tolerance for Pump Units: Section: 23 05 48 Vibration and Seismic Controls for HVAC.

1.6. **SUBMITTALS**

1.6.1. Submit in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.6.2. Manufacturer's Literature and Data:

1.6.2.1. Pumps and accessories.
1.6.2.2. Motors and drives.
1.6.2.3. Variable speed motor controllers.
1.6.2.4. Manufacturer's installation, maintenance and operating instructions, in accordance with Section: 23 05 00 Common Work Results for HVAC.
1.6.2.5. Characteristic Curves: Head capacity, efficiency capacity, brake horsepower capacity, and NPSHR capacity for each pump and for combined pumps in parallel or series service. Identify pump and show fluid pumped, specific gravity, pump speed and curves plotted from zero flow to maximum for the impeller being furnished and at least the maximum diameter impeller that can be used with the casing.

1.7. **CLOSEOUT SUBMITTALS**

1.7.1. Operation and Maintenance Data: Supply maintenance data including marked performance curves for each hydronic pump for incorporation into manual

1.8. **APPLICABLE PUBLICATIONS**

1.8.1. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only:

1.8.2. American National Standards Institute (ANSI):

1.8.2.1. ANSI B15.1-00(R2008) Safety Standard for Mechanical Power Transmission Apparatus

1.8.2.2. ANSI B16.1 05 Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250 and 800

1.8.3. American Society for Testing and Materials (ASTM):

1.8.3.1. A48-03 (2008) Standard Specification for Gray Iron Castings

1.8.3.2. B62 2009 Standard Specification for Composition Bronze or Ounce Metal Castings

1.8.3.3. Maintenance and Operating Manuals in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.9. **DEFINITIONS**

1.9.1. Capacity: Liters per second (L/s) (Gallons per minute (GPM) of the fluid pumped.

1.9.2. Head: Total dynamic head in kPa (feet) of the fluid pumped.

1.9.3. Flat head capacity curve: Where the shutoff head is less than 1.16 times the head at the best efficiency point.

1.10. **DELIVERY STORAGE AND HANDLING**

1.10.1. Delivery and Requirements:

1.10.1.1. Deliver materials and components in manufacturer’s original packaging with identification labels intact and in sizes to suit project.

1.10.1.2. Include manufacturer's name, job number, pump location, and pump model and series numbers on identification labels.

1.10.1.3. Storage and Handling Requirements: Store materials off ground and protected from exposure to harmful weather conditions and at temperature conditions recommended by manufacturer. Storage must be weather tight, rain proof, and dust proof.

1.10.1.4. Exercise care to avoid damage during unloading and storing.

1.10.1.5. Leave pump port protection plates in place until pumps are ready to connect to piping.

1.10.1.6. Do not place cable slings around pump shaft or integrated control enclosure.

1.10.1.7. Once installed the contractor must keep a dust proof cover over the drive, motor, and integral controller.

1.11. **SPARE MATERIALS**

1.11.1.1. Furnish one spare seal and casing gasket for each pump to the Client Representative.

1.12. **WARRANTY**

1.12.1. Provide a complete parts and labor warranty for a minimum of one year from the date of Substantial Completion.

1.13. **STANDARDS OF ACCEPTANCE**

1.13.1. Armstrong

1.13.2. Taco

1.13.3. Bell & Gossett

1.13.4. Grundfoss

PART 2 - PRODUCTS

2.1. **GENERAL PUMP REQUIREMENTS:**

2.1.1. Unless noted otherwise, provide pumps meeting these general requirements.

2.1.2. Suitable for the service, rated for the temperature and pressure indicated. When not indicated, pump and pump seals shall be rated for not less than 1,200 kPa (175 psig) working pressure and 107 deg.C (225 degrees F) continuous water temperature. Provide pumps with capacities and performance as scheduled on the Drawings.

2.1.3. Flanged pumps shall have suction and discharge taps in flanges, and drain and vent taps in the volute. Piping connections shall be flanged for connection sizes 65 mm (2½ inches) and larger.

2.1.4. Pumps shall have statically and dynamically balanced impeller, with a constantly dropping head curve from shutoff to cutoff, and shall not overload their respective motors on any point throughout the head capacity curve. Key and lock impeller to shaft.

2.1.5. Motors shall be factory coupled to pump and with rpm, voltage and HP as scheduled. Single phase motors shall have built-in overload protection.

2.1.6. Where flexible coupling is specified, coupling shall be EPDM, center dropout type, capable of absorbing torsional vibration and shaft misalignment, complete with ANSI B15.1/OSHA 1910.219 coupling guard.

2.1.7. Pumps for domestic water systems shall be lead free (less than 0.25 percent lead by weight in all wetted surfaces) all bronze or stainless steel construction.

2.1.8. Pump seals shall be unaffected by chloramines.

2.1.9. Pumps used for glycol shall have seals rated for glycol service.

2.1.10. Pump selection:

2.1.10.1. Select pumps so an impeller/volute is sized to accommodate 10 percent more head than at duty point, unless noted otherwise on pump schedule.
2.1.10.2. Select pump no greater than 85 percent of end of curve flow.
2.1.10.3. Select pump at the point of best efficiency for a given impeller-casing combination. Deviations shall be within 3 percent of maximum efficiency point on the increasing capacity side of the maximum efficiency point.
2.1.10.4. Pumps inlet/outlet connections shall not be less than 1 pipe size smaller than the main pipe connecting to the pumps.
2.1.10.5. Maximum Pump Suction/Discharge velocities:
2.1.10.5.1. Inline: 3 m/s (10 fps) for both inlet and discharge sizes
2.1.10.5.2. End Suction: 3 m/s (10 fps) for both inlet and discharge sizes
2.1.10.6. Balance pumps per ANSI / Hydraulic Institute procedures.
2.1.10.7. For pumps to be applied in variable speed applications, balance and test to assure the vibration limit does not exceed 3.3 mm/s (0.13 inches/sec) at any pump speed. Pumps may be field tested after installation by an independent testing agency. Any pump found to exceed the specified vibration limits shall be corrected to perform within those limits without cost to the Client.

2.2. **IN-LINE CLOSE COUPLED CIRCULATORS**

2.2.1. The pumps shall be single stage horizontal inline design. The seal shall be serviceable without disturbing the piping connections. The capacities and characteristics shall be as called for in the plans/schedules.

2.2.2. Pump shall be constructed of ASTM A48 class 30 cast iron. The pump casing shall be drilled and tapped for gauge ports on both the suction and discharge connections.

2.2.3. All casings shall be flanged connections.

2.2.4. The impeller shall be ASTM C87500 or C89833 bronze and hydraulically balanced. The impeller shall be dynamically balanced to ANSI Grade G6.3 and shall be fitted with a holding taper and left handed 431 series stainless steel bolt. The impeller shall be cast by the hydraulically efficient lost foam technique to ensure repeatability of high quality.

2.2.5. The pump shall incorporate a dry shaft design to prevent the circulating fluid from contacting the shaft. The pump shaft shall be AISI 1045 carbon steel with field replaceable copper nickel 90-10 shaft sleeve. In order to improve serviceability and reduce the cost of ownership the shaft sleeve must be slip on (press on not allowable) and must be easily replaced in the field.

2.2.6. The pump shall be fitted with a single mechanical seal, with EPT elastomers and Carbon/Ceramic faces, rated up to 250ºF. The pump shall be coupled to a NEMA 56C face motor with threaded on shaft extension.

PART 3 - EXECUTION

3.1. INSTALLATION

3.1.1. Follow manufacturer's written instructions for pump mounting and start up. Access/Service space around pumps shall not be less than minimum space recommended by pumps manufacturer.

3.1.2. Ensure that pump is pipe-mounted and free to float with any movement, expansion and contraction of piping system.

3.1.3. Ensure that pump body does not support piping or equipment. Provide stanchions or hangers for this purpose. Refer to drawings and manufacturer's installation instructions for details.

3.1.4. Provide vibration isolation between the pumps and pipes, and between the pumps and the concrete curbs.

3.1.5. Support pump using floor mounted saddle as required. i. For vertical in-line pumps supported from structure, ensure no pipe strain is imposed on pump flanges

3.1.6. Power wiring, as required, shall be the responsibility of the electrical contractor. All wiring shall be performed per manufacturer’s instructions and all applicable codes.

3.1.7. Control wiring for shall be the dual responsibility of the electrical and BAS contractors. All wiring shall be performed per manufacturer’s instructions and all applicable codes.

3.1.8. Provide drains for bases and seals for base mounted pumps, piped to and discharging into floor drains.

3.1.9. Coordinate location of thermometer and pressure gauges as per Section: 23 21 13 Hydronic Piping.

3.2. **ACCESSORIES**

3.2.1. Install a suction guide upstream of each floor mounted vertical in-line pump unless specified or shown otherwise on the drawings. The mechanical contractor shall inspect the strainer prior to activating the pump and, further, shall remove the fine mesh start-up strainer after a short running period. (24 hours maximum). Space shall be provided for removal of the strainer and connection of a blow-down valve.

3.2.2. Install a strainer upstream of each floor mounted horizontal inlet/vertical discharge pump and upstream of each vertical in-line close coupled circulator pumps. The mechanical contractor shall inspect the strainer prior to activating the pump and, further, shall remove the fine mesh start-up strainer after a short running period. (24 hours maximum). Space shall be provided for removal of the strainer and connection of a blow-down valve.

3.2.3. Install a triple duty valve on the discharge of each vertical in-line pump or horizontal inlet/vertical discharge floor mounted pump, unless specified or shown otherwise on the drawings. Angle style or straight in-line arrangement, as suitable to the pump type and local conditions.

3.2.4. Install a manual circuit balancing valve on the discharge of each vertical in-line close coupled circulator pumps.

3.2.5. Install a check valve on the discharge of each pump where more than 1 pump discharges into a common header.

3.2.6. Contractor to provide and install one pressure gauge, piped to pump suction, pump discharge and strainer inlet (suction guide). Pressure gauge tappings with necessary isolating valves to enable differential pressure reading across pump and strainer to be taken.

3.2.7. Where applicable, the motors shall be rated for variable speed duty. Contractor shall cover motor during construction and have area clean of construction debris before starting the motor.

3.3. **START UP**

3.3.1. Verify that the piping system has been flushed, cleaned and filled.

3.3.2. Lubricate pumps before start-up.

3.3.3. Prime the pump, vent all air from the casing and verify that the rotation is correct. To avoid damage to mechanical seals, never start or run the pump in dry condition.

3.3.4. Verify that correct size heaters-motor over-load devices are installed for each pump controller unit.

3.3.5. Sensor-less pumps: final adjustments and start-up: by manufacturer's representatives together with the hydronic balancer and the BAS vendor.

3.3.6. Field modifications to the bearings and or impeller (including trimming) are not permitted. If the pump does not meet the specified vibration tolerance send the pump back to the manufacturer for a replacement pump. All modifications to the pump shall be performed at the factory.

3.3.7. Ensure the disposable strainer is free of debris prior to testing and balancing of the hydronic system.

3.3.8. After several days of operation, replace the disposable start up strainer with a regular strainer in the suction diffuser.

TABLE OF CONTENTS

PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. Refrigerating system: Combination of interconnected refrigerant containing parts constituting one closed refrigeration circuit in which a refrigerant is circulated for the purpose of extracting heat.

1.1.2. Low side means the parts of a refrigerating system subjected to evaporator pressure.

1.1.3. High side means the parts of a refrigerating system subjected to condenser pressure.

1.1.4. Brazed joint: A gas tight joint obtained by the joining of metal parts with alloys which melt at temperatures higher than 449 degrees C (840 degrees F) but less than the melting temperatures of the joined parts.

1.2. RELATED WORK

1.2.1. Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.2.2. Section: 22 05 00 Common Work Results for Plumbing.

1.3. QUALITY ASSURANCE

1.3.1. Refer to specification Section: 23 05 00 Common Work Results for HVAC.

1.3.2. Comply with ASHRAE Standard 15, Safety Code for Mechanical Refrigeration. The application of this Code is intended to assure the safe design, construction, installation, operation, and inspection of every refrigerating system employing a fluid which normally is vaporized and liquefied in its refrigerating cycle.

1.3.3. Comply with ASME B31.5: Refrigerant Piping and Heat Transfer Components.

1.3.4. Products shall comply with UL 207 "Refrigerant–Containing Components and Accessories, "Nonelectrical"; or UL 429 "Electrical Operated Valves."

1.4. SUBMITTALS

1.4.1. Submit in accordance with specification Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.4.2. Shop Drawings:

1.4.2.1. Complete information for components noted, including valves and refrigerant piping accessories, clearly presented, shall be included to determine compliance with drawings and specifications for components noted below:

1.4.2.1.1. Tubing and fittings

1.4.2.1.2. Valves
1.4.2.1.3. Strainers
1.4.2.1.4. Moisture liquid indicators
1.4.2.1.5. Filter driers
1.4.2.1.6. Flexible metal hose
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1.4.2.1.8. Oil separators (when specified)
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1.4.2.1.10. Pipe and equipment supports
1.4.2.1.11. Refrigerant and oil
1.4.2.1.12. Pipe/conduit roof penetration cover
1.4.2.1.13. Soldering and brazing materials

1.4.3. Layout of refrigerant piping and accessories, including flow capacities, valves locations, and oil traps slopes of horizontal runs, floor/wall penetrations, and equipment connection details.

1.4.4. Refrigerant piping shall be sized, selected, and designed either by the equipment manufacturer or in strict accordance with the manufacturer's published instructions. The schematic piping diagram shall show all accessories such as, stop valves, level indicators, liquid receivers, oil separator, gauges, thermostatic expansion valves, solenoid valves, moisture separators and driers to make a complete installation.

1.4.5. Design Manual: Furnish two copies of design manual of refrigerant valves and accessories.

1.5. **APPLICABLE PUBLICATIONS**

1.5.1. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.

1.5.2. Air Conditioning, Heating, and Refrigeration Institute (ARI/AHRI):

1.5.2.1. 495-1999 (R2002) Standard for Refrigerant Liquid Receivers
1.5.2.2. 730-2005 Flow Capacity Rating of Suction-Line Filters and Suction-Line Filter-Driers
1.5.2.3. 750-2007 Thermostatic Refrigerant Expansion Valves
1.5.2.4. 760 2007 Performance Rating of Solenoid Valves for Use with Volatile Refrigerants

1.5.3. American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE):

1.5.3.1. ANSI/ASHRAE 15 2007 Safety Standard for Refrigeration Systems (ANSI)
1.5.3.2. ANSI/ASHRAE 17 2008 Method of Testing Capacity of Thermostatic Refrigerant Expansion Valves (ANSI)

1.5.3.3. 63.1-95 (RA 01) Method of Testing Liquid Line Refrigerant Driers (ANSI)

1.5.4. American National Standards Institute (ANSI):

1.5.4.1. ASME (ANSI)A13.1-2007Scheme for Identification of Piping Systems
1.5.4.2. Z535.1-2006 Safety Color Code

1.5.5. American Society of Mechanical Engineers (ASME):

1.5.5.1. ANSI/ASME B16.22 2001 (R2005)
1.5.5.2. Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings (ANSI)
1.5.5.3. ANSI/ASME B16.24 2006 Cast Copper Alloy Pipe Flanges and Flanged Fittings, Class 150, 300, 400, 600, 900, 1500 and 2500 (ANSI)
1.5.5.4. ANSI/ASME B31.5-2006 Refrigeration Piping and Heat Transfer Components (ANSI)
1.5.5.5. ANSI/ASME B40.100-2005 Pressure Gauges and Gauge Attachments
1.5.5.6. ANSI/ASME B40.200-2008 Thermometers, Direct Reading and Remote Reading

1.5.6. American Society for Testing and Materials (ASTM)

1.5.6.1. B88 03 Standard Specification for Seamless Copper Water Tube
1.5.6.2. B88M-05 Standard Specification for Seamless Copper Water Tube (Metric)
1.5.6.3. B280 08 Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
1.5.6.4. Underwriters Laboratories (U.L.):
1.5.6.5. U.L.207-2009 Standard for Refrigerant-Containing Components and Accessories, Nonelectrical
1.5.6.6. U.L.429-99 (Rev.2006) Standard for Electrically Operated Valves

PART 2 - PRODUCTS

2.1. PIPING AND FITTINGS

2.1.1. Refrigerant Piping: For piping up to 100 mm (4 inch) use Copper refrigerant tube, ASTM B280, cleaned, dehydrated and sealed, marked ACR on hard temper straight lengths. Coils shall be tagged ASTM B280 by the manufacturer. For piping over 100 mm (4 inch) use A53 Black SML steel.

2.1.2. Pre-Insulated refrigerant piping/lines shall not be accepted.

2.1.3. Fittings, Valves and Accessories:

2.1.3.1. Copper fittings: Wrought copper fittings, ASME B16.22.

2.1.3.2. Brazed Joints, refrigerant tubing: Cadmium free, AWS A5.8/A5.8M, 45 percent silver brazing alloy, Class BAg-5.

2.1.3.3. Solder Joints, water and drain: 95 5 tin antimony, ASTM B32 (95TA).

2.1.3.4. Refrigerant piping – Welded Joints.

2.1.3.5. Flanges and flanged fittings: ASME B16.24.

2.1.4. Flexible connectors

2.1.4.1. Install at all locations where refrigerant piping is connected to equipment containing moving or rotating parts (compressors, supply fans, condenser fans, etc)

2.1.4.2. Also refer to Section: 23 05 48 Vibration and Seismic Controls for HVAC.

2.2. **REFRIGERATION VALVES:**

2.2.1. Stop Valves:

2.2.1.1. Brass or bronze alloy, packless, or packed type with gas tight cap, frost proof, back seating.

2.2.2. Pressure Relief Valves:

2.2.2.1. Comply with ASME Boiler and Pressure Vessel Code; UL listed. Forged brass with nonferrous, corrosion resistant internal working parts of high strength, cast iron bodies conforming to ASTM A126, Grade B. Set valves in accordance with ASHRAE Standard 15.

2.2.3. Solenoid Valves:

2.2.3.1. UL-listed, 250 deg. F temperature rating, 400 psig working pressure; forged brass, with Teflon valve seat, two-way straight through pattern, and solder end connections. Provide manual operator to open valve. Furnish complete with NEMA 1 solenoid enclosure with ½ inch conduit adapter, holding coil, voltage to meet controls requirements.

2.2.3.2. Comply with ARI 760 and UL 429, UL-listed, two-position, direct acting or pilot-operated, moisture and vapor proof type of corrosion resisting materials, designed for intended service, and solder-end connections. Fitted with suitable NEMA 250 enclosure of type required by location and normally open or closed holding coil (as specified)

2.2.4. Thermostatic Expansion Valves:

2.2.4.1. Comply with ARI 750. Brass body with stainless-steel or non-corrosive non ferrous internal parts, diaphragm and spring-loaded (direct-operated) type with sensing bulb and distributor having side connection for hot-gas bypass and external equalizer. Size and operating characteristics as recommended by manufacturer of evaporator and factory set for superheat requirements. Solder-end connections. Testing and rating in accordance with ASHRAE Standard 17.

2.2.5. Check Valves:

2.2.5.1. Brass or bronze alloy with swing or lift type, with tight closing resilient seals for silent operation; designed for low pressure drop, and with solder-end connections. Direction of flow shall be legibly and permanently indicated on the valve body.

2.2.6. Strainers:

2.2.6.1. Designed to permit removing screen without removing strainer from piping system, and provided with screens 80 to 100 mesh in liquid lines DN 25 (NPS 1) and smaller, 60 mesh in liquid lines larger than DN 25 (NPS 1), and 40 mesh in suction lines. Provide strainers in liquid line serving each thermostatic expansion valve, and in suction line serving each refrigerant compressor not equipped with integral strainer.

2.2.7. Refrigerant Moisture/Liquid Indicators:

2.2.7.1. Double ported type having heavy sight glasses sealed into forged bronze body and incorporating means of indicating refrigerant charge and moisture indication. Provide screwed brass seal caps.

2.2.8. Refrigerant Filter Dryers:

2.2.8.1. UL listed, angle or in line type, as shown on drawings. Conform to ARI Standard 730 and ASHRAE Standard 63.1. Heavy gage steel shell protected with corrosion-resistant paint; perforated baffle plates to prevent desiccant bypass. Size as recommended by manufacturer for service and capacity of system with connection not less than the line size in which installed. Filter driers with replaceable filters shall be furnished with one spare element of each type and size.

2.2.9. Flexible Metal Hose:

2.2.9.1. Seamless bronze corrugated hose, covered with bronze wire braid, with standard copper tube ends. Provide in suction and discharge piping of each compressor and connections to air handling equipment. As manufactured by Anaconda or equal

2.2.10. Oil Separators:

2.2.10.1. Provide for condensing units, as shown. All welded steel construction with capacity to eliminate a minimum of 95 percent of the oil from the hot gas flowing through it. Provide manufacturer's published ratings for minimum and maximum refrigeration tonnage corresponding to this oil separating efficiency. Separator shall be equipped with a float valve to prevent return of the hot gas to crankcase, and shall have isolating stop valves so it can be opened and services without pumping out any other part of the system. ASME construction or UL listed.

2.2.11. Receivers:

2.2.11.1. Conform to AHRI 495, steel construction, equipped with tappings for liquid inlet and outlet valves, pressure relief valve and liquid level indicator.

2.2.12. Standards of Acceptance for Refrigerant Valves and Specialties:

2.2.12.1. Emerson Electric, Danfoss, Henry Industries

2.3. **GAGES**

2.3.1. Temperature Gages: Comply with ASME B40.200. Industrial duty type and in required temperature range for service in which installed. Gages shall have Celsius scale in 1-degree (Fahrenheit scale in 2-degree) graduations and with black number on a white face. The pointer shall be adjustable. Rigid stem type temperature gages shall be provided in thermal wells located within 1525 mm (5 feet) of the finished floor. Universal adjustable angle type or remote element type temperature gages shall be provided in thermal wells located 1525 to 2135 mm (5 to 7 feet) above the finished floor. Remote element type temperature gages shall be provided in thermal wells located 2135 mm (7 feet) above the finished floor.

2.3.2. Vacuum and Pressure Gages: Comply with ASME B40.100 and provide with throttling type needle valve or a pulsation dampener and shut-off valve. Gage shall be a minimum of 90 mm (3-1/2 inches) in diameter with a range from 0 kPa (0 psig) to approximately 1.5 times the maximum system working pressure. Each gage range shall be selected so that at normal operating pressure, the needle is within the middle-third of the range.

2.3.3. Suction: 101 kPa (30 inches Hg) vacuum to 1723 kPa (gage) (250 psig).

2.3.4. Discharge: 0 to 3445 kPa (gage) (0 to 500 psig).

2.4. **PIPE SUPPORTS**

2.4.1. Indoor supports

2.4.1.1. Refer to specification Section: 23 05 00 Common Work Results for HVAC.

2.4.2. Outdoor supports

2.4.2.1. The roof block is an assembled product comprised of two major components including the support shell which is a one piece, UV resistant, thermoplastic injection molded Polypropylene Impact Copolymer and the Type 3, 20 psi extruded polystyrene non-marring base. The support shell is designed with an interior web creating eight symmetrical cavities. Design maximizes support strength while substantially reducing the overall weight. Interior cavities allow for expansion and contraction under extreme temperature conditions over its lifetime. The lower portion of the one piece support shell incorporates a ¾” high wall which reduces UV exposure to the extruded polystyrene base.

2.4.2.2. Straps: install 2-hole galvanized pipe straps, mounted to the roof block using fasteners available locally. Ensure that there is no direct contact between the copper refrigerant piping and the galvanized straps.

2.4.2.3. Standard of Acceptance: Miro Industries, Block-Ease, Portable Pipe Hangers. Min. height above roof: 150 mm.

2.5. REFRIGERANTS AND OIL

2.5.1. Provide EPA approved refrigerant and oil for proper system operation.

2.6. PIPE INSULATION FOR DX HVAC SYSTEMS

2.6.1. Application: all refrigerant suction lines, all hot gas discharge lines.

2.6.2. Insulation materials shall have a closed cell structure to prevent moisture from wicking which makes it an efficient insulation.

2.6.3. Insulation materials shall be manufactured without the use of CFC’s, HFC’s or HCFC’s. It is also formaldehyde free, low VOCs, fiber free, dust free and resists mold and mildew.

2.6.4. Insulation materials shall have a flame-spread index of less than 25 and a smoke-developed index of less than 50 as tested in accordance with ASTM E 84. In addition, the products, when tested, shall not melt or drip flaming particles, and the flame shall not be progressive.

2.6.5. Insulation materials shall have a maximum thermal conductivity of 0.27 Btu-in./h-ft2-°F at a 75°F mean temperature as tested in accordance with ASTM C 177 or ASTM C 518.

2.6.6. Insulation materials shall have a maximum water vapor transmission of 0.08 perm-inches when tested in accordance with ASTM E 96, Procedure A.

2.6.7. Standard of Acceptance: Armaflex

2.6.8. Insulation shall be a flexible, closed-cell elastomeric pipe insulation: AP Armaflex, AC Accoflex. Adhesive shall be Armaflex 520, 520 Black or 520 BLV Adhesive. The insulation must conform to ASTM C534 Grade 1, Type I.

2.6.9. Sizes

2.6.9.1. Wall Thickness (nominal): 3/8”, 1/2”, 3/4”, 1”, 1-1/2”, 2” (10, 13, 19, 25, 38, 50mm)

2.6.9.2. Inside Diameter, Tubular: 3/8” ID to 10”ID (10mm ID to 250mm)

2.6.10. Specifications Compliance:

2.6.10.1. ASTM C 534, Type I — Grade 1

2.6.10.2. ASTM D 1056, 2B1

2.6.10.3. ASTM E 84, NFPA 255, UL723

2.6.10.4. ASTM G21/C1338

2.6.10.5. ASTM G22

2.6.10.6. CAN/ULC S102

2.6.11. Outdoor protection:

2.6.11.1.1. Aluminum Jackets – Outdoor Piping and Fittings

- Aluminum Jacket-Piping systems: ASTM B209, 3003 alloy, H-14 temper, 0.6 mm (0.023 inch) minimum thickness with locking longitudinal joints. Jackets for elbows, tees and other fittings shall be factory-fabricated to match shape of fitting and of 0.6 mm (0.024) inch minimum thickness aluminum. Fittings shall be of same construction as straight run jackets but need not be of the same alloy. Factory-fabricated stainless steel bands shall be installed on all circumferential joints. Bands shall be 13 mm (0.5 inch) wide on 450 mm (18 inch) centers. System shall be weatherproof if utilized for outside service.
- Field applied vapor barrier jackets shall be provided, in addition to the specified facings and jackets, on all exterior piping as well as on interior piping exposed to outdoor air (i.e.; in ventilated attics, piping in ventilated (not air conditioned) spaces, etc.) The vapor barrier jacket shall consist of a multi-layer laminated cladding with a maximum water vapor permeance of 0.001 perms. The minimum puncture resistance shall be 35 cm-kg (30 inch-pounds) for interior locations and 92 cm-kg (80 inch-pounds) for exterior or exposed locations or where the insulation is subject to damage.
- Neither rivets, screws, staples nor any other fastener capable of penetrating the underlying vapor retarder shall be used to secure the aluminum jacketing.
- Standards of Acceptance: Childers-Lock-on, Pabco-Surfeit, Johns Mansville.

2.6.12. Accessories

2.6.12.1. ArmaFlex 520 and 520 Black Adhesive – Air-drying, solvent-based contact adhesive for strong bonds and tight seams.

2.6.12.2. ArmaFlex BLV – Black Low VOC Air-drying, solvent-based contact adhesive

2.6.12.3. ArmaFlex Insulation Tape – black foam, pressure-sensitive seam tape

2.6.12.4. Armacell Fabricated Fittings – Made to order pre-fabricated fittings in Tees, Elbows, P-Traps and more

2.6.12.5. ArmaFix Insulation Pipe Hangers – Easy-to-use insulated pipe hanger supports that protect against compression, up to 1” wall thickness.

PART 3 - EXECUTION

3.1. INSTALLATION

3.1.1. Install refrigerant piping and refrigerant containing parts in accordance with ASHRAE Standard 15 and ASME B31.5

3.1.2. Install piping as short as possible, with a minimum number of joints, elbow and fittings.

3.1.2.1. Install piping with adequate clearance between pipe and adjacent walls and hangers to allow for service and inspection. Space piping, including insulation, to provide 25 mm (1 inch) minimum clearance between adjacent piping or other surface. Use pipe sleeves through walls, floors, and ceilings, sized to permit installation of pipes with full thickness insulation.

3.1.2.2. Locate and orient valves to permit proper operation and access for maintenance of packing, seat and disc. Generally locate valve stems in overhead piping in horizontal position. Provide a union adjacent to one end of all threaded end valves. Control valves usually require reducers to connect to pipe sizes shown on the drawing.

3.1.2.3. Install hangers and supports per ASME B31.5 and the refrigerant piping manufacturer's recommendations.

3.1.2.4. Slope refrigerant piping as follows:

3.1.2.4.1. Install horizontal hot gas discharge piping with 1/2" per 10 feet downward slope away from the compressor.

3.1.2.4.2. Install horizontal suction lines with 1/2 inch per 10 feet downward slope to the compressor, with no long traps or dead ends which may cause oil to separate from the suction gas and return to the compressor in damaging slugs.

3.1.2.4.3. Install traps and double risers where indicated, and where required to entrain oil in vertical runs.

3.1.2.4.4. Liquid lines may be installed level.

3.1.2.5. Install strainers immediately ahead of each expansion valve, solenoid valve, hot gas bypass valve, compressor suction valve, and as required to protect refrigerant piping system components.

3.1.2.6. Install moisture/liquid indicators in liquid lines between filter/driers and thermostatic expansion valves and in liquid line to receiver (where applicable).

3.1.2.7. Install unions to allow removal of solenoid valves, pressure regulating valves, expansion valves, and at connections to compressors and evaporators.

3.1.2.8. Joint Construction:

3.1.2.8.1. Brazed Joints: Comply with AWS "Brazing Handbook" and with filler materials complying with AWS A5.8/A5.8M.

3.1.2.8.2. Use Type BcuP, copper-phosphorus alloy for joining copper socket fittings with copper tubing.

3.1.2.8.3. Use Type BAg, cadmium-free silver alloy for joining copper with bronze or steel.

3.1.2.8.4. Swab fittings and valves with manufacturer's recommended cleaning fluid to remove oil and other compounds prior to installation.

3.1.2.8.5. Pass nitrogen gas through the pipe or tubing to prevent oxidation as each joint is brazed. Cap the system with a reusable plug after each brazing operation to retain the nitrogen and prevent entrance of air and moisture.

3.1.2.8.6. Protect refrigerant system during construction against entrance of foreign matter, dirt and moisture; have open ends of piping and connections to compressors, condensers, evaporators and other equipment tightly capped until assembly.

3.1.2.8.7. Pipe relief valve discharge to outdoors for systems containing more than 45 kg (100 lbs) of refrigerant.

3.1.2.9. Firestopping: Fill openings around uninsulated piping penetrating floors or fire walls, with firestop material.

3.2. PIPE AND TUBING INSULATION

3.2.1. Insulate all suction piping, including traps

3.2.2. Outdoors: Apply two coats of weather resistant finish as recommended by the manufacturer to insulation exposed to outdoor weather.

3.2.3. Protect insulation at all support points; use galvanized metallic saddles.

3.3. SIGNS AND IDENTIFICATION

3.3.1. Each refrigerating system erected on the premises shall be provided with an easily legible permanent sign securely attached and easily accessible, indicating thereon the name and address of the installer, the kind and total number of pounds of refrigerant required in the system for normal operations, and the field test pressure applied.

3.3.2. Systems containing more than 50 kg (110 lb) of refrigerant shall be provided with durable signs, in accordance with ANSI A13.1 and ANSI Z535.1, having letters not less than 13 mm (1/2 inch) in height designating:

3.3.3. Valves and switches for controlling refrigerant flow, the ventilation and the refrigerant compressor(s).

3.3.4. Signs on all exposed high pressure and low pressure piping installed outside the machinery room, with name of the refrigerant and the letters "HP" or "LP."

3.4. **VALVE INSTALLATION**

3.4.1. General: Install refrigerant valves where indicated, and in accordance with manufacturer's instructions.

3.4.2. Install globe valves on each side of strainers and driers, in liquid and suction lines at evaporators, and elsewhere as indicated.

3.4.3. Install a full sized, 3-valve bypass around each drier.

3.4.4. Install solenoid valves ahead of each expansion valve and hot-gas bypass valve. Install solenoid valves in horizontal lines with coil at the top.

3.4.5. Coordinate electrical requirements and connections.

3.4.6. Thermostatic expansion valves may be mounted in any position, as close as possible to the evaporator.

3.4.7. Where refrigerant distributors are used, mount the distributor directly on the expansion valve outlet.

3.4.8. Install the valve in such a location so that the diaphragm case is warmer than the bulb. Verify proper location for bulb with valve manufacturer.

3.4.9. Secure the bulb to a clean, straight, horizontal section of the suction line using two bulb straps. Do not mount bulb in a trap or at the bottom of the line.

3.4.10. Where external equalizer lines are required make the connection where it will clearly reflect the pressure existing in the suction line at the bulb location.

3.4.11. Install pressure regulating and relieving valves as required by ASHRAE Standard 15.

3.5. **FIELD QUALITY CONTROL**

3.5.1. Prior to initial operation examine and inspect piping system for conformance to plans and specifications and ASME B31.5. Correct equipment, material, or work rejected because of defects or nonconformance with plans and specifications, and ANSI codes for pressure piping.

3.5.2. After completion of piping installation and prior to initial operation, conduct test on piping system according to ASME B31.5. Furnish materials and equipment required for tests. Perform tests in the presence of Resident Engineer. If the test fails, correct defects and perform the test again until it is satisfactorily done and all joints are proved tight.

3.5.3. Every refrigerant-containing parts of the system that is erected on the premises, except compressors, condensers, evaporators, safety devices, pressure gages, control mechanisms and systems that are factory tested, shall be tested and proved tight after complete installation, and before operation.

3.5.4. The high and low side of each system shall be tested and proved tight at not less than the lower of the design pressure or the setting of the pressure relief device protecting the high or low side of the system, respectively, except systems erected on the premises using non-toxic and non-flammable Group A1 refrigerants with copper tubing not exceeding DN 18 (NPS 5/8). This may be tested by means of the refrigerant charged into the system at the saturated vapor pressure of the refrigerant at 20 degrees C (68 degrees F) minimum.

3.5.5. Test Medium: A suitable dry gas such as nitrogen or shall be used for pressure testing. The means used to build up test pressure shall have either a pressure limiting device or pressure-reducing device with a pressure-relief device and a gage on the outlet side. The pressure relief device shall be set above the test pressure but low enough to prevent permanent deformation of the system components.

3.6. SYSTEM TEST AND CHARGING

3.6.1. Provide a full charge of refrigerant and oil, to suit the capacity of the system, including lengths of refrigerant piping and receivers. System Test and Charging: As recommended by the equipment manufacturer or as follows:

3.6.2. Connect a drum of refrigerant to charging connection and introduce enough refrigerant into system to raise the pressure to 70 kPa (10 psi) gage. Close valves and disconnect refrigerant drum. Test system for leaks with halide test torch or other approved method suitable for the test gas used. Repair all leaking joints and retest.

3.6.3. Connect a drum of dry nitrogen to charging valve and bring test pressure to design pressure for low side and for high side. Test entire system again for leaks.

3.6.4. Evacuate the entire refrigerant system by the triplicate evacuation method with a vacuum pump equipped with an electronic gage reading in mPa (microns). Pull the system down to 665 mPa (500 microns) 665 mPa (2245.6 inches of mercury at 60 degrees F) and hold for four hours then break the vacuum with dry nitrogen (or refrigerant). Repeat the evacuation two more times breaking the third vacuum with the refrigeration to be charged and charge with the proper volume of refrigerant.

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PART 1 - GENERAL

1.1. **DESCRIPTION**

1.1.1. Ductwork and accessories for HVAC including the following:

1.1.1.1. Supply air, return air, outside air, exhaust, make-up air, and relief systems.
1.1.1.2. Exhaust duct for chemical fume hoods, kitchen hood exhaust (grease) and “wet exhaust” ducts.

1.1.2. Section Includes:

1.1.2.1. Ductwork materials, plenums, construction, fabrication, and support
1.1.2.2. Galvanized steel ductwork (rectangular, round)
1.1.2.3. Reinforcing and supports.
1.1.2.4. Flexible duct.
1.1.2.5. Special ductwork construction including exhaust plenums;
1.1.2.6. Duct sealants.
1.1.2.7. Ductwork sealing, inspection, and leakage testing.
1.1.2.8. Ductwork accessories.

1.1.3. *Section does not include*:

1.1.3.1. *Dust or particle collection ductwork*

1.1.4. Definitions:

1.1.4.1. SMACNA standards as used in this specification means the HVAC Duct Construction Standards, Metal And Flexible.
1.1.4.2. Seal or sealing: use of liquid or mastic sealant, with or without compatible tape overlay, or gasketing of flanged joints, to keep air leakage at duct joints, seams and connections to an acceptable minimum.
1.1.4.3. Duct pressure classification: SMACNA HVAC Duct Construction Standards, Metal and Flexible.
1.1.4.4. Exposed duct: exposed to view in a finished room
1.1.4.5. Outdoor duct: exposed to weather.

1.2. **QUALITY ASSURANCE**

1.2.1. Reference Standards: Products in this section shall be built, tested, and installed in compliance with the following quality assurance standards; latest editions, unless noted otherwise.

1.2.2. Duct system construction and installation: referenced SMACNA standards are the minimum acceptable quality.

1.2.3. Duct sealing, air leakage criteria, and air leakage tests: ducts shall be sealed as per duct sealing requirements of SMACNA HVAC air duct leakage test manual for duct pressure classes shown on the drawings.

1.2.4. Duct accessories exposed to the air stream, such as dampers of all types (except smoke dampers) and access openings, shall be of the same material as the duct or provide at least the same level of corrosion resistance.

1.3. **SUBMITTALS**

1.3.1. Provide the following information and product data:

1.3.1.1. Sealants and gaskets
1.3.1.2. Access doors
1.3.1.3. Hangers and supports
1.3.1.4. Duct fittings
1.3.1.5. Turning vanes
1.3.1.6. Flexible duct
1.3.1.7. Volume control dampers
1.3.1.8. Fire and smoke dampers

1.3.2. Applicable Publications

1.3.2.1. American Society for Testing and Materials (ASTM):
1.3.2.1.1. A167 99(2009) Standard Specification for Stainless and Heat Resisting Chromium Nickel Steel Plate, Sheet, and Strip
1.3.2.1.2. A653-09 Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron Alloy coated (Galvannealed) by the Hot-Dip process
1.3.2.1.3. A1011-09a 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
1.3.2.1.4. B209 07 Standard Specification for Aluminum and Aluminum Alloy Sheet and Plate
1.3.2.1.5. C1071-05e1 Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)
1.3.2.1.6. E84-09a Standard Test Method for Surface Burning Characteristics of Building Materials
1.3.2.2. National Fire Protection Association (NFPA):
1.3.2.2.1. 90A-09 Standard for the Installation of Air Conditioning and Ventilating Systems
1.3.2.2.2. 96-08 Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations

1.3.2.2.3. E. Sheet Metal and Air Conditioning Contractors National Association (SMACNA):
1.3.2.2.4. 2nd Edition – 2005 HVAC Duct Construction Standards, Metal and Flexible
1.3.2.2.5. 1st Edition - 1985 HVAC Air Duct Leakage Test Manual
1.3.2.2.6. 6th Edition – 2003 Fibrous Glass Duct Construction Standards
1.3.2.3. Underwriters Laboratories, Inc. (UL):
1.3.2.3.1. 181 08 Factory Made Air Ducts and Air Connectors
1.3.2.3.2. 555 06 Standard for Fire Dampers
1.3.2.3.3. 555S 06 Standard for Smoke Dampers

1.4. **WARRANTY**

1.4.1. Provide a complete parts and labor warranty for a minimum of one year from the date of Substantial Completion.

PART 2 - PRODUCTS

2.1. **GENERAL USE DUCTWORK**

2.1.1. General: Except for systems specified otherwise, construct ducts, casings, and accessories of galvanized sheet steel of lock-forming quality to ASTM A653, coating G90; or, aluminum sheet, ASTM B209, alloy 1100, 3003 or 5052.

2.1.2. Specified Corrosion Resistant Systems: Stainless steel sheet, ASTM A167, Class 302 or 304, Condition A (annealed) Finish No. 4 for exposed ducts and Finish No. 2B for concealed duct or ducts located in mechanical rooms.

2.1.3. Approved factory made joints may be used.

2.1.4. Provide fittings, branches, inlets and outlets in such a manner that air turbulence is reduced to a minimum.

2.1.5. <u>Rectangular Duct Construction</u>

2.1.5.1. Rectangular duct longitudinal seams shall be Pittsburgh lock 3/8 in. minimum pocket. Crossbreak or bead rectangular ductwork
2.1.5.2. Thickness shall be the more restrictive between the SMACANA Standards and the following:
2.1.5.2.1. Ducts through 12 in. wide: 24 Gage
2.1.5.2.2. Ducts 13 in. through 30 in. wide: 22 Gage.
2.1.5.2.3. Ducts 31 in. through 84 in. wide: 20 Gage.
2.1.5.2.4. Ducts 84 in. and larger: 18 Gage
2.1.5.3. Elbows

2.1.5.3.1. Unless shown otherwise on the drawings, install a 1.5 times width to centerline radius elbow (full radius elbow). Where not possible, use lesser radii configurations, with 'radius-proportional' splitter vanes permanently installed within.

2.1.5.3.2. Only where shown specifically on the drawings, provide square elbows with double thickness vanes.

2.1.5.4. Transitions

2.1.5.4.1. Limit transition angles (for each side) to 15 degrees diverging and 30 degrees converging.

2.1.5.5. Offsets:

2.1.5.5.1. Radiused elbows, as indicated.

2.1.5.6. Take-Off Fittings:

2.1.5.6.1. For take-offs carrying more than 25 percent of duct main, provide an increasing branch elbow with an inside radius equal to branch duct width. Size branch and main at elbow for equal velocity.

2.1.5.6.2. For take-offs carrying 25 percent or less of duct main, provide flanged increased area branch take-off (45 degree entry, "shoe" type) or 45 degree lateral wye takeoffs. Conical fittings shall be used for spiral, round, and oval ductwork.

2.1.5.6.3. For take-offs directly to side outlet for register or grille, provide an increased area tap. For take-offs directly to diffusers see appropriate SMACNA figures.

2.1.5.7. Turning vanes

2.1.5.7.1. Install double wall, airfoil, 2 inch radius vanes in ducts with vane runner length 18" or greater and air velocity less than 2000 fpm. Install double wall, airfoil, 4-1/2 inch radius vanes in ducts with vane runner length 18" or greater and air velocity 2000 fpm or greater.

2.1.5.7.2. If duct size changes in a mitered elbow, use single wall type vanes with a trailing edge extension. If duct size changes in a radius elbow or if short radius elbows must be used, install sheet metal turning vanes in accordance with SMACNA Chart 4-1 and Figure 4-9.

2.1.6. <u>Round Duct Construction</u>

2.1.6.1. All round and oval duct shall be manufactured of spiral lock seams. Ductwork up to 12 in. diameter and 2 in. w.g. can be manufactured with longitudinal lock seams.

2.1.6.2. Minimum galvanized rectangular duct gage shall be the more restrictive between the SMACANA Standards and the following:

2.1.6.2.1. Ducts less than 10" diam: 26 ga spiro duct without ribs

2.1.6.2.2. Ducts 12" to 16" in. diam: 24 Gage

2.1.6.2.3. Ducts 18" through 24" diam: 22 Gage.

2.1.6.2.4. Ducts 26 in. through 30" diam: 20 Gage.

2.1.6.2.5. Ducts 32" diam and larger: 18 Gage

2.1.6.3. Tees shall be conical. Laterals shall be straight. Taps through 10 in. diameter in size shall have a machine drawn entrance and fittings shall have longitudinal seams, continuously welded. Both sides of welds shall be primed with zinc chromate. Tap entrances shall be free of weld build-up.

2.1.6.4. Elbows in diameters 2 in. through 10 in. shall be stamped or pleated. Elbows shall be 5 gore for 90 degrees and 3 gore for 45 degrees. Elbows shall have 1.5 times width to centerline radius (full radius elbow).

2.1.6.5. Flanges, access doors and taps into spiral ducts shall be factory fabricated.

2.1.6.6. Field joints in diameters through 48 in. shall be made with 2 in. long slip-fit, sleeve coupling, or flanges. Duct sealer to be applied on male end connectors before insertion and afterwards to cover the entire joint and sheet metal screws. Sheet metal screws shall be installed at a maximum 300 mm spacing, with a minimum of 3 screws per joint.

2.1.6.7. Ductwork 48 in. diameter and over, and for all sizes where disassembly or removal is required, shall be joined with flanges.

2.2. SEALING CLASSIFICATION

2.2.1. Sealant: Elastomeric compound, gun or brush grade, maximum 25 flame spread and 50 smoke developed (dry state) compounded specifically for sealing ductwork as recommended by the manufacturer. Generally provide liquid sealant, with or without compatible tape, for low clearance slip joints and heavy, permanently elastic, mastic type where clearances are larger. Oil base caulking and glazing compounds are not acceptable because they do not retain elasticity and bond.

2.2.2. Tape: Use only tape specifically designated by the sealant manufacturer and apply only over wet sealant. Pressure sensitive tape shall not be used on bare metal or on dry sealant.

2.2.3. Gaskets in Flanged Joints: Soft neoprene.

2.2.4. Sealing classification as per the following table

SEAL CLASS	SEALING REQUIREMENTS	STATIC PRESSURE	ALLOWABLE LEAKAGE RATE
A	All traverse duct joints, all longitudinal duct seams and all duct wall penetrations	-4” to +4” w.g. (1,000 to +1,000 Pa)	1% of total design air flow at 4” w.g. (+1,000 Pa) operating pressure
B	All traverse duct joints, all longitudinal duct seams	-3” to +3” w.g. (-750 to +750 Pa)	1% of total design air flow at 3” w.g. (+750 Pa) operating pressure

C	All traverse duct joints	-2” to +2” w.g. (-500 to +500 Pa)	1.5% of total design air flow at 2” w.g. (+500 Pa) operating pressure
D	Not sealed	-1” to +1” w.g. (-250 to +250 Pa)	5% of total design air flow at 1” w.g. (+250 Pa) operating pressure

Note: Dust collection exhaust ductwork not included.

2.3. **PRESSURE CLASSIFICATIONS**

2.3.1. Ductwork material shall be constructed in accordance with SMACNA ratings for the following pressure classifications. Seal classifications shall be in accordance with the following table:

DUCTWORK	OPERATING PRESSURE	SEAL CLASS	REMARKS
All supply ductwork	-3” to +3” w.g. (-750 to +750 Pa)	B	
All return ductwork	-2” to +2” w.g. (-500 to +500 Pa)	C	
All exhaust ductwork	-2” to +2” w.g. (-500 to +500 Pa)	C	
All other ductwork not listed herein	-1” to +1” w.g. (-250 to +250 Pa)	D	

2.4. **PLENUMS**

2.4.1. Intake and Exhaust plenums shall be double wall with 2 in. thick duct liner, G-90 galvanized steel solid inner wall (gauge per specified duct minimum standards) and minimum 18 gauge, G-90 galvanized steel outer wall.

2.5. **FLEXIBLE AIR DUCT**

2.5.1. General: Factory fabricated, complying with NFPA 90A for connectors not passing through floors of buildings. Flexible ducts shall not penetrate any fire or smoke barrier which is required to have a fire resistance rating of one hour or more. Flexible duct length shall not exceed 1.5 m (5 feet). Provide insulated acoustical air duct connectors in supply air duct systems and elsewhere as shown.

2.5.2. Flexible ducts shall be listed by Underwriters Laboratories, Inc., complying with UL 181. Ducts larger than 200 mm (8 inches) in diameter shall be Class 1. Ducts 200 mm (8 inches) in diameter and smaller may be Class 1 or Class 2.

2.5.3. Insulated Flexible Air Duct: Factory made including mineral fiber insulation with maximum C factor of 0.25 at 24 degrees C (75 degrees F) mean temperature, encased with a low permeability moisture barrier outer jacket, having a puncture resistance of not less than

50 Beach Units. Acoustic insertion loss shall not be less than 3 dB per 300 mm (foot) of straight duct, at 500 Hz, based on 150 mm (6 inch) duct, of 750 m/min (2500 fpm).

2.5.4. Application Criteria:

2.5.4.1. Temperature range: -18 to 93 degrees C (0 to 200 degrees F) internal.
2.5.4.2. Maximum working velocity: 1200 m/min (4000 feet per minute).
2.5.4.3. Minimum working pressure, inches of water gage: 2500 Pa (10 inches) positive, 500 Pa (2 inches) negative.

2.5.5. Duct Clamps: 100 percent nylon strap, 80 kg (175 pounds) minimum loop tensile strength manufactured for this purpose or stainless steel strap with cadmium plated worm gear tightening device. Apply clamps with sealant and as approved for UL 181, Class 1 installation.

2.6. **DUCT ACCESS DOORS**

2.6.1. Provide access doors, sized and located for maintenance work, upstream, in the following locations:

2.6.1.1. Each in-duct coil (hydronic or DX)
2.6.1.2. Each duct mounted coil and humidifier.
2.6.1.3. Each fire damper (for link service), smoke damper and automatic control damper.
2.6.1.4. Each duct mounted smoke detector.

2.6.2. Openings shall be as large as feasible in small ducts, 300 mm by 300 mm (12 inch by 12 inch) minimum where possible. Access sections in insulated ducts shall be double wall, insulated. Transparent shatterproof covers are preferred for uninsulated ducts.

2.6.3. For rectangular ducts: Refer to SMACNA HVAC Duct Construction Standards (Figure 2 12).

2.6.4. For round and flat oval duct: Refer to SMACNA HVAC duct Construction Standards (Figure 2-11).

2.6.5. Access doors to be designed and constructed for the pressure class of the duct in which the door is to be installed. Doors in exposed areas shall be hinged type with cam sash lock. Hinges shall be aluminum or steel full length continuous piano type. Doors in concealed spaces shall be secured in place with cam sash latches.

2.6.6. For both hinged and non-hinged doors provide sufficient number of camp sash latches to provide air tight seal when door is closed. Do not use hinged doors in concealed spaces if this will restrict access.

2.6.7. Use minimum 1” deep 24 gauge galvanized steel double wall access doors with minimum 24 gauge galvanized steel frames. For non-galvanized ductwork, use minimum 1” deep double wall access door with frame that shall use materials of construction identical to adjacent ductwork.

2.6.8. Provide double neoprene gasket that shall provide seals from the frame to the door and frame to the duct. When access doors are installed in insulated ductwork or equipment provide insulated doors with insulation equivalent to what is provided for adjacent ductwork or equipment. Access doors constructed with sheet metal screw fasteners will not be accepted.

2.7. **VOLUME CONTROL DAMPERS (MANUAL ADJUSTMENT)**

2.7.1. Single or multi-blade in opposed arrangement, as detailed in SMACNA Standards. Refer to SMACNA Detail Figure 2-12 for Single Blade and Figure 2.13 for Multi-blade Volume Dampers.

2.8. **INSTRUMENT TEST FITTINGS**

2.8.1. Manufactured type with a minimum 50 mm (two inch) length for insulated duct, and a minimum 25 mm (one inch) length for duct not insulated. Test hole shall have a flat gasket for rectangular ducts and a concave gasket for round ducts at the base, and a screw cap to prevent air leakage.

2.8.2. Provide instrument test holes at each duct or casing mounted temperature sensor or transmitter, and at entering and leaving side of each heating coil, cooling coil, and heat recovery unit.

2.9. **DUCTWORK HANGERS AND SUPPORTS**

2.9.1. Generally, hang and support ductwork per the latest edition of SMACNA. Additionally, adhere to the more specific requirements found in this specification section, the Related Sections, and as indicated on the project drawings.

2.9.2. Hanging duct, equipment, or accessories with cables or wires is prohibited.

2.9.3. Provide vibration isolation as specified in Related Section.

2.9.4. Ductwork shall be supported and anchored to structure so that horizontal ducts are without sag or sway, vertical ducts without buckle and all ducts are free from deformation, collapse or vibration

2.9.5. Upper hanger attachments:

2.9.5.1. For concrete: manufactured concrete inserts.

2.9.5.1.1. Standard of Acceptance: Myatt fig 485.

2.9.5.2. For concrete after concrete pour:

2.9.5.2.1. Expanded concrete anchors shall be made of steel.

2.9.5.3. Powder actuated fasteners shall only be utilized for slabs that are thicker than 100 mm (4'') and shall not be utilized in lightweight aggregate concretes.

2.9.5.4. Holes for expanding fasteners shall be drilled either by a carbide bit or by the teeth on the fastener itself. Expansion shield shall be “set'' by driving it into the hole and expanding it with a conical plug.

2.9.5.5. For steel joist: manufactured joist clamp or steel plate washer.

2.9.5.5.1. Standard of Acceptance: Grinnell fig 61 or 86 for joist clamps.

2.9.5.6. For steel beams: manufactured beam clamps:

2.9.5.6.1. Standard of Acceptance: Grinnell fig. 60

2.9.6. Support un-insulated rectangular ducts in sizes up to 600 mm (24 in.) by non-perforated galvanized steel strap or by trapeze hangers. Support insulated rectangular ducts and ducts larger than 36 in. with trapeze hangers. Straps shall be one gauge thicker that the duct material being supported.

2.9.7. Support rectangular ducts in sizes 350 mm (26 in) and larger by galvanized steel angle with black galvanized steel rods to ASHRAE and SMACNA. Space the angle supports in accordance with the following table:

DUCT SIZE	ANGLE SIZE (mm)	ROD SIZE (mm)
Up to 750 mm (30”)	25 x 25 x 3	6
800-1500 mm (32”-60”)	40 x 40 x 3	10
1500-2400 mm (60”-96”)	50 x 50 x 5	10
> 2400 mm (96”)	50 x 50 x 6	10

2.9.8. For round ductwork the duct shall be supported as follows:

2.9.8.1.1. For duct dimensions 900 mm (36'') single strap hangers are acceptable.

2.9.8.1.2. For duct dimensions over 900 mm (36") use trapeze hangers with rods provided on both sides of the duct.

2.9.8.2. Minimum hanger sizes shall be in accordance with Table 4-2 of SMACNA.

2.9.8.3. Loading on trapeze bars shall be in accordance with Table 4-3 of SMACNA

2.9.9. Install supports on both ends of duct turns, branch fittings and transitions.

2.9.10. Do not hang ductwork from piping, ducts, other trades hangers, existing hangers, or equipment.

2.9.11. Provide supports on each side of any duct mounted equipment or device, including fans, coils, dampers, etc, to permit removal of item without removal of adjacent duct sections.

2.9.12. Provide supplemental steel required to support ductwork in shafts, mechanical rooms or on the floor where structural steel is not properly positioned.

2.9.13. Beam clamps shall be double sided on ducts over 36 in. by 36 in. Use double sided or single sided beam clamps with retaining clips on all other sizes.

2.9.14. Do not modify existing structural steel without approval and a structural engineer’s review.

2.9.15. Provide clamping systems that are compatible with the structural steel system of the building.

2.9.16. Use angle iron "V" construction supports or similarly rigid construction for vertical ducting that requires lateral support.

2.9.17. Ductwork mounted on roof or otherwise exposed to elements shall be supported with non-penetrating supports constructed of galvanized steel angles and channels, regardless of duct size. Standard of Acceptance: Portable Pipe Hangers (Canada)

2.9.18. Provide angle sway bracing and diagonal cross bracing to the structure to provide support against maximum lateral loads that may be imposed on the ductwork installed downstream of fan discharges and ductwork exposed to wind loads, and any other locations exposed to lateral loads.

PART 3 - EXECUTION

3.1. INSTALLATION

3.1.1. Comply with provisions of Section 23 05 00 Common Work Results for HVAC, particularly regarding coordination with other trades and work in existing buildings.

3.1.2. Comply with the provisions of Section 23 07 11 HVAC System Insulation.

3.1.3. Drawings show the general layout of ductwork and accessories but do not show all required fittings and offsets that may be necessary to connect ducts to equipment, boxes, diffusers, grilles, etc., and to coordinate with other trades. Fabricate ductwork based on field measurements. Provide all necessary fittings and offsets at no additional cost to the government. Coordinate with other trades for space available and relative location of HVAC equipment and accessories on ceiling grid. Duct sizes on the drawings are inside dimensions which shall be altered by Contractor to other dimensions with the same air handling characteristics where necessary to avoid interferences and clearance difficulties.

3.1.4. Ductwork shall be installed to true alignment, parallel or perpendicular to adjacent building walls, floors and ceilings, to present a neat and workmanlike appearance.

3.1.5. Provide duct transitions, offsets and connections to dampers, coils, and other equipment in accordance with SMACNA Standards, Section II. Provide streamliner, when an obstruction cannot be avoided and must be taken in by a duct. Repair galvanized areas with galvanizing repair compound.

3.1.6. Provide bolted construction and tie rod reinforcement in accordance with SMACNA Standards.

3.1.7. Construct casings, eliminators, and pipe penetrations in accordance with SMACNA Standards, Chapter 6. Design casing access doors to swing against air pressure so that pressure helps to maintain a tight seal.

3.1.8. Install duct hangers and supports in accordance with SMACNA Standards, Chapter 4.

3.1.9. For ductwork mounted outdoors, install duct with slight lateral pitch to prevent water ponding on top of duct.

3.1.10. Install special equipment items in ductwork systems including, but not limited to: control dampers, thermometers, airflow measuring devices and other related items, according to manufacturer's recommendations.

3.1.11. Seal openings around duct penetrations of floors and fire rated partitions with fire stop material as required by NFPA 90A.

3.1.12. Flexible duct installation: Refer to SMACNA Standards, Chapter 3. Ducts shall be continuous, single pieces not over 1.5 m (5 feet) long (NFPA 90A), as straight and short as feasible, adequately supported. Centerline radius of bends shall be not less than two duct diameters. Make connections with clamps as recommended by SMACNA. Clamp per SMACNA with one clamp on the core duct and one on the insulation jacket. Flexible ducts shall not penetrate floors, or any chase or partition designated as a fire or smoke barrier, including corridor partitions fire rated one hour or two hour. Support ducts SMACNA Standards.

3.1.13. Where diffusers, registers and grilles cannot be installed to avoid seeing inside the duct, paint the inside of the duct with flat black paint to reduce visibility.

3.1.14. Protection and Cleaning:

3.1.14.1. Adequately protect equipment and materials against physical damage. Place equipment in first class operating condition, or return to source of supply for repair or replacement, as determined by the Consultant. Protect equipment and ducts during construction against entry of foreign matter to the inside and clean both inside and outside before operation and painting. When new ducts are connected to existing ductwork, clean both new and existing ductwork by mopping and vacuum cleaning inside and outside before operation.

3.2. **DUCT LEAKAGE TESTS AND REPAIR**

3.2.1. Ductwork leakage testing shall be performed by the Testing and Balancing Contractor. For maximum leakage rates, refer to pressure classifications and sealing classifications included in part 2 of these specifications

3.2.2. Ductwork leakage testing shall be performed for the entire air distribution system (including all supply, return, exhaust and relief ductwork), section by section, including fans, coils and filter sections.

3.2.3. All ductwork shall be leak tested first before enclosed in a shaft or covered in other inaccessible areas.

3.2.4. If any portion of the duct system tested fails to meet the permissible leakage level, the Contractor shall rectify sealing of ductwork to bring it into compliance and shall retest it until acceptable leakage is demonstrated to the Resident Engineer.

3.2.5. All tests and necessary repairs shall be completed prior to insulation or concealment of ductwork.

3.2.6. Duct Leakage Testing Procedures:

3.2.6.1. Prior to fabrication and installation, develop and submit for approval a ductwork testing plan, indicating locations of temporary caps, surface area of ductwork test sections, test pressure, leakage class and allowable leakage in cubic feet per minute.

3.2.6.2. Notify the Client's Representative at least 2 days prior to each test.

3.2.6.3. Provide all blank-off plates, flanges, and safing required to isolate each section of duct to be tested.

3.2.6.4. Provide necessary testing apparatus.

3.2.6.5. For all ducts, pressurize ductwork to the specified pressure class and inspect ductwork for visual and audible leaks, and leaks perceptible to a hand 2 in. from duct. Reseal all perceptible leaks until acceptable to Client's Representative.

3.2.6.6. After completing visual and audible inspection, conduct measured ductwork leakage tests at the specified pressure class for the duct. Reseal and retest as required until successfully achieving the specified leakage class.

3.2.6.7. Submit leakage test report for approval, using SMACNA or other approved form.

3.2.6.8. Make sure all openings used for testing flow and temperatures by TAB Contractor are sealed properly.

3.3. **DUCT PAINTING**

3.3.1. Where the interior of duct is visible through grilles, registers, diffusers or other air diffusion devices, paint the interior flat black. Coordinate work with Architectural Trade.

3.3.2. For plenum returns, where equipment and structure above ceiling is visible through return air grilles, provide black sheet metal baffle with turned edges suspended from building construction. Size and position the baffle to prevent restriction of air flow. Where space above ceiling precludes use of a baffle, paint visible building surfaces flat black.

3.4. DUCTWORK EXPOSED TO WIND VELOCITY

3.4.1. Provide additional support and bracing to all exposed ductwork installed on the roof or outside the building to withstand wind velocity of145 km/h (90 mph).

3.4.2. All bracing to be to be stamped and sealed by a licensed Structural Professional Engineer and submitted for review. All engineering services required for additional strapping to be provided by the roof duct support manufacturer and paid for by the Contractor.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. Air terminal units, air flow control valves.

1.2. RELATED WORK

1.2.1. Section 01 33 23, SHOP DRAWINGS.

1.2.2. Section 23 05 11, COMMON WORK RESULTS FOR HVAC and STEAM GENERATION.

1.2.3. Section 23 05 41, NOISE and VIBRATION CONTROL

1.2.4. Section 23 05 93, TESTING, ADJUSTING, and BALANCING FOR HVAC.

1.2.5. Section 23 31 00, HVAC DUCTS and CASINGS.

1.3. SUBMITTALS

1.3.1. Product Data shall be provided with data indicating configuration, general assembly, and materials used in fabrication, including catalog performance ratings that indicate air flow, static pressure, NC designation, electrical characteristics, and connection requirements.

1.3.2. Shop Drawings shall indicate configuration, general assembly, and materials used in fabrication, and electrical characteristics and connection requirements.

1.3.3. Manufacturer shall include schedules listing discharge and radiated sound power level for each of the second through seventh octave bands (125 – 4000 Hertz) at specified differential static pressures.

1.3.4. Manufacturer shall include schedules listing discharge and radiated sound power level for each of second through sixth octave bands at inlet static pressures from 1 to 4 inch water gauge.

1.3.5. Certificates shall be issued to certify that the air coil capacities, pressure drops, and selection procedures meet or exceed specified requirements or coils are tested and rated in accordance with AHRI 410.

1.3.6. Manufacturer's Installation Instructions shall indicate support and hanging details, installation instructions, recommendations, and service clearances required.

1.3.7. Project Record Documents shall record actual locations of units and controls components and locations of access doors.

1.3.8. Operation and Maintenance Data shall include manufacturer's descriptive literature, operating instructions, maintenance and repair data, and parts lists. Include directions for resetting constant-volume regulators.

1.3.9. Manufacturer’s warranty shall be submitted and ensure forms have been completed in Owner's name and registered with manufacturer.

1.3.10. Maintenance Materials shall be furnished for the Owner's use in maintenance of the project.

1.4. **QUALITY ASSURANCE**

1.4.1. Manufacturer Qualifications shall be specified in this section, with minimum ten years of documented experience.

1.4.2. Product Listing Organization Qualifications: The manufacturer shall be listed with an organization recognized by OSHA as a Nationally Recognized Testing Laboratory (NRTL) and acceptable to authorities having jurisdiction.

1.5. **WARRANTY**

1.5.1. Provide 18-month manufacturer warranty from date of shipment for air terminal units, integral sound attenuators, integral heating coils, and integral controls.

1.6. **APPLICABLE PUBLICATIONS**

1.6.1. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.

1.6.2. National Fire Protection Association (NFPA):

1.6.2.1. 90A-09 Standard for the Installation of Air Conditioning and Ventilating Systems

1.6.3. Underwriters Laboratories, Inc. (UL):

1.6.3.1. 181 08 Standard for Factory-Made Air Ducts and Air Connectors

1.6.4. American Society for Testing and Materials (ASTM):

1.6.4.1. C 665-06 Standard Specification for Mineral-Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing

1.7. **DELIVERY, STORAGE, AND HANDLING**

1.7.1. Mark each terminal unit before shipment to the job site with a unique identifier corresponding to its location and function in the building. Identifier nomenclature shall correspond to the Terminal Airflow Unit Detail.

PART 2 - PRODUCTS

2.1. GENERAL

2.1.1. Factory built, pressure independent units, factory set field adjustable air flow rate, suitable for single duct applications.

2.1.2. Clearly show on each unit the unit number and on the equipment schedules, factory set air volumes corresponding to the contract drawings.

2.1.3. Capacity and Performance: as noted in the equipment schedules. If not otherwise noted, the maximum capacity of a single terminal unit shall not exceed 566 Liters/second (1,200 CFM)

2.2. ADMINISTRATIVE REQUIREMENTS

2.2.1. Controls Contractor shall coordinate with the terminal airflow unit manufacturer to provide a complete operating system.

2.3. SINGLE-DUCT TERMINAL UNITS WITH DIRECT DIGITAL CONTROLS

2.3.1. Standard of Acceptance

2.3.1.1. Price Industries, Inc.
2.3.1.2. Titus

2.3.2. Performance Requirements:

2.3.2.1. The assemblies shall be pressure independent and shall reset to any air flow between zero and the maximum cataloged air volume.
2.3.2.2. For performance details, refer to the equipment schedules
2.3.2.3. Sound attenuation: Use attenuation values found in AHRI 885 Appendix E.

2.3.3. General:

2.3.3.1. The terminal units shall be factory-assembled, AHRI 880 rated and bearing the AHRI seal for an air volume control terminal with damper assembly and flow sensor.

2.3.4. Description:

2.3.4.1. Furnish and install single duct terminal units in the sizes and configurations as indicated on the plans.

2.3.5. Unit Casing:

2.3.5.1. The unit casing shall be constructed of a minimum 22 gauge, 0.032 inch galvanized steel.
2.3.5.2. The casing shall be assembled with longitudinal lock seam construction.
2.3.5.3. Casing leakage shall be tested in accordance with ASHRAE 130.
2.3.5.4. Casing leakage for the basic assembly shall not exceed 1.0 percent of the maximum rated airflow at 1.0 inches of water gauge.
2.3.5.5. Casing leakage for the basic assembly shall not exceed 2.0 percent of the maximum rated airflow at 3.0 inches of water gauge.

2.3.6. Unit Discharge:

2.3.6.1. Manufacturer shall provide rectangular unit discharges with slip-and-drive connections.

2.3.7. Liners:

2.3.7.1. Fiber-Free Foam Insulation

- Insulation shall comply with the requirements of UL 181 (erosion, mold growth and humidity) and ASHRAE 62.1, and shall have a maximum flame/smoke spread of 25/50 for both the insulation and the adhesive when tested in accordance with ASTM E84.
- The insulation shall be secured with adhesive.
- Insulation thickness shall be (select one): 1/2 inch thick, R-value of 2.0.

2.3.8. Primary Air Damper Assembly:

2.3.8.1. The damper assembly shall be heavy-gauge, galvanized steel with a solid shaft rotating in bearings.
2.3.8.2. The damper shaft shall incorporate a visual position indicator etched into the end of the damper shaft to clearly indicate damper position over the full range of 90 degrees.
2.3.8.3. The damper shaft shall be mounted on the left, right, top, or bottom of the damper when looking in the direction of airflow, as warranted by the site conditions.
2.3.8.4. The 18 gauge damper assembly shall incorporate a peripheral gasket on the damper blades for tight airflow shutoff.
2.3.8.5. Air leakage past the closed damper shall not exceed 2 percent of the unit maximum rated airflow at 3.0 inch water gauge inlet static pressure, tested in accordance with ASHRAE 130.

2.3.8.6. The damper, seal, and bearing system shall be tested to 1.25 million cycles, or the equivalent of 100 full open/closures per day for 35 years, with no visible signs of wear, tear, or failure of the damper assembly after such testing.

2.3.9. Airflow Sensor:

2.3.9.1. The airflow sensor shall be a differential pressure airflow device measuring total and static pressures, and mounted to the inlet valve.
2.3.9.2. Plastic parts shall be fire-resistant, complying with UL 94.
2.3.9.3. The airflow sensor shall be RoHS (Restriction of Hazardous Substances) compliant. Material containing polybrominated compounds shall not be acceptable.
2.3.9.4. Control tubing shall be protected by grommets at the wall of the airflow sensor's housing.
2.3.9.5. The airflow sensor shall be furnished with twelve total pressure sensing ports and four static pressure sensing ports, and shall include a center averaging chamber that amplifies the sensed airflow signal.
2.3.9.6. After balancing, the airflow sensor signal accuracy shall be plus or minus five percent throughout terminal operating range.

2.3.10. Inlet Valve - Standard:

2.3.10.1. The inlet valve shall be a consistent diameter to retain flex duct and provide a stop for hard duct.
2.3.10.2. The inlet valve shall include a 1/8 inch raised single bead weld for added strength.
2.3.10.3. The gasket seal shall be a low leakage continuous piece with a peripheral gasket for tight airflow shutoff.
2.3.10.4. The inlet valve shall include two heavy duty stop pins to accurately position the damper in the closed and open positions.

2.3.11. Options:

2.3.11.1. Bottom Access Door:
2.3.11.1.1. The unit shall be supplied with a 4-inch x 6-3/4-inch bottom access door, secured to the casing with quarter turn sash latches.
2.3.11.2. Hot Water Heating Coil:
2.3.11.2.1. The hot water coil casing shall be constructed from a minimum 22-gauge, 0.032-inch galvanized steel, factory-installed on the terminal discharge with slip-and drive attachment for downstream ductwork.
2.3.11.2.2. A gasketed access door shall be provided, located on bottom of unit.
2.3.11.2.3. Coil handing shall be supplied as right hand or left hand when looking into the coil inlet in the direction of airflow, to suit local conditions.
2.3.11.2.4. The water coil shall be supplied with an access door located downstream of the water coil in a common casing with the coil.

2.3.11.2.5. The water coil access door shall be secured to the casing with quarter turn sash latches.

2.3.11.2.6. The water coil fins shall be 0.0045-inch aluminum fins, mechanically-bonded to seamless 0.50 by 0.016-inch copper tubes.

2.3.11.2.7. Fins shall be formed in a high heat transfer sine wave configuration.

2.3.11.2.8. Standard coil shall be a 10 fins-per-inch fin construction. High-capacity coil shall be a12 fins-per-inch fin construction. Refer to equipment schedules

2.3.11.2.9. The water coil shall be leak tested to a minimum 390 pounds per square inch, with a minimum burst pressure of 1800 pounds per square inch.

2.3.11.2.10. The water coil shall be certified in accordance with AHRI 410 and units shall bear an AHRI 410 label.

2.3.11.3. Sound Attenuator:

2.3.11.3.1. The manufacturer shall supply sound attenuators to meet scheduled acoustical performance requirements. The attenuators shall be supplied in the following configuration (refer to drawings):

2.3.11.3.2. Three-foot integral discharge attenuator.

2.3.11.3.3. Three-foot discharge attenuator supplied as a separate piece.

2.3.11.4. Control Transformers:

2.3.11.4.1. The terminal unit shall be supplied with a factory mounted 50 VA control transformer.

2.3.11.5. Low Leakage Construction:

2.3.11.5.1. The terminals shall be provided with factory certified low leakage construction up to [three], [four]-, or [six]-inches water gauge internal pressure.

2.3.11.5.2. Inlet dampers shall exhibit leakage rates of less than 0.5% of maximum nominal catalog airflow

2.3.11.5.3. Single duct casings shall exhibit external leakage rates of less than 1% of maximum nominal catalog airflow

2.3.11.5.4. Terminals with low leakage construction shall include the following design features:

- The access door shall be supplied with compression style gasketing and quarter turn latches.
- The unit casing shall be flanged and gasketed at all external casing seams.
- All production units shall be individually factory tested to ensure compliance with project specific leakage requirements.
- Leakage test results shall be documented on a label affixed to each certified low leakage unit.

2.3.12. Electrical Requirements:

2.3.12.1. Single duct terminal units shall be provided with single-point power connection.

2.3.12.2. The terminal unit equipment wiring shall comply with the requirements of CESC and NFPA 70.

2.3.13. Controls:

2.3.13.1. Equipment shall be equipped with a dedicated controller supplied by the BAS vendor.
2.3.13.2. The control installation can take place at the factory (pre-wired) or field provided by the BAS installer.
2.3.13.3. The temperature sensor shall be supplied and installed by the BAS vendor
2.3.13.4. Controls Sequence:
Refer to sequences noted on the drawings.

PART 3 - EXECUTION

3.1. **EXAMINATION AND PREPARATION**

3.1.1. Review and examine conditions affecting work. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2. **HANGER AND SUPPORT INSTALLATION**

3.2.1. Comply with applicable SMACNA HVAC Duct Construction Standards and Hanger and Support construction standards, and applicable Division 23 Sections.

3.2.2. Support terminal air units independently from adjacent ductwork. Ensure supports do not interfere with accessibility of other equipment, e.g., access to terminal air units BAS control enclosure. Do not hang terminal air units from piping, other ducts or equipment.

3.3. **INSTALLATION**

3.3.1. Work shall be installed as shown and according to the manufacturer’s diagrams and recommendations.

3.3.2. Handle and install units in accordance with manufacturer's written instructions.

3.3.3. Support units rigidly so they remain stationary at all times. Cross bracing or other means of stiffening shall be provided as necessary. Method of support shall be such that distortion and malfunction of units cannot occur.

3.3.4. Locate air terminal units to provide a straight section of inlet duct for proper functioning of volume controls.

3.4. **CLEANING AND PROTECTION**

3.4.1. Protect open end of terminal boxes, flow sensors and controllers throughout the entire construction period, until Substantial Completion.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. Air Outlets and Inlets: Diffusers, Registers, and Grilles.

1.2. RELATED WORK

1.2.1. Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.2.2. Section: 23 05 93 Testing, Adjusting and Balancing For HVAC.

1.3. REFERENCE STANDARDS

1.3.1. The latest published edition of a reference shall be applicable to this Project unless identified by a specific edition date.

1.3.2. All reference amendments adopted prior to the effective date of this Contract shall be applicable to this Project.

1.3.3. All materials, installation and workmanship shall comply with the applicable requirements and standards addressed within the following references:

1.3.3.1. AMCA 500 Test Method for Louvers, Dampers and Shutters.
1.3.3.2. ANSI/NFPA 90A Installation of Air Conditioning and Ventilating Systems.
1.3.3.3. ARI 890 – Rating of Air Diffusers and Air Diffuser Assemblies.

1.3.3.4. ASHRAE 70 Method of Testing for Rating the Air Flow Performance of Outlets and Inlets.
1.3.3.5. SMACNA 1035 - HVAC Duct Construction Standards - Metal and Flexible.

1.4. **QUALITY ASSURANCE**

1.4.1. Test and rate performance of air outlets and inlets in accordance with ASHRAE 70.

1.4.2. Test and rate performance of louvers in accordance with AMCA 500.

1.4.3. Fire Safety Code: Comply with NFPA 90A.

1.5. **SUBMITTALS**

1.5.1. All air distribution equipment to be the product of the same manufacturer.

1.5.2. Submit in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples the following:

1.5.2.1. Manufacturer's name and model number
1.5.2.2. Identification as referenced in the documents
1.5.2.3. Capacities/ratings
1.5.2.4. Materials of construction
1.5.2.5. Sound ratings
1.5.2.6. Dimensions
1.5.2.7. Finish
1.5.2.8. Color selection charts where applicable
1.5.2.9. Manufacturer's installation instructions
1.5.2.10. Mounting methods and frames

PART 2 - PRODUCTS

2.1. **STEEL LOUVERED RETURN GRILLE- FIRE RATED**

2.1.1. Construction:

2.1.1.1. Grilles shall be 45 degree deflection fixed louver type, and shall have (as noted on the drawings and equipment schedule)
2.1.1.1.1. One set of blades with 3/4 inch on center blade spacing
2.1.1.1.2. One set of blades with 1/2 inch on center blade spacing
2.1.1.2. The grilles front blade orientation shall be front blades parallel to the long dimension.
2.1.1.3. The blades and border shall be extruded steel construction.
2.1.1.4. The minimum grille size shall be 6x4 inches (150x100mm). The maximum one-piece grille size shall be 36 inches x 96 inches (900x2,400 mm)

2.1.1.5. Material:
2.1.1.5.1. Steel construction
2.1.1.5.2. Ceiling radiation damper: galvanized steel, butterfly type
2.1.1.5.3. Thermal blanket: non-asbestos
2.1.1.5.4. 165°F (74°C) fusible link

2.1.2. Paint Specification:

2.1.2.1. All components shall have a baked-on powder coat finish; finish color as per architectural finishes schedules.
2.1.2.2. The paint finish must demonstrate no degradation when tested in accordance with ASTM D1308 (covered and spot immersion) and ASTM D4752 (MEK double rub) paint durability tests.
2.1.2.3. The paint film thickness shall be a minimum of 2.0 mils.
2.1.2.4. The finish shall have a hardness of 2H.
2.1.2.5. The finish shall withstand a minimum salt spray exposure of 1000 hours with no measurable creep in accordance with ASTM D1654, and 1000 hours of exposure with no rusting or blistering as per ASTM D610 and ASTM D714.
2.1.2.6. The finish shall have an impact resistance of 80 inch-pounds.
2.1.2.7. All components shall have a custom finish in a color to match a customer supplied sample.

2.1.3. Volume controls:

2.1.3.1. The grille shall be supplied with a coated steel opposed blade damper.

2.1.4. Border Style:

2.1.4.1. To suit installation surface, suitable for sidewall mounting or T-bar lay-in mounting, complete with a suitable border. For details, refer to drawings and schedules. Options shall include:
2.1.4.1.1. 1 inch narrow border.
2.1.4.1.2. Panel mount border for T-bar installation.

2.1.5. Mounting Frames: To suit installation location - refer to drawings and schedules. Options shall include:

2.1.5.1. 3/8 inch flat border mounting frame.
2.1.5.2. spiral duct mounting frame (round exposed duct installation).

2.1.6. Fastening:

2.1.6.1. The grille shall be supplied with: refer to drawings layout:
2.1.6.1.1. countersunk screw holes complete with Philips-head screws (exposed installation, side-wall or dry-wall ceiling).

2.1.6.1.2. no screw holes for T-bar installation.

2.1.7. Fire Rated:

2.1.7.1. Fire rated 3 hour
2.1.7.2. UL Classified fire rated ceiling diffuser assembly. Listed in Underwriters Laboratories fire resistance directory.
2.1.7.3. ULC Classified fire rated ceiling diffuser assembly. Listed in Underwriters Laboratories list of equipment and materials.

2.1.8. Standard of Acceptance:

2.1.8.1. E.H.Price 530-FR series, Titus, Ruskin

2.2. **OUTDOOR LOUVER 4" DEEP, 39° EXTRUDED DRAINABLE BLADE**

2.2.1. General

2.2.1.1. Louver performance shall be based on tests and procedures in accordance with AMCA publication 500-L.
2.2.1.2. Size: as indicated on the drawings

2.2.2. Construction:

2.2.2.1. Louvers shall be constructed of 6063-T5 alloy extruded aluminum.
2.2.2.2. Louver blades and frames shall be minimum 0.081 inch wall thickness. Louver assemblies shall be 4 inches deep with 39-degree stationary drainable blades. Louvers shall be welded construction.
2.2.2.3. Louvers shall be designed to withstand a 25 pound per square foot (100 mile per hour equivalent) wind load.
2.2.2.4. Each louver shall be fitted with 1/2 inch x 0.051 inch flattened expanded mesh. Bird screen shall be mounted on interior louver face.
2.2.2.5. Louvers shall be supplied with a 1.5 inch flanged frame.
2.2.2.6. Louvers shall be supplied with a continuous blade appearance and concealed mullions.
2.2.2.7. Louvers shall be supplied with a standard mill finish.

2.2.3. Insect Screen:

2.2.3.1. Each louver shall be fitted with 1/2 inch x 0.051 inch flattened expanded mesh. Bird screen shall be permanently secured to a formed aluminum frame and mounted on interior louver face.

2.2.4. Finish:

2.2.4.1. Louvers shall be factory primed and finished-after-assembly with a fluoropolymer based resin coating. Primer and resin coating shall be oven cured in accordance with the coating manufacturer’s instructions.

2.2.4.2. The coating system shall have a minimum dry film thickness of 0.25 mil primer and 1.0 mil color coat in accordance with ASTM D7091.

2.2.4.3. The coating system product shall meet salt spray and hardness specifications of AAMA 2605.

2.2.4.4. Louvers shall receive an anodized colour finish in accordance with architectural finishing schedules and AAMA 611. The finish shall be applied to chemically etched and pretreated aluminum with a minimum thickness of 0.4 – 0.7 mils.

2.2.5. Standard of Acceptance:

2.2.5.1. E.H.Price model DE439, Titus, Ruskin

PART 3 - EXECUTION

3.1. **GENERAL**

3.1.1. All installation shall be in accordance with manufacturer’s published recommendations.

3.1.2. Check location of air outlets and inlets and make necessary adjustments in position to conform to architectural features, reflected ceiling plans, symmetry, and lighting arrangement. Coordinate location of air distribution equipment with lighting fixtures, fire alarm and PA devices.

3.1.3. Install air outlets and inlets to ductwork with airtight connection.

3.1.4. Provide balancing dampers on duct take off to diffusers, grilles and registers, regardless of whether dampers are specified as part of the diffuser, grille, or register assembly.

3.1.5. Provide all specialties and frames for air distribution devices as required for proper installation in ceiling type as indicated on Architectural Drawings. Provide all cutting and patching of T-bars, gypsum board, and other ceiling systems as required for installation of air devices.

3.1.6. Where diffusers, registers and grilles cannot be installed to avoid seeing inside duct, paint inside of duct with flat black paint to reduce visibility.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. Outdoor-mounted, air-cooled condensing unit with Puron® refrigerant (R-410A) suitable for on-the ground or rooftop installation.

1.1.2. Units shall have air-cooled coils, propeller-type condenser fans, a control box, and shall discharge condenser air vertically upward as shown on certified drawings. Unit shall be used in refrigeration circuit with a central station air-handling unit or direct-expansion coils.

1.2. QUALITY ASSURANCE

1.2.1. Unit performance shall be rated in accordance with AHRI (Air-Conditioning, Heating, and Refrigeration Institute) Standard 365, latest edition.

1.2.2. Unit construction shall comply with latest edition of ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) 15 Safety Code, UL 1995, and ASME (American Society of Mechanical Engineers)

1.2.3. The management system governing the manufacturer of the product is ISO (International Organization for Standardization) 9001: 2008 certified.

1.2.4. Base unit shall be constructed in accordance with UL (Underwriters Laboratories) standards and CSA (Canadian Standards Association).

1.2.5. Unit cabinet shall be capable of withstanding 500-hour salt-spray exposure per ASTM (American Society for Testing and Materials) B117 (scribed specimen).

1.2.6. Design pressure shall be 650 psig (4482 kPa).

1.2.7. Unit shall be functional checked at the factory.

1.3. DELIVERY, STORAGE, AND HANDLING

1.3.1. Unit shall be shipped as single package and shall be stored and handled per unit manufacturer's recommendations.

1.4. SUBMITTALS

1.4.1. Product Data: For each compressor and condenser unit. Include rated capacities, operating characteristics, and furnished specialties and accessories. Include equipment dimensions, weights and structural loads, required clearances, method of field assembly, components, and location and size of each field connection.

1.4.2. Shop Drawings: For compressor and condenser units. Include plans, elevations, sections, details, and attachments to other work.

1.4.3. Wiring Diagrams: For power, signal, and control wiring.

1.5. **COORDINATION AND ACCESSORIES**

1.5.1. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

1.5.1.1. Structural members to which compressor and condenser units will be attached.
1.5.1.2. Liquid and vapor pipe sizes.
1.5.1.3. Refrigerant specialties.
1.5.1.4. Piping including connections, oil traps, and double risers.
1.5.1.5. Compressors.
1.5.1.6. Evaporators.

1.5.2. Field quality-control reports.

1.5.3. Warranty: Sample of special warranty.

1.6. **CLOSEOUT SUBMITTALS**

1.6.1. Operation and Maintenance Data: For compressor and condenser units to include in emergency, operation, and maintenance manuals.

1.7. **WARRANTY**

1.7.1. The equipment manufacturer shall provide, at no additional cost, a parts and labour warranty in which manufacturer agrees to repair or replace components of compressor and condenser units that fail in materials or workmanship within the warranty period.

1.7.2. Failures include, but are not limited to, compressor failures and condenser coil leaks.

1.7.3. Warranty periods shall be as follows:

1.7.3.1. Provide full labour and materials warranty for 12 months after equipment installation or 18 months after equipment delivery.
1.7.3.2. Provide full labour and material warranty for 5 years for the compressors after equipment delivery.

1.8. **REFRIGERANT ACCESSORIES**

1.8.1. Unless specified otherwise in section 23 23 00 provide the following:

1.8.1.1. Flexible pipe connectors: Double braided bronze hose flexible pipe connectors with solder end connections.

1.8.1.2. Filter Dryers: For circuits 15 tons and over provide angle pattern filter dryers with replaceable core. For circuits below 15 tons provide straight pattern filter dryers without replaceable core.

1.8.1.3. Sight glasses: Two piece brass construction with solder end connections. Include color indicator for sensing moisture.

1.8.1.4. Solenoid Valves: Two way normally closed with two piece brass body, full port, stainless steel plug, stainless steel spring, teflon diaphragm and solder end connections. Provide replaceable coil assembly.

1.8.1.5. Thermostatic Expansion Valves: Brass body, bronze disc, neoprene seat, bronze bonnet, stainless steel spring and solder end connections.

1.8.1.6. Charging Valves: Provide ¼” SAE brass male flare access ports with finger tight, quick seal caps. Provide 2-inch long copper extension sections.

1.8.1.7. Check valves: Spring loaded type with bronze body, bronze disc, neoprene seat, bronze bonnet, stainless steel spring and solder end connections.

1.8.2. All refrigerant piping specialties with a maximum working pressure of full vacuum to 450 psig and a maximum working temperature of 225 deg F. For systems using R-410A, provide all refrigerant piping specialties with a maximum working pressure of full vacuum to 850 psig and a maximum working temperature of 225 deg F.

1.9. CONVENIENCE OUTLET PLUG

1.9.1. Outlet shall be factory-installed and internally mounted with easily accessible 115-v female receptacle.

1.9.2. Outlet shall include 15 amp GFI (ground fault interrupter) receptacle with independent fuse protection. Outlet shall be powered by a different source than the equipment; refer to electrical drawings and specifications.

PART 2 - PRODUCTS

2.1. AIR COOLED CONDENSING UNITS 5 TO 20 TON CAPACITY

2.1.1. General

2.1.1.1. Weatherproofed steel mounting/lifting rails

2.1.1.2. Hermetic scroll compressors

2.1.1.3. Microchannel condenser coils

2.1.1.4. Fans and motors

2.1.1.5. Standard operating range 50-125°F (min. 0°F with low ambient accessory)

2.1.1.6. Nitrogen holding charge

2.1.1.7. Certified and rated in accordance with AHRI and DOE standards

2.1.1.8. Certified to UL 1995

2.1.1.9. Capacities and efficiencies for split systems are rated within the scope of the Air Conditioning, Heating, & Refrigeration Institute (AHRI) certification program and display the AHRI Standard 340-360 (I-P) mark. This standard applies to units between 65,000 and 250,000btu/hr.

2.1.1.10. Capacities and efficiencies for split system cooling condensers are rated within the scope of the Air-Conditioning, Heating, & Refrigeration Institute (AHRI) certification program and display the AHRI Standard 365 (I-P) mark. This standard applies to cooling units between 135,000 and 250,000 btu/hr.

2.1.2. Casing

2.1.2.1. Heavy gauge satin coat galvanized sheet metal
2.1.2.2. Weather resistant baked enamel finish
2.1.2.3. Meets ASTM B117, 672 hour salt spray test
2.1.2.4. Removable single side maintenance access panels
2.1.2.5. Lifting handles in maintenance access panels
2.1.2.6. Unit base provisions for forklift and/or crane lifting

2.1.3. Refrigeration

2.1.3.1. Two (2) separate and independent refrigerant circuits
2.1.3.2. Each refrigeration circuit equipped with integral subcooling circuit
2.1.3.3. Front or rear refrigerant line connections (TTA180**D/240**D)
2.1.3.4. Two (2) direct drive hermetic scroll compressor
2.1.3.5. Suction gas-cooled motors w/ ± 10% voltage utilization range of unit nameplate voltage
2.1.3.6. Crankcase Heaters
2.1.3.7. Internal temperature and current sensitive motor overloads
2.1.3.8. Factory installed liquid line filter driers
2.1.3.9. Phase loss/reverse rotation monitor
2.1.3.10. No compressor suction and/or discharge valves (reduced vibration/sound)
2.1.3.11. External high pressure cutout devices
2.1.3.12. External low pressure cutout devices
2.1.3.13. Evaporator defrost control
2.1.3.14. Loss of charge protection (discharge temperature limit)

2.1.4. Coils

2.1.4.1. Microchannel coils burst tested by the manufacturer
2.1.4.2. Coils shall be leak tested to ensure the pressure integrity
2.1.4.3. Factory pressure and leak tested to 660 psig
2.1.4.4. Perforated steel hail guards available (factory installed option or field installed accessory)

2.1.5. Condenser Fan

2.1.5.1. 26" or 28" propeller fan(s)
2.1.5.2. Direct drive
2.1.5.3. Statically and dynamically balanced

2.1.6. Condenser Motor(s)

2.1.6.1. Permanently lubricated totally enclosed or open construction
2.1.6.2. Built-in current and thermal overloads
2.1.6.3. Ball or sleeve bearing type

2.1.7. Controls

2.1.7.1. Fully compatible with the building BAS
2.1.7.2. Capable of interfacing with the building automation control as follows:
2.1.7.2.1. Enable/disable by BAS
2.1.7.2.2. Modulation of refrigeration circuits to meet setpoint target by BAS
2.1.7.2.3. Feed-back to BAS: each compressor status
2.1.7.3. Controls: Centralized processor
2.1.7.4. Indoor and outdoor temperature sensors drive algorithms
2.1.7.5. Integrated anti-short cycle timer
2.1.7.6. Integrated time delay between compressors
2.1.7.7. Completely internally wired
2.1.7.8. Numbered and colored wires
2.1.7.9. Contactor pressure lugs or terminal block
2.1.7.10. Unit external mounting location for disconnect device
2.1.7.11. Single point power entry

2.1.8. Factory Installed Options

2.1.8.1. Weather-proof non-fused disconnect
2.1.8.2. Complete charge of refrigerant R-410A and oil
2.1.8.3. Hail Guards
2.1.8.3.1. Condenser coil protection from hail, vandals, etc.
2.1.8.3.2. Perforated, painted galvanized steel
2.1.8.3.3. Factory or field installed

2.1.9. Vibration Isolators

2.1.9.1. Neoprene-in-shear or spring flex choice
2.1.9.2. Reduce vibration transmission to building structures, equipment, and adjacent spaces

2.1.9.3. Reduce noise transmission to building structures, equipment, and adjacent spaces

2.1.10. Standard of Acceptance: Engineered Air, Daikin, Trane

2.1.11. Note that although multiple manufacturers are listed in the standard of acceptance, the selected equipment will have to meet performance and spatial criteria (i.e. fit into the allocated space, allow for maintenance, not exceed the allocated weight, match electrical requirements, etc). The base of design unit is indicated in the equipment schedule

PART 3 - EXECUTION

3.1. EXAMINATION

3.1.1. Examine rough-in for refrigerant piping systems to verify actual locations of piping connections before equipment installation.

3.1.2. Examine condition of locations where the packaged compressor and condenser unit will be installed.

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

3.2. INSTALLATION

3.2.1. Comply with manufacturer’s instructions and adhere to the manufacturer’s instructions regarding clearances. Unit to be installed level

3.2.2. Secure lower frame of the equipment to vibration isolation devices and the vibration isolation devices to the structural supports.

3.2.3. Comply with ASHRAE 15 procedures for charging and purging of systems and for disposal of refrigerant.

3.2.4. Comply with requirements for vibration isolation devices specified in Section 23 05 51.

3.2.5. Install packaged units’ level and plumb, firmly anchored in locations indicated; and maintain manufacturer's recommended clearances for service and maintenance.

3.2.6. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

3.2.7. Make all connections to power supply and building automation to make equipment fully functional as specified herein and noted on the drawings.

3.3. CONNECTIONS

3.3.1. Install refrigerant piping in accordance with the manufacturer's instructions; provide flexible hose connectors.

3.3.2. Install refrigerant piping and refrigerant specialties (pressure relief, service valve, filter-dryer, and moisture indicator on each refrigerant-circuit liquid line) in accordance with Section 23 23 00.

3.3.3. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.

3.3.4. Install tubing so it does not interfere with access to unit. Install all furnished accessories.

3.3.5. Install electrical components, devices, and accessories and connection to electrical power wiring that are not factory mounted. Make all connections to power supply and building automation.

3.4. **FIELD QUALITY CONTROL**

3.4.1. Perform field tests and inspections and prepare test reports.

3.4.2. Tests and Inspections:

3.4.2.1. Perform each visual and mechanical inspection and electrical test. Certify compliance with test parameters.
3.4.2.2. Leak Test: After installation, charge system with refrigerant and oil and test for leaks. Repair leaks, replace lost refrigerant and oil, and retest until no leaks exist.
3.4.2.3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor operation and unit operation, product capability, and compliance with requirements.
3.4.2.4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3.4.2.5. Verify proper airflow over coils.
3.4.2.6. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

3.5. **STARTUP SERVICE**

3.5.1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:

3.5.1.1. Inspect for physical damage to unit casing.
3.5.1.2. Verify that access doors move freely and are weathertight.
3.5.1.3. Clean units and inspect for construction debris.
3.5.1.4. Verify that all bolts and screws are tight.
3.5.1.5. Adjust vibration isolation and flexible connections.

3.5.1.6. Verify that controls are connected and operational.

3.5.1.7. Lubricate bearings on fans.

3.5.1.8. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.

3.5.1.9. Start unit according to manufacturer's written instructions and complete manufacturer's startup checklist.

3.5.1.10. Verify proper operation of capacity control device.

3.5.1.11. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

3.5.1.12. After startup and performance test, lubricate bearings.

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PART 1 - GENERAL

1.1. SUMMARY

1.1.1. Perform all Work required to provide and install modular air handling units for indoor applications, including factory installed fans, dampers, coils, motors, and any specialty equipment as indicated or noted in the Contract Documents with supplementary items necessary for proper installation and operation.

1.1.2. This section includes factory-assembled modular air handling units (AHU) that include, but is not limited to the following:

1.1.2.1. Casing.
1.1.2.2. Fans (including integral return/exhaust fan where specified).
1.1.2.3. Coils.
1.1.2.4. Filter sections.
1.1.2.5. Dampers.
1.1.2.6. Additional sections.
1.1.2.7. Accessories.

1.2. REFERENCE STANDARDS

1.2.1. The latest published edition of a reference shall be applicable to this Project unless identified by a specific edition date.

1.2.2. All reference amendments adopted prior to the effective date of this Contract shall be applicable to this Project.

1.2.3. All materials, installation and workmanship shall comply with the applicable requirements and standards addressed within the following references:

1.2.3.1. AMCA 99 Standards Handbook.
1.2.3.2. AMCA 210 Laboratory Methods of Testing Fans for Rating Purposes.
1.2.3.3. AMCA 300 Test Code for Sound Rating Air Moving Devices.
1.2.3.4. AMCA 301 Method of Publishing Sound Ratings for Air Moving Devices.
1.2.3.5. AMCA 500 Test Methods for Louver, Dampers, and Shutters.
1.2.3.6. AHRI 260 Sound Rating of Ducted Air Moving and Conditioning Equipment
1.2.3.7. AHRI 410 Forced Circulation Air Cooling and Air Heating Coils.
1.2.3.8. AHRI 430 – Standard for Central Station Air Handling Units.
1.2.3.9. AHRI 435 – Application for Central Station Air-Handling Units.
1.2.3.10. AHRI 610 Central System Humidifiers.
1.2.3.11. NEMA MG1 Motors and Generators.
1.2.3.12. NFPA 70 National Electrical Code.

1.2.3.13. NFPA 90A – Standard for the Installation of Air-Conditioning and Ventilating Systems.
1.2.3.14. NFPA 262 - Standard Method of Test for Flame Travel and Smoke of Wires and Cables for use in Air-Handling Spaces.
1.2.3.15. SMACNA HVAC Duct Construction Standards Metal and Flexible.
1.2.3.16. UL 900 Test Performance of Air Filter Units.
1.2.3.17. ANSI/ASHRAE/IESNA Standard 90.1 - Energy Standard for Buildings Except Low-Rise Residential Buildings.

1.3. **QUALITY ASSURANCE**

1.3.1. Manufacturer: Regularly engaged in production of components that issues complete catalog data on total product and has at least five (5) years of manufacturing experience for the product specified.

1.3.2. Performance Ratings: Conform to AHRI Standards; bear AHRI 430 certified rating seal. If unit is not AHRI 430 rated, unit shall be tested in accordance with the standards to establish acceptability.

1.3.3. Sound Ratings: Test air handling unit in accordance with AMCA 300 (ASHRAE 68) and AHRI 260 Guidelines.

1.3.4. Air Coils: Certify capacities, pressure drops, and selection procedures in accordance with AHRI 410.

1.3.5. Base performance on sea level conditions, unless otherwise scheduled.

1.3.6. Provide complete unit including components designed to operate within range of 35 degrees F to 135 degrees F ambient temperature, 20 to 70 percent relative humidity in conditioned mechanical rooms and 100 percent relative humidity in unconditioned mechanical rooms.

1.3.7. The Contract Documents are based on the equipment scheduled. Contractor is advised that the use of equipment other than that scheduled may directly affect and require coordination with (but not limited to) the following items:

1.3.7.1. Mechanical room sizes and building structural conditions, with required clearances.
1.3.7.2. Electrical starter/disconnect switch, wire and conduit sizes; electrical clearances as per NEC.
1.3.7.3. Ductwork and piping layouts and return air opening sizes and locations.
1.3.7.4. Plumbing floor drain location.

1.3.8. Units shall fit into the space available with adequate clearances meeting manufacturer’s requirements for service and as determined by the Consultant. Submitted units, which do not meet these criteria, shall be rejected. The Contractor shall not assume that all of the manufacturers listed as acceptable manufacturers will provide a unit that will fit in the space allocated for the unit(s).

1.4. SUBMITTALS

1.4.1. Product Data and Record Documents:

1.4.1.1. Provide literature that indicates dimensions, weights, required clearances, capacities, ratings, fan performance, gages and finishes of materials, electrical characteristics and connection requirements. Refer to detailed list of submittal data in this Section.

1.4.1.2. Provide data of filter media, filter performance data, filter assembly, and filter frames as tested and certified per ASHRAE 52.2 and UL-900 class 1.

1.4.1.3. Provide fan curves with specified operating point clearly plotted, as tested and certified per AMCA standards. Ratings to include system effects. Bare fan ratings will not satisfy this requirement, but shall be submitted for comparison purposes. All fan data shall be generated from specified testing. The fan shall compare favorably with the scheduled data listed in the Drawings.

1.4.1.4. Submit sound power level data for both fan outlet and casing radiation at rated capacity, as tested and certified per AMCA and AHRI 260 standards.

1.4.1.5. Provide data on all coils as tested and certified per AHRI standards.

1.4.1.6. Submit electrical requirements for power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory installed and field installed wiring.

1.4.1.7. All electrical power, lighting, control, sensor, and pressure taps, and TAB access ports are to be noted on the submittal Drawings.

1.4.1.8. Wiring shall have smoke and flammability of 25/50 or better per test method of NFPA 262.

1.4.1.9. Note each deviation and reason for the deviation on the shop drawing submittal.

1.4.2. Operation and Maintenance Data

1.4.2.1. Include instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams.

1.4.2.2. Provide Operating and Maintenance (O&M) Manuals for air handling units.

1.4.2.3. Manufacturer's Instructions: Provide Start-up information and maintenance required prior to Start-up.

1.5. DELIVERY, STORAGE AND HANDLING

1.5.1. Deliver, store, protect and handle products to the Project.

1.5.2. Accept products on Site in factory fabricated protective containers or covered to protect from weather and construction debris, with factory installed shipping skids and lifting lugs. Inspect for damage and make any necessary repairs at no expense to the Owner.

1.5.3. Store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures, and finish. Replace damaged equipment.

1.5.4. Protect openings in casing and seal them with plastic wrap to keep out dirt and debris. Protect coils from entry of dirt and debris with pipe caps or plugs.

1.6. SCHEDULES ON DRAWINGS

1.6.1. In general, all capacities of equipment, and motor and starter characteristics are shown in schedules on the Drawings. Reference shall be made to the schedules for such information. The capacities shown are minimum capacities. Variations in the capacities of the scheduled equipment supplied under this Contract will be permitted only with the written direction of the Consultant and Client.

1.6.2. Where installation instructions are not included in the Contract Documents, the manufacturer’s instructions shall be followed.

1.6.3. Motor and wheel diameters scheduled on the Drawings are the minimum. If a larger fan wheel diameter or motor horsepower is required than shown on the Drawings, each deviation and the reason for the deviation shall be noted on the manufacture’s submittal.

PART 2 - PRODUCTS

2.1. GENERAL

2.1.1. All materials shall meet or exceed all applicable referenced standards, federal, provincial and local requirements, and conform to codes and ordinances of authorities having jurisdiction.

2.1.2. All internal components specified shall be factory furnished and installed. Units shall be post and panel bolted modular and sectionalized construction for ease of disassembly and reassembly for maintenance, cleaning, and inspection in accordance with the most recent edition of ASHRAE Standard 62. At a minimum, sectionalized modules shall consist of fan, coils, access and filter sections. All internal components specified shall be factory furnished and installed as applicable.

2.1.3. Provide all necessary and required tags and decals to aid in the service or indicate caution areas.

2.1.4. Ship unitS in sections small enough to fit through existing lovers opening. whenever possible. The manufacturer to visit the site prior to shop drawings issuance to confirm the size of sections. The unit must be assembled, with all required gasketing, under direct supervision of factory trained and employed personnel from the unit manufacturer. If assembled on-site, unit shall comply with casing leakage requirements of Section 2 of these specifications. Written approval from the equipment manufacturer certifying the installing Contractor as qualified for assembly is acceptable as an alternative for supervision. The equipment manufacturer, however, shall not relinquish its responsibility for the correct assembly of units.

2.1.5. Provide complete unit with segments as indicated on Drawings and in this Specification or as required for unit operation in accordance with performance requirements specified herein.

2.2. **STANDARD OF ACCEPTANCE**

2.2.1. Engineered Air (basis of Design)
2.2.2. Haacon
2.2.3. Trane
2.2.4. Mafna

2.3. **UNIT CASING, FRAME, AND GENERAL CONSTRUCTION**

2.3.1. Base Rail

2.3.1.1. Minimum 12 gage, continuous full-length galvanized structural steel unit perimeter base frame rail to form a unitized assembly.

2.3.1.2. Base rail height shall be sufficient to allow proper condensate trapping. Lowest coil condensate drain connection shall not be less than a minimum of 6 inches from the bottom of the rail.

2.3.2. Unit Casings

2.3.2.1. The air-handling unit shall be specifically designed for indoor applications. The construction of the air handling unit shall consist of a complete structural frame with removable panels. Casing shall be supported in such a manner so that maximum allowable air leakage shall not exceed 1% and panel deflection shall not exceed a L/240 ratio when subjected to 8-in. w.g. static pressure. This maximum leakage shall include the access doors. All panels shall be completely gasketed prior to shipment and shall be completely removable for unit access and removal of components. Removal of any or all panels shall not affect the structural integrity of the unit.

2.3.2.2. The air handling unit casing shall be constructed of 2” thick double wall roof panels, floor panels, and wall panels having exterior construction of a minimum of 18 gage G90 galvanized steel. The interior lining shall be a solid lining of minimum 22 gage galvanized steel (perforated lining in specific segments as indicated). Exterior casing screws shall be zinc chromate coated.

2.3.2.3. Floor panels shall be double wall construction, designed to provide at most L/200 deflection based on 300 lb. concentrated load at mid-span. The interior liner of the floor panels shall be a solid lining of minimum 20 gauge galvanized steel.

2.3.2.4. The manufacturer shall certify that the unit casing leakage and panel deflecting shall not exceed the above requirements.

2.3.3. Casing Integrity

2.3.3.1. No field penetrations through the air handler casing are permitted.

2.3.3.2. Contractor shall coordinate with the manufacturer to allow for all necessary penetrations to provide a complete, functioning, and maintainable system. Internal control devices and sensor shall be shipped to the air handler manufacturer for installation at no added cost to the Client.

2.3.4. Insulation

2.3.4.1. The air-handling unit shall be completely insulated throughout all panels and structural frame members with spray injected foam to thoroughly insulate and seal the air unit structure. Openings in structural channels shall be covered. If structural channels are not internally insulated, then structural channels must be wrapped with an armaflex type insulation to maintain unit thermal performance and prevent sweating. Any portion of the unit that is not insulated (gaps) or has less than 2” of insulation shall be the responsibility of the contractor to modify.

2.3.4.2. Insulation shall be a full 2" throughout the entire unit including all raceway channels. Units with less than 2" of insulation in any part of the walls, floor, access doors, raceway channels or roof shall not be acceptable

2.3.4.3. Panels shall have a minimum thermal conductivity R of 12.5 BTU/hr-ft2-°F.

2.3.4.4. All drain pans shall have double-wall construction and be insulated with spray injected foam.

2.3.4.5. Insulation and adhesive shall meet requirements of NFPA 90A. Insulation shall meet the erosion requirements of UL181.

2.3.4.6. No insulation surfaces shall be exposed to the airstream. Install insulation in manner to not be disturbed when panels are removed.

2.3.5. Access/Inspection Doors

2.3.5.1. Provide galvanized steel double wall inspection doors of the same thickness and construction as the casing panels. Provide full-perimeter flush mounted and gasketed doors with a latch and handle assembly.

2.3.5.2. Provide heavy-duty cadmium plated steel or stainless steel hinges.

2.3.5.3. Provide minimum 18 inch access doors on fan, cooling and / or heating coil and filter sections of the unit and additional locations where specified on the Drawings.

2.3.5.4. Hinges shall be interchangeable with the door handle hardware to allow for alternating door swing in the field to minimize access interference. Door handle hardware shall visually indicate locking position of door latch external to the module. Door latching hardware shall not penetrate the access doors.

2.3.5.5. All access doors shall open against air pressure. Where scheduled on the Drawings, dual thermal pane windows shall be provided in all access doors. Minimum window dimensions shall be 8-inch x 8-inch.

2.3.6. Drain Pans

2.3.6.1. Provide drain pans constructed of Type 304 stainless steel on airside with insulation between pan and casing for all cooling coils. The drain pan insulation shall be closed cell foam injected water impervious rigid type, minimum R-value of 14, and shall occupy all voids and areas between the drain pan and outer wall to prevent the occurrence of trapped water, condensation, and microbial growth. Fiberglass drain pan insulation is not acceptable.

2.3.6.2. Any condensation from the drain pan or drain connection shall be corrected by unit manufacturer to the satisfaction of the Client, and at no expense to the Client.

2.3.6.3. Drain pan shall have raised lips, welded corners, and stainless steel threaded pipe drain connection to match the drain pan and prevent dielectric corrosion.

2.3.6.4. Drain pan connections that penetrate the base rail must be a minimum of 6 inches in height as described above, and shall come factory insulated in a permanent aluminum jacket to prevent condensation of moisture under the unit.

2.3.6.5. Drain pans must be sloped for complete drainage and in compliance with ASHRAE Standard 62. Unit condensate drain inlet shall be centered on bottom of drain pan to allow complete drainage. Provide drain pans extending under complete cooling coil section and extending 24 inches minimum downstream of cooling coil. Provide intermediate drain pans that extend minimum of 6 inches from the coil face with downspouts to bottom drain pan for cooling coil banks more than one coil high. Intermediate drain pans shall be stainless steel to match the main drain pan.

2.3.6.6. Provide 2-inch deep floor drain sumps used for coil clearing maintenance. The recessed drain sumps shall be seal welded and slope a minimum of ¼- inch/ft in the floor of the unit on the entering and leaving air side of hot water or steam finned tube coils. Drain piping from the sumps shall have NPT end caps that will only be removed temporary to drain water during coil cleaning or for in place coil tube repairs. The pipe drains from the sumps are to be located on the same side(s) as the condensate drain pan piping for the cooling coil(s).

2.3.7. Test and Balancing Ports

2.3.7.1. Provide a permanent factory-installed sealable port on each section of unit to allow for testing and balancing of system, except where port would be blocked by filters or coils.

2.4. **FANS AND RELATED COMPONENTS**

2.4.1. Fan Sections:

2.4.1.1. Fans shall be plenum type configuration direct drive where noted in schedules. Fan wheels shall be of the non –overloading airfoil type, constructed of aluminum and containing matching inlet venture for optimum unit performance. EngArray fan block(s) have thrust restraint isolators that shall be provided for each fan block to minimize movement of the assembly(s). Each fan housing shall be square in shape and readily attachable in column sections as required.

2.4.1.2. Higher RPM AF and BI fan casings shall come equipped with additional heavy duty rectangular angle framework for increased strength and stability.

2.4.1.3. Fan and unit performance shall be rated and certified in accordance with AHRI 430, AMCA300 and AHRI 260 as specified elsewhere herein.

2.4.1.4. Fan wheels shall be constructed aluminum or steel, keyed to the fan shaft, and shall be statically and dynamically balanced at the factory as a complete fan assembly regardless of duty. Dynamic fan balancing shall be conducted from 16Hz to 105Hz to identify and eliminate critical speeds to ensure stable operation through the entire operating range of the fan and drive assembly.

2.4.1.5. Forward factory balancing test report upon request of Consultant.

2.4.1.6. Mount motor drive and fan on integral framework, internally isolated from the casing with factory installed 1-inch deflection spring vibration isolators on units with 8 square feet of coil area or less, and 2-inch deflection on units with coils greater than 8 square feet in area. The fan, and base assembly shall be factory point load tested and balanced on corner isolators selected accordingly for increased stability and to minimize fan assembly noise and vibration.

2.4.1.7. Provide internal flexible connection on the fan inlet cone to isolate the fan vibration from casing. Additionally, provide spring loaded fan-shroud-to-casing thrust restraints for plug fans, and on all units with coil face areas greater than 30 square feet.

2.4.2. Motors and Drives:

2.4.2.1. Fan motor shall be premium efficiency and compatible for inverter duty and meet the endurance and bearing performance requirements for the standard nominal horsepower rating.

2.4.2.2. Fan motors shall have permanently sealed non-greasable bearings.

2.4.2.3. Units with scheduled plug fans and variable frequency drives shall be direct drive.

2.4.3. All motors with VFDs shall be compatible with the VFD and tested at the factory Variable Frequency Drives (VFD)

2.4.3.1. Refer to Section 26 29 23 – Variable Frequency Drives.

2.4.3.2. Where indicated on the Drawings, furnish as a part of the unit assembly by the AHU manufacturer, with drive matched to motor without noise or vibration over the entire operating range.

2.4.3.3. Drives shall be erected on wall where shown on Drawings with support from floor or wall. All power and controls wiring between VFDs and air handling unit included in the scope of work.

2.5. HYDRONIC COIL SECTION

2.5.1. Coil Casing

2.5.1.1. Construct coil section so coils can be removed without affecting structural integrity of casing. Completely enclose connections, coil headers, and return bends.

2.5.1.2. Provide Type 304 stainless steel coil frame with intermediate casing supports as required.

2.5.2. Chilled and Hot Water Coils

2.5.2.1. Provide counterflow chilled water and hot water coils as scheduled on the Drawings. Provide right or left hand horizontal coil connections entry as scheduled or shown on the Drawings. The locations of coil header piping connections need to maximize accessibility while minimizing interference between the coil piping and valves.

2.5.2.2. Coil pull arrangement from the AHU casing shall be as shown on the Drawings.

2.5.2.3. Coils are to be rated in accordance with AHRI certified data to meet or exceed the required capacities in accordance with listed parameters, water flow, temperatures and airflow rates as scheduled on the Drawings.

2.5.2.4. Maximum coil water and air pressure losses are as scheduled on the drawings and a maximum velocity in tubes of 6 feet per second. The coil finned area shall be properly sized based on the maximum allowable coil face velocity shown on the Drawings.

2.5.2.5. Provide either a ½ inch or 5/8 inch outside diameter copper tube coils based on tube water velocity being not less than 3 and no greater than 6 feet per second.

2.5.2.6. If steel pipe connections are provided they shall be welded to the copper headers with silica-bronze weld to prevent dielectric corrosion of dissimilar metals and extend the life of the coils. The coil shall have maximum of six (6) tube rows and a maximum of nine (9) fins per inch.

2.5.2.7. Provide coils with aluminum fins and copper tubes. Fins shall have a minimum thickness of 0.075-inch and copper tubes shall have a minimum wall thickness of 0.025 inch for 5/8-inch diameter tubes and a nominal 0.025-inch thickness for 1/2-inch diameter tubes. Connect tubes to header that provides equal flow to all tubes and provide single point connections for supply and return piping per coil. Coil shall be rated for a maximum factory test pressure of 300 psig and a maximum working pressure of 200 psig.

2.6. **DX COOLING COILS**

2.6.1. Direct-expansion coils shall be aluminum plate fins with belled collars and bonded to ½ in. OD copper tubes by mechanical expansion. Coils shall be provided with pressure type brass distributors with solder-type connections and shall have a minimum of 2 distributors.

2.6.2. Coils for full face active or face split operation shall have intertwined circuits for equal loading on each circuit. Suction and discharge connections shall be on the same end.

2.6.3. After testing, coils shall be dehydrated and charged with dry air. Coils shall be designed and tested in accordance with American National Standards Safety Code for Mechanical Refrigeration (ANSI/ASHRAE 15).

2.7. **FILTER SECTIONS**

2.7.1. General

2.7.2. Construction: filter sections shall be fabricated as part of the air-handling unit.

2.7.3. Filter sections shall be provided with adequately sized access doors to allow easy removal of filters. Filter removal shall be from one side of the unit as noted on the drawings.

2.7.4. The filters shall be designed to slide out of the unit or be lifted out from an access plenum upstream of the filters. Side removal filters shall slide into a formed metal track sealing against metal spacers at each end of the track. Lift out filters shall fit into a horizontal track from which they are lifted up and out. Refer to equipment details on the drawings.

2.7.5. Filters shall be inserted into a frame grid from the upstream side of the filter section. Air filter holding frames shall be satin coated galvanized steel with filter sealing flange, centering dimples, sealing gasket, and lances for appropriate air filter fasteners. Fasteners shall be capable of being installed without the use of tools, nuts, or bolts.

2.7.6. A ¾” (19 mm) filter sealing flange shall be an integral component of the holding frame complete with a foam gasket to assure filter to frame sealing integrity.

2.7.7. Filter-holding frames are provided to accommodate scheduled filters. Filter frames shall be 16 gage 304 stainless steel and shall be welded to reduce leakage of air through orners.

2.7.8.

2.7.9. Filters shall have a maximum width of 24 inches.

2.7.10. Filters shall be extended surface pleated complete with 100% synthetic media that does not support microbial growth. Frame shall be a high wet strength beverage board with a cross member design that increases filter rigidity and prevent breaching. Frames shall be recyclable.

2.7.11. The filters shall be MERV 13 per ASHRAE 52.2. and rated U.L. 900 Class II.

2.7.12. Air shall not be allowed to bypass around filters. Provision shall be made to positively lock filters in place to prevent shifting.

2.7.13. The air handling unit manufacturer shall provide one (1) set of spare scheduled filters for each air handling unit as shown on the Drawings. The filters shall be boxed and placed within the air handling unit during shipment. The box shall identify the type of filter and be labeled with the corresponding air handling unit identification tag number.

2.7.14. Filter Gauges: Magnahelic differential pressure gauges shall be installed and mounted on drive side of unit to measure the pressure drop across the filter sections as indicated on the Drawings.

2.8. DAMPERS

2.8.1. Dampers shall be supplied with low leak extruded aluminum airfoil blades. Blades shall be supplied with rubber edge seals and stainless steel arc end seals. Rubber edge seals shall be backed by the damper blade to assure a positive seal in the closed position. Dampers shall be provided with nylon bearings within extruded openings.

2.8.2. Damper types: opposed blades for modulating service, parallel blades for on/off service

2.8.3. Damper leakage shall not exceed 6 cfm/ft2 at 5.0 in. Of static pressure. Leakage testing shall be in accordance with AMCA standard 500 figure 5.5. Test results must be from an independent testing laboratory.

2.8.4. All dampers in contact with the outside air (intake and exhaust) shall aluminum double-skin insulated type. Outside intake air louvers shall be sized for a maximum face velocity of 500 ft/min based on gross louver face area. Louvers shall have zero water penetration at 600 ft/min air velocities.

2.8.5. Blades shall have vinyl or rubber blade edge seals and compressible jamb seals. Blades shall rotate on stainless steel sleeve bearings.

2.8.6. Maximum louver pressure drop shall be 0.03 in. wg at 500 ft/min. Test results are provided from an independent testing laboratory. Test must be conducted in accordance to AMCA standard 500 figure 5.5.

2.8.7. Intake louver water carry over must be less than 0.01 oz./ft2 at 1100 ft/min. of free louver face area. Test must be conducted by independent testing laboratory per AMCA 500-89 figure 5.6.

2.9. **ADDITIONAL SECTIONS**

2.9.1. All additional sections of the unit, including blank sections and turning sections required for proper unit operation, maintenance, and configuration, shall meet the unit casing requirements listed in this Section. Refer to Drawings for additional sections required.

2.9.2. Mixing Box Section: Where specified or shown on the Drawings, provide with factory-mounted interconnected outside air and return air dampers mounted in a galvanized frame.

2.9.3. Access Section(s): Provide access sections with door where specified or shown on Drawings. Floors of access section must be heavy-duty to accommodate maintenance personnel/equipment. Door size shall be at least 18 inches wide and full panel height up to 72- inch tall units.

2.9.4. Discharge Plenum: Provide a discharge plenum as the last section in the direction of airflow where specified or shown on the Drawings. The plenum shall be suitable for single or multiple discharges as indicated on the Drawings. Positive pressure plenum access doors must swing inward against air pressure to prevent personnel injury.

2.10. **ELECTRICAL PROVISIONS**

2.10.1. Fan motors shall be factory mounted and wired to an external disconnect switch within sight of the motor access door. Fan motors shall be interlocked with fan access door to shut down fan when door is opened.

2.10.2. Disconnect switches and starters shall be mounted independent of the unit to allow for maintenance access and access to AHU components. Locate disconnect switches within close proximity and sight of the electrical component. Interlock fan motor starters with a position limit switch located at the fan section access door. The limit switch shall de-energize the fan motor or other electrical components when the access door is opened.

2.10.3. All wiring shall be 600V rated type MTW/THWN #12 stranded copper in EMT or liquid tight conduit (maximum three (3) feet). All junction boxes shall be UL approved and gasketed. All conduits installed on the floor inside air handling units shall be rigid steel with steel fittings and diecast boxes. All EMT conduit and fittings on unit walls and ceiling shall be water tight type.

2.10.4. Provide liquid tight flexible connection to motor; 36-inch maximum length.

2.10.5. All penetrations shall not represent through-metal contact. Penetrations shall be made and sealed before unit factory testing.

2.10.6. Fire alarm circuits (where required) shall be powered from a relay in unit circuitry. Connect all units to the fire alarm system. Where applicable, re-install all duct smoke dampers and reconnect to the fire alarm system. If necessary, carry the cost of replacing the smoke dampers with new ones.

2.10.7. All control wiring shall be shielded.

2.11. **CONTROLS**

2.11.1. Equipment controls shall be fully compatible with Board's building automation system. Units to be supplied with terminal strip for direct connection to BAS.

2.11.2. All controls shall be factory mounted by the air-handling unit manufacturer. These controls shall include all damper actuators, temperature sensors, pressure sensors, and airflow measuring sensors, filter switches, smoke and fire detectors as indicated on the control drawings. Type of installation must be specified on the approved submittal or open plenum cable will be installed.

2.11.3. Electric and electronic controls shall be wired to a terminal block in a sheet metal enclosure located at a common location mounted on the air-handling unit. All pressure sensing controls shall be piped to a common point on the unit with ¼-in. compression fittings.

2.11.4. Filter gages shall be connected with barb fittings for access.

2.11.5. Units with splits shall have cable or tubing by the first split for the contractor to make final connections through the remaining splits of the unit.

PART 3 - EXECUTION

3.1. **INSTALLATION**

3.1.1. Installation shall meet or exceed all applicable federal, provincial and local requirements, referenced standards and conform to codes and ordinances of authorities having jurisdiction.

3.1.2. All installation shall be in accordance with manufacturer's published recommendations.

3.1.3. Install in conformance with AHRI 435.

3.1.4. Condensate drain piping shall be pitched at ¼ inch per foot from the air handling unit.

3.1.5. Make joints and connections fully gasketed and air tight.

3.1.6. Contractor shall furnish and maintain and replace clean pre-filter media in each air handling unit as listed in the equipment schedule on the Drawings during start-up and construction. The Contractor shall install the tagged set of new filter products provided by the air handling unit manufacturer for each unit after it has been tested, commissioned and receives final acceptance by the Owner.

3.1.7. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings have been lubricated, and fan has been test run under Client's representatives' observation.

3.2. **DX COILS**

3.2.1. Coordinate the installation of refrigeration accessories (TX valves, temperature sensing bulbs, filter dryers, solenoid valves and isolation valves). Connect all devices to power and controls, as required to make a fully operational system.

3.2.2. **B**oth exchanger airstreams to ensure optimum performance and minimum maintenance.

3.3. **START-UP SERVICE**

3.3.1. Equipment start-up and adjustment shall be provided by the manufacturer's trained representatives.

3.3.2. Extended warranty of components may require installation by factory-certified technicians who are certified by the component manufacturer.

3.3.3. Reconnect all equipment to the fire alarm system. Verify and test operation to the satisfaction of the Authorities Having Jurisdiction.

3.3.4. Re-instate all duct heat and smoke detectors temporarily removed during demolition work and reconnect to the existing fire alarm. Any detectors damaged during the demolition work shall be replaced with new, at no cost to the Board. Verify and test operation to the satisfaction of the Authorities Having Jurisdiction.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section applies to all sections of Division 26 - Electrical.

1.1.2. Furnish and install electrical systems, materials, equipment, and accessories in accordance with the specifications and drawings. Capacities and ratings of motors, transformers, conductors and cable, switchboards, switchgear, panelboards, motor control centers, generators, automatic transfer switches, and other items and arrangements for the specified items are shown on the drawings.

1.1.3. Electrical service entrance equipment and arrangements for temporary and permanent connections to the electric utility company’s system shall conform to the electric utility company's requirements. Coordinate fuses, circuit breakers and relays with the electric utility company’s system, and obtain electric utility company approval for sizes and settings of these devices.

1.1.4. The electrical work scope includes but is not limited to:

1.1.4.1. Disconnect from power all the equipment that is to be removed. Remove all redundant conduits, wiring, starters and disconnects.
1.1.4.2. Remove the existing UV filters and all associated power wiring.
1.1.4.3. Provide new power supply for the new equipment, including new disconnects, fuses, VFDs, conduits and wiring.
1.1.4.4. Connect the new equipment to the fire alarm. Provide new duct mounted smoke detectors and install to the fire alarm. Provide fire alarm verification.
1.1.4.5. Provide all required power, wiring and conduits to reinstall the UV filters at the new location.
1.1.4.6. Replace existing MCC in mechanical room with new. Reconnect all existing users that are to remain. Contractor to verify all connections, fuses and wiring prior to demolition.
1.1.4.7. Temporary remove and reinstate at the completion of the work any electrical and fire devices attached to the ceiling that is demolished. Coordinate with the mechanical contractor.
1.1.4.8. Provide ESA and Fire alarm report.

1.1.5. Conductor ampacities specified or shown on the drawings are based on copper conductors, with the conduit and raceways sized per NEC. Aluminum conductors are prohibited.

1.2. MINIMUM REQUIREMENTS

1.2.1. Canadian Electrical Safety Code, (CESC), National Electrical Code (NEC), Underwriters Laboratories, Inc. (UL), and National Fire Protection Association (NFPA) codes and standards are the minimum requirements for materials and installation.

1.2.2. The drawings and specifications shall govern in those instances where requirements are greater than those stated in the above codes and standards.

1.3. **TEST STANDARDS**

1.3.1. All materials and equipment shall be listed, labeled, or certified by a Nationally Recognized Testing Laboratory (NRTL) to meet Underwriters Laboratories, Inc. (UL), standards where test standards have been established. Materials and equipment which are not covered by UL standards will be accepted, providing that materials and equipment are listed, labeled, certified or otherwise determined to meet the safety requirements of a NRTL. Materials and equipment which no NRTL accepts, certifies, lists, labels, or determines to be safe, will be considered if inspected or tested in accordance with national industrial standards, such as ANSI, NEMA, and NETA. Evidence of compliance shall include certified test reports and definitive shop drawings.

1.4. **DEFINITIONS**

1.4.1. Listed: Materials and equipment included in a list published by an organization that is acceptable to the Authority Having Jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production or listed materials and equipment or periodic evaluation of services, and whose listing states that the materials and equipment either meets appropriate designated standards or has been tested and found suitable for a specified purpose.

1.4.2. Labeled: Materials and equipment to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the Authority Having Jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled materials and equipment, and by who’s labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

1.4.3. “Concealed” means hidden from normal sight in furred spaces, shafts, ceiling spaces, walls, or partitions. Wiring, raceways, and electrical boxes for all new or relocated devices shall be concealed.

1.4.4. “Exposed” means work normally visible to any person standing, sitting, or otherwise using the occupied space, including work in equipment rooms, tunnels, and similar spaces.

1.4.5. “Provide” (and all tenses) means supply and install for a complete, operational, and code-compliant system, including all devices/equipment as specified complete with wiring, raceways (conduit), electrical boxes, and all other accessories required for a complete, operational, and code compliant installation.

1.4.6. “Install” (and all tenses) means secure in position, connect as specified, test, and verify.

1.4.7. “Supply” means to supply all devices/equipment to the responsible trade.

1.4.8. “Remove” means to isolate, disconnect, disassemble, remove, and dispose of all devices, equipment, wiring, raceways, and connections to other equipment all the way to the main source. Patch and make good all surfaces affected by the removal. Include for all disposal costs in the tender price.

1.4.9. The term "approved", "approval", etc., shall be understood to mean approved by authorities having jurisdiction as conforming to Codes, Standards, By-laws, etc.

1.4.10. The term “accessible” shall be understood to mean readily accessible by a person using necessary tools but without cutting or breaking out material.

1.4.11. The term “listed” shall be understood to mean that the materials or equipment have been tested in accordance with applicable standards, and have been approved and listed for their intended use by a testing company approved by the Authorities having jurisdiction.

1.4.12. Where used, wordings such as "approved, to approval, as directed, permitted, permission, accepted, acceptance", shall mean: approved, directed, permitted, accepted, by an authorized representative of the Owner. and Install: material, equipment and labor shall be provided as required to make the equipment or system fully operational. Include all required wiring, conduit and other electrical devices as required, whether shown on the drawings, specified herein or not.

1.4.13. Certified: Materials and equipment which:

1.4.13.1. Have been tested and found to meet nationally recognized standards or to be safe for use in a specified manner.
1.4.13.2. Bear a label, tag, or other record of certification.

1.5. **QUALIFICATIONS (PRODUCTS AND SERVICES)**

1.5.1. Manufacturer’s Qualifications: The manufacturer shall regularly and currently produce, as one of the manufacturer's principal products, the materials and equipment specified for this project, and shall have manufactured the materials and equipment for at least three years.

1.5.2. Product Qualification:

1.5.2.1. Manufacturer's materials and equipment shall have been in satisfactory operation, on three installations of similar size and type as this project, for at least three years.

1.5.2.2. Service Qualifications: There shall be a permanent service organization maintained or trained by the manufacturer which will render satisfactory service to this installation within eight hours of receipt of notification that service is needed. Submit name and address of service organizations.

1.6. APPLICABLE PUBLICATIONS, CODES AND STANDARDS

1.6.1. Applicable publications listed in all Sections of Division 26 are the latest issue, unless otherwise noted.

1.6.2. Products specified in all sections of Division 26 shall comply with the applicable publications listed in each section.

1.6.3. Publications:

1.6.3.1. CAN/CSA C22.1-015, Canadian Electrical Code Part 1 (23nd Edition), Safety Standard for Electrical Installations.
1.6.3.2. Ontario Electrical Safety Code 26th Edition / 2015 or later.
1.6.3.3. CAN3-C235-83 (R2010), Preferred Voltage Levels for AC Systems, 0 to 50,000V.
1.6.3.4. National Building Code of Canada.
1.6.3.5. National Fire Code of Canada.
1.6.3.6. Ontario Building Code 2012.
1.6.3.7. National Fire Protection Code NFPA-70

1.7. MANUFACTURED PRODUCTS

1.7.1. Materials and equipment furnished shall be of current production by manufacturers regularly engaged in the manufacture of such items, and for which replacement parts shall be available.

1.7.2. When more than one unit of the same class or type of materials and equipment is required, such units shall be the product of a single manufacturer.

1.7.3. Equipment Assemblies and Components:

1.7.3.1. Components of an assembled unit need not be products of the same manufacturer.
1.7.3.2. Manufacturers of equipment assemblies, which include components made by others, shall assume complete responsibility for the final assembled unit.

1.7.4. Components shall be compatible with each other and with the total assembly for the intended service.

1.7.5. Constituent parts which are similar shall be the product of a single manufacturer.

1.7.6. Factory wiring and terminals shall be identified on the equipment being furnished and on all wiring diagrams.

1.7.7. When Factory Testing Is Specified:

1.7.7.1. The Board shall have the option of witnessing factory tests. The Contractor shall notify the Board a minimum of 15 working days prior to the manufacturer's performing the factory tests.

1.7.7.2. When materials and equipment fail factory tests, and re-testing and re-inspection is required, the Contractor shall be liable for all additional expenses for the Board to witness re-testing.

1.8. **VARIATIONS FROM CONTRACT REQUIREMENTS**

1.8.1. Where the Board or the Contractor requests variations from the contract requirements, the connecting work and related components shall include, but not be limited to additions or changes to branch circuits, circuit protective devices, conduits, wire, feeders, controls, panels and installation methods.

1.9. **MATERIALS AND EQUIPMENT PROTECTION**

1.9.1. Materials and equipment shall be protected during shipment and storage against physical damage, vermin, dirt, corrosive substances, fumes, moisture, cold and rain.

1.9.2. Store materials and equipment indoors in clean dry space with uniform temperature to prevent condensation.

1.9.3. During installation, equipment shall be protected against entry of foreign matter, and be vacuum-cleaned both inside and outside before testing and operating. Compressed air shall not be used to clean equipment. Remove loose packing and flammable materials from inside equipment.

1.9.4. Damaged equipment shall be repaired or replaced, as determined by the Consultant.

1.9.5. Painted surfaces shall be protected with factory installed removable heavy kraft paper, sheet vinyl or equal.

1.9.6. Damaged paint on equipment shall be refinished with the same quality of paint and workmanship as used by the manufacturer so repaired areas are not obvious.

1.10. **WORK PERFORMANCE**

1.10.1. All electrical work shall comply with the requirements of CESC, NFPA 70 (NEC), NFPA 70B, NFPA 70E, OSHA Part 1910 subpart J – General Environmental Controls, OSHA Part 1910 subpart K – Medical and First Aid, and OSHA Part 1910 subpart S – Electrical, in addition to other references required by contract.

1.10.2. Job site safety and worker safety is the responsibility of the Contractor.

1.10.3. Electrical work shall be accomplished with all affected circuits or equipment de-energized. When an electrical outage cannot be accomplished in this manner for the required work, the following requirements are mandatory:

1.10.4. Electricians must use full protective equipment (i.e., certified and tested insulating material to cover exposed energized electrical components, certified and tested insulated tools, etc.) while working on energized systems in accordance with NFPA 70E.

1.10.5. Work on energized circuits or equipment cannot begin until prior written approval is obtained from the Consultant

1.10.6. For work that affects existing electrical systems, arrange, phase and perform work to assure minimal interference with normal functioning of the facility.

1.10.7. New work shall be installed and connected to existing work neatly, safely and professionally. Disturbed or damaged work shall be replaced or repaired to its prior conditions.

1.10.8. Coordinate location of equipment and conduit with other trades to minimize interference.

1.11. **COORDINATION AND INTERFERENCE DRAWINGS**

1.11.1. Provide information and cooperate with the General/Mechanical Contractor for the preparation of interference and coordination drawings.

1.11.2. Interference and coordination drawings to be provided in order to make clear the Work intended or to show how it affects other trades.

1.11.3. interference and coordination drawings to be provided for:

1.11.3.1. Mechanical, Electrical, Communications Rooms
1.11.3.2. Service corridors and tunnels
1.11.3.3. Corridor, lobbies and all public spaces
1.11.3.4. Crawl spaces
1.11.3.5. Attic spaces
1.11.3.6. Underground Trenches
1.11.3.7. Raised floor spaces

1.12. **EQUIPMENT INSTALLATION AND REQUIREMENTS**

1.12.1. Equipment location shall be as close as practical to locations shown on the drawings.

1.12.2. Working clearances shall not be less than specified in the CEC.

1.12.3. Inaccessible Equipment:

1.12.3.1. Where the Consultant determines that the Contractor has installed equipment not readily accessible for operation and maintenance, the equipment shall be removed and reinstalled as directed at no additional cost to the Board.

1.12.3.2. "Readily accessible" is defined as being capable of being reached quickly for operation, maintenance, or inspections without the use of ladders, or without climbing or crawling under or over obstacles such as, but not limited to, motors, pumps, belt guards, transformers, piping, ductwork, conduit and raceways.

1.12.4. Electrical service entrance equipment and arrangements for temporary and permanent connections to the electric utility company's system shall conform to the electric utility company's requirements. Coordinate fuses, circuit breakers and relays with the electric utility company's system, and obtain electric utility company approval for sizes and settings of these devices.

1.13. **EQUIPMENT IDENTIFICATION**

1.13.1. In addition to the requirements of the CEC, install an identification sign which clearly indicates information required for use and maintenance of items such as switchboards and switchgear, panelboards, cabinets, motor controllers, fused and non-fused safety switches, generators, automatic transfer switches, separately enclosed circuit breakers, individual breakers and controllers in switchboards, switchgear and motor control assemblies, control devices and other significant equipment.

1.13.2. Identification signs for Normal Power System equipment shall be laminated black phenolic resin with a white core with engraved lettering. Identification signs for Essential Electrical System (EES) equipment, as defined in the NEC, shall be laminated red phenolic resin with a white core with engraved lettering. Lettering shall be a minimum of 12 mm (1/2 inch) high. Identification signs shall indicate equipment designation, rated bus amperage, voltage, number of phases, number of wires, and type of EES power branch as applicable. Secure nameplates with screws.

1.13.3. Install adhesive arc flash warning labels on all equipment as required by NFPA 70E. Label shall indicate the arc hazard boundary (inches), working distance (inches), arc flash incident energy at the working distance (calories/cm2), required PPE category and description including the glove rating, voltage rating of the equipment, limited approach distance (inches), restricted approach distance (inches), prohibited approach distance (inches), equipment/bus name, date prepared, and manufacturer name and address.

1.14. **SUBMITTALS**

1.14.1. All submittals shall include copies of adequate descriptive literature, catalog cuts, shop drawings, test reports, certifications, samples, and other data necessary for the Board to ascertain that the proposed materials and equipment comply with drawing and specification requirements. Catalog cuts submitted for approval shall be legible and clearly identify specific materials and equipment being submitted.

1.14.2. Submittals for individual systems and equipment assemblies which consist of more than one item or component shall be made for the system or assembly as a whole. Partial submittals will not be considered for approval.

1.14.3. The Consultant's approval shall be obtained for all materials and equipment before delivery to the job site. Delivery, storage or installation of materials and equipment which has not had prior approval will not be permitted.

1.14.4. The submittals shall include the following:

1.14.4.1. Information that confirms compliance with contract requirements. Include the manufacturer's name, model or catalog numbers, catalog information, technical data sheets, shop drawings, manuals, pictures, nameplate data, and test reports as required.

1.14.4.2. Elementary and interconnection wiring diagrams for communication and signal systems, control systems, and equipment assemblies. All terminal points and wiring shall be identified on wiring diagrams.

1.14.4.3. Parts list which shall include information for replacement parts and ordering instructions, as recommended by the equipment manufacturer.

1.14.5. Maintenance and Operation Manuals:

1.14.5.1. Submit as required for systems and equipment specified in the technical sections. Furnish in hardcover binders or an approved equivalent.

1.14.5.2. Inscribe the following identification on the cover: the words "MAINTENANCE AND OPERATION MANUAL," the name and location of the system, material, equipment, building, name of Contractor, and contract name and number. Include in the manual the names, addresses, and telephone numbers of each subcontractor installing the system or equipment and the local representatives for the material or equipment.

1.14.5.3. Provide a table of contents and assemble the manual to conform to the table of contents, with tab sheets placed before instructions covering the subject. The instructions shall be legible and easily read, with large sheets of drawings folded in.

1.14.6. The manuals shall include:

1.14.6.1. Internal and interconnecting wiring and control diagrams with data to explain detailed operation and control of the equipment.

1.14.6.2. A control sequence describing start-up, operation, and shutdown.

1.14.6.3. Description of the function of each principal item of equipment.

1.14.6.4. Installation instructions.

1.14.6.5. Safety precautions for operation and maintenance.

1.14.6.6. Diagrams and illustrations.

1.14.6.7. Periodic maintenance and testing procedures and frequencies, including replacement parts numbers.

1.14.6.8. Performance data.

1.14.6.9. Pictorial "exploded" parts list with part numbers. Emphasis shall be placed on the use of special tools and instruments. The list shall indicate sources of supply, recommended spare and replacement parts, and name of servicing organization.

1.14.6.10. List of factory approved or qualified permanent servicing organizations for equipment repair and periodic testing and maintenance, including addresses and factory certification qualifications.

1.14.6.11. Approvals will be based on complete submission of shop drawings, manuals, test reports, certifications, and samples as applicable.

1.15. **RECORD DRAWINGS**

1.15.1. The Consultant will provide to the Electrical Contractor one set of AutoCad computer files and one set of white prints of all drawings relating to the work of this contract, for the purpose of preparing record drawings. As the job progresses, mark up the white prints to accurately indicate installed work, i.e. location and elevations, etc. On completion of the work, the Electrical Contractor to transfer the information neatly onto the computer files based on AutoCad 2007 or higher, and submit the electronic files and one set of prints for review and comment. Correct the files as directed by the Consultant and hand these over to the Board, together with a set of white prints, on completion.

1.15.2. Record, as the job progresses, all approved changes and deviations made to any work shown on the original contract drawings whether by addenda, requested changes, job instructions, and changes due to job conditions.

1.15.3. Indicate on the drawings all conduits, pull boxes, junction boxes, empty conduits, concealed main and sub-feeder conduits and any other equipment not clearly in view, with exact dimensions for future reference. Tie dimensions by measurement to existing topographical features, and include changes in directions as well as at least three points on straight runs of conduits on raceways.

1.15.4. All conduits in slabs, under slab and direct buried are to be shown on the Record drawings.

1.15.5. Record drawings to be kept up to date and be available for checking at any time by Boards and Consultant. Progress draws will not be reviewed unless the record drawing set is up to date.

1.15.6. All equipment schedules, panel schedules, system schedules, riser diagrams, details, etc. to be updated to reflect the as installed condition and included as part of the record drawing submission.

1.15.7. Provide a schedule indicating the protective device trip setting of all Air Circuit Breakers and Electronic Solid State Circuit Breakers which are reflected on each of the Power Distribution Single Line Riser Diagram drawings. The protective device trip settings that are to be listed in the schedule are to be those which are based upon the final reviewed and accepted version of the short circuit and protection and coordination as well as the arc flash study.

1.15.8. Branch circuiting, lighting zoning, switching, etc. methodology to be the same as that indicated on the electrical contract documents that are issued for construction.

1.15.9. Electrical record drawings to be submitted in both AutoCad and PDF format.

1.15.10. Record drawings will not be reviewed for acceptance until project substantial completion has been issued.

1.16. **ACCEPTANCE CHECKS AND TESTS**

1.16.1. The Contractor shall furnish the instruments, materials, and labor for tests.

1.16.2. Where systems are comprised of components specified in more than one section of Division 26, the Contractor shall coordinate the installation, testing, and adjustment of all components between various manufacturer's representatives and technicians so that a complete, functional, and operational system is delivered to the Board.

1.16.3. When test results indicate any defects, the Contractor shall repair or replace the defective materials or equipment, and repeat the tests. Repair, replacement, and retesting shall be accomplished at no additional cost to the Board.

1.17. **CODES, PERMITS AND INSPECTIONS**

1.17.1. All work to meet or exceed the latest requirements of the Codes and Standards as listed in PART 1 of these specifications, supplements, local inspection bulletins and all Authorities Having Jurisdiction.

1.17.2. Arrange for inspection of all work and pay all fees in this regard. On completion of the work, deliver the final unconditional certificate of approval of the Electrical Safety Authority (ESA).

1.17.3. It is hereby agreed that all requirements meet CAN/CSA requirements and a complete installation in accordance with these requirements to be provided.

1.17.4. Keep a permanent record of each inspection made by the Electrical Safety Authority showing the date, inspector's name, scope of the inspection and statement of special decisions or permissions granted. Make these records available to the Consultant at any time, and turn them over at completion of the work.

1.18. **WARRANTY**

1.18.1. All work performed and all equipment and material furnished under this Division shall be free from defects and shall remain so for a period of one year from the date of acceptance of the entire installation by the Board’s representative.

1.19. **INSTRUCTION**

1.19.1. Instruction to designated Board personnel shall be provided for the particular equipment or system as required in each associated technical specification section.

1.19.2. Furnish the services of competent instructors to give full instruction in the adjustment, operation, and maintenance of the specified equipment and system, including pertinent safety requirements. Instructors shall be thoroughly familiar with all aspects of the installation, and shall be trained in operating theory as well as practical operation and maintenance procedures.

1.19.3. A training schedule shall be developed and submitted by the Contractor and approved by the Consultant at least 15 days prior to the planned training.

PART 2 - PRODUCTS

2.1. **MATERIALS AND EQUIPMENT**

2.1.1. All materials and equipment to be new and free from defects.

2.1.2. All material and equipment to be CAN/CSA certified. Where CAN/CSA certified material and equipment is not available, obtain special approval from authority having jurisdiction before delivery to site and submit such approval as described in PART 1 - SUBMITTALS.

2.1.3. Where materials, equipment, apparatus, or other products are specified by the manufacturer, brand name, type or catalogue number, such designation is to establish the standards of desired quality, style or dimensions and to be the basis of the Bid. Furnish materials so specified under this Contract unless changed by mutual agreement. Where two or more designations are listed, the Electrical Contractor to choose one of those listed.

2.1.4. Where the use of equivalent, alternate or substitute equipment alters the design or space requirements indicated on the plans, the Electrical Contractor for this contract to include all items of cost for the revised design and construction, including the cost of all the other trades involved.

2.1.5. Acceptance of the proposed equivalents, alternates or substitutions to be subject to the review by the Consultant, and if requested, the Electrical Contractor to submit for inspection, samples of both the specified and the proposed alternate items.

2.1.6. In all cases where the use of equivalents, alternates or substitutions is permitted, the Electrical Contractor to bear any extra costs of evaluating the quality of materials and the equipment to be installed.

2.2. **EQUIVALENTS AND ALTERNATES**

2.2.1. Should the Electrical Contractor propose to furnish material and equipment other than those specified, he is to apply in writing to the Consultant for approval of equivalents at least ten working days prior to the closing of Bids, submitting with his request for approval, complete descriptive and technical data on the item or items he proposes to furnish. Approval for changes in the base bid specifications will be considered only upon the individual requests of the Electrical Contractor. No blanket approval for equipment will be given to suppliers, distributors or contractors.

2.2.2. Unless requests for changes in base bid specifications are received and approved prior to the opening of the bids, as defined above, the Electrical Contractor will be held to furnish all specified items under his base bid. After the Contract is awarded, changes in specifications will be made only as defined in the Article dealing with Material Substitution.

2.2.3. Replace unspecified materials or rejected equivalents and alternates built into the work with specified or accepted materials at no additional cost to the Owner.

2.2.4. If any material or equipment being considered for substitution involves additional design, architectural or engineering fees or other costs in checking whether or not the substitute material or equipment is suitable for the project, such fees or costs to be paid for by the Electrical Contractor. A minimum of five hundred dollars ($500.00) to be applied to each piece of device or equipment requested for review. There is no guarantee that the reviewed product will be accepted by the Board or the reviewing Consultant.

2.3. **MATERIAL SUBSTITUTION**

2.3.1. After award of the Contract, requests for substitution of materials of makes other than those specifically named in the Contract Documents may be considered by the Consultant subject to the following:

2.3.1.1. The specified material cannot be delivered to the job in time to complete the work in proper sequence to work of other trades, due to conditions beyond the control of the Electrical Contractor.

2.3.1.2. Requests for substitutions to be accompanied by documentary proof of equality, difference in price and delivery, if any, in the form of certified quotations from suppliers of both specified and proposed equipment.

2.3.1.3. In case of difference in price, the Owner is to receive all benefit of the difference in cost involved in any substitution and the Contract altered by change order to credit the Owner with any savings so obtained.

2.3.1.4. Materials and equipment substituted or offered as alternatives to have spare parts and servicing available and to fit into the space allocation shown on the drawings.

2.3.1.5. If any material or equipment being considered for substitution involves additional design, architectural or engineering fees or other costs in checking whether or not the substitute material or equipment is suitable for the project, such fees or costs to be paid for by the Electrical Contractor. A minimum of five hundred dollars ($500.00) to be applied to each piece of device or equipment requested for review. There is no guarantee that the reviewed product will be accepted by the Board or the reviewing Consultant.

2.4. **WARNING SIGNS**

2.4.1. Warning Signs: in accordance with requirements of Authority Having Jurisdiction and Consultants.

2.4.2. Comply with Health Canada/Workplace Hazardous Materials Information System (WHMIS).

2.4.3. Provide warning labels in both English and French where project requires.

2.5. **FINISHES**

2.5.1. Shop finish metal enclosure surfaces by application of rust resistant primer inside and outside, and two coats of finish enamel.

2.5.2. Paint outdoor electrical distribution equipment green finish to EEMAC Y1-2.

2.5.3. Paint indoor normal power distribution equipment enclosures light grey to EEMAC 2Y-1.

2.5.4. Paint indoor emergency power “Life Safety” distribution equipment enclosures Red.

2.5.5. Paint indoor emergency power “Non-life Safety” distribution equipment enclosures International Orange, RAL #2009.

2.5.6. Paint indoor UPS power distribution equipment enclosures Blue, RAL #5017.

2.6. **CAN/CSA/NEMA RATING**

2.6.1. All electrical equipment provided for this project to be CAN/CSA/NEMA Rated only. IEC Rated equipment is not acceptable and will not be accepted.

PART 3 - EXECUTION

3.1. **INSTALLATION**

3.1.1. Comply with all Codes and Standards listed in PART 1 – GENERAL.

3.1.2. Comply with manufacturer's written data, including product technical bulletins, product catalog installation instructions, product carton installation instructions, MSDS, and product datasheets.

3.1.3. Protect electrical equipment from dust and dirt. Plug or cap openings of conduits, fixtures and equipment during construction with approved materials for such use.

3.1.4. The Electrical Contractor to be responsible for the layout of the work of this contract, and for any damage caused to site or existing building, or other Contracts by improper location or carrying out of this work.

3.1.5. Ensure the prompt installation of the work of this contract in advance of concrete pouring or similar work.

3.1.6. No conduits for any power or systems to be permitted to be installed within the concrete slabs or concrete walls for this project except in select identified areas as per the drawings and specifications.

3.1.7. Furnish items to be "built-in" in ample time and give any necessary information and assistance in connection with the building-in of the same.

3.1.8. Manufactured products supplied with instructions for their use to be used in strict accordance with those instructions.

3.1.9. Ensure that all equipment and material is ordered in time to meet the building schedule. Provide a schedule of equipment deliveries to the Construction Manager within the time limit stipulated.

3.2. **SITE SERVICES**

3.2.1. Site services: acquire a full working knowledge of the building site, services and any existing conditions thereon that may impact the project implementation. Review and examine the contract drawings and schedules of all trades prior to bid submittal to ensure full knowledge of the contract scope of work is ascertained.

3.2.2. The location of equipment indicated or specified is considered approximate. Review proposed locations with Consultant prior to installation.

3.2.3. Locate equipment, piping, duct and/or conduit to provide minimum interference and maximum usable space and in accordance with manufacturer's recommendations for safety, access and maintenance.

3.3. **CONTRACTOR'S SHOP**

3.3.1. Provide job site office, workshop, tools, scaffolds, material storage, etc., as required to complete the work of this contract and as directed by the Consultant.

3.3.2. The electrical contractor’s office should as a minimum have the following capabilities, Phone, fax, email, High speed internet connection, router with a spare port and patch cable in order that the consultant can access the internet to deal with project related issues, copier and printer.

3.4. **TEMPORARY SERVICES**

3.4.1. Provide temporary electrical services with all poles, transformer and protection equipment from the locations as coordinated with the Owner. Provide all power panels at various locations on the site required to perform the work and as specified by the Consultant. All temporary services must be coordinated with the Owner. Do not use the permanent service of new or existing building for temporary power for construction unless specific written approval is obtained from the Consultant and coordinated with the Board

3.5. **ACCESS TO ELECTRICAL EQUIPMENT, JUNCTION BOXES AND PULL BOXES**

3.5.1. Clear access of a minimum of 1 meter must be provided for all electrical equipment, junction boxes and pull boxes.

3.5.2. All junction boxes and pull boxes to be within 600mm of an access panel or access luminaire and be easily accessed.

3.5.3. All electrical boxes that have free sides (IE: no conduits entering or leaving a side) to be kept clear in order to permit installation of conduits at a later date. Hence free sides of all electrical boxes to be clear of other conduits and services.

3.6. **NAMEPLATES**

3.6.1. Ensure manufacturer's nameplates, CAN/CSA labels and identification nameplates are visible and legible after equipment is installed.

3.7. **LOCK OFF TABS**

3.7.1. Provide lock off tabs on all panel boards for circuits that serve:

3.7.1.1. Emergency lighting;
3.7.1.2. Exit lighting;
3.7.1.3. Fire alarm equipment
3.7.1.4. Security equipment.

3.8. **FIRESTOPPING**

3.8.1. Where cables, sleeves or conduits, pass through floors and fire rated walls pack space between wiring and sleeve or opening and seal with Hilti fire stopping system that is appropriate. The fire stopping installation must meet one of the approved details as required to meet the rating of the assembly. Contact the Hilti representative to ensure that the installation meet Hilti requirements.

3.8.2. Care must be taken to keep integrity of all assemblies and maintain good finishes of surrounding areas, use tape for finish at edges when apply fire stopping materials. Provide at the end of the project a letter from Hilti indicating that the installation meets all requirements.

3.8.3. Meet all requirements of the Codes and fire proofing requirements as specified within the Contract Documents.

3.8.4. Provide Shop drawings for the various Fire stopping assemblies that will be utilized on the project to achieve the fire rating for construction assemblies or methods.

3.8.5. Refer (where applicable) to architectural drawings for fire separation diagrams. Such drawings may not be issued as part of the electrical documents; it is the electrical contractor's obligation to review all contract documentation of all involved disciplines (drawings and specifications).

3.9. **BASES AND SUPPORTS**

3.9.1. Where conduit and equipment are located on walls or slabs which will not permit the support of equipment, provide suitable supports to the building structure. Supports to be constructed of steel members or of steel pipe and fittings designed to safely support the equipment.

3.9.2. All equipment bases to be set on pads of kinetic pre-compressed fiberglass or vibration isolators sized to suit the equipment which they ought to support.

3.10. **INSERTS, SLEEVES AND CURBS**

3.10.1. Provide all inserts, sleeves and curbs required for the work of this contract.

3.10.2. Use only factory made threaded or toggle type inserts as required for support and anchors, properly sized for the load to be carried. Place inserts only in portions of the main structure and not in any finishing material.

3.10.3. Use factory made expansion shields where inserts cannot be placed, but only where approved by the Structural Engineer and only for loads of 50 kg or less.

3.10.4. Do not use powder activated tools unless with written permission of the Board's Representative.

3.10.5. Supply and locate all inserts, holes, anchor bolts and sleeves in time when walls, floors and roof are erected.

3.10.6. Size sleeves to provide 25 mm clearance all around.

3.10.7. Pack all sleeves between the conduit or cable passing through the sleeve and the sleeve and all spare sleeves with loose fiberglass insulation. Seal the annular space both sides as follows:

3.10.7.1. For all horizontal sleeves in exposed areas, use a seal of equal or better fire rating than the wall to be sealed.

3.10.7.2. For all horizontal concealed sleeves through fire walls and through walls separating areas of different air pressure, use a permanently resilient silicone base or equal sealing compound.

3.10.7.3. For all vertical sleeves through roofs, washrooms, janitor closets, equipment rooms, use permanently resilient silicone base or equal compound, non-flammable and waterproof. Ensure that the seal is compatible with floor and ceiling finishes. Check the room finishes schedules for further information.

3.11. **CUT PATCH AND MAKE GOOD**

3.11.1. All drilling, cutting, patching, concrete curbs, housekeeping pads and similar work required for installation of the specified systems shall be done under this contract.

3.11.2. Do not use powder actuated tools using explosives, unless permitted expressly by the Board in writing.

3.11.3. All cutting of steel shall be by mechanical cutters or saws. Torches and abrasives will only be permitted if there is no alternative. Prior to using torches or abrasives obtain Hot Work Permit in accordance with the Board's hot work procedure.

3.11.4. Scan the walls/floor slabs using ground penetrating radar (GPR) technology prior to making openings to determine the presence and location of embedded conduits or rebar. Clean the floors/walls immediately after core drilling/saw cutting is complete. All core drilling and loud and/or prolonged drilling shall be done after normal working hours (during silent hours) or as permitted by the “hammer drilling” schedule and 48 hour lead notice is to be provided to the building Owner to confirm contractor has met all mandatory conditions.

3.11.5. Core drilling through floors and walls shall be done with diamond drills only. The use of pneumatic hammers will not be permitted.

3.11.6. Patch and make good all surfaces cut, damaged or disturbed to the Board 's approval. Match existing material, colour, finish and texture.

3.11.7. Welding and cutting: conform to Ontario Health and Safety Act O.Reg. 213/91 amended to O.Reg. 628/05 Construction Projects. Obtain a Hot Work Permit from the PM prior to welding and cutting operations. Follow the PM’s hot work procedures.

3.11.8. Do not dispose of cement, mortar, plaster or other similar materials into drainage system. Contractor shall be liable for all costs associated with cleanup and reinstatement to original condition after doing so.

3.11.9. Dispose of sediment-containing liquids such as those resulting from core drilling or concrete cutting into designated drains. Flush drain with sufficient quantity of clean water to ensure that drain is free-flowing and unobstructed. Be liable for all costs associated with cleanup and reinstatement of drain and piping to original condition if found to be blocked by sediment.

3.11.10. Firestop all penetrations through wall and floor assemblies with Hilti Firestop solutions having a fire resistance rating not less than the assembly penetrated, colour: red. Unless otherwise noted, use the following assembly ratings: floors 2-hours; walls except around stairways – 1½ hours; walls around stairways: 2 – hours. Submit to Consultant for approval the proposed system detail sheets bearing the UL/CUL system number. Provide specified firestopping compound on both sides of assembly penetrated regardless of UL/CUL detail requirements.

3.12. **REMOVALS AND DEMOLITION**

3.12.1. The drawings indicate the general scope of electrical removals. Verify on site the exact requirements and extent of removals.

3.12.2. Visit the site to determine the extent of all removals.

3.12.3. Maintain, retain and make good as required all existing systems, branch wiring and feeders intended to remain operational in areas which are affected by these renovations.

3.12.4. Schedule all demolition work with project manager prior to any service interruption in occupied building area.

3.12.5. All shutdowns of existing base building systems shall be coordinated with the Board's representative. Pay for any cost incurred. All building services to remain fully operational during construction. Include in tender for off hours to install new breaker in existing panels and connection for feeders.

3.12.6. Remove electrical equipment as required complete with wiring up to associated panel. Remove all electrical components to be demolished or to be relocated and make safe all wiring. Hand over removed items to owner if requested. Dispose of the equipment properly which Owner does not wish to retain. Update existing panel directory which is affected.

3.12.7. Inform the Consultant and the Board immediately if any contaminated materials are found on site. Remove the items so that they can be packed and removed from the site. Provide assistance and cooperation for the complete removal.

3.12.8. The contractor shall be responsible to relocate any existing electrical equipment and/or wiring that will interfere with new construction.

3.12.9. The contractor shall be responsible for reconnection of any services that are to remain and have been disconnected during the course of demolition or construction.

3.12.10. All systems and components which are affected by the renovation shall remain operational subsequent to project completion. Reinstate immediately any services disrupted during demolition not intended to be removed as part of this contract at no extra cost.

3.12.11. Retain continuity of service of the fire alarm system to all occupied areas of the building.

3.12.12. The contractor shall advise security in the event that fire alarm system continuity is disrupted such that a fire watch can commence immediately.

3.12.13. Repair all damages inside and outside of the renovated areas caused by the demolition/construction without extra cost to the Owner.

3.13. **REMOVED MATERIAL**

3.13.1. All material removed during demolition shall become the property of the Contractor. The contractor shall remove material from the site and dispose of in accordance with provincial regulations. Under no circumstances is the contractor to use the building Owner's refuse containers for disposal.

3.14. **NUMBER AND LOCATION OF OUTLETS**

3.14.1. Provide outlets for power and systems of the number and in the locations shown on the drawings. Locate all outlets accurately with respect to building lines and in centering outlets due allowance to be made for overhead pipes, ducts, equipment and for variations in wall or ceiling finishes, window trim, paneling, etc. When necessary, make adjustments to ensure that all outlets are properly centered.

3.14.2. The location of any outlet may be changed without extra cost or credit providing that the new location is within 6 metres (20 feet) of that originally shown on the drawings and that instructions for the change are issued before installation of the outlet.

3.14.3. Do not mount outlet boxes in walls and partitions back-to-back and provide a minimum of 150 mm (6 inch) between boxes. Provide acoustic insulating medium in conduits which join boxes on opposite sides of same wall or partition. Acoustic properties of the wall to be matched or exceeded. Where applicable, for acoustically sensitive/critical rooms, more spacing separation and acoustic box seal is required. Refer to acoustic specifications and electrical drawings for detailed requirements.

3.15. **MOUNTING HEIGHTS**

3.15.1. The mounting height of equipment is measured from the finished floor to the centerline of the equipment unless specified or otherwise indicated.

3.15.2. If the mounting height of any equipment is not indicated, verify the mounting height before proceeding with the installation.

3.15.3. Install electrical equipment at the following mounting heights unless otherwise detailed or indicated. Refer to Architectural reflected ceiling plans, elevations, sections and details for final device location and to confirm all mounting heights.

3.15.4. All device mounting heights and orientation to be coordinated and confirmed by the Prime Consultant prior to installation.

3.15.4.1. Local switches and control devices: 1100 mm (42 inch)
3.15.4.2. Wall receptacles:
3.15.4.2.1. General: 400 mm (15 inch)
3.15.4.2.2. Above top of counters or backsplash: 175 mm (7 inch)
3.15.4.2.3. In mechanical rooms: 1400 mm (55 inch)

3.15.5. Panelboards:

3.15.5.1. 1800 mm (70 inch) to the top except that the panelboard not to be lower than 150 mm (6 inch) above the floor.
3.15.5.2. Where multiple panelboards are mounted together, align the tops of all the panelboards or trims with the highest panelboard determining the height.

3.15.6. Fire alarm system pull stations: 1200 mm (48 inch)

3.15.6.1. Fire alarm system speakers/strobes: 2300 mm (90 inch) and at least 150 mm (6 inch) below the ceiling measured to the top of device, or on ceiling.

3.15.6.2. Fire Alarm System end of line resistors as per code requirements. EOL resistors to be grouped in service spaces.

3.15.6.3. Fire fighter’s phone: 1400 mm (55 inch) measured to the centerline of the enclosure.

3.15.7. Individual starters:

3.15.7.1. 1500 mm (60 inch) to the top.

3.15.7.2. Where multiple starters are mounted together, align the tops of all the starters or trims with the highest starter determining the height.

3.15.8. Splitters: 100 mm (4 inch) below the lowest equipment connected to the splitter.

3.16. **MECHANICAL AND ELECTRICAL CO-ORDINATION OF RESPONSIBILITIES**

3.16.1. The following is a list of mechanical and electrical responsibilities for the above-mentioned project:

3.16.1.1. The Electrical Contractor to provide all starters or combinations starters/disconnects (fused or non-fused, as specified) for Mechanical Motors along with Line and Load side power wiring with the exception of Packaged Mechanical Equipment or Units.

3.16.1.2. Where so specified, Packaged Mechanical Equipment to be provided with its own integral disconnect(s), starters(s) or unit mounted VFD(s). With respect to Packaged Mechanical Equipment or Units the Electrical Contractor to provide the Line Side power wiring and connection(s) to the equipment connection point(s).

3.16.1.3. The Electrical Contractor to provide equipment isolation disconnect switches for all remote mechanical equipment unless otherwise indicated within the Mechanical Contract Documents or unless equipment is already furnished with a local disconnect. Where applicable, weather-proof enclosures shall be used. Remote definition: not in sight, as per NFPA-70 article 430.102

3.16.1.4. All BAS equipment and devices, to be supplied by the BAS vendor and installed by the mechanical Contractor.

3.16.1.5. The Mechanical Contractor to provide all control wiring, BAS wiring, and 120 volt control wiring for Mechanical Equipment or Units.

3.16.1.6. The Mechanical Contractor to provide all motors.

3.16.1.7. The Electrical Contractor to provide all fire alarm interface wiring to the Mechanical Equipment or Units for fire alarm Fan Shut Down, Fan Start-up as and for fire alarm Smoke Control.

3.16.1.8. The Electrical Contractor to provide all fire alarm wiring.

3.16.1.9. The Electrical Contractor to provide all relays for interface to control wiring for fan shutdown and fan start up for air handling units used as part of the smoke control system(s).

3.16.1.10. The Mechanical Contractor to provide all relays as required by the Mechanical Equipment or Units to connect to the various building systems.

3.16.1.11. The Mechanical Contractor to provide electric pipe heat tracing which to be based upon the self-limited type and be at 208 volts 1 Phase. The Electrical Contractor to provide 208 volts 1 Phase power connection(s) for the electric pipe heat tracing system(s). The Mechanical Contractor to provide loads requirements of the heat tracing to the Electrical Contractor prior to final power connection.

3.16.1.12. The Mechanical Contractor to provide electric heating, associated controls and control wiring. The Electrical Contractor to provide the Line Side power connection to the electric heating. The Mechanical Contractor to provide any framing required for recessed electric heating.

3.16.1.13. Separate Variable Frequency Drives (VFDs) to be provided by the Mechanical Contractor. Should the Mechanical Contractor change or modify motor sizes from what is specified within the Bid Documents during any stage of this project the Mechanical Contractor will be responsible to cover all associated electrical costs such as revised motor starter and feeds, etc.

3.17. **FLASHING**

3.17.1. Coordinate with requirements for roofing, waterproofing and flashing with the Roofing Contractor.

3.17.2. Flash electrical parts passing through or built into a roof, an outside wall or a waterproof floor.

3.17.3. Provide 8-pound sheet lead flashing for cast iron or wrought iron sleeves passing through roof.

3.17.4. Flashing shall suit roof angle and shall extend minimum 450 mm (18 inch) on all sides. Leave flashing as directed by the Roofing Contractor for him to build into roofing, rendering a watertight connection.

3.17.5. Provide counter flashing on stacks, ducts and pipes passing through roof to fit over flashing or curb.

3.17.6. Provide sleeves passing through outside walls with lead or copper flashing as directed.

3.18. **SYSTEM STARTUP**

3.18.1. Inform Consultant and operating personnel in operation, care and maintenance of systems, system equipment and components.

3.18.2. Arrange and pay for services of manufacturer's factory service engineer to supervise start-up of installation, check, adjust, balance and calibrate components and instruct operating personnel.

3.18.3. 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 will aspects of its care and operation.

3.19. **CLEANING**

3.19.1. Clean and touch up surfaces of shop-painted equipment scratched or marred during shipment or installation, to match original paint.

3.19.2. Clean and prime exposed non-galvanized hangers, racks and fastenings to prevent rusting.

3.19.3. During the performance of the work and on the completion, remove from the site and premises all debris, rubbish and waste materials caused by the performance of the work for this contract. Remove all tools and surplus materials after completion and acceptance of the work.

3.19.4. Vacuum all equipment thoroughly at the time of final acceptance of the work. Clean plastic components and exposed components of luminaires in accordance with the manufacturer's recommendation.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section specifies the furnishing, installation, connection, and testing of the electrical conductors and cables for use in electrical systems rated 600 V and below, indicated as cable(s), conductor(s), wire, or wiring in this section.

1.2. RELATED WORK

1.2.1. Section: 26 05 00 Common Work Results for Electrical.

1.2.2. Section: 26 05 26 Grounding and Bonding for Electrical Systems.

1.2.3. Section: 26 05 33 Raceway and Boxes for Electrical Systems.

1.3. FACTORY TESTS

1.3.1. Conductors and cables shall be thoroughly tested at the factory per NEMA to ensure that there are no electrical defects. Factory tests shall be certified.

1.4. SUBMITTALS

1.4.1. Shop Drawings:

1.4.1.1. Submit sufficient information to demonstrate compliance with drawings and specifications.
1.4.1.2. Submit the following data for approval:
1.4.1.3. Electrical ratings and insulation type for each conductor and cable.
1.4.1.4. Splicing materials and pulling lubricant.

1.4.2. Certifications: Two weeks prior to final inspection, submit the following.

1.4.2.1. Certification by the manufacturer that the conductors and cables conform to the requirements of the drawings and specifications.
1.4.2.2. Certification by the Contractor that the conductors and cables have been properly installed, adjusted, and tested.

1.5. APPLICABLE PUBLICATIONS

1.5.1. Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are reference in the text by designation only.

1.5.1.1. CAN/CSA-C22.2 NO.38-10, Thermoset-Insulated Wire and Cables (Tri-national
1.5.1.2. standard, with UL 44 and ANCE NMX-J-451).
1.5.1.3. CAN/CSA C22.2 NO.51-09, Armored Cables.

1.5.1.4. CAN/CSA C22.2 NO.75-08, Thermoplastic-Insulated Wires and Cables (Trinational
1.5.1.5. standard, with UL 83 and NMX-J-010-ANCE-2008).
1.5.1.6. CAN/CSA C22.2 NO.124-04 (R2009), Mineral-Insulated Cable.
1.5.1.7. CAN/CSA C22.2 NO.131-07, Type TECK 90 Cable.
1.5.1.8. CAN/CSA C22.2 NO. 239-09, Control and Instrumentation Cables.
1.5.1.9. American Society of Testing Material (ASTM):
1.5.1.9.1. D2301-10 Standard Specification for Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape
1.5.1.9.2. D2304-10 Test Method for Thermal Endurance of Rigid Electrical Insulating Materials
1.5.1.9.3. D3005-10 Low-Temperature Resistant Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape
1.5.1.10. National Electrical Manufacturers Association (NEMA):
1.5.1.10.1. WC 70-09 Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy
1.5.1.11. National Fire Protection Association (NFPA):
1.5.1.11.1. 70-11 National Electrical Code (NEC)
1.5.1.12. Underwriters Laboratories, Inc. (UL):
1.5.1.13. 44-10 Thermoset-Insulated Wires and Cables
1.5.1.14. 83-08 Thermoplastic-Insulated Wires and Cables
1.5.1.15. 467-07 Grounding and Bonding Equipment
1.5.1.16. 486A-486B-03 Wire Connectors
1.5.1.17. 486C-04 Splicing Wire Connectors
1.5.1.18. 486D-05 Sealed Wire Connector Systems
1.5.1.19. 486E-09 Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors
1.5.1.20. 514B-04 Conduit, Tubing, and Cable Fittings

PART 2 - PRODUCTS

2.1. CONDUCTORS AND CABLES

2.1.1. Conductors and cables shall be in accordance with NEMA, UL, as specified herein, and as shown on the drawings.

2.1.2. All conductors shall be copper.

2.1.3. Single Conductor and Cable:

2.1.3.1. No. 12 AWG: Minimum size, except where smaller sizes are specified herein or shown on the drawings.
2.1.3.2. No. 8 AWG and larger: Stranded.

2.1.3.3. No. 10 AWG and smaller: Solid; except shall be stranded for final connection to motors, transformers, and vibrating equipment.

2.1.4. Insulation: THHN-THWN and XHHW-2. XHHW-2 shall be used for isolated power systems.

2.2. **SPLICES**

2.2.1. Splices shall be in accordance with NEC and UL.

2.2.2. Above Ground Splices for No. 10 AWG and Smaller:

2.2.2.1. Solderless, screw on, reusable pressure cable type, with integral insulation, approved for copper and aluminum conductors.
2.2.2.2. The integral insulator shall have a skirt to completely cover the stripped conductors.
2.2.2.3. The number, size, and combination of conductors used with the connector, as listed on the manufacturer's packaging, shall be strictly followed.

2.2.3. Above Ground Splices for No. 8 AWG to No. 4/0 AWG:

2.2.3.1. Compression, hex screw, or bolt clamp type of high conductivity and corrosion resistant material, listed for use with copper and aluminum conductors.
2.2.3.2. Insulate with materials approved for the particular use, location, voltage, and temperature. Insulation level shall be not less than the insulation level of the conductors being joined.
2.2.3.3. Splice and insulation shall be product of the same manufacturer.
2.2.3.4. All bolts, nuts, and washers used with splices shall be cadmium-plated.

2.2.4. Above Ground Splices for 250 kcmil and Larger:

2.2.4.1. Long barrel “butt-splice” or “sleeve” type compression connectors, with minimum of two compression indents per wire, listed for use with copper and aluminum conductors.
2.2.4.2. Insulate with materials approved for the particular use, location, voltage, and temperature. Insulation level shall be not less than the insulation level of the conductors being joined.
2.2.4.3. Splice and insulation shall be product of the same manufacturer.

2.3. **CONNECTORS AND TERMINATIONS**

2.3.1. Mechanical type of high conductivity and corrosion resistant material, listed for use with copper and aluminum conductors.

2.3.2. Long barrel compression type of high conductivity and corrosion resistant material, with minimum of two compression indents per wire, listed for use with copper and aluminum conductors.

2.3.3. All bolts, nuts, and washers used to connect connections and terminations to bus bars or other termination points shall be cadmium-plated.

2.4. **CONTROL WIRING**

2.4.1. Unless otherwise specified elsewhere in these specifications, control wiring shall be as specified herein, except that the minimum size shall be not less than No. 14 AWG.

2.4.2. Control wiring shall be sized such that the voltage drop under in-rush conditions does not adversely affect operation of the controls.

2.5. **WIRE LUBRICATING COMPOUND**

2.5.1. Lubricating compound shall be suitable for the wire insulation and conduit, and shall not harden or become adhesive.

2.5.2. Shall not be used on conductors for isolated power systems.

PART 3 - EXECUTION

3.1. **GENERAL**

3.1.1. Install conductors in accordance with the CSEC, NEC, as specified, and as shown on the drawings.

3.1.2. Install all conductors in metallic conduits, unless specified otherwise. Where multiple conduits follow the same routing, provide raceway systems.

3.1.3. Splice conductors only in outlet boxes, junction boxes, pullboxes, manholes, or handholes.

3.1.4. Conductors of different systems (e.g., 120 V and 347 V) shall not be installed in the same raceway.

3.1.5. Install conduit supports for all vertical feeders in accordance with the NEC. Provide split wedge type which firmly clamps each individual cable and tightens due to cable weight.

3.1.6. In panelboards, cabinets, wireways, switches, enclosures, and equipment assemblies, neatly form, train, and tie the conductors with non-metallic ties.

3.1.7. For connections to motors, transformers, and vibrating equipment, stranded conductors shall be used only from the last fixed point of connection to the motors, transformers, or vibrating equipment.

3.1.8. Use expanding foam or non-hardening duct-seal to seal conduits entering a building or where penetrating building walls/floors, after installation of conduits.

3.1.9. Conductor and Cable Pulling:

3.1.9.1. Provide installation equipment that will prevent the cutting or abrasion of insulation during pulling. Use lubricants approved for the cable.
3.1.9.2. Use nonmetallic pull ropes.
3.1.9.3. Attach pull ropes by means of either woven basket grips or pulling eyes attached directly to the conductors.
3.1.9.4. All conductors in a single conduit shall be pulled simultaneously.
3.1.9.5. Do not exceed manufacturer’s recommended maximum pulling tensions and sidewall pressure values.
3.1.9.6. No more than three branch circuits shall be installed in any one conduit.
3.1.9.7. When stripping stranded conductors, use a tool that does not damage the conductor or remove conductor strands.

3.2. **SPLICE AND TERMINATION INSTALLATION**

3.2.1. Splices and terminations shall be mechanically and electrically secure, and tightened to manufacturer’s published torque values using a torque screwdriver or wrench.

3.2.2. Where the Consultant determines that unsatisfactory splices or terminations have been installed, replace the splices or terminations at no additional cost to the Board.

3.3. **CONDUCTOR IDENTIFICATION**

3.3.1. When using colored tape to identify phase, neutral, and ground conductors larger than No. 8 AWG, apply tape in half-overlapping turns for a minimum of 75 mm (3 inches) from terminal points, and in junction boxes, pullboxes, and manholes. Apply the last two laps of tape with no tension to prevent possible unwinding. Where cable markings are covered by tape, apply tags to cable, stating size and insulation type.

3.4. **FEEDER CONDUCTOR IDENTIFICATION**

3.4.1. In each interior pullbox, install brass tags on all feeder conductors to clearly designate their circuit identification and voltage. The tags shall be the embossed type, 40 mm (1-1/2 inches) in diameter and 40 mils thick. Attach tags with plastic ties.

3.5. **EXISTING CONDUCTORS**

3.5.1. Unless specifically indicated on the plans, existing conductors shall not be reused.

3.6. **CONTROL WIRING INSTALLATION**

3.6.1. Unless otherwise specified in other sections, install control wiring and connect to equipment to perform the required functions as specified or as shown on the drawings.

3.6.2. Install a separate power supply circuit for each system, except where otherwise shown on the drawings.

3.7. **CONTROL WIRING IDENTIFICATION**

3.7.1. Install a permanent wire marker on each wire at each termination.

3.7.2. Identifying numbers and letters on the wire markers shall correspond to those on the wiring diagrams used for installing the systems.

3.7.3. Wire markers shall retain their markings after cleaning.

3.8. **ACCEPTANCE CHECKS AND TESTS**

3.8.1. Perform in accordance with the manufacturer's recommendations. In addition, include the following:

3.8.1.1. Visual Inspection and Tests: Inspect physical condition.

3.8.2. Electrical tests:

3.8.2.1. After installation but before connection to utilization devices, such as fixtures, motors, or appliances, test conductors' phase-to-phase and phase-to-ground resistance with an insulation resistance tester. Existing conductors to be reused shall also be tested.

3.8.2.2. Applied voltage shall be 500 V DC for 300 V rated cable, and 1000 V DC for 600 V rated cable. Apply test for one minute or until reading is constant for 15 seconds, whichever is longer. Minimum insulation resistance values shall not be less than 25 megohms for 300 V rated cable and 100 megohms for 600 V rated cable.

3.8.2.3. Perform phase rotation test on all three-phase circuits

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PART 1 - GENERAL

1.1. **DESCRIPTION**

1.1.1. This section specifies the furnishing, installation, connection, and testing of grounding and bonding equipment, indicated as grounding equipment in this section.

1.1.2. “Grounding electrode system” refers to grounding electrode conductors and all electrodes required or allowed by CESC and NEC, as well as made, supplementary, and lightning protection system grounding electrodes.

1.1.3. The terms “connect” and “bond” are used interchangeably in this section and have the same meaning.

1.2. **RELATED WORK**

1.2.1. Section: 26 05 00 Common Work Results for Electrical.

1.2.2. Section: 26 05 19 Low-Voltage Electrical Power Conductors and Cables.

1.2.3. Section: 26 05 33 Raceway and Boxes for Electrical Systems.

1.2.4. Section: 26 24 19 Motor-Control Centers.

1.3. **QUALITY ASSURANCE**

1.3.1. Quality Assurance shall be in accordance with Section: 26 05 00 Common Work Results for Electrical.

1.4. **SUBMITTALS**

1.4.1. Submit in accordance with requirements of Section: 26 05 00 Common Work Results for Electrical, and the following requirements:

1.4.1.1. Shop Drawings:

1.4.1.1.1. Submit sufficient information to demonstrate compliance with drawings and specifications.

1.4.1.1.2. Submit plans showing the location of system grounding electrodes and connections, and the routing of aboveground and underground grounding electrode conductors.

1.4.1.2. Test Reports:

1.4.1.2.1. Two weeks prior to the final inspection, submit ground resistance field test reports to the Consultant

1.4.1.3. Certifications:

1.4.1.3.1. Certification by the Contractor that the grounding equipment has been properly installed and tested.

1.5. **APPLICABLE PUBLICATIONS**

1.5.1. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by designation only.

1.5.2. Canadian Standards Association (CSA)

1.5.2.1. CAN/CSA Standard C22.2 No.0.4-04(R2009) - Bonding of Electrical Equipment.
1.5.2.2. CAN/CSA Standard C22.2 No.41-07 - Grounding and Bonding Equipment (Bi-national standard, with UL 467).
1.5.2.3. Canadian and Ontario Electrical Safety Codes. (Latest Edition).

1.5.3. ANSI/TIA/EIA-607.

1.5.4. (CAN/CSA TS27) Best Practices for Ground and Bonding of Devices in Telecommunication Spaces.

1.5.5. Latest edition of IEEE Standard No. 80.

1.5.6. American Society for Testing and Materials (ASTM):

1.5.6.1. B1-13 Standard Specification for Hard-Drawn Copper Wire
1.5.6.2. B3-13 Standard Specification for Soft or Annealed Copper Wire
1.5.6.3. B8-11 Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

1.5.7. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

1.5.7.1. 81-12 IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part 1: Normal Measurements

1.5.8. National Fire Protection Association (NFPA):

1.5.8.1. 70-17 National Electrical Code (NEC)
1.5.8.2. 70E-15 National Electrical Safety Code

1.5.9. Underwriters Laboratories, Inc. (UL):

1.5.9.1. 44-14 Thermoset Insulated Wires and Cables
1.5.9.2. 83-14 Thermoplastic Insulated Wires and Cables
1.5.9.3. 467-13 Grounding and Bonding Equipment

PART 2 - PRODUCTS

2.1. **GROUNDING AND BONDING CONDUCTORS**

2.1.1. Install a complete, permanent and continuous system for earthling and grounding of networks, circuits and apparatus. The system shall include electrodes, conductor, connectors and required accessories on drawings to satisfy local authorities.

2.1.2. Install bonding/grounding connections from exposed non-current carrying metal parts of equipment including, but not necessarily limited to the following:

2.1.2.1. Frames of all motors.
2.1.2.2. All Starters.
2.1.2.3. Main Electrical Switchboards.
2.1.2.4. Medium Voltage Load Interrupter Switches.
2.1.2.5. Panelboards and Distribution Panels.
2.1.2.6. Isolations Switch(es).
2.1.2.7. Exterior mounted cable trays.
2.1.2.8. Raised floor pedestals.
2.1.2.9. Conductive Flooring.
2.1.2.10. Communication Rooms.
2.1.2.11. Transformers.
2.1.2.12. Transfer Switches.
2.1.2.13. Power Raceway System.
2.1.2.14. Generating equipment.

2.1.3. Install connectors according to manufacturer's recommendations.

2.1.4. Equipment grounding conductors shall be insulated stranded copper, except that sizes No. 10 AWG and smaller shall be solid copper. Insulation color shall be continuous green for all equipment grounding conductors, except that wire sizes No. 4 AWG and larger shall be identified per NEC.

2.1.5. Bonding conductors shall be bare stranded copper, except that sizes No. 10 AWG and smaller shall be bare solid copper. Bonding conductors shall be stranded for final connection to motors, transformers, and vibrating equipment.

2.1.6. Conductor sizes shall not be less than shown on the drawings, or not less than required by the NEC, whichever is greater.

2.1.7. Insulation: THHN-THWN and XHHW-2. XHHW-2 shall be used for isolated power systems.

2.2. GROUND RODS

2.2.1. Copper clad steel, 19 mm (0.75 inch) diameter by 3m (10 feet) long.

2.2.2. Quantity of rods shall be as required to obtain the specified ground resistance.

2.3. CONCRETE ENCASED ELECTRODE

2.3.1. Concrete encased electrode shall be No. 4 AWG bare copper wire, installed per NEC.

2.4. **GROUND CONNECTIONS**

2.4.1. Below Grade and Inaccessible Locations: Exothermic-welded type connectors.

2.4.2. Above Grade:

2.4.2.1. Bonding Jumpers: Listed for use with copper conductors. For wire sizes No. 8 AWG and larger, use compression-type connectors. For wire sizes smaller than No. 8 AWG, use mechanical type lugs. Connectors or lugs shall use zinc-plated steel bolts, nuts, and washers. Bolts shall be torqued to the values recommended by the manufacturer.

2.4.2.2. Connection to Building Steel: Exothermic-welded type connectors.

2.4.2.3. Connection to Grounding Bus Bars: Listed for use with aluminum and copper conductors. Use mechanical type lugs, with zinc-plated steel bolts, nuts, and washers. Bolts shall be torqued to the values recommended by the manufacturer.

2.4.2.4. Connection to Equipment Rack and Cabinet Ground Bars: Listed for use with aluminum and copper conductors. Use mechanical type lugs, with zinc-plated steel bolts, nuts, and washers. Bolts shall be torqued to the values recommended by the manufacturer.

2.5. **EQUIPMENT RACK AND CABINET GROUND BARS**

2.5.1. Provide solid copper ground bars designed for mounting on the framework of open or cabinet-enclosed equipment racks. Ground bars shall have minimum dimensions of 6.3 mm (0.25 inch) thick x 19 mm (0.75 inch) wide, with length as required or as shown on the drawings. Provide insulators and mounting brackets.

2.6. **GROUND TERMINAL BLOCKS**

2.6.1. At any equipment mounting location (e.g., backboards and hinged cover enclosures) where rack-type ground bars cannot be mounted, provide mechanical type lugs, with zinc-plated steel bolts, nuts, and washers. Bolts shall be torqued to the values recommended by the manufacturer.

2.7. **GROUNDING BUS BAR**

2.7.1. Pre-drilled rectangular copper bar with stand-off insulators, minimum 6.3 mm (0.25 inch) thick x100 mm (4 inches) high in cross-section, length as shown on the drawings, with hole size, quantity, and spacing per detail shown on the drawings. Provide insulators and mounting brackets.

PART 3 - EXECUTION

3.1. **GENERAL**

3.1.1. Installation shall be in accordance with the CEC, NEC, and manufacturer’s instructions.

3.1.2. System Grounding:

3.1.2.1. Secondary service neutrals: Ground at the supply side of the secondary disconnecting means and at the related transformer.

3.1.2.2. Separately derived systems (transformers downstream from the service entrance): Ground the secondary neutral.

3.1.2.3. Equipment Grounding: Metallic piping, building structural steel, electrical enclosures, raceways, junction boxes, outlet boxes, cabinets, machine frames, and other conductive items in close proximity with electrical circuits, shall be bonded and grounded.

3.2. **INACCESSIBLE GROUNDING CONNECTIONS**

3.2.1. Make grounding connections, which are normally buried or otherwise inaccessible, by exothermic weld.

3.3. **SECONDARY VOLTAGE EQUIPMENT AND CIRCUITS**

3.3.1. Main Bonding Jumper: Bond the secondary service neutral to the ground bus in the service equipment.

3.3.2. Metallic Piping, Building Structural Steel, and Supplemental Electrode(s):

3.3.2.1. Provide a grounding electrode conductor sized per CESC and NEC between the service equipment ground bus and all metallic water pipe systems, building structural steel, and supplemental or made electrodes. Provide jumpers across insulating joints in the metallic piping.

3.3.2.2. Provide a supplemental ground electrode to bond to the grounding electrode system.

3.3.3. Switchgear, Switchboards, Unit Substations, Panelboards, Motor Control Centers, Engine-Generators, Automatic Transfer Switches, and other electrical equipment:

3.3.3.1. Connect the equipment grounding conductors to the ground bus.

3.3.3.2. Connect metallic conduits by grounding bushings and equipment grounding conductor to the equipment ground bus.

3.3.4. Transformers:

3.3.4.1. Exterior: Exterior transformers supplying interior service equipment shall have the neutral grounded at the transformer secondary. Provide a grounding electrode at the transformer.

3.3.4.2. Separately derived systems (transformers downstream from service equipment): Ground the secondary neutral at the transformer. Provide a grounding electrode conductor from the transformer to the nearest suitable component of the grounding electrode system.

3.4. **RACEWAY**

3.4.1. Conduit Systems:

3.4.1.1. Ground all metallic conduit systems. All metallic conduit systems shall contain an equipment grounding conductor.

3.4.1.2. Nonmetallic conduit systems, except non-metallic feeder conduits that carry a grounded conductor from exterior transformers to interior or building-mounted service entrance equipment, shall contain an equipment grounding conductor.

3.4.1.3. Metallic conduit that only contains a grounding conductor, and is provided for its mechanical protection, shall be bonded to that conductor at the entrance and exit from the conduit.

3.4.1.4. Metallic conduits which terminate without mechanical connection to an electrical equipment housing by means of locknut and bushings or adapters, shall be provided with grounding bushings. Connect bushings with a equipment grounding conductor to the equipment ground bus.

3.4.2. Feeders and Branch Circuits: Install equipment grounding conductors with all feeders, and power and lighting branch circuits.

3.4.3. Boxes, Cabinets, Enclosures, and Panelboards:

3.4.3.1. Bond the equipment grounding conductor to each pullbox, junction box, outlet box, device box, cabinets, and other enclosures through which the conductor passes (except for special grounding systems for intensive care units and other critical units shown).

3.4.3.2. Provide lugs in each box and enclosure for equipment grounding conductor termination.

3.4.4. Wireway Systems:

3.4.4.1. Bond the metallic structures of wireway to provide electrical continuity throughout the wireway system, by connecting a No. 6 AWG bonding jumper at all intermediate metallic enclosures and across all section junctions.

3.4.4.2. Install insulated No. 6 AWG bonding jumpers between the wireway system, bonded as required above, and the closest building ground at each end and approximately every 16 M (50 feet).

3.4.4.3. Use insulated No. 6 AWG bonding jumpers to ground or bond metallic wireway at each end for all intermediate metallic enclosures and across all section junctions.

3.4.4.4. Use insulated No. 6 AWG bonding jumpers to ground cable tray to column-mounted building ground plates (pads) at each end and approximately every 15 M (49 feet).

3.4.4.5. Receptacles shall not be grounded through their mounting screws. Ground receptacles with a jumper from the receptacle green ground terminal to the device box ground screw and a jumper to the branch circuit equipment grounding conductor.

3.4.5. Ground lighting fixtures to the equipment grounding conductor of the wiring system. Fixtures connected with flexible conduit shall have a green ground wire included with the power wires from the fixture through the flexible conduit to the first outlet box.

3.4.6. Fixed electrical appliances and equipment shall be provided with a ground lug for termination of the equipment grounding conductor.

3.5. **OUTDOOR METALLIC FENCES AROUND ELECTRICAL EQUIPMENT**

3.5.1. Fences shall be grounded with a ground rod at each fixed gate post and at each corner post.

3.5.2. Drive ground rods until the top is 300 mm (12 inches) below grade. Attach a No. 4 AWG copper conductor by exothermic weld to the ground rods, and extend underground to the immediate vicinity of fence post. Lace the conductor vertically into 300 mm (12 inches) of fence mesh and fasten by two approved bronze compression fittings, one to bond the wire to post and the other to bond the wire to fence. Each gate section shall be bonded to its gatepost by a 3 mm x 25 mm (0.375 inch x 1 inch) flexible, braided copper strap and ground post clamps. Clamps shall be of the anti-electrolysis type.

3.6. **CORROSION INHIBITORS**

3.6.1. When making grounding and bonding connections, apply a corrosion inhibitor to all contact surfaces. Use corrosion inhibitor appropriate for protecting a connection between the metals used.

3.7. **CONDUCTIVE PIPING**

3.7.1. Bond all conductive piping systems, interior and exterior, to the grounding electrode system. Bonding connections shall be made as close as practical to the equipment ground bus.

3.7.2. In operating rooms and at intensive care and coronary care type beds, bond the medical gas piping and medical vacuum piping at the outlets directly to the patient ground bus.

3.8. **MAIN ELECTRICAL ROOM GROUNDING**

3.8.1. Provide ground bus bar and mounting hardware at each main electrical room where incoming feeders are terminated, as shown on the drawings. Connect to pigtail extensions of the building grounding ring, as shown on the drawings.

3.9. **GROUND RESISTANCE**

3.9.1. Grounding system resistance to ground shall not exceed 5 ohms. Make any modifications or additions to the grounding electrode system necessary for compliance without additional cost to the Government. Final tests shall ensure that this requirement is met.

3.9.2. Grounding system resistance shall comply with the electric utility company ground resistance requirements.

3.10. **GROUND ROD INSTALLATION**

3.10.1. For outdoor installations, drive each rod vertically in the earth, until top of rod is 610 mm (24 inches) below final grade.

3.10.2. For indoor installations, leave 100 mm (4 inches) of each rod exposed.

3.10.3. Where buried or permanently concealed ground connections are required, make the connections by the exothermic process, to form solid metal joints. Make accessible ground connections with mechanical pressure-type ground connectors.

3.10.4. Where rock or impenetrable soil prevents the driving of vertical ground rods, install angled ground rods or grounding electrodes in horizontal trenches to achieve the specified ground resistance.

3.11. **ACCEPTANCE CHECKS AND TESTS**

3.11.1. Resistance of the grounding electrode system shall be measured using a four-terminal fall-of-potential method as defined in IEEE 81. Ground resistance measurements shall be made before the electrical distribution system is energized or connected to the electric utility company ground system, and shall be made in normally dry conditions not fewer than 48 hours after the last rainfall.

3.11.2. Resistance measurements of separate grounding electrode systems shall be made before the systems are bonded together. The combined resistance of separate systems may be used to meet the required resistance, but the specified number of electrodes must still be provided.

3.11.3. Below-grade connections shall be visually inspected by the Consultant prior to backfilling. The Contractor shall notify the Consultant 24 hours before the connections are ready for inspection

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PART 1 - GENERAL

1.1. RELATED SECTIONS

1.1.1. Section: 26 05 00 Common Work Results for Electrical.

1.1.2. Section: 26 05 26 Grounding and Bonding for Electrical Systems.

1.1.3. Section: 26 24 13 Switchboards.

1.1.4. Section: 26 28 16.02 Moulded Case Circuit Breakers.

1.1.5. Section: 26 29 10 Motor Starters to 600 V.

1.2. REFERENCES

1.2.1. ANSI/IEEE 242-2001, Recommended practice for protection and coordination of commercial power systems.

1.2.2. ANSI Z535 SERIES 2011, Safety color code –environmental facility safety signs – criteria for safety symbols – product safety sign & labels and accident prevention tags.

1.2.3. ANSI/NETA ATS 2015: Electrical Acceptance Testing Specifications for electrical power equipment and systems.

1.2.4. NFPA 70E-2015, Standard for Electrical Safety in the Work Place.

1.2.5. ANSI/IEEE 1584-2002, Guide for performing Arc Flash Hazard Calculations.

1.2.6. Canadian Electrical Code 2015.

1.2.7. Ontario Electrical Safety Code 2012.

1.2.8. CAN/CSA Standard Z462-15, Workplace Electrical Safety.

1.2.9. ANSI/IEEE Standard 242-1986 Recommended practice for protection and coordination of commercial power system most current Edition.

1.2.10. ANSI/IEEE Standard 399-1997 Recommended practice for power system analysis most current Edition.

1.2.11. NEMA Standard ATS 2015: Electrical Acceptance Testing Specification for electrical power equipment and distribution system most current Edition.

1.2.12. IEEE STD-1584 Guide for performing Shock and Arc Flash Hazard Calculations most current Edition.

1.3. SUBMITTALS

1.3.1. Provide all studies as required by code and as outlined within this specification section. The studies shall cover all electrical distribution systems and all of the various modes of operation of the electrical distribution systems.

1.3.2. Submit the Studies to the Consultant for review.

1.3.3. Provide all clarifications as requested by the Consultant.

1.3.4. Re-submit studies, incorporating all clarifications, to the Consultant upon request.

1.3.5. The Short Circuit, System Protection & Coordination and Arc Flash Hazard Studies shall be completed and the consultant review process finalized prior to any electrical equipment being manufactured, ordered and delivered to the project.

1.4. **CLOSEOUT SUBMITTALS**

1.4.1. On completion of the calibration and testing, a full report shall be prepared by the testing specialists and submitted to the Consultant for review, comments and approval.

1.4.2. Upon completion of the project and as part of the building occupancy requirements the electrical Contractor shall conduct a complete thermo infrared scan of the entire electrical distribution systems. The timing of this scan shall be coordinated with the Construction Manager.

1.5. **SCOPE OF WORK**

1.5.1. The Short Circuit, System Protection & Coordination and Arc Flash Hazard Studies shall be completed for all distribution systems including each 120/208V panel.

1.5.2. The following minimum Utility Design Fault Levels shall be used in completion of the studies:

1.5.2.1. 4,160 volts the minimum Design Fault Level to be used is 500 MVA.
1.5.2.2. 13,800 volts the minimum Design Fault Level to be used is 500 MVA.
1.5.2.3. 27,600 volts the minimum Design Fault Level to be used is 835 MVA.
1.5.2.4. 44,000 volts the minimum Design Fault Level to be used is 1500 MVA.

1.5.3. The Professional Engineer completing the studies to confirm the Design Fault Levels with the Local Power Utility. The above is the minimum that shall be used in the completion of the studies.

1.5.4. The LEE Method of calculation for Shock and Arc Fault shall be employed where the Utility Grid incoming power is above 15,000 volts.

1.5.5. The power system(s) Short Circuit; Protection and Coordination; Shock and Arc Flash Studies shall be completed by a Professional Engineer specializing in this field. All information required to complete these studies shall be obtained through formal requests to related Trade(s) such as the Electrical and Mechanical Contractors, Local Power Utility and manufacturers supplying the equipment.

1.5.6. Once the required Short Circuit; Protection and Coordination and Shock and Arc Flash Studies have been completed and submitted for review by the Consultant and clarification have been provided and the reviewed Studies have been acknowledged by the Consultant. The recommendations shall be implemented by the Electrical Contractor and a letter confirming that the implementation of the recommendations have been completed shall be submitted by the Electrical Contractor to the Consultant.

1.5.7. No exceptions shall be permitted with respect to these required studies.

1.6. **ACCEPTABLE MANUFACTURER**

1.6.1. Schneider Electric Canada.

1.6.2. Eaton Electrical.

1.6.3. Siemens Canada.

PART 2 - PRODUCTS

2.1. **DESCRIPTION OF WORK**

2.1.1. This Electrical Contractor shall provide all studies as required by code and as outlined within this specification section. The studies shall cover all electrical distribution systems and all of the various modes of operation of the electrical distribution systems.

2.1.2. No electrical distribution equipment shop drawings for any of the electrical distribution systems will be processed by the Consultant prior to the required studies being submitted and the review process for the studies completed. Should the Electrical Contractor order any or all of the electrical distribution equipment they do so at their own risk. Should changes be required to be made to any or all of the distribution equipment the Electrical Contractor will cover all costs.

2.1.3. It is important that all requests to related trades such as mechanical, equipment suppliers be completed and information obtained in less than 10 working days of commencing of the contract.

2.1.4. No assumption shall be made where it is possible to obtain the information from the manufacturer and equipment suppliers regarding impedances, protective device time current curves and cable lengths, type and size from the site contractors.

2.1.5. The Electrical Contractor to provide the following information to the Professional Engineer completing the studies:

2.1.5.1. Cable/feeder types and cable lengths.
2.1.5.2. Obtain and provide all of the required electrical equipment data from the electrical equipment vendor(s).
2.1.5.3. Obtain and provide all of the required electrical equipment data from the Generator.
2.1.5.4. Obtain and provide all of the required electrical equipment data from the UPS vendor(s).
2.1.5.5. Obtain and provide all of the required electrical equipment data from the Transformers (Power and Distribution transformers) vendor(s).
2.1.5.6. Obtain and provide all Protective Device co-ordination curves.
2.1.5.7. Obtain and provide all Protective Device Ground Fault curves.
2.1.5.8. Obtain and provide all Damage Curves for electrical and mechanical equipment and cables.
2.1.5.9. Obtain and provide all required electrical data for Elevators.
2.1.5.10. Obtain and provide all required electrical data for Mechanical equipment.
2.1.5.11. Other data as required and requested by the Professional Engineer completing the studies.

2.1.6. The studies will be required to be updated and resubmitted to the Consultant once the Electrical Contractor has finalized all of his actual electrical cable types and feeder lengths.

2.1.7. These studies are of high important and shall be completed and submitted within thirty (30) working days after the letter of intent has been issued to the Electrical Contractor.

2.2. **SYSTEM PROTECTION AND CO-ORDINATION**

2.2.1. Retain one of the designated testing companies who specialize in this type of work to prepare an equipment coordination and protective study and schedule for all protective devices in the system in cooperation with suppliers of all pertinent Electrical Distribution Equipment and include the cost of these services in the Tender Price.

2.2.2. The firm of testing specialists shall be responsible for calculating short circuit kA rating, checking, adjusting, calibration and setting up of protective devices in accordance with the values shown in the reviewed coordination study under this contract.

2.2.3. Coordinate the relays, breakers and fuses to provide selective tripping or blowing.

2.2.4. Coordinate the breakers, fuses, protective relaying and ground fault protection so that the breaker or fuse immediately ahead of a fault will trip or blow clearing the fault and leaving the system ahead of the tripped or blown protective device in the normal operating mode the study must also address the other distribution system modes of operation.

2.2.5. The curves shall be accompanied by the individual time current curves of each device to enable the verification of the ratings and settings used. These coordination curves shall be submitted for review and the various ratings and settings shall be made by the manufacturer before the equipment is shipped. Review of these coordination curves will not eliminate the responsibility of the Electrical Contractor to provide correct protection and coordination.

2.2.6. Co-ordination curves shall be plotted showing the following:

2.2.6.1. Supply Authority's relays or fuses protecting the incoming service. This information shall be obtained directly from the Local Utility.
2.2.6.2. Main and feeder protection devices at every voltage level.
2.2.6.3. Main and feeder protection devices ground fault curves at every voltage levels.
2.2.6.4. Protection devices associated with the largest motor or refrigeration compressor
2.2.6.5. Protection devices associated with the emergency power distribution system; and the UPS power distribution systems and showing all fault levels.

2.2.7. Each co-ordination time-current curve shall include:

2.2.7.1. A single line diagram for the portion of the system involved.
2.2.7.2. Transformer and cable damage curves where applicable.
2.2.7.3. Available fault current level on the portion of the system involved.
2.2.7.4. Ground fault curves.
2.2.7.5. Generator fault and damage curves where applicable.

2.2.8. Protection and Coordination curves shall be submitted as part of a report outlining the protection and coordination procedures, final breaker and relay settings and fuse ratings for the entire power distribution system(s) and modes of operation. The report shall clearly list all the breakers with their tag and final settings even if there are identical systems on the project. I.e. information about the same settings can be duplicated if applicable with breaker in different locations. This list will be checked, sealed and signed-off by the professional engineer who prepared and completed the studies.

2.2.9. Co-ordinate with the electrical equipment vendors; mechanical equipment vendors and manufacturer of the refrigeration and elevator equipment and obtain the recommended settings on protection devices (re: breaker and overloads). Incorporate this information on the associated studies.

2.2.10. The goal of this portion of the study is to achieve selective protection and coordination of protective devices including ground fault and to reduce the Shock and Arc Flash levels to within “Category 2” where possible. All transformers over 75 KVA will be provided with a Solid State Circuit Breaker, LSI type.

2.3. **SHOCK AND ARC FLASH HAZARDS**

2.3.1. This portion of the study shall be prepared and completed by a professional engineer who has been working in this area for at least five (5) years. The study shall be based on power distribution systems diagrams and the various power distribution operating modes.

2.3.2. The Electrical Contractor shall obtain and provide all required information as required for the study to be completed.

2.3.3. The study and the report shall provide a full summary of the Shock and Arc flash hazard. The completion of the study shall with compliance with CAN/CSA Z462-15 or latest edition and related standards and methods established in the industry.

2.3.4. The IEEE-1584 must be used for the calculation of the incident energy.

2.3.5. The study will ensure that worst case hazards are identified. This means that Arc Flash Energy is calculated at the maximum fault and to include overloads conditions where applicable.

2.3.6. The study to cover all electrical distributed equipment and distribution systems operating modes and voltage levels within the facility and site as well as the main incoming service to the building(s) and site.

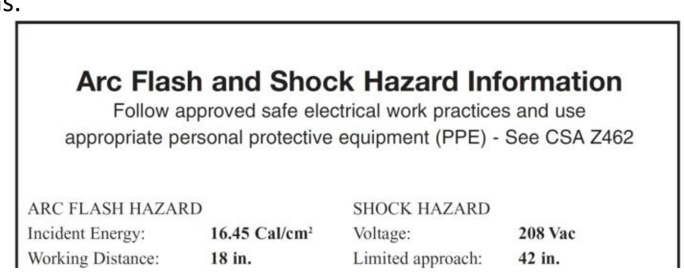
2.3.7. The study will identify the arc flash boundaries, and incident energy at suggested distance of working. Determination of system operating modes and conditions that can impact short circuit currents and arc flash hazard energy levels shall be identified well in advance and shall be conveyed to the Consultant for confirmation.

2.3.8. The study will clearly state any assumptions made for arc-fault currents. L-G ground fault and L-L-L. The worst case scenario(s) shall be reflected in the reported as minimum requirement.

2.3.9. Arc-Flash labels shall be created and installed on each piece of electrical distribution equipment for all electrical distribution systems.

2.3.10. The labels shall be per ANSI Z535. The labels shall identify the hazard level and protective clothing required.

2.3.11. The Label below is an example, required detail of what is to be on the label is reflected below. A separate label shall be provided for each piece of the electrical distribution systems.


Arc Flash and Shock Hazard Information
Follow approved safe electrical work practices and use appropriate personal protective equipment (PPE) - See CSA Z462

ARC FLASH HAZARD		SHOCK HAZARD	
Incident Energy:	**16.45 Cal/cm²**	Voltage:	**208 Vac**
Working Distance:	**18 in.**	Limited approach:	**42 in.**

2.3.12. At least one 8-hour days of training shall be provided to the staff employed at the facility to explain meaning of labels and protective equipment, and work permits for energized work. This is to ensure the implementation of the safety program that addresses the following as a minimum:

2.3.12.1. Ministry of Labour Requirements.
2.3.12.2. Personal Protective Equipment.
2.3.12.3. Understanding of the Shock and Arc Flash Categories.
2.3.12.4. Electrical equipment labeling requirements.

2.3.13. Development of local Standard Operating Procedures (SOPs).

2.3.13.1. Lock out and Tag Out.
2.3.13.2. Remote switching of equipment.

PART 3 - EXECUTION

3.1. EXECUTION

3.1.1. On completion of the calibration and testing, a full report shall be prepared by the testing specialists and submitted to the Consultant for review, comments and acceptance.

3.1.2. The report shall confirm that all protective devices have been adjusted and set in accordance with the protection and coordination study and that the protective systems provide the necessary degree of selective protection as well as selective ground fault protection.

3.1.3. The report shall include tabulation of settings and/or rating of all protective devices.

3.1.4. Each protective device shall be labelled with the proper setting for the device. Labels shall be installed or marked on the protective device behind glass windows. Fusible devices shall be labeled showing the size, type and current rating of the fuse element.

3.1.5. The firm conducting the protection and coordination study shall conduct on-site verification testing to ensure that all relays, breaker settings and fuse sizing has been set in accordance with the coordination study recommendations, and all Shock and Arc Flash Labels have been installed.

3.1.6. The facility Owner reserves the right to retain the services of an independent testing company to monitor, review and verify the results of the test report submitted by the Electrical Contractor.

3.1.7. Provide the services of electricians to assist in equipment tests performed by the independent testing companies appointed by the Departmental Representative, including thermo graphic (infrared) testing of bus bar joints and contacts of circuit breakers, etc. Remove cover plates, etc. to enable testing company to gain access to the equipment.

3.1.8. The Electrical Contractor shall be responsible to co-ordinate with equipment manufacturers to ensure that the equipment is furnished with protection as recommended in the co-ordination study.

3.1.9. It is to be expected that these studies will need to be updated several times prior to being accepted by the Consultant.

3.1.10. Be responsible to co-ordinate with equipment manufacturers to ensure that the equipment is furnished with protection as recommended in the co-ordination study.

3.1.11. On completion of the calibration and testing, a full report shall be prepared and submitted to the Consultant for review, comments and approval.

3.1.12. Testing in accordance with ANSI/NETA ATS-2015.

3.1.13. The report shall confirm that all protective devices have been adjusted and set in accordance with the protection and coordination study and that the protective systems provide the necessary degree of selective protection as well as selective ground fault protection.

3.1.14. The report shall include tabulation of settings and/or rating of all protective devices.

3.1.15. Each protective device shall be labelled with the proper setting for the device. Labels shall be installed or marked on the protective device behind glass windows. Fusible devices shall be labelled showing the size, type and current rating of the fuse element.

3.1.16. Conduct on-site verification to ensure that all relays, breaker settings and fuse sizing have been set in accordance with the coordination study recommendations.

3.1.17. Verify that all Arc Flash and Shock Hazard Warning Labels have been installed.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section specifies the furnishing, installation, connection, and testing of low-voltage dry-type general-purpose transformers, indicated as transformers in this section.

1.2. RELATED WORK

1.2.1. Section 26 05 11

1.2.2. Section 26 05 19

1.2.3. Section 26 05 33

1.3. QUALITY ASSURANCE

1.3.1. Quality Assurance shall be in accordance with Section 26 05 11, COMMON RESULTS – ELECTRICAL WORK.

1.4. SUBMITTALS

1.4.1. Shop Drawings

1.4.1.1. Include electrical ratings, dimensions, mounting details, materials, required clearances, terminations, weight, temperature rise, wiring and connection diagrams, plan, front, side, and rear elevations, accessories, and device nameplate data.

1.4.2. Manuals

1.4.2.1. Submit, simultaneously with the shop drawings, companion copies of complete maintenance and operating manuals including technical data sheets and wiring diagrams.
1.4.2.2. Schematic signal and control diagrams, with all terminals identified, matching terminal identification in the transformers.
1.4.2.3. Include information for testing, repair, troubleshooting, assembly, disassembly, and factory recommended/required periodic maintenance procedures and frequency.
1.4.2.4. Certifications: Two weeks prior to final inspection, submit the following.
1.4.2.5. Certification by the manufacturer that the transformers conform to the requirements of the drawings and specifications.
1.4.2.6. Certification by the Contractor that the transformers have been properly installed, adjusted, and tested.

PART 2 - PRODUCTS

2.1. **TRANSFORMERS**

2.1.1. Unless otherwise specified, transformers shall be in accordance with CESC, NEMA, NFPA, UL and as shown on the drawings.

2.1.2. Transformers shall have the following features:

2.1.2.1. Self-cooled by natural convection, isolating windings, dry-type. Rating and winding connections shall be as shown on the drawings.
2.1.2.2. Ratings shown on the drawings are for continuous duty without the use of cooling fans.
2.1.2.3. Copper windings.

2.1.3. Insulation systems:

2.1.3.1. Transformers 30 kVA and larger: UL rated 220 °C (428 °F) system with an average maximum rise by resistance of 150 °C (302 °F) in a maximum ambient of 40 °C (104 °F).
2.1.3.2. Transformers below 30 kVA: Same as for 30 kVA and larger or UL rated 185 °C (365 °F) system with an average maximum rise by resistance of 115 °C (239 °F) in a maximum ambient of 40 °C (104 °F).

2.1.4. Core and coil assemblies:

2.1.4.1. Rigidly braced to withstand the stresses caused by short-circuit currents and rough handling during shipment.
2.1.4.2. Cores shall be grain-oriented, non-aging, and silicon steel.
2.1.4.3. Coils shall be continuous windings without splices except for taps.
2.1.4.4. Coil loss and core loss shall be minimized for efficient operation.
2.1.4.5. Primary and secondary tap connections shall be brazed or pressure type.
2.1.4.6. Coil windings shall have end filters or tie-downs for maximum strength.
2.1.4.7. Average audible sound levels shall comply with NEMA.
2.1.4.8. If not shown on drawings, nominal impedance shall be as permitted by NEMA.
2.1.4.9. Single phase transformers rated 15 kVA through 25 kVA shall have two 5% full capacity taps below normal rated primary voltage. All transformers rated 30 kVA and larger shall have two 2.5% full capacity taps above, and four 2.5% full capacity taps below normal rated primary voltage.
2.1.4.10. Core assemblies shall be grounded to their enclosures with adequate flexible ground straps.

2.1.5. Enclosures:

2.1.5.1. Comprised of not less than code gauge steel.
2.1.5.2. Outdoor enclosures shall be NEMA 3R.

2.1.5.3. Temperature rise at hottest spot shall conform to NEMA Standards, and shall not bake and peel off the enclosure paint after the transformer has been placed in service.

2.1.5.4. Ventilation openings shall prevent accidental access to live components.

2.1.5.5. The enclosure at the factory shall be thoroughly cleaned and painted with manufacturer's prime coat and standard finish.

2.1.5.6. Standard NEMA features and accessories, including ground pad, lifting provisions, and nameplate with the wiring diagram and sound level indicated.

2.1.5.7. Dimensions and configurations shall conform to the spaces designated for their installations.

2.1.6. Standard of Acceptance:

2.1.6.1. Eaton

2.1.6.2. Cutler Hammer

2.1.6.3. General Electric

PART 3 - EXECUTION

3.1. **INSTALLATION**

3.1.1. Installation of transformers shall be in accordance with the CEC, NEC, as recommended by the equipment manufacturer and as shown on the drawings.

3.1.2. Anchor transformers with rustproof bolts, nuts, and washers, in accordance with manufacturer’s instructions, and as shown on drawings.

3.1.3. Exterior Location: Mount transformers on concrete slab. Unless otherwise indicated, the slab shall be at least 200 mm (8 inches) thick, reinforced with a 150 by 150 mm (6 by 6 inches) No. 6 mesh placed uniformly 100 mm (4 inches) from the top of the slab. Slab shall be placed on a 150 mm (6 inches) thick, well-compacted gravel base. The top of the concrete slab shall be approximately 100 mm (4 inches) above the finished grade. Edges above grade shall have 15 mm (1/2 inch) chamfer. The slab shall be of adequate size to project at least 200 mm (8 inches) beyond the equipment. Provide conduit turn-ups and cable entrance space required by the equipment to be mounted. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant. Cut off and bush conduits 75 mm (3 inches) above slab surface.

3.1.4. Install transformers with manufacturer's recommended clearance from wall and adjacent equipment for air circulation. Minimum clearance shall be 150 mm (6 inches).

3.1.5. Install transformers on vibration pads designed to suppress transformer noise and vibrations.

3.2. **ACCEPTANCE CHECKS AND TESTS**

3.2.1. Perform tests in accordance with the manufacturer's recommendations. In addition, include the following:

3.2.1.1. Visual Inspection and Tests.
3.2.1.2. Compare equipment nameplate data with specifications and approved shop drawings.
3.2.1.3. Inspect physical and mechanical condition.
3.2.1.4. Inspect all field-installed bolted electrical connections, using the calibrated torque-wrench method to verify tightness of accessible bolted electrical connections.
3.2.1.5. Perform specific inspections and mechanical tests as recommended by manufacturer.
3.2.1.6. Verify correct equipment grounding.
3.2.1.7. Verify proper secondary phase-to-phase and phase-to-neutral voltage after energization and prior to connection to loads.

3.3. **FOLLOW-UP VERIFICATION**

3.3.1. Upon completion of acceptance checks, settings, and tests, the contractor shall demonstrate that the transformers are in good operating condition, and properly performing the intended function.

TABLE OF CONTENTS

PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section specifies the furnishing, installation, connection, and testing of the low-voltage circuit-breaker distribution panels/load centers.

1.2. FACTORY TESTS

1.2.1. Distribution panels/load centers shall be thoroughly tested at the factory to assure that there are no electrical or mechanical defects. Tests shall be conducted as per NEMA PB 2. Factory tests shall be certified.

1.2.2. The following additional tests shall be performed:

1.2.2.1. Verify that circuit breaker sizes and types correspond to drawings,
1.2.2.2. Verify tightness of bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
1.2.2.3. Exercise all active components.

1.3. SUBMITTALS

1.3.1. Submit the following:

1.3.1.1. Shop Drawings:
1.3.1.1.1. Complete electrical ratings.
1.3.1.1.2. Circuit breaker sizes.
1.3.1.1.3. Interrupting ratings.
1.3.1.1.4. Safety features.
1.3.1.1.5. Accessories and nameplate data.
1.3.1.1.6. Switchboard one line diagram, showing ampere rating, number of bars per phase and neutral in each bus run (horizontal and vertical), bus spacing, equipment ground bus, and bus material.
1.3.1.1.7. Elementary and interconnection wiring diagrams.
1.3.1.1.8. Technical data for each component.
1.3.1.1.9. Dimensioned exterior views of the switchboard.
1.3.1.1.10. Dimensioned section views of the switchboard.
1.3.1.1.11. Floor plan of the switchboard.
1.3.1.1.12. Foundation plan for the switchboard.
1.3.1.1.13. Provisions and required locations for external conduit and wiring entrances.
1.3.1.1.14. Approximate design weights.
1.3.1.2. Manuals:

1.3.1.2.1. Submit, simultaneously with the shop drawings, companion copies of complete maintenance and operating manuals, including technical data sheets, wiring diagrams, and information for ordering replacement parts.

1.3.1.2.2. Schematic signal and control diagrams, with all terminals identified, matching terminal identification in the switchboard.

1.3.1.2.3. Include information for testing, repair, trouble shooting, assembly, disassembly, and factory recommended/required periodic maintenance procedures and frequency.

1.3.1.2.4. Provide a replacement and spare parts list. Include a list of tools and instruments for testing and maintenance purposes.

1.3.1.3. If changes have been made to the maintenance and operating manuals originally submitted, submit updated maintenance and operating manuals two weeks prior to the final inspection.

1.3.1.4. Certifications: Two weeks prior to final inspection, submit the following.

1.3.1.4.1. Certification by the manufacturer that the switchboards conform to the requirements of the drawings and specifications.

1.3.1.4.2. Certification by the Contractor that the switchboards have been properly installed, adjusted, and tested.

1.4. **APPLICABLE PUBLICATIONS**

1.4.1. Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by basic designation only.

1.4.2. Institute of Engineering and Electronic Engineers (IEEE):

1.4.2.1. C37.13-08 Low Voltage AC Power Circuit Breakers Used in Enclosures

1.4.2.2. C57.13-08 Instrument Transformers

1.4.2.3. C62.41.1-03 Surge Environment in Low-voltage (1000V and less) AC Power Circuits

1.4.2.4. C62.45-92 Surge Testing for Equipment connected to Low-Voltage AC Power Circuits

1.4.3. National Electrical Manufacturer's Association (NEMA):

1.4.3.1. PB-2-06 Deadfront Distribution Switchboards

1.4.3.2. PB-2.1-07 Proper Handling, Installation, Operation, and Maintenance of Deadfront Distribution Switchboards Rated 600 Volts or Less

1.4.4. National Fire Protection Association (NFPA):

1.4.4.1. 70-11 National Electrical Code (NEC)

1.4.5. Underwriters Laboratories, Inc. (UL):

1.4.5.1. 67-09 Panelboards

1.4.5.2. 489-09 Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures

1.4.5.3. 891-05 Switchboards

1.5. **STANDARD OF ACCEPTANCE**

1.5.1. Eaton

1.5.2. Siemens

1.5.3. Schneider Electric

1.5.4. General Electric

PART 2 - PRODUCTS

2.1. **GENERAL**

2.1.1. Voltage and phases: as noted on the drawings and equipment schedules.

2.1.2. Shall be in accordance with CSA C22.2 (#14), ANSI, IEEE, NEMA, NFPA, UL, as shown on the drawings, and have the following features:

2.1.2.1. Distribution panels/Load Centers shall be a complete, grounded, continuous duty, integral assembly, dead front, dead rear, self supporting, indoor type switchboard assembly. Incorporate devices shown on the drawings and all related components required to fulfill operational and functional requirements.

2.1.2.2. Ratings shall not be less than shown on the drawings.

2.1.2.3. Switchboard shall conform to the arrangements and details shown on the drawings.

2.1.2.4. Switchboards shall be assembled, connected, and wired at the factory so that only external circuit connections are required at the construction site. Split the structure only as required for shipping and installation. Packaging shall provide adequate protection against rough handling during shipment.

2.1.2.5. All non-current-carrying parts shall be grounded

2.2. **POWER AND DISTRIBUTION PANELS/LOAD CENTERS - FUSIBLE SWITCH TYPE**

2.2.1. Power and distribution panelboards shall be of the voltage and amperage shown, 3 phase, 4 wire, 200,000 amps AIC, dead front, fusible switch type, with main fused switch or main lugs only as shown, copper bus, fully rated neutral and ground bars, NEMA Type 1 enclosure and surface trim. Provide switches and Class R dual element fuses as shown.

2.2.2. Blank switch positions shall be fully bused and ready to accept future switches.

2.2.3. Bus and switch terminals shall be identified as accepting copper cables.

2.2.4. Enclosure shall be sized to provide adequate conduit knockout space and gutter wire bending space for future conduits and cables. When aluminum feeder cables are being used, oversize the enclosure for aluminum cables.

2.2.5. Door shall have concealed hinge, flush handle, lock, with 2 keys and panel directory frame. All panel locks shall be keyed alike.

2.3. **POWER AND DISTRIBUTION PANELS/LOAD CENTERS - CIRCUIT BREAKER TYPE**

2.3.1. Power and distribution panelboards shall be of the voltage and amperage shown, 3 phase, 4 wire, 50,000 amps AIC minimum, dead front, circuit breaker type, with main circuit breaker or main lugs only as shown, copper bus, fully rated neutral and ground bars, NEMA Type 1 enclosure and surface trim. Provide circuit breakers as shown.

2.3.2. Blank circuit breaker spaces shall be fully bused and ready to accept future circuit breakers.

2.3.3. Bus and circuit breaker terminals shall be identified as accepting copper cables.

2.3.4. Enclosure shall be sized to provide adequate conduit knockout space and gutter wire bending space for future conduits and cables.

2.3.5. Door shall have concealed hinge, flush handle, lock with 2 keys, and panel directory frame. All panel locks shall be keyed alike.

2.4. **LIGHTING AND RECEPTACLE PANELS/LOAD CENTERS**

2.4.1. Lighting and receptacle panels shall be of the voltage, amperage and number of positions shown, 3 phase, 4 wire, 22,000 amps AIC minimum unless shown otherwise, circuit breaker type, with main circuit breaker or main lugs only as shown, copper bus, fully rated neutral and ground bars, NEMA Type 1 enclosure and surface or flush trim as shown. In main circuit breaker panels, the main circuit breaker shall be separate from and not mounted in feeder breaker positions. Load center type panels are not acceptable. Provide circuit breakers as shown.

2.4.2. Bus and circuit breaker terminals shall be identified as accepting copper cables.

2.4.3. Enclosure shall be sized to provide adequate conduit knockout space and wire bending space for future conduits and cables.

2.4.4. Front cover shall be factory manufactured, UL/NRTL listed, one-piece, hinged "door-in-door" type with: Interior hinged door with hand-operated latch or latches as required to provide access to circuit breaker operating handles only; not energized parts. Outer hinged door to provide access to the entire closure including the dead front and all wiring gutters. Outer door shall be kept securely closed with factory bolts, screws, clips or other fasteners to the panel box, requiring a tool for entry; hand operated latches are not acceptable. Both inner and outdoor doors shall open left to right. Include one-piece, removable, inner dead front cover, independent of the panelboard cover. Door shall have concealed hinge, flush handle, lock with 2 keys and panel directory frame. All panel locks shall be keyed alike.

2.5. **HOUSING**

2.5.1. Shall have the following features:

2.5.1.1. Frames and enclosures:

2.5.1.1.1. The assembly shall be braced with reinforcing gussets using jig welds to assure rectangular rigidity.

2.5.1.1.2. The enclosure shall be steel, leveled, and not less than the gauge required by applicable publications.

2.5.1.1.3. Die-pierce the holes for connecting adjacent structures to ensure proper alignment, and to allow for future additions.

2.5.1.1.4. All bolts, nuts, and washers shall be cadmium-plated.

2.5.1.2. Finish:

2.5.1.2.1. All metal surfaces shall be thoroughly cleaned, phosphatized and factory primed prior to applying baked enamel or lacquer finish.

2.6. **BUSES**

2.6.1. Bus Bars and Interconnections:

2.6.1.1. Provide copper phase and neutral buses, fully rated for the amperage as shown on the drawings for the entire length of the switchboard. Bus laminations shall have a minimum of 6 mm (1/4 inch) spacing.

2.6.1.2. Mount the buses on appropriately spaced insulators and brace to withstand the available short circuit currents.

2.6.1.3. The bus and bus compartment shall be designed so that the acceptable NEMA standard temperature rises are not exceeded.

2.6.1.4. Install a copper ground bus the full length of the switchboard assembly.

2.6.1.5. Main Bonding Jumper: An un-insulated copper bus, size as shown on drawings, shall interconnect the neutral and ground buses, when the switchboard is used to establish the system common ground point.

2.6.1.6. All bolts, nuts, and washers shall be cadmium-plated steel. Bolts shall be torqued to the values recommended by the manufacturer.

2.6.1.7. Make provisions for future bus extensions by means of bolt holes or other approved method.

2.7. **MAIN CIRCUIT BREAKERS**

2.7.1. Provide molded case main circuit breakers as shown on the drawings. Circuit breakers shall be the solid state adjustable trip type.

2.7.2. Trip units shall have field adjustable tripping characteristics as follows:

2.7.2.1. Long time pickup.
2.7.2.2. Long time delay.
2.7.2.3. Short time pickup.
2.7.2.4. Short time delay.
2.7.2.5. Instantaneous.

2.7.3. Breakers with same frame size shall be interchangeable with each other.

2.7.3.1. General: Circuit breakers shall be dead front, drawout, stored energy type with solid state trip devices. Arcing contacts shall be renewable.
2.7.3.2. Rating: Circuit breakers shall be 3 pole, 600 V AC and below, 60 cycle with frame size, trip rating and functions, and system voltage as shown on drawings. Breakers shall have 30 cycle short time current ratings.
2.7.3.3. Drawout Mounting: Provide a racking mechanism to position and hold the breaker in the connected, test, or disconnected position. Provide an interlock to prevent movement of the breaker into or out of the connected position unless the breaker is tripped open.
2.7.3.4. Trip Devices: Breakers shall be electrically and mechanically trip free and shall have trip devices in each pole. Unless otherwise indicated on drawings, each breaker shall have overcurrent and short-circuit trip devices. Trip devices shall be of the solid state type with adjustable pick-up settings, with both long time and short time elements, and integral trip unit testing provisions. Devices shall have time-delay band adjustment. Long-time delay element shall have inverse time characteristics. Main circuit breakers shall not have instantaneous trip function.
2.7.3.5. Position Indicator: Provide a mechanical indicator visible from the front of the unit to indicate whether the breaker is open or closed.
2.7.3.6. Trip Button: Equip each breaker with a mechanical trip button accessible from the front of the door.
2.7.3.7. Padlocking: Provisions shall be included for padlocking the breaker in the open position.
2.7.3.8. Operation: Unless otherwise indicated herein or on the drawings, breakers shall be manually operated.

2.8. **FEEDER CIRCUIT BREAKERS**

2.8.1. Provide molded case circuit breakers as shown on the drawings.

2.8.2. Non-adjustable Trip Molded Case Circuit Breakers:

2.8.2.1. Molded case circuit breakers shall have automatic, trip free, non-adjustable, inverse time characteristics, and instantaneous magnetic trip.

2.8.3. Breaker features shall be as follows:

2.8.3.1. A rugged, integral housing of molded insulating material.
2.8.3.2. Silver alloy contacts.
2.8.3.3. Arc quenchers and phase barriers for each pole.
2.8.3.4. Quick make, quick break, operating mechanisms.
2.8.3.5. A trip element for each pole, thermal magnetic type with long time delay and instantaneous characteristics, a common trip bar for all poles and a single operator.
2.8.3.6. Electrically and mechanically trip free.
2.8.3.7. An operating handle which indicates ON, TRIPPED, and OFF positions.
2.8.3.8. Line and load connections shall be bolted.
2.8.3.9. An overload on one pole of a multipole breaker shall automatically cause all the poles of the breaker to open.

2.8.4. Adjustable Trip Molded Case Circuit Breakers:

2.8.4.1. Provide molded case, solid state adjustable trip type circuit breakers.

2.8.5. Trip units shall have field adjustable tripping characteristics as follows:

2.8.5.1. Long time pickup.
2.8.5.2. Long time delay.
2.8.5.3. Short time pickup.
2.8.5.4. Short time delay.
2.8.5.5. Instantaneous.

2.8.6. Breakers with same frame size shall be interchangeable with each other

2.9. **OTHER EQUIPMENT**

2.9.1. Furnish tools and accessories required for circuit breaker and switchboard test, inspection, maintenance, and proper operation.

2.10. **NAMEPLATES**

2.10.1. Nameplates: For Normal Power system, provide laminated black phenolic resin with white core with 12 mm (1/2 inch) engraved lettered nameplates next to each circuit breaker. For Essential Electrical System, provide laminated red phenolic resin with white core with 12 mm (1/2 inch) engraved lettered nameplates next to each circuit breaker. Nameplates shall indicate equipment served, spaces, or spares in accordance with one line diagram shown on drawings. Nameplates shall be mounted with plated screws on front of breakers or on equipment enclosure next to breakers. Mounting nameplates only with adhesive is not acceptable.

PART 3 - EXECUTION

3.1. INSTALLATION

3.1.1. Install switchboards in accordance with the CSA 22.2, CESC, NEC, as shown on the drawings, and as recommended by the manufacturer.

3.1.2. Anchor distribution panels/load centers with rustproof bolts, nuts, and washers not less than 13 mm (1/2 inch) diameter, in accordance with manufacturer’s instructions, and as shown on drawings.

3.1.3. Furnish a complete printed directory of all loads fed from each distribution panel/load center.

3.2. ACCEPTANCE CHECKS AND TESTS

3.2.1. Perform in accordance with the manufacturer's recommendations. In addition, include the following:

3.2.1.1. Visual Inspection and Tests:

3.2.1.1.1. Compare equipment nameplate data with specifications and approved shop drawings.
3.2.1.1.2. Inspect physical, electrical, and mechanical condition.
3.2.1.1.3. Verify appropriate anchorage, required area clearances, and correct alignment.
3.2.1.1.4. Verify that circuit breaker sizes and types correspond to approved shop drawings.
3.2.1.1.5. Verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey after energization.
3.2.1.1.6. Vacuum-clean switchboard enclosure interior. Clean switchboard enclosure exterior.
3.2.1.1.7. Inspect insulators for evidence of physical damage or contaminated surfaces.
3.2.1.1.8. Verify correct shutter installation and operation.
3.2.1.1.9. Exercise all active components.

3.2.1.1.10. Verify the correct operation of all sensing devices, alarms, and indicating devices.

3.2.1.2. Verify that vents are clear.

3.2.1.3. Electrical tests:

3.2.1.3.1. Perform insulation-resistance tests on each bus section.

3.2.1.3.2. Perform insulation-resistance test on control wiring; do not perform this test on wiring connected to solid-state components.

3.2.1.3.3. Perform phasing check on double-ended switchboards to ensure correct bus phasing from each source.

3.3. **FOLLOW-UP VERIFICATION**

3.3.1. Upon completion of acceptance checks, settings, and tests, the Contractor shall show by demonstration in service that the distribution panels/load centers are in good operating condition and properly performing the intended function.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section specifies the furnishing, installation, connection, and testing of the motor control centers.

1.2. RELATED WORK

1.2.1. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS:

1.2.2. Section 26 05 19, ELECTRICAL POWER CONDUCTORS AND CABLES:

1.2.3. Section 26 05 26, GROUNDING

1.3. QUALITY ASSURANCE

1.3.1. Quality Assurance shall be in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

1.4. SUBMITTALS

1.4.1. Shop Drawings:

1.4.1.1. Submit sufficient information to demonstrate compliance with drawings and specifications.

1.4.1.2. Prior to fabrication of motor control centers, submit the following data for approval:

1.4.1.2.1. Single line diagram showing each bus, instrument and control power transformer, relay, motor starter, circuit breaker, fuse, motor circuit protector, overload, and other components.

1.4.1.2.2. Control wiring diagram for each motor starter.

1.4.1.2.3. Complete electrical ratings for all components.

1.4.1.2.4. Interrupting ratings.

1.4.1.2.5. Safety features.

1.4.1.2.6. Accessories and nameplate data.

1.4.1.2.7. Dimensioned exterior views of the motor control centers.

1.4.1.2.8. Dimensioned section views of the motor control centers.

1.4.1.2.9. Floor plan of the motor control centers.

1.4.1.2.10. Approximate design weights.

1.4.2. Manuals:

1.4.2.1. Submit as part of the project documentation copies of complete maintenance and operating manuals, including technical data sheets, wiring diagrams, and information for ordering replacement parts, including the following:

1.4.2.1.1. Schematic control diagrams, with all terminals identified, matching terminal identification in the motor control centers.

1.4.2.1.2. Include information for testing, repair, troubleshooting, assembly, disassembly, and factory recommended periodic maintenance procedures and their frequency.

1.4.2.1.3. Provide a replacement and spare parts list. Include a list of tools, and instruments for testing and maintenance purposes.

1.4.2.1.4. If changes have been made to the maintenance and operating manuals originally submitted, submit updated maintenance and operating manuals two weeks prior to the final inspection.

1.4.3. Test Reports:

1.4.3.1. Two weeks prior to the final inspection, submit certified field test reports and data sheets to the Consultant

1.4.4. Certifications:

1.4.4.1. Two weeks prior to final inspection, submit the following.

1.4.4.2. Certification by the manufacturer that the motor control centers conform to the requirements of the drawings and specifications.

1.4.4.3. Certification by the Contractor that the motor control centers have been properly installed, adjusted, and tested.

1.5. **APPLICABLE PUBLICATIONS**

1.5.1. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by designation only.

1.5.2. National Electrical Manufacturers Association (NEMA):

1.5.2.1. ICS 1-15 Industrial Control and Systems: General Requirements

1.5.2.2. ICS 2-20 Industrial Control and Systems: Controllers, Contactors and Overhead Relays Rated 600 volts

1.5.2.3. ICS 6-16 Industrial Control and Systems: Enclosures

1.5.2.4. FU 1-12 Low-Voltage Cartridge Fuses

1.5.2.5. 250-20 Enclosures for Electrical Equipment (1000 Volts Maximum)

1.5.3. National Fire Protection Association (NFPA):

1.5.3.1. 70-23 National Electrical Code (NEC)

1.5.4. Underwriters Laboratories, Inc. (UL):

1.5.4.1. 845-21 Motor Control Centers

PART 2 - PRODUCTS

2.1. GENERAL REQUIREMENTS

2.1.1. Motor control centers shall comply with NFPA, NEMA, UL, and as shown on drawings.

2.1.2. Motor control centers shall be complete, free-standing, floor-mounted, dead-front and metal-enclosed.

2.1.3. Ratings shall be not less than shown on drawings. Interrupting ratings shall be not less than the maximum short circuit currents available at the motor control center location

2.1.4. Enclosure shall be NEMA-type rated 1, 3R, or 12 as indicated on drawings or as required per the installed environment.

2.1.5. Motor control centers shall conform to the arrangements and details of drawings and to the spaces designated for installation.

2.1.6. Wiring: The motor control centers shall be NEMA Standard, Class 1, Type B.

2.1.7. Finish:

2.1.7.1. All metal surfaces shall be thoroughly cleaned, phosphatized and factory primed prior to applying baked enamel or lacquer finish.
2.1.7.2. Provide a light gray finish for indoor motor control centers.
2.1.7.3. The underside of the motor control centers shall be treated with corrosion resistant compounds, epoxy resin, or rubberized sealing compound.
2.1.7.4. All steel parts shall be factory-phosphatized, painted with primer, and baked enamel or lacquer finishes, except for ground connections.

2.2. VERTICAL SECTIONS

2.2.1. Shall be designed to permit connection of future additional vertical sections, and installation of future motor controller units in available space in each vertical section.

2.2.2. Spaces within the vertical sections shall be suitable and adequately sized for motor controller units and accessories as indicated on drawings.

2.2.3. End panels shall be removable to facilitate future additions.

2.2.4. All vertical section parts shall be accessible from the front for maintenance rearrangement.

2.2.5. Screws in the removable panels shall remain in the panels when the panels are removed. Self-aligning, self-retaining nuts, which are parts of the screw assembly, shall remain intact.

2.2.6. Each vertical section shall have a minimum 300 mm (12 inches) high horizontal wireway at the top, section and a minimum 150 mm (6 inches) high horizontal wireway at the bottom.

2.2.7. Each vertical section shall have minimum 100 mm (4 inches) wide vertical full height wireways. Vertical wireways shall connect with both the top and bottom horizontal wireways.

2.2.8. Each vertical section for motor controller units shall be equipped with all necessary hardware and busing for the units to be added or relocated. All unused space shall be covered by hinged doors and equipped to accept future units.

2.3. **BUS BARS AND INTERCONNECTIONS**

2.3.1. Horizontal bus bars shall be fully rated for the entire length of the motor control centers.

2.3.2. Bus bars shall be tin-plated copper.

2.3.3. All bolts, nuts, and washers shall be zinc-plated steel, torqued to the values recommended by the manufacturer.

2.3.4. A ground bus shall extend across the entire length of the motor control centers.

2.3.5. Bus bars and interconnections shall include provisions to extend the motor control center horizontal bus into additional future vertical sections.

2.3.6. Provide shutter mechanism to isolate vertical bus when the motor controller unit is withdrawn.

2.3.7. Buses shall be braced for 65,000 Amps RMS symmetrical.

2.4. **MOTOR CONTROLLERS**

2.4.1. Product of the same manufacturer as the motor control centers.

2.4.2. Plug-in, draw-out type up through NEMA size 4. NEMA size 5 and above require bolted connections.

2.4.3. Doors for each space shall be interlocked to prevent their opening unless disconnect is open. A "defeater" mechanism shall be incorporated for inspection by qualified personnel.

2.5. **COMBINATION MOTOR STARTERS**

2.5.1. Combination motor starters shall be of the voltage and NEMA type shown, horsepower rated for the motors shown, 3 pole, fusible disconnect switch type, with "hand-off-auto" selector switch, red "run" pilot light, 120 volt control transformer with 3 amp maximum fuses, 2 N.O. and 2 N.C. auxiliary contacts, and a NEMA Type 1 enclosure indoors or a NEMA Type 3R enclosure outdoors. Terminals shall be identified as accepting copper and aluminum cables. Provide fuse rejection kits, Class R dual element fuses and overload heaters sized in accordance with the motor nameplate.

2.5.2. Motor starter hand-off-auto switches shall be wired so that in the "hand" position, the motor runs independently of automatic start/stop controls. Only the safety and modulating controls shall remain active. In the "auto" position, all start/stop controls shall be active.

2.5.3. Motor starters shall be wired so that the motors automatically restart after a power disruption. Time delay relays shall be provided for large pumps and fans so that they can coast down before restarting after a momentary outage, and to prevent all of the large motors from restarting simultaneously.

2.6. DISCONNECT SWITCHES

2.6.1. Disconnect switches shall be of the voltage and amperage shown, horsepower rated for motor applications, fusible or non-fusible as shown, 3 pole, NEMA Type HD heavy duty, in a NEMA Type 1 enclosure indoors or NEMA Type 3R enclosure outdoors. Terminals shall be identified as accepting copper and aluminum cables.

2.6.2. Provide fuse rejection kits and Class R dual element fuses in fusible disconnect switches. Provide early break auxiliary contacts in motor disconnect switches used with variable frequency drives. Disconnect switches shall be lockable in the open and closed positions.

2.7. MOTOR CONTROL CIRCUIT DEVICES

2.7.1. Motor control circuit devices shall be heavy duty, rated for operation at 120 volts AC, and contained in a NEMA Type 1 enclosure indoors or a NEMA Type 3R enclosure outdoors. Pilot lights shall be "push-to-test" transformer type.

2.8. STANDARD OF ACCEPTANCE

2.8.1. Siemens, Schneider, Eaton, Cutler Hammer.

PART 3 - EXECUTION

3.1. INSTALLATION

3.1.1. Install motor control centers in accordance with the NEC, as shown on the drawings, and as recommended by the manufacturer.

3.1.2. Anchor motor control centers with rustproof bolts, nuts, and washers not less than 13 mm (1/2 inch) diameter, in accordance with manufacturer's instructions, and as shown on drawings.

3.1.3. Interior Location. Mount motor control centers on concrete curbs sized to exceed the footprint of the MCC by 4" (100 mm) on each side. Unless otherwise indicated, the support curb shall be at least 100 mm (4 inches) thick. The top of the concrete curb shall be approximately 100 mm (4 inches) above finished floor. Edges above floor shall have 15 mm (1/2 inch) chamfer.

3.1.4. Motor controls installed below piping or in areas with fire protection sprinklers shall be protected by drip shields.

3.1.5. Provide conduit turnups and cable entrance space required by the equipment to be mounted. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant. Cut off and bus conduits 75 mm (3 inches) above slab surface.

3.2. **IDENTIFICATION**

3.2.1. Each component of the MCC shall bear an engraved identification nameplate, min 1.0 x 2.5-inch. The lettering shall be 3/16-inch high, black on a white background.

3.3. **ACCEPTANCE CHECKS AND TESTS**

3.3.1. Perform in accordance with the manufacturer's recommendations. In addition, include the following:

3.3.2. Visual Inspection and Tests:

3.3.2.1. Compare equipment nameplate data with specifications and approved shop drawings.
3.3.2.2. Inspect physical, electrical, and mechanical condition.
3.3.2.3. Verify appropriate anchorage and required area clearances.
3.3.2.4. Verify that circuit breaker, fuse, motor circuit protector, and motor controller sizes and types correspond to approved shop drawings.
3.3.2.5. Use calibrated torque-wrench method to verify the tightness of accessible bolted electrical connections, or perform a thermographic survey after energization.
3.3.2.6. Vacuum-clean motor control center enclosure interior. Clean motor control center enclosure exterior.
3.3.2.7. Inspect insulators for evidence of physical damage or contaminated surfaces.
3.3.2.8. Exercise all active components.
3.3.2.9. Verify the correct operation of all indicating devices.
3.3.2.10. If applicable, inspect control power transformers.

3.3.3. Electrical Tests:

3.3.3.1. Perform insulation-resistance tests on each bus section.

3.3.3.2. Perform insulation-resistance test on control wiring. Do not perform this test on wiring connected to electronic components.

3.4. FOLLOW-UP VERIFICATION

3.4.1. Upon completion of acceptance checks, settings, and tests, the Contractor shall demonstrate that the motor control centers are in good operating condition and properly performing the intended function.

3.5. TRAINING

3.5.1. Furnish the services of a competent, factory-trained engineer or technician for a 2-hour period to instruct Board personnel in operation and maintenance of the equipment, including review of the operation and maintenance manual.

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PART 1 - GENERAL

1.1. RELATED SECTIONS

1.1.1. Section: 26 24 16.01 Panelboards Breaker Type.

1.1.2. Section: 26 05 73.19 Arc-Flash Hazard Analysis.

1.2. REFERENCES

1.2.1. CAN/CSA-C22.2 No. 5-09, Moulded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures (Tri-national standard, with UL 489 and NMX-J-266-ANCE-2010).

1.2.2. AN/CSA-C22.2 No. 144-M91 (R2011): Ground Fault Circuit Interrupters.

1.2.3. CAN/CSA-C22.2 No. 144.1- 06 (R2011): Ground-Fault Circuit-Interrupters (Tri-National standard, with UL 943 and NMX-J-520-ANCE).

1.3. SUBMITTALS

1.3.1. Submit product data in accordance with Section: 01 33 23 Shop Drawings, Product Data, and Samples.

1.3.2. Include time-current characteristic curves for breakers with ampacity of 200A and over or with interrupting capacity of 22,000A symmetrical (rms) and over at system voltage.

1.3.3. Acceptable Materials

1.3.3.1. Schneider Electric Canada;
1.3.3.2. Siemens Canada;
1.3.3.3. Eaton Electric.

PART 2 - PRODUCTS

2.1. BREAKERS GENERAL

2.1.1. Molded case circuit breakers and Ground-fault circuit interrupters: to C22.2 NO. 5.

2.1.2. Comply with UL 489, NEMA AB 1, and NEMA AB 3, fully rated with interrupting capacity to comply with available fault currents.

2.1.3. Bolt-on moulded case circuit breakers: quick-make, quick-break type, for manual and automatic operation with temperature compensation for 40 degrees C ambient.

2.1.4. Common-trip breakers: with single handle for multi-pole applications.

2.1.5. Magnetic instantaneous trip elements in circuit breakers to operate only when the value of the current reaches the setting.

2.1.6. Trip settings on breakers with adjustable trips to range of 3 to 8 times the rated current.

2.1.7. Provide pad locking devices where indicated on breakers to lock the handle of a breaker in the "on" or "off" position with the trip units to remain free to function and protect the circuit from both overload and short circuit conditions.

2.2. **GENERAL REQUIREMENTS**

2.2.1. Circuit breakers 250 Amps and larger shall be rated to carry 100% of their current rating continuously.

2.2.2. Thermal-Magnetic Circuit Breakers:

2.2.2.1. Molded case circuit breakers to operate automatically by means of thermal and magnetic tripping devices to provide inverse time current tripping and instantaneous tripping for short circuit protection.
2.2.2.2. Inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A up to 400 A.
2.2.2.3. Adjustable, Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.

2.2.3. Solid State Trip Breakers (LSI)

2.2.3.1. Moulded case circuit breakers to operate by means of solid-state trip unit with associated current monitors and self-powered shunt trip to provide inverse time current trip under overload condition, and long time, short time, instantaneous tripping for circuit protection.
2.2.3.2. Electronic Trip Circuit Breakers: 400 A and larger. Field-replaceable rating plug, rms sensing, with the following field-adjustable settings:
2.2.3.3. Instantaneous trip.
2.2.3.4. Long- and short-time pickup levels.
2.2.3.5. Long- and short-time time adjustments.
2.2.3.6. Ground-fault pickup level, time delay, and I^2t response

2.2.4. Each adjustment shall have discrete settings (fully adjustable) and shall be independent of all other adjustments.

2.2.5. Long Time Pickup indication to signal when loading approaches or exceeds the adjustable ampere rating of the circuit breaker shall be provided.

PART 3 - EXECUTION

3.1. **INSTALLATION**

3.1.1. Circuit breakers in panelboards shall be factory installed.

3.1.2. Install individual breakers where indicated.

3.1.3. New Circuit Breakers in Existing Panelboards:

3.1.3.1. Circuit breakers shall be of standard manufacture and match existing devices.
3.1.3.2. Circuit breakers shall be "bolt-on" type.
3.1.3.3. Circuit breakers shall have an AIC rating compatible with the Building's short circuit analysis report.

3.2. **FIELD QUALITY CONTROL**

3.2.1. Perform tests and inspections.

3.2.2. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

3.2.3. Acceptance Testing Preparation:

3.2.3.1. Test insulation resistance for each enclosed switch and circuit breaker, component, connecting supply, feeder, and control circuit.
3.2.3.2. Test continuity of each circuit.

3.2.4. Tests and Inspections:

3.2.4.1. Perform each visual and mechanical inspection and electrical test stated in Acceptance Testing Specification. Certify compliance with test parameters.
3.2.4.2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
3.2.4.3. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.
3.2.4.4. Enclosed switches and circuit breakers will be considered defective if they do not pass tests and inspections.
3.2.4.5. Prepare test and inspection report, including a certified report that identifies enclosed switches and circuit breakers and that describes scanning results. Include notation of deficiencies detected, remedial action taken and observations after remedial action.

3.3. **ADJUSTING**

3.3.1. Adjust moving parts and operable components to function smoothly, and lubricate as recommended by manufacturer.

3.3.2. Set field-adjustable circuit-breaker trip ranges. Provide list of “as left” settings and submit to Client

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section specifies the furnishing, installation, and connection of fused and unfused disconnect switches (indicated as switches in this section), circuit breaker distribution panels and separately-enclosed circuit breakers for use in electrical systems rated 600 V and below.

1.2. RELATED WORK

1.2.1. Section: 26 05 00 Common Work Results for Electrical.

1.2.2. Section: 26 05 19 Low-Voltage Electrical Power Conductors and Cables.

1.2.3. Section: 26 05 33 Raceway and Boxes for Electrical Systems.

1.3. SUBMITTALS

1.3.1. Submit the following.

1.3.1.1. Shop Drawings:

1.3.1.1.1. Submit sufficient information to demonstrate compliance with drawings and specifications.

1.3.1.1.2. Submit the following data for approval:

1.3.1.1.3. Electrical ratings, dimensions, mounting details, materials, required clearances, terminations, weight, fuses, circuit breakers, wiring and connection diagrams, accessories, and device nameplate data.

1.3.1.2. Manuals:

1.3.1.2.1. Submit complete maintenance and operating manuals including technical data sheets, wiring diagrams, and information for ordering fuses, circuit breakers, and replacement parts.

1.3.1.2.2. Include schematic diagrams, with all terminals identified, matching terminal identification in the enclosed switches and circuit breakers.

1.3.1.2.3. Include information for testing, repair, troubleshooting, assembly, and disassembly.

1.3.1.2.4. If changes have been made to the maintenance and operating manuals originally submitted, submit updated maintenance and operating manuals two weeks prior to the final inspection.

1.3.1.2.5. Certifications: Two weeks prior to final inspection, submit the following.

1.3.1.2.6. Certification by the manufacturer that the enclosed switches and circuit breakers conform to the requirements of the drawings and specifications.

1.3.1.2.7. Certification by the Contractor that the enclosed switches and circuit breakers have been properly installed, adjusted, and tested.

1.4. **APPLICABLE PUBLICATIONS**

1.4.1. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by designation only.

1.4.2. CAN/CSA-22.2

1.4.2.1. CAN/CSA-C22.2 No. 4-04 (R2009), Enclosed Switches.
1.4.2.2. CAN/CSA C22.2 NO.39-M1987 (R2007) Fuseholder Assemblies).

1.4.3. National Electrical Manufacturers Association (NEMA):

1.4.3.1. Low Voltage Cartridge Fuses
1.4.3.2. Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)

1.4.4. National Fire Protection Association (NFPA):

1.4.4.1. 70-11 National Electrical Code (NEC)

1.4.5. Underwriters Laboratories, Inc. (UL):

1.4.5.1. 98-07 Enclosed and Dead-Front Switches
1.4.5.2. 248-00 Low Voltage Fuses
1.4.5.3. 489-09 Molded Case Circuit Breakers and Circuit Breaker Enclosures

PART 2 - PRODUCTS

2.1. **PANELBOARD-MOUNTED FUSED DISCONNECTS**

2.1.1. Circuit breakers shall be per CAN/CSA22.2 #4, UL, NEC, as shown on the drawings, and as specified.

2.1.2. For circuit breakers being added to existing panelboards, coordinate the breaker type with existing panelboards. Modify the panel directory accordingly.

2.1.3. Circuit breakers shall be bolt-on type.

2.1.4. Circuit breakers shall have minimum interrupting rating as required to withstand the available fault current, but not less than:

2.1.4.1. 120/208 V Panelboard: 10,000 A symmetrical.
2.1.4.2. 120/240 V Panelboard: 10,000 A symmetrical.
2.1.4.3. 347/575 V Panelboard: 14,000 A symmetrical.

2.1.4.4. Circuit breakers shall have automatic, trip free, non-adjustable, inverse time, and instantaneous magnetic trips for less than 400 A frame. Circuit breakers with 400 A frames and above shall have magnetic trip, adjustable from 5x to 10x.

2.1.5. Circuit breaker features shall be as follows:

2.1.5.1. A rugged, integral housing of molded insulating material.
2.1.5.2. Silver alloy contacts.
2.1.5.3. Arc quenchers and phase barriers for each pole.
2.1.5.4. Quick-make, quick-break, operating mechanisms.
2.1.5.5. A trip element for each pole, thermal magnetic type with long time delay and instantaneous characteristics, a common trip bar for all poles and a single operator.
2.1.5.6. Electrically and mechanically trip free.
2.1.5.7. An operating handle which indicates closed, tripped, and open positions.
2.1.5.8. An overload on one pole of a multi-pole breaker shall automatically cause all the poles of the breaker to open.
2.1.5.9. Ground fault current interrupting breakers, shunt trip breakers, lighting control breakers (including accessories to switch line currents), or other accessory devices or functions shall be provided where shown on the drawings.

2.2. **FUSED DISCONNECT SWITCHES RATED 600 AMPERES AND LESS**

2.2.1. Switches shall be in accordance with CAN/CSA22.2 #4, NEMA, NEC, UL, as specified, and as shown on the drawings.

2.2.2. Shall be NEMA classified General Duty (GD) for 240 V switches, and NEMA classified Heavy Duty (HD) for 575 V switches.

2.2.3. Shall be horsepower (HP) rated.

2.2.4. NEMA 1 (indoor applications), NEMA 3R (outdoor or wet environment))

2.2.5. Shall have the following features:

2.2.5.1. Switch mechanism shall be the quick-make, quick-break type.
2.2.5.2. Copper blades, visible in the open position.
2.2.5.3. An arc chute for each pole.
2.2.5.4. External operating handle shall indicate open and closed positions, and have lock open padlocking provisions.
2.2.5.5. Mechanical interlock shall permit opening of the door only when the switch is in the open position, defeatable to permit inspection.
2.2.5.6. Fuse holders for the sizes and types of fuses specified.

2.2.5.7. Solid neutral for each switch being installed in a circuit which includes a neutral conductor.

2.2.5.8. Ground lugs for each ground conductor.

2.2.6. Enclosures:

2.2.6.1. Shall be the NEMA types shown on the drawings.

2.2.6.2. Where the types of switch enclosures are not shown, they shall be the NEMA types most suitable for the ambient environmental conditions.

2.2.6.3. Shall be finished with manufacturer's standard gray baked enamel paint over pretreated steel.

2.2.7. Standards of Acceptance: Eaton, Cutler Hammer, Siemens, Square D

2.3. **UNFUSED DISCONNECT SWITCHES RATED 600 AMPERES AND LESS**

2.3.1. Shall be the same as fused switches, but without provisions for fuses.

2.3.2. Standards of acceptance: same as fused disconnects

2.4. **CIRCUIT BREAKER TYPE DISTRIBUTION PANELS**

2.4.1. Distribution panels conforming to CSA C22.2 no. 29 standard.

2.4.2. Supplied by the same and only manufacturer.

2.4.3. As specified on the drawings

2.4.4. Arrange bus bars per phase order. All circuits shall be identified by a letter, as shown on drawings.

2.4.5. Panels shall have bus bars, and number of branch circuits and circuit breakers as shown.

2.4.6. Panels to be complete with door, lock and two keys, locks and keys to be interchangeable for all panels of the same type.

2.4.7. Bus bars shall be copper as the supports and circuit breakers material have the same expansion coefficients, with full capacity neutral.

2.4.8. For surface or flush mounting as shown on drawings.

2.4.9. Panel bus bars to be compatible with bolted-on circuit breakers.

2.4.10. Standard finish: ASA 61 grey baked enamel.

2.4.11. Circuit breakers: conforming to article "Molded Case Circuit Breakers" described herein.

2.4.12. The grounding bus bar shall conform to article Grounding and Bonding.

2.4.13. Acceptable manufacturers:

2.4.13.1. Eaton, Siemens, GE.

2.5. **MOTOR RATED TOGGLE SWITCHES**

2.5.1. Not applicable

2.6. **CARTRIDGE FUSES**

2.6.1. Shall be in accordance with CSA C22.2 no. 106 and C22.2 no. 248 standards.

2.6.2. High rupturing capacity (HRC) fuses 200kA RMS symmetrical and current limiting fuses.

2.6.3. Supplied by the same and only manufacturer.

2.6.4. Service Entrance: Class L, fast acting.

2.6.5. Feeders: Class L, fast acting

2.6.6. Motor and Transformer Branch Circuits: Class RK1 time delay.

2.6.7. Other Branch Circuits: Class J (less than 600A) or Class L (over 600A), fast acting.

2.6.8. Control Circuits: Class CC fast acting

2.6.9. Standard of Acceptance: Cooper Busman, Eaton

2.7. **MOLDED CASE CIRCUIT BREAKERS**

2.7.1. Molded case circuit breakers conforming to CSA C22.2 no. 5 standard.

2.7.2. Circuit protection devices contained in plastic insulated enclosures.

2.7.3. Bolted to the panel bus bars.

2.7.4. Quick make quick break mechanism.

2.7.5. Manually operated.

2.7.6. Complete with thermal and magnetic trip unit compensated for an ambient temperature of 40 °C (104 °F).

2.7.7. Multi-pole breakers to have a common trip device and operating lever.

2.7.8. In 120 or 208 Volts circuits use, unless otherwise noted on the distribution diagram or on the panel description sheets, single, two or three pole circuit breakers having the ratings as shown and with a 10 kA minimum RMS, symmetrical rupturing capacity.

2.7.9. Authentication of new breakers (not counterfeited)

2.7.9.1. Except otherwise noted, all breakers installed in panels (new or existing) shall be new and obtained exclusively from a distributor authorized by manufacturer.

2.7.9.2. Submit with breaker shop drawings, a copy of the purchase order to the distributor. Quantities, models and sizes shown on the purchase order shall correspond to those indicated on the shop drawings.

PART 3 - EXECUTION

3.1. **INSTALLATION**

3.1.1. Installation shall be in accordance with the manufacturer’s instructions, the CEC, as shown on the drawings, and as specified.

3.1.2. Fused switches shall be furnished complete with fuses. Arrange fuses such that rating information is readable without removing the fuses.

3.1.3. All disconnect switches and fuses supplied by the same manufacturer.

3.1.4. Safety switches in the circuit between a motor and a variable frequency drive shall be fitted with one type C auxiliary contact. Connect this contact to the variable frequency drive with two (2) # 14 AWG conductors inside a 12 mm (½") conduit.

3.2. **MOLDED CASE CIRCUIT BREAKER**

3.2.1. Install circuit breakers and connect as shown.

3.2.2. When a panel is replaced with a new one, the contractor shall verify the compatibility of the existing breakers with the new panel type. New breakers shall be supplied if the existing breakers are not compatible with the new panel and cannot be relocated.

3.3. **FUSES**

3.3.1. Install fuses in fuse holders just before energizing.

3.3.2. Ensure that fuses and holders are perfectly matched.

3.3.3. Ensure that the right fuse is used to protect the corresponding circuit.

3.3.4. Store the spare fuses in an orderly manner

3.4. **IDENTIFICATION**

3.4.1. Identify switches, as to equipment served, with engraved laminated phenolic name plates.

3.5. **ACCEPTANCE CHECKS AND TESTS**

3.5.1. Perform in accordance with the manufacturer's recommendations. In addition, include the following:

3.5.2. Visual Inspection and Tests:

3.5.2.1. Compare equipment nameplate data with specifications and approved shop drawings.
3.5.2.2. Inspect physical, electrical, and mechanical condition.
3.5.2.3. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method.

3.5.3. Vacuum-clean enclosure interior. Clean enclosure exterior.

3.6. **SPARE PARTS**

3.6.1. Two weeks prior to the final inspection, furnish one complete set of spare fuses for each fused disconnect switch installed on the project. Deliver to the Board representative.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This section specifies the furnishing, installation, connection, and testing of motor controllers, including all low-voltage motor controllers and manual motor controllers, indicated as motor controllers in this section except and low-voltage variable speed motor controllers (see Section: 26 29 23 Variable-Frequency Motor Controllers).

1.1.2. Motor controllers, whether furnished with the equipment specified in other sections or otherwise (with the exception of fire pump controllers), shall meet this specification and all related specifications.

1.2. RELATED WORK

1.2.1. Section: 26 05 00 Common Work Results for Electrical.

1.2.2. Section: 26 05 19 Low-Voltage Electrical Power Conductors and Cables.

1.3. QUALITY ASSURANCE

1.3.1. Refer to Section: 26 05 00 Common Work Results for Electrical.

1.4. SUBMITTALS

1.4.1. Submit documentation in accordance with Section: 26 05 00 Common Work Results for Electrical.

1.4.2. Shop Drawings:

1.4.2.1. Submit sufficient information to demonstrate compliance with drawings and specifications.
1.4.2.2. Include electrical ratings, dimensions, weights, mounting details, materials, over current protection devices, overload relays, sizes of enclosures, wiring diagrams, starting characteristics, interlocking, and accessories.

1.4.3. Manuals:

1.4.3.1. Submit, simultaneously with the shop drawings, companion copies of complete maintenance and operating manuals, including technical data sheets, wiring diagrams, and information for ordering replacement parts.
1.4.3.2. Wiring diagrams shall have their terminals identified to facilitate installation, maintenance, and operation.
1.4.3.3. Wiring diagrams shall indicate internal wiring for each item of equipment and interconnections between the items of equipment.
1.4.3.4. Elementary schematic diagrams shall be provided for clarity of operation.

1.4.3.5. Include the catalog numbers for the correct sizes of overload relays for the motor controllers.

1.4.3.6. If changes have been made to the maintenance and operating manuals originally submitted, submit updated maintenance and operating manuals two weeks prior to the final inspection.

1.4.3.7. Certifications: Two weeks prior to final inspection, submit the following.

1.4.3.8. Certification by the manufacturer that the motor controllers conform to the requirements of the drawings and specifications.

1.4.3.9. Certification by the Contractor that the motor controllers have been properly installed, adjusted, and tested.

1.5. **APPLICABLE PUBLICATIONS**

1.5.1. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by basic designation only.

1.5.1.1. CSA22.1 – Canadian Electrical Code part 1

1.5.1.2. UL® 198C - High-Interrupting Capacity Fuses; Current Limiting Type.

1.5.1.3. UL 198E - Class R Fuses.

1.5.1.4. NECA, "Standard of Installation" - published by National Electrical Contractors Association.

1.5.1.5. NEMA AB 1 - Molded Case Circuit Breakers.

1.5.1.6. NEMA ICS 2 - Industrial Control Devices, Controllers, and Assemblies.

1.5.1.7. NEMA ICS 6 - Enclosures for Industrial Controls and Systems.

1.5.1.8. NEMA KS 1 - Enclosed Switches.

1.5.1.9. Institute of Electrical and Electronic Engineers (IEEE):

1.5.1.9.1. 519-92 Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

1.5.1.9.2. C37.90.1-02Standard Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus

1.5.1.10. National Electrical Manufacturers Association (NEMA):

1.5.1.10.1. ICS 1-08 Industrial Control and Systems: General Requirements

1.5.1.10.2. ICS 1.1-09 Safety Guidelines for the Application, Installation and Maintenance of Solid State Control

1.5.1.10.3. ICS 2-05 Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 Volts

1.5.1.10.4. ICS 4-05 Industrial Control and Systems: Terminal Blocks

1.5.1.10.5. ICS 6-06 Industrial Control and Systems: Enclosures

1.5.1.10.6. ICS 7-06 Industrial Control and Systems: Adjustable-Speed Drives

1.5.1.10.7. ICS 7.1-06 Safety Standards for Construction and Guide for Selection, Installation, and Operation of Adjustable-Speed Drive Systems

1.5.1.10.8. MG 1 Part 31 Inverter Fed Polyphase Motor Standards

1.5.1.11. National Fire Protection Association (NFPA):

1.5.1.11.1. 70-11 National Electrical Code (NEC)

1.5.1.12. Underwriters Laboratories Inc. (UL):

1.5.1.12.1. 508A-07 Industrial Control Panels

1.5.1.12.2. 508C-07 Power Conversion Equipment

1.5.1.12.3. UL 1449-06 Surge Protective Devices

1.6. **STANDARDS OF ACCEPTANCE**

1.6.1. Cutler Hammer

1.6.2. Square D/Schneider Electric

1.6.3. Siemens

1.6.4. Eaton Canada

PART 2 - PRODUCTS

2.1. **MOTOR STARTERS**

2.1.1. Starters shall be CSA and ULC approved. Motor controllers shall comply with IEEE, NEMA, NFPA, UL, and as shown on the drawings.

2.1.2. Starters shall be full voltage, non-reversing magnetic starters. Full protection is to be provided in the starters by means of one thermal overload relay per phase per starter with manual reset button to suit the service factor and acceleration time of the motor served.

2.1.3. Unless specified otherwise, motor starters shall be combination type, with magnetic controller and with circuit breaker, fused disconnect switch, motor circuit protector or disconnecting means, with external operating handle with lock-open padlocking positions and ON-OFF position indicator, as applicable to the project and as indicated on the drawings.

2.1.4. Starters shall be equipped with auxiliary contacts to satisfy interlocking and automatic control requirements, “Hand-Off-Automatic” switches, pilot lights (green-On; red-Off), thermal overloads, necessary fuses and control transformer (if required) for operation of all controls on 120V single phase.

2.1.5. Where required by applicable codes, starters shall be equipped with “quick-make” and “quick-break” fused disconnects.

2.1.6. Motor controllers shall be separately enclosed, unless part of another assembly. For installation in motor control centers, provide plug-in, draw-out type motor controllers up through NEMA size 4. NEMA size 5 and above require bolted connections.

2.1.7. Motor Circuit Protectors:

2.1.7.1. Magnetic trip only.
2.1.7.2. Bolt-on type with a minimum interrupting rating as indicated on the drawings.
2.1.7.3. Equipped with automatic, adjustable magnetic trip. Magnetic trip shall be adjustable up to 1300% of the motor full load amperes.

2.1.8. Enclosures:

2.1.8.1. Enclosures shall be NEMA-type rated 1, 3R, or 12 as indicated on the drawings or as required per the installed environment.
2.1.8.2. Enclosure doors shall be interlocked to prevent opening unless the disconnecting means is open. A "defeater" mechanism shall allow for inspection by qualified personnel with the disconnect means closed. Provide padlocking provisions.
2.1.8.3. All metal surfaces shall be thoroughly cleaned, phosphatized, and factory primed prior to applying light gray baked enamel finish.

2.1.9. Motor control circuits:

2.1.9.1. Shall operate at not more than 120 Volts.
2.1.9.2. Shall be grounded, except where the equipment manufacturer recommends that the control circuits be isolated.
2.1.9.3. For each motor operating over 120 Volts, incorporate a separate, heavy duty, control transformer within each motor controller enclosure.
2.1.9.4. Incorporate primary and secondary overcurrent protection for the control power transformers.

2.1.10. Overload relays:

2.1.10.1. Thermal type. Devices shall be NEMA type.
2.1.10.2. One for each pole.
2.1.10.3. External overload relay reset pushbutton on the door of each motor controller enclosure.
2.1.10.4. Overload relays shall be matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
2.1.10.5. Thermal overload relays shall be tamperproof, not affected by vibration, manual reset, sensitive to single-phasing.

2.1.11. Incorporate into each control circuit a 120 Volt, electronic time-delay relay (ON delay), minimum adjustable range from 0.3 to 10 minutes, with transient protection. Time-delay relay is not required where H O A switch is not required.

2.1.12. Unless noted otherwise, equip each motor controller with not less than two normally open (N.O.) and two normally closed (N.C.) auxiliary contacts.

2.1.13. Provide green (RUN) and red (STOP) pilot lights.

2.1.14. Motor controllers incorporated within equipment assemblies shall also be designed for the specific requirements of the assemblies.

2.1.15. Additional requirements for specific motor controllers, as indicated in other specification sections, shall also apply.

2.2. **COMBINATION MAGNETIC STARTER-FUSED/NON-FUSED DISCONNECT**

2.2.1. Description: Combine magnetic motor controllers as noted above with non-fusible or fusible switch disconnect in common enclosure (as specified and shown on the drawings). Switch shall have a color coded externally operated handle. Operating handle shall give positive visual indication of ON/OFF with red and black color-coding.

2.2.2. Non-fusible Switch Assemblies: NEMA KS 1, enclosed knife switch with externally operable handle and visible blades. Operating handle shall give positive visual indication of ON/OFF with a color-coded operating handle.

2.2.3. Fusible Switch Assemblies: NEMA KS 1, enclosed knife switch with externally operable handle. Fuse clips: Designed to accommodate Class [R] [J] fuses and visible blades. Operating handle shall give positive visual indication of ON/OFF with a color-coded operating handle.

2.2.4. Switch shall have fuse clips to accept time delay, one-time fuse, voltage as noted on the drawings, UL 198E, Class RK 1. Interrupting Rating: 200,000 rms amperes.

2.2.5. Magnetic Motor Controllers: NEMA ICS 2, ac general-purpose Class A magnetic controller for induction motors rated in horsepower.

2.2.6. Coil: Be of encapsulated type.

2.2.7. Poles: as indicated on the drawings and wiring schedules

2.2.8. Contacts: Totally enclosed, double-break, silver-cadmium-oxide power contacts. Contact inspection and replacement shall be possible without disturbing line or load wiring.

2.2.9. Wiring: Straight-through wiring with all terminals clearly marked.

2.2.10. Overload Relay: NEMA ICS

2.2.11. Melting Alloy: With one-piece thermal unit construction. Thermal units shall be interchangeable. Overload relay control circuit contact shall be replaceable. Thermal units shall be required for starter to operate.

2.2.12. Solid State: Trip current rating will be established by selection of overload relay and shall be adjustable (3 to 1 current range). The overload shall be self-powered, provide phase loss and phase unbalance protection, have a permanent tamper guard and be ambient insensitive. It will also be available in Trip Class 10 or 20 and have a mechanical test function.

2.2.13. Outputs: Unit will be designed for addition of either a normally open or normally closed

2.2.14. auxiliary contact and be field convertible.

2.2.15. Reset: Unit shall offer both manual reset and remote reset using an external module.

2.2.16. Enclosure: ANSI/NEMA ICS 6, Type 1 or 3R as required to meet conditions of installation.

2.2.17. Auxiliary Contacts: NEMA ICS 2 normally open and two normally closed contacts in addition to seal-in contact.

2.2.18. Cover Mounted Pilot Devices: NEMA ICS 2, standard duty type.

2.2.19. Pilot Device Contacts: NEMA ICS 2, Form Z, rated A150

2.2.20. Push Buttons: Unguarded Shrouded type.

2.2.21. Indicating Lights: incandescent type.

2.2.22. Selector Switches: Rotary type.

2.2.23. Relays: NEMA ICS 2.

PART 3 - EXECUTION

3.1. INSTALLATION

3.1.1. Install motor controllers in accordance with the CEC, NEC, as shown on the drawings, and as recommended by the manufacturer.

3.1.2. Install manual motor controllers in flush enclosures in finished areas. Select location to maintain handle at 1.5 m (5 ft) above the floor level.

3.1.3. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and electronic overload relay pickup and trip ranges.

3.1.4. Adjust trip settings of circuit breakers and motor circuit protectors with adjustable instantaneous trip elements (where applicable).

3.2. ACCEPTANCE CHECKS AND TESTS

3.2.1. Perform manufacturer’s required field tests in accordance with the manufacturer's recommendations. In addition, include the following:

3.2.1.1. Visual Inspection and Tests:
3.2.1.2. Compare equipment nameplate data with specifications and approved shop drawings.
3.2.1.3. Inspect physical, electrical, and mechanical condition.
3.2.1.4. Verify appropriate anchorage, required area clearances, and correct alignment.
3.2.1.5. Verify that circuit breaker, motor circuit protector, and fuse sizes and types correspond to approved shop drawings.
3.2.1.6. Verify overload relay ratings are correct.
3.2.1.7. Vacuum-clean enclosure interior. Clean enclosure exterior.
3.2.1.8. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data.
3.2.1.9. Test all control and safety features of the motor controllers.
3.2.1.10. For low-voltage variable speed motor controllers, final programming and connections shall be by a factory-trained technician. Set all programmable functions of the variable speed motor controllers to meet the requirements and conditions of use.

3.3. FOLLOW-UP VERIFICATION

3.3.1. Upon completion of acceptance checks, settings, and tests, the Contractor shall show by demonstration in service that the motor controllers are in good operating condition and properly performing the intended functions.

3.4. SPARE PARTS

3.4.1. Two weeks prior to the final inspection, provide one complete set of spare fuses for each motor controller.

3.5. INSTRUCTION

3.5.1. Furnish the services of a factory trained technician for two 4 hour training periods for instructing personnel in the maintenance and operation of the motor controllers, on the dates requested by the Board.

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PART 1 - GENERAL

1.1. DESCRIPTION

1.1.1. This specification is to cover a complete Variable Frequency Drive (VFD aka: VSD, AFD, ASD, Inverter, AC Drive, et al) consisting of a pulse width modulated (PWM) inverter designed for use with a standard NEMA Design B induction motor.

1.1.2. The drive manufacturer shall supply the drive and all necessary options as herein specified. The manufacturer shall have been engaged in the production of this type of equipment for a minimum of twenty years. VFDs that are manufactured by a third party and “brand labeled” shall not be acceptable. Drive manufacturers who do not build their own power boards and assemblies, or do not have full control of the power board manufacturing and quality control, shall be considered as a “brand labeled” drive. All VFDs installed on this project shall be from the same manufacturer.

1.2. QUALITY ASSURANCE

1.2.1. Referenced Standards and Guidelines:

1.2.1.1. Institute of Electrical and Electronic Engineers (IEEE)
1.2.1.2. IEEE 519-1992, Guide for Harmonic Content and Control.
1.2.1.3. Underwriters Laboratories (as appropriate)
1.2.1.3.1. UL508
1.2.1.3.2. UL508A
1.2.1.3.3. UL508C
1.2.1.4. National Electrical Manufacturer’s Association (NEMA)
1.2.1.5. ICS 7.0, AC Adjustable Speed Drives
1.2.1.6. International Electrotechnical Commission (IEC)
1.2.1.7. EN/IEC 61800-3
1.2.1.8. National Electric Code (NEC)
1.2.1.9. NEC 430.120, Adjustable-Speed Drive Systems

1.2.2. Qualifications:

1.2.3. VFDs and options shall be UL508 listed as a complete assembly. The base VFD shall be UL labeled 100 kA RMS Symmetrical, 600V max. C

1.2.4. CE Mark – The base VFD shall conform to the European Union Electromagnetic Compatibility directive, a requirement for CE marking. The VFD shall meet product standard EN 61800-3 for the First Environment restricted level (Category C2). Base drives that only meet the Second Environment (Category C3, C4) shall be supplied with filters to bring the drive in compliance with the First Environment levels.

1.2.5. The entire VFD assembly, including the bypass (if specified), shall be seismically certified and labeled as such in accordance with the 2012 International Building Code (IBC)

1.3. **STANDARD OF ACCEPTANCE**

1.3.1. ABB ACH Series.

1.3.2. Danfoss

1.4. **SUBMITTALS**

1.4.1. Submittals shall include the following information:

1.4.1.1. Outline dimensions, conduit entry locations and weight.
1.4.1.2. Customer connection and power wiring diagrams.
1.4.1.3. Complete technical product description includes a complete list of options provided.
1.4.1.4. Any portions of this specification not met must be clearly indicated or the supplier and contractor shall be liable to provide all additional components required to meet this specification.

PART 2 - PRODUCTS

2.1. **VARIABLE FREQUENCY DRIVES**

2.1.1. The VFD package as specified herein and defined on the VFD schedule shall be enclosed in a UL Type enclosure (enclosures with only NEMA ratings are not acceptable), completely assembled and tested by the manufacturer in an ISO9001 facility.

2.1.2. The VFD shall provide full rated output from a line of ±10% of nominal voltage. The VFD shall continue to operate without faulting from a line of +30% to -35% of nominal voltage.

2.1.3. VFDs shall be capable of continuous full load operation under the following environmental operating conditions:

2.1.3.1. -15 to 40° C (5 to 104° F) ambient temperature. Operation to 50° C shall be allowed with a 10% reduction from VFD full load current.
2.1.3.2. Altitude 0 to 3300 feet above sea level. Operation to 6600 shall be allowed with a 10% reduction from VFD full load current.
2.1.3.3. Humidity less than 95%, non-condensing.

2.1.4. All VFDs shall have the following standard features:

2.1.4.1. All circuit boards shall be coated to protect against corrosion.
2.1.4.2. All VFDs shall have the same customer interface, including digital display, and keypad, regardless of horsepower rating. The keypad shall be removable, capable

of remote mounting and allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs.

2.1.4.3. The keypad shall include Hand-Off-Auto selections and manual speed control. The drive shall incorporate “bumpless transfer” of speed reference when switching between “Hand” and “Auto” modes. There shall be fault reset and “Help” buttons on the keypad. The Help button shall include “on-line” assistance for programming and troubleshooting.

2.1.4.4. There shall be a built-in time clock in the VFD keypad. The clock shall have a battery backup with 10 years minimum life span. The clock shall be used to date and time stamp faults and record operating parameters at the time of fault. VFD programming shall be held in non-volatile memory and is not dependent on battery power

2.1.4.5. The VFD’s shall utilize pre-programmed application macros specifically designed to facilitate start-up. The Application Macros shall provide one command to reprogram all parameters and customer interfaces for a particular application to reduce programming time. The VFD shall have two user macros to allow the end-user to create and save custom settings.

2.1.4.6. The VFD shall have cooling fans that are designed for easy replacement. The fans shall be designed for replacement without requiring removing the VFD from the wall or removal of circuit boards. The VFD cooling fans shall operate only when required, based on the temperature of and run command to the drive. VFD protection shall be based on thermal sensing and not cooling fan operation.

2.1.4.7. The VFD shall be capable of starting into a coasting load (forward or reverse) up to full speed and accelerate or decelerate to set point without tripping or component damage (flying start).

2.1.4.8. The VFD shall have the ability to automatically restart after an over-current, over-voltage, under-voltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between attempts shall be programmable.

2.1.4.9. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 seconds every minute. The minimum FLA rating shall meet or exceed the values in the NEC/UL table 430.250 for 4-pole motors.

2.1.4.10. VFDs through 200 HP shall have internal swinging (non-linear) chokes providing impedance equivalent to 5% to reduce the harmonics to the power line. Swinging choke shall be required resulting in superior partial load harmonic reduction. Linear chokes are not acceptable. 5% impedance may be from dual (positive and negative DC bus) chokes, or 5% swinging AC line chokes. VFD’s with only one DC choke shall add an AC line choke.

2.1.4.11. The input current rating of the VFD shall not be greater than the output current rating. VFD’s with higher input current ratings require the upstream wiring, protection devices, and source transformers to be oversized per NEC 430.122. Input and output current ratings must be shown on the VFD nameplate.

2.1.4.12. The VFD shall include a coordinated AC transient surge protection system consisting of 4 MOVs (phase to phase and phase to ground), a capacitor clamp, 1600 PIV Diode Bridge and internal chokes. The MOV's shall have a minimum 125 joule rating per phase across the diode bridge. VFDs that do not include coordinated AC transient surge protection shall include an external TVSS (Transient Voltage Surge Suppressor).

2.1.4.13. The VFD shall provide a programmable loss-of-load (broken belt / broken coupling) Form-C relay output. The drive shall be programmable to signal the loss-of-load condition via a keypad warning, Form-C relay output, and / or over the serial communications bus. The loss-of-load condition sensing algorithm shall include a programmable time delay that will allow for motor acceleration from zero speed without signaling a false loss-of-load condition.

2.1.4.14. The VFD shall include multiple "two zone" PID algorithms that allow the VFD to maintain PID control from two separate feedback signals (4-20mA, 0-10V, and / or serial communications). The two zone control PID algorithm will control motor speed based on a minimum, maximum, or average of the two feedback signals. All of the VFD PID controllers shall include the ability for "two zone" control.

2.1.4.15. If the input reference is lost, the VFD shall give the user the 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. The drive shall be programmable to signal this condition via a keypad warning, Form-C relay output and / or over the serial communication bus.

2.1.4.16. The VFD shall have programmable "Sleep" and "Wake up" functions to allow the drive to be started and stopped from the level of a process feedback signal.

2.1.5. All VFDs to have the following adjustments:

2.1.5.1. Three (3) programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed. The lockout range must be fully adjustable, from 0 to full speed.

2.1.5.2. Two (2) PID Set point controllers shall be standard in the drive, allowing pressure or flow signals to be connected to the VFD, using the microprocessor in the VFD for the closed-loop control. The VFD shall have 250 ma of 24 VDC auxiliary power and be capable of loop powering a transmitter supplied by others. The PID set point shall be adjustable from the VFD keypad, analog inputs, or over the communications bus. There shall be two independent parameter sets for the PID controller and the capability to switch between the parameter sets via a digital input, serial communications or from the keypad. The independent parameter sets are typically used for night setback, switching between summer and winter set points, etc.

2.1.5.3. There shall be an independent, second PID loop that can 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.). All set points, process variables, etc. to be accessible from the serial communication network.

2.1.5.4. Two (2) programmable analog inputs shall accept current or voltage signals.

2.1.5.5. Two (2) programmable analog outputs (0-20ma or 4-20 ma). The outputs may be programmed to output proportional to Frequency, Motor Speed, Output Voltage, Output Current, Motor Torque, Motor Power (kW), DC Bus voltage, Active Reference, Active Feedback, and other data.

2.1.5.6. Six (6) programmable digital inputs for maximum flexibility in interfacing with external devices. All digital inputs shall be programmable to initiate upon an application or removal of 24VDC.

2.1.5.7. Three (3) programmable, digital Form-C relay outputs. The relay outputs shall include programmable on and off delay times and adjustable hysteresis. The relays shall be rated for maximum switching current 8 amps at 24 VDC and 0.4 A at 250 VAC; Maximum voltage 300 VDC and 250 VAC; continuous current rating of 2 amps RMS. Outputs shall be true Form-C type contacts; open collector outputs are not acceptable. Drives that have only two (2) relay outputs must provide an option card that provides additional relay outputs.

2.1.5.8. Run permissive circuit - There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad, input contact closure, time-clock control, or serial communications), the VFD shall provide a dry contact closure that will signal the damper to open (VFD motor does not operate). When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a VFD digital input and allows VFD motor operation. Two separate safety interlock inputs shall be provided. When either safety is opened, the motor shall be commanded to coast to stop and the damper shall be commanded to close. The keypad shall display "start enable 1 (or 2) missing". The safety input status shall also be transmitted over the serial communications bus.

2.1.5.9. The VFD control shall include a programmable time delay for VFD start and a keypad indication that this time delay is active. A Form C relay output provides a contact closure to signal the VAV boxes open. This will allow VAV boxes to be driven open before the motor operates. The time delay shall be field programmable from 0 – 120 seconds. Start delay shall be 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.

2.1.5.10. Seven (7) programmable preset speeds.

2.1.5.11. Two independently adjustable accel and decel ramps with 1 – 1800 seconds adjustable time ramps.

2.1.5.12. The VFD shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and reduce audible motor noise. The VFD shall have selectable software for optimization of motor noise, energy consumption, and motor speed control.

2.1.5.13. The VFD shall include a carrier frequency control circuit that reduces the carrier frequency based on actual VFD temperature that allows higher carrier frequency settings without derating the VFD.

2.1.5.14. The VFD shall include password protection against parameter changes.

2.1.5.15. The Keypad shall include a backlit LCD display. The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable). All VFD faults shall be displayed in English words. The keypad shall include a minimum of 14 assistants including:

2.1.5.15.1. Start-up assistant
2.1.5.15.2. Parameter assistants
2.1.5.15.3. PID assistant
2.1.5.15.4. Reference assistant
2.1.5.15.5. I/O assistant
2.1.5.15.6. Serial communications assistant
2.1.5.15.7. Option module assistant
2.1.5.15.8. Panel display assistant
2.1.5.15.9. Low noise set-up assistant
2.1.5.15.10. Maintenance assistant
2.1.5.15.11. Troubleshooting assistant
2.1.5.15.12. Drive optimizer assistants

2.1.6. All applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of three operating values from the list below shall be capable of being displayed at all times. The display shall be in complete English words (alpha-numeric codes are not acceptable):

2.1.6.1. Output Frequency
2.1.6.2. Motor Speed (RPM, %, or Engineering units)
2.1.6.3. Motor Current
2.1.6.4. Motor Torque
2.1.6.5. Motor Power (kW)
2.1.6.6. DC Bus Voltage
2.1.6.7. Output Voltage

2.1.7. The VFD shall include a fireman's override input. Upon receipt of a contact closure from the fire / smoke control station, the VFD shall operate in one of two modes: 1) Operate at a programmed predetermined fixed speed ranging from -500Hz (reverse) to 500Hz (forward). 2) Operate in a specific fireman's override PID algorithm that automatically adjusts motor speed based on override set point and feedback. The mode shall override all other inputs (analog/digital, serial communication, and all keypad commands), except customer defined safety run interlocks, and force the motor to run in one of the two modes above. "Override Mode" shall be displayed on the keypad. Upon removal of the override signal, the VFD shall resume normal operation, without the need to cycle the normal digital input run command.

2.2. **SERIAL COMMUNICATIONS**

2.2.1. The VFD shall have an EIA-485 port as standard. The standard protocols shall be Modbus, Johnson Controls N2, Siemens Building Technologies FLN, and BACnet. [Optional protocols for LonWorks, Profibus, EtherNet, BACnet IP, and DeviceNet shall be available.] Each individual drive shall have the protocol in the base VFD. The use of third party gateways and multiplexers is not acceptable. All protocols shall be "certified" by the governing authority (i.e. BTL Listing for BACnet). Use of non-certified protocols is not allowed.

2.2.2. The BACnet connection shall be an EIA-485, MS/TP interface operating at 9.6, 19.2, 38.4, or 76.8 Kbps. The connection shall be tested by the BACnet Testing Labs (BTL) and be BTL Listed. The BACnet interface shall conform to the BACnet standard device type of an Applications Specific Controller (B-ASC). The interface shall support all BIBBs defined by the BACnet standard profile for a B-ASC including, but not limited to:

2.2.2.1. Data Sharing – Read Property – B.
2.2.2.2. Data Sharing – Write Property – B.
2.2.2.3. Device Management – Dynamic Device Binding (Who-Is; I-Am).
2.2.2.4. Device Management – Dynamic Object Binding (Who-Has; I-Have).
2.2.2.5. Device Management – Communication Control – B.

2.2.3. Serial communication capabilities shall include, but not be limited to; run-stop controls, speed set adjustment, and lock and unlock the keypad. The drive shall have the capability of allowing the BAS to monitor feedback such as process variable feedback, output speed / frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), and drive temperature. The BAS shall also be capable of monitoring the VFD relay output status, digital input status, and all analog input and analog output values. All diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote VFD fault reset shall be possible.

2.2.4. Serial communication in bypass (if bypass is specified) shall include, but not be limited to; bypass run-stop control, the ability to force the unit to bypass, and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the BAS to monitor feedback such as, current (in amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The BAS shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible.

2.2.5. The VFD / bypass shall allow the BAS to control the drive and bypass digital and analog outputs via the serial interface. This control shall be independent of any VFD function. The analog outputs may be used for modulating chilled water valves or cooling tower bypass valves. The drive and bypass' digital (Form-C relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. In addition, all of the drive and bypass' digital inputs shall be capable of being monitored by the BAS system. This allows for remote monitoring of which (of up to 4) safeties are open.

2.2.6. The VFD shall include an independent PID loop for customer use. The independent PID loop may be used for cooling tower bypass value control, chilled water value / hot water valve control, etc. Both the VFD PID control loop and the independent PID control loop shall continue functioning even if the serial communications connection is lost. As default, the VFD shall keep the last good set point command and last good DO & AO commands in memory in the event the serial communications connection is lost and continue controlling the process.

2.2.7. EMI / RFI filters. All VFD's shall include EMI/RFI filters. The onboard filters shall allow the VFD assembly to be CE Marked and the VFD shall meet product standard EN 61800-3 for the First Environment restricted level (Category C2) with up to 100 feet of motor cable. Second environment (Category C3, C4) is not acceptable, no Exceptions. Certified test reports shall be provided with the submittals confirming compliance to EN 61800-3, First Environment (C2).

2.3. DRIVE OPTIONS

2.3.1. Options shall be furnished and mounted by the drive manufacturer as defined on the VFD schedule. All optional features shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.

2.3.2. Circuit Breaker - Door interlocked padlockable circuit breaker that will disconnect all input power from the drive and all internally mounted options. Circuit breaker option shall be available with or without systems requiring bypass.

2.3.3. Disconnect Switch with Fuses - Door interlocked, padlockable disconnect switch that will disconnect all input power from the drive and all internally mounted options. Drive input fusing is included.

2.3.4. Fieldbus adapters – The following optional fieldbus adapters shall be available as a plug in modules.

2.3.4.1. LonWorks
2.3.4.2. DeviceNet
2.3.4.3. Ethernet IP
2.3.4.4. ControlNet over Ethernet & ModBus TCP
2.3.4.5. BACnet IP
2.3.4.6. Profibus

2.4. **BYPASS**

2.4.1. Bypasses shall be furnished and mounted by the drive manufacturer as defined on the VFD schedule. All VFD with bypass configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.

2.4.2. A complete factory wired and tested bypass system consisting of a door interlocked, padlockable circuit breaker, output contactor, bypass contactor, and fast acting VFD input fuses. UL Listed motor overload protection shall be provided in both drive and bypass modes.

2.4.3. The bypass enclosure door and VFD enclosure must be mechanically interlocked such that the disconnecting device must be in the “Off” position before either enclosure may be accessed.

2.4.4. The VFD and bypass package shall have a UL listed short circuit current rating (SCCR) of 100,000 Amps and this rating shall be indicated on the UL data label.

2.4.5. Drive Isolation Fuses - To ensure maximum availability of bypass operation, fast acting fuses, exclusive to the VFD, shall be provided to allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection. This maintains bypass operation capability in the event of a VFD failure. Bypass designs which have no such fuses, or that incorporate fuses common to both the VFD and the bypass, will not be accepted. Third contactor “isolation contactors” are not an acceptable alternative to fuses, as contactors could weld closed and are not an NEC recognized disconnecting device.

2.4.6. The bypass shall maintain positive contactor control through the voltage tolerance window of nominal voltage +30%, -35%. This feature is designed to avoid contactor coil failure during brown out / low line conditions and allow for input single phase operation when in the VFD mode. Designs that will not allow input single phase operation in the VFD mode are not acceptable.

2.4.7. Motor protection from single phase power conditions - the bypass system must be able to detect a single-phase input power condition while running in bypass, disengage the motor in a controlled fashion, and give a single-phase input power indication. Bypass systems not incorporating single phase protection in bypass mode are not acceptable.

2.4.8. The bypass system shall be designed for stand-alone operation and shall be completely functional in both Hand and Automatic modes even if the VFD has been removed from the system for repair / replacement. Serial communications shall remain functional even with the VFD removed. Bypass systems that do not maintain full functionality with the drive removed are not acceptable.

2.4.9. Serial communications – the bypass shall be capable of being monitored and / or controlled via serial communications. On-board communications protocols shall include ModBus RTU; Johnson Controls N2; Siemens Building Technologies FLN (P1); and BACnet MS/TP.

2.4.10. Serial communication capabilities shall include, but not be limited to: bypass run-stop control, the ability to force the unit to bypass, and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the BAS to monitor feedback such as, current (Amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The BAS shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible. The following additional status indications and settings shall be transmitted over the serial communications bus and / or via a Form-C relay output – keypad “Hand” or “Auto” selected, bypass selected, and broken belt indication. The BAS system shall also be able to monitor if the motor is running in the VFD mode or bypass mode over serial communications. A minimum of 50 field serial communications points shall be capable of being monitored in the bypass mode.

2.4.11. The bypass serial communications shall allow control of the drive/bypass (system) digital outputs via the serial interface. This control shall be independent of any bypass function or operating state. The system digital (relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. All system analog and digital I/O shall be capable of being monitored by the BAS system.

2.4.12. There shall be an adjustable motor current sensing circuit for the bypass and VFD modes to provide proof of flow (broken belt) indication. The condition shall be indicated on the keypad display, transmitted over the BAS and / or via a Form-C relay output contact closure. The broken belt indication shall be programmable to be a system (drive and bypass) indication. The broken belt condition sensing algorithm shall be programmable to cause a warning or system shutdown.

2.4.13. The digital inputs for the system shall accept 24VDC. The bypass shall incorporate an internally sourced power supply and not require an external control power source. The bypass power board shall supply 250 mA of 24 VDC for use by others to power external devices.

2.4.14. There shall be a coordinated run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad command, time-clock control, digital input, or serial communications) the bypass shall provide a dry contact closure that will signal the damper to open before the motor can run. When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a bypass system input and allows motor operation. Up to four separate safety interlock inputs shall be provided. When any safety is opened, the motor shall be commanded to coast to stop, and the damper shall be commanded to close. This feature will also operate in Fireman’s override / smoke control mode.

2.4.15. The bypass control shall monitor the status of the VFD and bypass contactors and indicate when there is a welded contactor contact or open contactor coil. This failed contactor condition shall be indicated on the bypass LCD display, programmed to activate a Form-C relay output, and / or over the serial communications protocol.

2.4.16. The bypass control shall include a programmable time delay bypass start including keypad indication of the time delay. A Form C relay output commands the VAV boxes open. This will allow VAV boxes to be driven open before the motor operates at full speed in the bypass mode. The time delay shall be field programmable from 0 – 120 seconds.

2.4.17. There shall be a keypad adjustment to select manual or automatic transfer to bypass. The user shall be able to select via keypad programming which drive faults will result in an automatic transfer to bypass mode and which faults require a manual transfer to bypass. The user may select whether the system shall automatically transfer from drive to bypass mode on the following drive fault conditions:

2.4.17.1. Over current
2.4.17.2. Over voltage
2.4.17.3. Under voltage
2.4.17.4. Loss of analog input
2.4.17.5. The following operators shall be provided:
2.4.17.6. Bypass Hand-Off-Auto
2.4.17.7. Drive mode selector
2.4.17.8. Bypass mode selector
2.4.17.9. Bypass fault reset
2.4.17.10. The bypass shall include the ability to select the operating mode of the system (VFD/Bypass) from either the bypass keypad or digital input.
2.4.17.11. The bypass shall include a two line, 20 character LCD display. The display shall allow the user to access and view:
2.4.17.12. Energy savings – in US dollars

2.4.17.13. Bypass motor amps
2.4.17.14. Bypass input voltage– average and individual phase voltage
2.4.17.15. Bypass power (kW)
2.4.17.16. Bypass faults and fault logs
2.4.17.17. Bypass warnings
2.4.17.18. Bypass operating time (resettable)
2.4.17.19. Bypass energy (kilowatt hours – resettable)
2.4.17.20. I/O status
2.4.17.21. Parameter settings / programming
2.4.17.22. Printed circuit board temperature
2.4.17.23. The following indicating lights (LED type) or keypad display indications shall be provided. A test mode or push to test feature shall be provided.
2.4.17.24. Power-on (Ready)
2.4.17.25. Run enable
2.4.17.26. Drive mode selected
2.4.17.27. Bypass mode selected
2.4.17.28. Drive running
2.4.17.29. Bypass running
2.4.17.30. Drive fault
2.4.17.31. Bypass fault
2.4.17.32. Bypass H-O-A mode
2.4.17.33. Automatic transfer to bypass selected
2.4.17.34. Safety open
2.4.17.35. Damper opening
2.4.17.36. Damper end-switch made

2.4.18. The Bypass controller shall have six programmable digital inputs, and five programmable Form-C relay outputs. This I/O allows for a total System (VFD and Bypass) I/O count of 24 points as standard. The bypass I/O shall be available to the BAS system even with the VFD removed.

2.4.19. The on-board Form-C relay outputs in the bypass shall programmable for any of the following indications.

2.4.19.1. System started
2.4.19.2. System running
2.4.19.3. Bypass override enabled
2.4.19.4. Drive fault
2.4.19.5. Bypass fault
2.4.19.6. Bypass H-O-A position
2.4.19.7. Motor proof-of-flow (broken belt)
2.4.19.8. Overload

2.4.19.9. Bypass selected
2.4.19.10. Bypass run
2.4.19.11. System started (damper opening)
2.4.19.12. Bypass alarm
2.4.19.13. Over temperature

2.4.20. The bypass shall provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external safety interlocks shall remain fully functional whether the system is in VFD or Bypass mode. The remote start/stop contact shall operate in VFD and bypass modes. The terminal strip shall allow for independent connection of up to four (4) unique safety inputs.

2.4.21. The bypass shall include a supervisory control mode. In this bypass mode, the bypass shall monitor the value of the VFD’s analog input (feedback). This feedback value is used to control the bypass contactor on and off state. The supervisory mode shall allow the user to maintain hysteresis control over applications such as cooling towers and booster pumps.

2.4.22. The user shall be able to select the text to be displayed on the keypad when an external safety opens. Example text display indications include “FireStat”, “FreezStat”, “Over pressure” and “Low suction”. The user shall also be able to determine which of the four (4) safety contacts is open over the serial communications connection.

2.4.23. Smoke Control Override Mode (Override 1) – The bypass shall include a dedicated digital input that will transfer the motor from VFD mode to Bypass mode upon receipt of a dry contact closure from the Fire / Smoke Control System. The Smoke Control Override Mode action is not programmable and will always function as described in the bypass User’s Manual documentation. In this mode, the system will ignore low priority safeties and acknowledge high priority safeties. All keypad control, serial communications control, and normal customer start / stop control inputs will be disregarded. This Smoke Control Mode shall be designed to meet the intent of UL864/UUKL.

2.4.24. Fireman’s Override Mode (Override 2) – the bypass shall include a second, programmable override input which will allow the user to configure the unit to acknowledge some digital inputs, all digital inputs, ignore digital inputs or any combination of the above. This programmability allows the user to program the bypass unit to react in whatever manner the local Authority Having Jurisdiction (AHJ) requires. The Override 2 action may be programmed for “Run-to-Destruction”. The user may also force the unit into Override 2 via the serial communications link.

2.4.25. Class 10, 20, or 30 (programmable) electronic motor overload protection shall be included.

2.4.26. Drive Service Switch – Drive service switches shall be furnished and mounted by the drive manufacturer as defined on the VFD schedule. VFD/Bypass configurations that utilize contactors as a means to remove VFD input power for the purpose of VFD servicing are not acceptable. NEC Code does not recognize a contactor as a means of disconnect in a motor control circuit.

PART 3 - EXECUTION

3.1. INSTALLATION

3.1.1. Installation shall be the responsibility of the mechanical contractor. The contractor shall install the drive in accordance with the recommendations of the VFD manufacturer as outlined in the VFD installation manual.

3.1.2. Power wiring shall be completed by the electrical contractor, to NEC code 430.122 wiring requirements based on the VFD input current. The contractor shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.

3.2. START-UP

3.2.1. Factory start-up shall be provided for each drive by a factory authorized service center. A start-up form shall be filled out for each drive with a copy provided to the owner, and a copy kept on file at the manufacturer.

3.3. PRODUCT SUPPORT

3.3.1. Factory trained application engineering and service personnel that are thoroughly familiar with the VFD products offered shall be locally available at both the specifying and installation locations. A toll free 24/365 technical support line connected to factory support personnel located in the US shall be available. Technical support offered only through the local sales office is not acceptable.

3.3.2. Training shall include installation, programming and operation of the VFD, bypass and serial communication. Factory authorized start up and owner training to be provided locally upon request.

3.4. WARRANTY

3.4.1. The VFD Product Warranty shall be 36 months from the date of factory shipment. The warranty shall include all parts, labor, travel time and expenses. A toll free 24/365 technical support line shall be available.