

GPY +
Associates Engineering Inc.



**Mechanical Specification
For**

York Region Administrative Centre

RENOVATION PROJECT – PACKAGE 'E'

**17250 Yonge Street
Newmarket, Ontario L3Y 4W5**

**Prepared for
THE REGIONAL MUNICIPALITY OF YORK**

ISSUED FOR CONSTRUCTION

**Prepared by
GPY+ Associates Engineering Inc.**

**GPY Project No. 17000
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1. GENERAL

1.1 Applicable Standards

- .1 2015 ASHRAE Handbook – HVAC Applications Chapter 43 HVAC Commissioning
- .2 ASHRAE Guideline 1.1 – 2007 – The HVAC&R Technical Requirements for the Commissioning Process
- .3 CSA Z320-11 (R2016) Building Commissioning Standard & Check Sheets

1.2 Description

- .1 Commissioning is a systematic process of ensuring that all building systems perform interactively according to the requirements of the Contract Documents and the Region's operational needs. The commissioning process begins in the design phase and continues through construction, acceptance and the warranty period. The commissioning process shall encompass and coordinate the traditionally separate functions of system documentation, equipment startup, control system calibration, testing and balancing, functional testing and training.
- .2 Commissioning during the construction phase is intended to achieve the following specific objectives according to the Contract Documents:
 - .1 Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and industry best practices, and that they receive adequate operational checkout by installing Subcontractors;
 - .2 Verify and document proper performance of equipment and systems;
 - .3 Verify that Operations and Maintenance documentation left on Site is complete; and
 - .4 Verify that the Region's operating personnel are adequately trained.
- .3 The commissioning process does not take away from or reduce the responsibility of the system designers or the Contractor to provide a finished and fully functioning product.

1.3 Abbreviations

- .1 The following are common abbreviations used in the Commissioning Specifications and in the Commissioning Plan. Definitions are found in Section 1.8.

A/E-	Architect and Design Engineers (the "Consultant")	FT-	Functional performance test
CA-	Commissioning Authority	GC-	General Contractor, including its project manager (the 'Contractor')
CC-	Controls Subcontractor	MC-	Mechanical Subcontractor
		PC-	Pre-functional checklists
Cx-	Commissioning	Subs-	Subcontractors to GC
Cx Plan-	Commissioning Plan document	TAB-	Test and Balance Subcontractor
EC-	Electrical Subcontractor	FM-	Facility Management
DDC-	Direct Digital Control	EMS-	Energy Management System

1.4 COORDINATION

- .1 Commissioning Team. The commissioning team consists of the representatives from the Region, the Facility Management (FM) Staff, Commissioning Authority (CA), the General Contractor (GC or Contractor), the Architect and Design Engineers (A/E) (the "Consultant"), the mechanical Subcontractor (MC), the Electrical Subcontractor (EC), the Testing and Balancing (TAB) Subcontractor, the Controls Subcontractor (CC), any other installing subcontractors or suppliers of equipment.
- .2 Management. The CA is hired by the Region and follows the rules of an Independent Commissioning Authority. The CA directs and coordinates the commissioning activities and reports to the Region. All members work together to fulfill their contracted responsibilities and meet the objectives of the Contract Documents.
- .3 Scheduling. The CA will work with the Region and GC to schedule the commissioning activities. The CA will provide sufficient notice to the Region and GC for scheduling commissioning activities. The GC shall integrate all commissioning activities into the master schedule. All parties will address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process. The CA will work with the GC to provide the initial schedule of primary commissioning events at the commissioning scoping meeting. The Commissioning Plan provides a format for this schedule. As construction progresses more detailed schedules are developed by the GC and the CA. The Commissioning Plan also provides a format for detailed schedules.

1.5 COMMISSIONING PROCESS

- .1 Commissioning Plan. The commissioning plan provides guidance in the execution of the commissioning process. Following the commissioning scoping meeting, the CA will update the plan which is then considered the "final" plan, though it will continue to evolve and expand as the project progresses. The Specifications will take precedence over the Commissioning Plan.
- .2 Commissioning Process. The following narrative provides a brief overview of the typical commissioning tasks during construction and the general order in which they occur.
 - .1 Commissioning during construction begins with a scoping meeting conducted by the CA where the commissioning process is reviewed with the commissioning team members.
 - .2 Additional meetings will be required throughout construction, scheduled by the CA with necessary parties attending, to plan, scope, coordinate, schedule future activities and resolve problems.
 - .3 Equipment documentation is submitted to the CA during normal submittals, including detailed start-up procedures and Shop Drawings.
 - .4 The CA works with the Subs in developing start-up plans and start-up documentation formats, including providing the Subs with pre-functional test sheets to be completed during the startup process.
 - .5 In general, the checkout and performance verification proceeds from simple to complex; from component level, to equipment, to systems, and finally intersystem levels with pre-functional test sheets being completed before functional testing.
 - .6 The Subs, under their own direction, execute and document the pre-functional test sheets and perform startup and initial checkout. The CA documents that the test sheets and startup were completed according to the approved plans. This may include the CA witnessing start-up of selected equipment.
 - .7 The CA develops specific equipment and system functional performance test procedures with the assistance of Subs as required. The Subs review the test procedures once prepared.

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- .8 The procedures are executed by the Subs, under the supervision of, and documented by the CA.
- .9 Items of non-compliance in material, installation or setup are corrected at the Sub's expense and the system retested.
- .10 The CA reviews the O&M documentation for completeness.
- .11 Commissioning is completed before Substantial Performance of the Contract.
- .12 Deferred testing is conducted, as specified or required.

1.6 RELATED WORK

- .1 Specific commissioning requirements are given in the following Sections of these Specifications. All of the following sections apply to the Work of this Section.

01 91 00	Commissioning	<i>Describes the commissioning process, responsibilities common to all parties, responsibilities of the Consultant, CA, GC and Suppliers, focusing on the CA. The unique MC, CC, TAB and EC (including the Subcontractors for the Special Systems) responsibilities are included in Divisions 21, 22, 23, 25 and 26</i>
21 08 00	Fire Suppression	<i>Describes the Cx responsibilities of the Fire Protection, Plumbing, Mechanical, TAB and Controls Contractors and the pre-functional testing and startup responsibilities of each. Points to 01 91 00 for functional testing requirements and provides the pre-functional and the specific functional testing requirements for Division 21, 22, 23 and 25 equipment, for use on this project.</i>
	System Cx	
22 08 00	Plumbing Cx	
23 05 93	TAB	
23 08 00	HVAC Cx	
25 08 00	Integrated Automation Cx	
26 08 00	Electrical Cx	<i>Describes the specific Cx responsibilities of the Division 26 Subcontractor.</i>

1.7 RESPONSIBILITIES

- .1 General: General Commissioning Responsibilities are as follows:
 - .1 The responsibilities of various parties in the commissioning process are provided in this Section. The responsibilities of the mechanical Subcontractor and TAB are in Division 23 and controls Subcontractor are in Division 25; those of the electrical Subcontractor in Division 26, and Electronic Safety and Security in Division 28. It is noted that the services for the Region, and the Consultants including HVAC, Mechanical, and Electrical Designers/Engineers, are not provided for in this Section. That is, the Contractor is not responsible for providing services covered under these parties' scope; their responsibilities are listed here to clarify the commissioning process.
- .2 All Parties: Commissioning responsibilities for all parties are as follows:
 - .1 Attend commissioning scoping meeting and additional meetings, as necessary.
- .3 Architect (of the Consultant): Commissioning responsibilities of the Architect are as follows:
 - .1 Attend the commissioning scoping meeting and selected commissioning team meetings.

- .2 Perform normal submittal review, construction observation, as-built drawing preparation, O &M manual preparation, etc., as contracted.
- .3 Provide any design narrative documentation requested by the CA.
- .4 Coordinate resolution of system deficiencies identified during commissioning, according to the Contract Documents.
- .5 Prepare and submit final as-built design intent documentation for inclusion in the O&M manuals. Review the O&M manuals.
- .6 Coordinate resolution of design non-conformance and design deficiencies identified during warranty-period commissioning.
- .4 Mechanical and Electrical Designers/Engineers as subconsultants to G. Bruce Stratton Architects:
Commissioning responsibilities of the Mechanical and Electrical Engineers are as follows:
 - .1 Perform normal submittal review, construction observation, as-built drawing preparation, etc., as contracted. One Site observation should be completed just prior to system startup.
 - .2 Provide any design narrative and sequences documentation requested by the CA. The Designers shall assist (along with the GC and/or Subcontractors) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
 - .3 Attend commissioning scoping meetings and other selected commissioning team meetings.
 - .4 Participate in the resolution of system deficiencies identified during commissioning, according to the Contract Documents.
 - .5 Prepare and submit the final as-built design intent and operating parameters documentation for inclusion in the O&M manuals. Review the O&M manuals.
 - .6 From the Contractor's red-line drawings, edit and update one-line diagrams developed as part of the design narrative documentation and those provided by the vendor as Shop Drawings for the chilled and hot water, condenser water, domestic water, steam and condensate systems; supply, return and exhaust air systems and emergency power system.
 - .7 Provide a presentation at one of the training sessions for the Region's personnel.
 - .8 Witness testing of selected pieces of equipment and systems.
 - .9 Participate in the resolution of non-compliance, non-conformance and design deficiencies identified during commissioning during warranty-period commissioning.

- .5 Commissioning Authority (CA): Commissioning Responsibilities of the Commissioning Authority are as follows:
- .1 The CA is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management. The CA may assist with problem-solving non-conformance or deficiencies, but ultimately that responsibility resides with the General Contractor and the Consultant. The primary role of the CA is to develop and coordinate the execution of a testing plan, observe and document performance that systems are functioning in accordance with the documented design intent and in accordance with the Contract Documents. The GC and/or Subcontractors will provide all tools or the use of tools to start, check-out and functionally test equipment and systems, except for specified testing with portable data-loggers, which shall be supplied and installed by the CA.
 - .2 Coordinates and directs the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consultations with all necessary parties, frequently updated timelines and schedules and technical expertise.
 - .3 Coordinate the commissioning work and, with the GC ensure that commissioning activities are being scheduled into the master schedule.
 - .4 Develop and issue the Commissioning Plan.
 - .5 Plan and conduct a commissioning scoping meeting and other commissioning meetings.
 - .6 Before startup, review the current control sequences and interlocks and work with the GC and Subcontractors and Design Engineers until sufficient clarity has been obtained, in writing, to be able to write detailed functional testing procedures.
 - .7 Review submittals provided by the GC and Subcontractors applicable to systems being commissioned for compliance with commissioning needs, concurrent with the Consultant reviews. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures.
 - .8 Write and distribute pre-functional tests and test sheets.
 - .9 Develop an enhanced start-up and initial systems checkout plan with Subs.
 - .10 Perform Site visits, as necessary, to observe component and system installations. Attend selected planning and Site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies.
 - .11 Witness all or part of the HVAC piping test and flushing procedure, sufficient to be confident that proper procedures were followed. Notify the Region of any deficiencies in results or procedures.
 - .12 Witness all or part of any ductwork testing and cleaning procedures, sufficient to be confident that proper procedures were followed. Notify the Region of any deficiencies in results or procedures.
 - .13 Approve pre-functional tests and checklist completion by reviewing pre-functional checklist reports and by selected Site observation and spot checking.
 - .14 Approve systems start-up by reviewing start-up reports and by selected Site observation.
 - .15 Review TAB execution plan.

- .16 Oversee sufficient functional testing of the control system and approve it to be used for TAB, before TAB is executed.
 - .17 Review air and water systems balancing by spot testing, by reviewing completed reports, and by selected Site observation.
 - .18 With necessary assistance and review from installing Subcontractors, write the functional performance test procedures for equipment and systems. This may include energy management control system trending, stand-alone data-logger monitoring, or manual functional testing.
 - .19 Analyze any functional performance trend logs and monitoring data to verify performance.
 - .20 Coordinate, witness and approve manual functional performance tests performed by installing Subcontractors. Coordinate retesting as necessary until satisfactory performance is achieved. Perform actual functional testing with contractors on equipment so specified in Section 01 91 00 sub-section 1.9.
 - .21 Maintain a master deficiency and resolution log and a separate testing record. Provide the Region with written progress reports and test results with recommended actions.
 - .22 Witness performance testing of smoke control systems by others and all other Region contracted tests or tests by manufacturer's personnel over which the CA may not have direct control. Document these tests and include this documentation in Commissioning Binders.
 - .23 Review equipment warranties to ensure that the Region's responsibilities are clearly defined.
 - .24 Oversee and approve the training of the Region's operating personnel. Compile and maintain a commissioning record book(s).
 - .25 Review the preparation of the O&M manuals. Provide a final commissioning report (as described in this Section).
 - .26 Develop a Systems Operating Manual.
 - .27 Coordinate and supervise required seasonal or deferred testing and deficiency corrections.
 - .28 Return to the Site at 20 months into the 24-month warranty period and review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. Also interview facility staff and identify problems or concerns they have operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify areas that may come under warranty or under the original construction contract. Assist facility staff in developing reports, documents and requests for services to remedy outstanding problems.
- .6 Contractor/Project Manager (PM): Commissioning Responsibilities of the Contractor/Project Manager are as follows:
- .1 Facilitate the coordination of the commissioning work by the CA, and ensure that commissioning activities are being scheduled into the master schedule.
 - .2 Review the final Commissioning Plan.
 - .3 Attend a commissioning scoping meeting and other commissioning team meetings.
 - .4 Include the cost of commissioning in the total Contract Price submitted in the Contractor's bid.

- .5 Perform the normal review of the Contractor's submittals.
- .6 Furnish a copy of all construction documents, addenda, change orders and approved submittals and Shop Drawings related to commissioned equipment to the CA.
- .7 In each purchase order or subcontract written, include requirements for submittal data, O&M data, commissioning tasks and training.
- .8 Ensure that all Subs execute their commissioning responsibilities according to the Contract Documents and schedule.
- .9 Observe and witness pre-functional test sheets, startup and functional testing.
- .10 Review commissioning progress and deficiency reports.
- .11 Coordinate the resolution of non-compliance and design deficiencies identified in all phases of commissioning.
- .12 Sign-off on individual commissioning tests as completed and passing.
- .13 Coordinate the training of Region personnel.
- .14 Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training sessions according to the Final Commissioning Program.
- .15 Assist the CA as necessary in the seasonal or deferred testing and deficiency corrections required by the specifications.
- .16 Ensure that Subs execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.
- .17 Ensure that Subs correct deficiencies and make necessary adjustments to O&M manuals and As-Built Drawings for applicable issues identified in any seasonal testing.
- .7 Equipment Suppliers: Commissioning Responsibilities of the Equipment Suppliers are as follows:
 - .1 Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the Region to keep warranties in force.
 - .2 Assist in equipment testing per agreements with Subs, which may include factory tests and the development of associated reports.
 - .3 All costs associated with provision of all special tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment according to these Contract Documents shall be included in the total Contract Price submitted in the Contractor's bid, except for stand-alone data-logging equipment that may be used by the CA.
 - .4 Through the Contractors to which products are supplied, analyze specified products and verify that the Consultant has specified the newest most updated equipment reasonable for this project's scope and budget.
 - .5 Provide information requested by CA regarding equipment sequence of operation and testing procedures.
 - .6 Review test procedures for equipment installed by factory representatives.

1.8 DEFINITIONS

The following definitions apply to this Section in addition to the defined term included in the Definitions Section of the Contract:

- .1 Approval - acceptance that a piece of equipment or system has been properly installed and is functioning in the tested modes according to the Contract Documents.
- .2 Basis of Design - The basis of design is the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the design intent. The basis of design describes the systems, components, conditions and methods chosen to meet the intent. The basis of design is the technical response to the design intent.
- .3 Commissioning Authority (CA) – The CA works independent of the design and constructions teams. The CA directs and coordinates the day-to-day commissioning activities. The CA does not take an oversight role like the Contractor. The CA is part of the Region's project team or shall report directly to the Region.
- .4 Commissioning Plan - an overall plan that provides the structure, schedule and coordination planning for the commissioning process.
- .5 Control system - the central building energy management control system.
- .6 Direct Digital Control (DDC) – Automated building control utilizing analog or digital signals to building controllers, actuators, valves, sensors, and other HVAC control related components
- .7 Data-logging - monitoring flows, currents, status, pressures, etc. of equipment using stand-alone data-loggers separate from the control system.
- .8 Deferred Functional Tests – FT's that are performed later, after achieving Substantial Performance of the Contract, due to partial occupancy, equipment, seasonal requirements, design or other Site conditions that disallow the test from being performed.
- .9 Deficiency - a condition in the installation or function of a component, piece of equipment or system that is not in compliance with the Contract Documents (that is, does not perform properly or is not compliant with the design intent).
- .10 Design Narrative or Design Documentation - sections of either the Design Intent or Basis of Design.
- .11 Energy Management System (EMS) – an integrated software system that collects, logs and displays data from sources of energy use
- .12 Factory Testing - testing of equipment on Site or at the factory by factory personnel with a Region representative present.
- .13 Functional Test (FT) - test of the dynamic function and operation of equipment and systems using manual (direct observation) or monitoring methods. Functional testing is the dynamic testing of systems (rather than just components) under full operation (e.g., the chiller pump is tested interactively with the chiller functions to see if the pump ramps up and down to maintain the differential pressure setpoint). Systems are tested under various modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, fire alarm, power failure, etc. The systems are run through all the control system's sequences of operation and components are verified to be responding as the sequences state. Traditional air or water test and balancing (TAB) is not functional testing, in the commissioning sense of the word. TAB Subcontractor's primary work is setting up the system flows and pressures as specified, while functional testing is verifying that which has already been set up. The Commissioning Authority develops the functional test procedures in a sequential written form, coordinates, oversees and documents the actual testing, which is usually performed by the installing Subcontractor or vendor. FTs are performed after pre-functional test sheets and startup are complete.
- .14 Manual Test - using hand-held instruments, immediate control system readouts or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the "observation").

- .15 Monitoring - the recording of parameters (flow, current, status, pressure, etc.) of equipment operation using data-loggers or the trending capabilities of control systems.
- .16 Non-Compliance - see Deficiency.
- .17 Non-Conformance - see Deficiency.
- .18 Over-written Value - writing over a sensor value in the control system to see the response of a system (e.g., changing the outside air temperature value from 50F to 75F to verify economizer operation). See also "Simulated Signal."
- .19 Region-Contracted Tests - tests paid for by the Region outside the GC's Contract and for which the CA does not oversee. These tests will not be repeated during functional tests if properly documented.
- .20 Phased Commissioning - commissioning that is completed in phases (by floors, for example) due to the size of the structure or other scheduling issues, in order minimize the total construction time.
- .21 Pre-functional Checklist (PC) - a list of items to inspect and elementary component tests to conduct to verify proper installation of equipment, provided by the CA to the Sub. Pre-functional test sheets are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension, oil levels satisfactory, labels affixed, gages in place, sensors calibrated, etc.). However, some pre-functional checklist items entail simple testing of the function of a component, a piece of equipment or system (such as measuring the voltage imbalance on a three-phase pump motor of a chiller system). Pre-functional refers to before functional testing and shall be completed by the installing Subcontractor. Pre-functional test sheets augment and are combined with the manufacturer's start-up checklist. The CA may choose to witness pre-functional tests for large/critical pieces of equipment.
- .22 Project Manager (PM) - the General Contractor's representative in the day-to-day activities of construction.
- .23 Sampling - functionally testing only a fraction of the total number of identical or near identical pieces of equipment. Refer to Section 01 91 00, Part 3.5.9.8 for details.
- .24 Seasonal Performance Tests - FT's that are deferred until the system(s) will experience conditions closer to their design conditions.
- .25 Simulated Condition - condition that is created for the purpose of testing the response of a system (e.g., applying a hair blower to a space sensor to see the response in a VAV box).
- .26 Simulated Signal - disconnecting a sensor and using a signal generator to send an amperage, resistance or pressure to the transducer and Direct Digital Control (DDC) system to simulate a sensor value.
- .27 Startup - the initial starting or activating of dynamic equipment, including executing pre-functional test sheets.
- .28 Test Procedures - the step-by-step process which must be executed to fulfill the test requirements. The test procedures are developed by the CA.
- .29 Test Requirements - requirements specifying what modes and functions, etc. shall be tested. The test requirements are not the detailed test procedures. The test requirements are specified in the Contract Documents (Sections 25 08 00 and 26 08 00)
- .30 Trending - monitoring using the building control system.
- .31 Vendor - supplier of equipment.
- .32 Warranty Period - warranty period for entire project as set out in Article A-6 of the Articles of Agreement and GC 38 -Warranty of the General Conditions, including equipment components.

1.9 SYSTEMS TO BE COMMISSIONED

- .1 Systems to be commissioned have been detailed below:
 - .1 Building Automation System – For Equipment/Systems in scope of work only
 - .2 Fan Coil Units
 - .3 Valves
 - .4 Air Handling Units
 - .5 Humidifiers
 - .6 Lighting and Lighting Controls

PART 2- PRODUCTS

2.1 Test Equipment

- .1 The Contractor shall ensure that all standard testing equipment required to perform startup and initial checkout and required functional performance testing be provided by the GC or Division Subcontractor for the equipment being tested. For example, the HVAC Subcontractor of Division 23 shall ultimately be responsible for all standard testing equipment for the HVAC system and controls systems except for equipment specific to and used by TAB in their commissioning responsibilities.
- .2 All costs associated with the special equipment, tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment, according to these Contract Documents shall be included in the total Contract Price submitted by the Contractor in its Bid, except for stand-alone data-logging equipment that may be used by the CA.
- .3 Data-logging equipment and software required to test equipment will be provided by the CA, but shall not become the property of the Region.
- .4 All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the Specifications. Temperature sensors and digital thermometers shall have a certified calibration within the past year to accuracy of 0.28°C (0.5°F) and a resolution of $\pm 0.056^{\circ}\text{C}$ (0.1°F). Pressure sensors shall have an accuracy of $\pm 2.0\%$ of the value range being measured (not full range of meter) and have been calibrated within the last year. All equipment shall be calibrated according to the manufacturer's recommended intervals and when dropped or damaged. Calibration tags shall be affixed or certificates readily available.

PART 3- EXECUTION

3.1 Meetings

- .1 The CA will schedule, plan and conduct a commissioning scoping meeting with the entire commissioning team in attendance. Meeting minutes will be distributed to all parties by the CA. Information gathered from this meeting will allow the CA to create the Commissioning Plan to its "final" version, which will also be distributed to all parties.
- .2 Miscellaneous Meetings. Other meetings will be planned and conducted by the CA as construction progresses. These meetings will cover coordination, deficiency resolution and planning issues with particular Subs. The CA will plan these meetings and will minimize unnecessary time being spent by Subs.

3.2 Reporting

- .1 The CA will provide regular reports to the Contractor and the Region, depending on the management structure, with increasing frequency as construction and commissioning progresses. Standard forms are provided and referenced in the Commissioning Plan.
- .2 The CA will regularly communicate with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling changes through memos, progress reports, etc.
- .3 Testing or review approvals and non-conformance and deficiency reports are made regularly with the review and testing as described in later sections.
- .4 A final summary report developed by the CA will be provided to the Contractor and the Region, focusing on evaluating commissioning process issues and identifying areas where the process could be improved. Pre-functional test sheets and functional tests will not be part of the final report.

3.3 Submittals

- .1 The Contractor and its Subcontractors shall provide the CA standard submittals required to facilitate the commissioning work. This process will be integrated into the normal submittal process and protocol of the construction team. At a minimum, the submittals will include equipment Shop Drawings, the manufacturer's printed installation and detailed start-up procedures, full sequences of operation, O&M data, performance data, any performance test procedures, control drawings, and details of Region contracted tests. In addition, the installation and checkout materials that are shipped inside the equipment and the field checkout forms to be used by the factory or field technicians shall be submitted to the Commissioning Authority. The Contractor shall ensure that all documentation requested by the CA is included by the Subs in their O&M manual contributions.
- .2 The Commissioning Authority will review submittals related to the commissioned equipment for conformance to Region's project requirements as they relate to the commissioning process.
- .3 The CA may request additional design narrative from the Consultant and controls Subcontractor, depending on the completeness of the design intent documentation and sequences provided with the Specifications.
- .4 These submittals to the CA do not constitute compliance for O&M manual documentation. The O&M manuals are the responsibility of the Contractor, though the CA will review them.

3.4 Start-up, Pre-Functional Test Sheets and Initial Checkout

- .1 The following procedures apply to all equipment to be commissioned. Some systems that are not comprised so much of actual dynamic machinery (e.g. electrical system power quality) may have very simplified PCs and startup.
 - .1 General. Pre-functional test sheets are a critical commissioning piece in order to ensure functional performance testing (in-depth system checkout) may proceed without unnecessary delays. Each piece of equipment receives full pre-functional checkout. No sampling strategies are used. The pre-functional testing for a given system must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.

- .2 Start-up and Initial Checkout Plan. The CA shall assist the commissioning team members responsible for startup of any equipment in developing detailed start-up plans for all equipment. The primary role of the CA in this process is to ensure that there is written documentation that each of the manufacturer recommended procedures have been completed. Parties responsible for pre-functional test sheets and startup are identified in the commissioning scoping meeting and in the checklist forms. The parties responsible for executing functioning performance testing are detailed in specific commissioning specification sections (refer to Section 01 91 00 subsection 1.6 of this document for details).
- .3 Pre-functional test scripts are provided by the CA to the Contractor. The Contractor determines which trade is responsible for executing and documenting each of the line item tasks and notes that trade on the form. Each form will have more than one trade responsible for its execution.
- .4 The Contractor shall ensure that the Subcontractor responsible for the purchase of the equipment develops the full start-up plan by combining (or adding to) the CA's test sheets with the manufacturer's detailed start-up and checkout procedures from the O&M manual and the normally used field checkout sheets. The plan will include test sheets and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan. The full start-up plan could consist of something as simple as:
 - .1 The CA's pre-functional test sheets.
 - .2 The manufacturer's standard written start-up procedures copied from the installation manuals with check boxes by each procedure and a signature block added by hand at the end.
 - .3 The manufacturer's normally used field checkout sheets.
- .5 The Contractor submits the full startup plan to the CA for review.
- .6 The CA reviews the procedures and the format for documenting them, noting any procedures that need to be added.
- .7 The full start-up procedures and the approval form may be provided to the Contractor for review depending on management protocol.
- .2 Sensor and Actuator Calibration:
 - .1 All field-installed temperature, relative humidity, CO/CO2, and pressure sensors/gauges, and all actuators (dampers and valves) on all equipment shall be calibrated using the methods described below. Alternate methods may be used, if accepted by the Region in advance. All test instruments shall have had a certified calibration within the last 12 months. Sensors installed in the unit at the factory with calibration certification provided need not be field calibrated.
 - .2 All procedures used shall be fully documented on the pre-functional test sheets or other suitable forms, clearly referencing the procedures followed and written documentation of initial, intermediate and final results.
- .3 Sensor Calibration Methods:
 - .1 All Sensors verify that all sensor locations are appropriate and away from causes of erratic operation. Verify that sensors with shielded cable are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, make sure they are reading within 0.2°F or .11°C of each other for temperature and within a tolerance equal to 2% of the reading, of each other, for pressure.

- .2 Sensors without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the Site sensor. Verify that the sensor reading (via the permanent thermostat, gage or Building Automation System (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- .3 Sensors with Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the Site sensor. Verify that the sensor reading (via the permanent thermostat, gage or BAS) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- .4 Tolerances, Standard Applications

Sensor	Required Tolerance [+/-]	Sensor	Required Tolerance (+/-)
Cooling coil, chilled and condenser water temps	0.22°C (0.4°F)	Flow rates, water	4% of design
AHU wet bulb or dew point	1.11°C (2.0°F)	Relative humidity	4% of design
Hot water coil and boiler water temp	0.83°C (1.5°F)	Combustion flue temps	2.78°C (5.0°F)
Outside air, space air, duct air temps	0.22°C (0.4°F)	Oxygen or CO ₂ monitor	0.1 % pts
Watt hour, voltage & amperage	1% of design	CO monitor	0.01 % pts
Pressures, air, water and gas	3% of design	Natural gas and oil flow rate	1% of design
Flow rates, air	10% of design	Steam flow rate	3% of design
		Barometric pressure	338.639 Pa (0.1 in. of Hg)

.5 Valve and Damper Stroke Setup and Check:

- .1 EMS Readout For all valve and damper actuator positions checked, verify the actual position against the BAS readout. Set pumps or fans to normal operating mode. Command valve or damper closed, visually verify that valve or damper is closed and adjust output zero signal as required. Command valve or damper open, verify position is full open and adjust output signal as required. Command valve or damper to a few intermediate positions. If actual valve or damper position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics).
- .2 Closure for heating coil valves (NO): Set heating setpoint 11.11°C (20°F) above room temperature. Observe valve open. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set heating setpoint to 11.11°C (20°F) below room temperature. Observe the valve close. Restore to normal.

- .3 Closure for cooling coil valves (NC): Set cooling setpoint 11.11 °C (20°F) above room temperature. Observe the valve close. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set cooling setpoint to 11.11 °C (20°F) below room temperature. Observe valve open. Restore to normal.
- .6 Execution of Pre-functional Test Sheets and Startup:
 - .1 The Contractor shall ensure that, a minimum of 28 Days prior to startup, the Subs and vendors schedule startup and checkout with the Contractor and CA. The performance of the pre-functional test sheets, startup and checkout are directed and executed by the Sub or vendor. When checking off pre-functional test sheets, signatures may be required of other Subs for verification of completion of their work.
 - .2 The CA shall observe, at minimum, the procedures for each piece of primary equipment, unless there are multiple units, (in which case a sampling strategy may be used as accepted by the PM).
 - .3 For lower-level components of equipment, (e.g., VAV boxes, sensors, controllers), the CA shall observe a sampling of the pre-functional and start-up procedures.
 - .4 The Contractor shall ensure that the Subs and vendors execute startup and provide the CA with a signed and dated copy of the completed start-up and pre-functional tests and test sheets.
 - .5 Only individuals that have direct knowledge and witnessed that a line item task on the pre-functional checklist was actually performed shall initial or check that item off. It is not acceptable for witnessing supervisors to fill out these forms.
- .7 Deficiencies, Non-Conformance and Approval in Test Sheets and Startup:
 - .1 The Contractor shall ensure that the Subs clearly list any outstanding items of the initial start-up and pre-functional procedures that were not completed successfully, at the bottom of the procedures form or on an attached sheet. The procedures form and any outstanding deficiencies are provided to the CA within two days of test completion.
 - .2 The CA reviews the report and submits either a non-compliance report or an approval form to the Region. The CA shall work with the Subs and vendors to correct and retest deficiencies or uncompleted items. The CA will involve the Contractor and others as necessary. The Contractor shall ensure that the installing Subs or vendors correct all areas that are deficient or incomplete in the test sheets and tests in a timely manner, and shall notify the CA as soon as outstanding items have been corrected and resubmit an updated start-up report and a Statement of Correction on the original non-compliance report. When satisfactorily completed, the CA recommends approval of the execution of the test sheets and startup of each system to the Contractor using a standard form.

3.5 Functional Testing

- .1 This sub-section applies to all commissioning functional testing for all divisions.
- .2 Systems to be Commissioned: The list of equipment to be commissioned is detailed in specific commissioning specification sections (refer to Section 01 91 00 subsection 1.6 of this document for details).
- .3 Objectives and Scope: The objective of functional performance testing is to demonstrate that each system is operating according to the Contract Documents. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and functioning of the systems.

- .4 In general, each system should be operated by the Contractor through all modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load) where there is a specified system response and from the approved Shop Drawings. Verifying each sequence in the sequences of operation is required. Proper responses to such modes and conditions as power failure, freeze condition, low oil pressure, no flow, equipment failure, etc. shall also be tested.
- .5 Development of Test Procedures: Before test procedures are written, the CA shall obtain all requested documentation and a current list of Change Orders affecting equipment or systems, including an updated points list, program code, control sequences and parameters. Using the testing parameters and requirements in specific commissioning specification sections (refer to Section 01 91 00 subsection 1.6 of this document for details), the CA shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. The Contractor shall ensure that each Sub or vendor responsible to execute a test provides limited assistance to the CA in developing the procedures review (answering questions about equipment, operation, sequences, etc.). Prior to execution, the CA shall provide a copy of the test procedures to the Sub(s) who shall review the tests for feasibility, safety, equipment and warranty protection. The CA may submit the tests to the Consultant for review, if requested.
- .6 The CA shall review Region-contracted, factory testing or required Region acceptance tests which the CA is not responsible to oversee, including documentation format, and shall determine what further testing or format changes may be required to comply with the Specifications. Redundancy of testing shall be minimized.
- .7 The purpose of any given specific test is to verify and document compliance with the stated criteria of acceptance given on the test form.
- .8 The test procedure forms developed by the CA shall include (but not be limited to) the following information:
 - .1 System and equipment or component name(s)
 - .2 Equipment location and ID number
 - .3 Date
 - .4 Project name
 - .5 Participating parties
 - .6 A copy of the specification section describing the test requirements
 - .7 A copy of the specific sequence of operations or other specified parameters being verified
 - .8 Required pre-test field measurements (filled-up pre-functional tests)
 - .9 Instructions for setting up the test.
 - .10 Specific step-by-step procedures to execute the test, in a clear, sequential and repeatable format
 - .11 Acceptance criteria of proper performance with a Yes / No check box to allow for clearly marking whether or not proper performance of each part of the test was achieved.
 - .12 A section for comments
 - .13 Signatures and date block for the CA and all participating parties.

.9 Test Methods:

- .1 Test Execution Functional performance testing and verification may be achieved by manual testing (persons manipulate the equipment and observe performance) or by monitoring the performance and analyzing the results using the control system's trend log capabilities or by stand-alone data-loggers. The CA may substitute specified methods or require an additional method to be executed, other than what was specified, with the approval of the Region. This may require a change order and adjustment in charge to the Region. The CA will determine which method is most appropriate for tests that do not have a method specified.
- .2 Simulated Conditions Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
- .3 Overwritten Values: Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used with caution and avoided when possible. Such testing methods often can only test a part of a system, as the interactions and responses of other systems will be erroneous or not applicable. Simulating a condition is preferable. e.g., for the above case, by heating the outside air sensor with a hair blower rather than overwriting the value or by altering the appropriate setpoint to see the desired response. Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.
- .4 Simulated Signals: Using a signal generator which creates a simulated signal to test and calibrate transducers and DDC constants is generally recommended over using the sensor to act as the signal generator via simulated conditions or overwritten values.
- .5 Altering Setpoints: Rather than overwriting sensor values, and when simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below 55°F or 13°C, when the outside air temperature is above 55°F or 13°C, temporarily change the lockout setpoint to be 2°F or 1.1°C above the current outside air temperature.
- .6 Indirect Indicators: Relying on indirect indicators for responses or performance shall be allowed only after visually and directly verifying and documenting, over the range of the tested parameters, that the indirect readings through the control system represent actual conditions and responses. Much of this verification is completed during pre-functional testing.
- .7 Setup: Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Contractor shall ensure that the Sub executing the test provides all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions. At completion of the test, the Sub shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.
- .8 Sampling: Multiple identical pieces of non-life-safety or otherwise non-critical equipment may be functionally tested using a sampling strategy. Significant application differences and significant sequence of operation differences in otherwise identical equipment invalidates their common identity. A small size or capacity difference, alone, does not constitute a difference. It is noted that no sampling by Subs is allowed in pre-functional checklist execution.

A common sampling strategy referenced in the Specifications as the “xx% Sampling— yy% Failure Rule” is defined by the following example.

xx = the percent of the group of identical equipment to be included in each sample.

yy = the percent of the sample that if failing, will require another sample to be tested.

The example below describes a 20% Sampling—10% Failure Rule.

- .9 Randomly test at least 20% (xx) of each group of identical equipment. In no case test less than three units in each group. This 20%, or three, constitute the “first sample.”
 - .10 If 10% (yy) of the units in the first sample fail the functional performance tests, test another 20% of the group (the second sample).
 - .11 If 10% of the units in the second sample fail, test all remaining units in the whole group.
 - .12 If at any point, frequent failures are occurring and testing is becoming more troubleshooting than verification as determined by the CA, the CA may stop the testing and require the responsible Sub to perform and document a checkout of the remaining units, prior to continuing with functionally testing the remaining units.
- .10 Coordination and Scheduling:
- .1 The Subs shall provide sufficient notice to the CA regarding their completion schedule for the pre-functional test sheets and startup of all equipment and systems. The CA will schedule functional tests through the Contractor and affected Subs. The CA shall direct, witness and document the functional testing of all equipment and systems. The Contractor shall ensure that the Subs execute the tests.
 - .2 In general, functional testing is conducted after pre-functional testing and startup has been satisfactorily completed. The control system is sufficiently tested and approved by the CA before it is used for TAB or to verify performance of other components or systems. The air balancing and water balancing is completed and debugged before functional testing of air-related or water-related equipment or systems. Testing proceeds from components to subsystems to systems. When the proper performance of all interacting individual systems has been achieved, the interface or coordinated responses between systems is checked.
- .11 Test Equipment: Refer to Section 01 91 00, Part 2 for test equipment requirements.
- .12 Problem Solving: The CA will recommend solutions to problems found, however it is the responsibility of the Subs, and the GC to solve, correct and retest problems.

3.6 Documentation, Non-Conformance and Approval of Tests

- .1 Documentation: The CA shall witness and document the results of all functional performance tests using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the Contractor and its Subs for review. The CA will include the filled-out forms in the Commissioning Binders.
- .2 Non-Conformance:
 - .1 All deficiencies or non-conformance issues shall be noted and reported to the Region on a standard non-compliance form.
 - .2 Corrections of minor deficiencies identified may be made during the tests at the discretion of the CA. In such cases the deficiency and resolution will be documented on the procedure form.

- .3 Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the CA will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues.
 - .4 As tests progress and a deficiency is identified, the CA discusses the issue with the executing Subcontractor.
 - .1 When there is no dispute on the deficiency and the Sub accepts responsibility to correct, the following course of action occurs:
 - .2 The CA documents the deficiency in deficiency tracking log and issues to the Project Team. The Sub corrects the issue and signs off on the deficiency tracking log indicating the issue has been resolved.
 - .3 The CA reschedules the test and the test is repeated. If the test is successful, the CA closes the item.
 - .5 If there is a dispute about a deficiency, regarding whether it is a deficiency or who is responsible:
 - .1 The deficiency shall be documented on the deficiency tracking log with the Sub's response and a copy given to the Contractor and to the Sub representative assumed to be responsible.
 - .2 Resolutions are made at the lowest management level possible. Other parties are brought into the discussions as needed. Final interpretive authority is with the Consultant. Final acceptance authority is with the Region.
 - .3 The CA documents the resolution process.
 - .4 Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency, signs off on the deficiency tracking log and provides it to the CA. The CA reschedules the test and the test is repeated until satisfactory performance is achieved, at which time the CA closes the item.
 - .6 Cost of Retesting:
 - .1 The cost for the Sub to retest a pre-functional or functional test, if they are responsible for the deficiency, shall be theirs. If they are not responsible, any cost recovery for retesting costs shall be negotiated with the GC. The Region shall not be responsible for any costs associated with retesting due to a deficiency caused by the GC or a Subcontractor.
 - .2 For a deficiency identified, not related to any pre-functional checklist or start-up fault, the following shall apply: The CA and the Contractor will direct the retesting of the equipment once at no "charge" to the GC for their time.
 - .3 Refer to the sampling section of Section 01 91 00, Part 3.5 for requirements for testing and retesting identical equipment.
 - .7 The Contractor shall respond in writing to the CA and the Region at least as often as commissioning meetings are being scheduled concerning the status of each apparent outstanding discrepancy identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.
 - .8 The CA retains the original deficiency tracking log until the end of the project.
 - .9 Any required retesting by any contractor shall not be considered a justified reason for a claim of delay or for a time extension by the Contractor.
- .3 Approval:

- .1 The CA notes each satisfactorily demonstrated function on the test form. Formal approval of the functional test is made later after review by the CA and by the Region, if necessary. The CA recommends acceptance of each test to the Region using a standard form. The Region gives final approval on each test using the same form, providing a signed copy to the CA and the Contractor.

3.7 Operation and Maintenance Manuals

- .1 The specific content and format requirements for the standard O&M manuals are detailed in Mechanical and Electrical Specifications by the Contractor.
- .2 Consultant Contribution: The Consultant will include in the beginning of the O&M manuals a separate section describing the systems including:
 - .1 The design intent narrative prepared by the Consultant and provided as part of the Contract Documents, updated to as-built status by the Consultant. These documents will be provided to the Contractor at time of Substantial Performance of the Work.
 - .2 Simplified professionally drawn single line system diagrams on 215.9mm x 279.4mm (8 1/2" x 11") or 279.4mm x 431.8mm (11" x 17") sheets. These shall include chilled water system, water system, heating system, steam system, supply air systems, exhaust systems, domestic hot water and electrical single lines. These shall show major pieces of equipment.
- .3 CA Review Prior to Substantial Performance of the Contract, the CA shall review the O&M manuals, documentation and redline as-builts for systems that were commissioned and to verify compliance with the Specifications. The CA will communicate deficiencies in the manuals to the Region or Consultant, as requested. Upon a successful review of the corrections, the CA recommends acceptance of these sections of the O&M manuals to the Region or Consultant. The CA also reviews each equipment warranty and verifies that all requirements to keep the warranty valid are clearly stated. This work does not supersede the Consultant's review of the O&M manuals.

3.8 Training of Region Personnel

- .1 The GC shall be responsible for training coordination and scheduling, and ultimately for ensuring that training is completed.
- .2 The CA shall interview the facility manager and Consultant to determine the special needs and areas where training will be most valuable. The Region and CA shall decide how rigorous the training should be for each piece of commissioned equipment. The CA shall communicate the results to the Subs and vendors who have training responsibilities.
- .3 In addition to these general requirements, the detailed training requirements of the Region personnel by Subs and vendors is detailed in specific commissioning specification sections (refer to Section 01 91 00 Subsection 1.6 of this document for details).
- .4 Each Sub and vendor responsible for training will submit a written training plan to the CA for review and written approval prior to training. The plan will cover the following elements:
 - .1 Equipment (included in training)
 - .2 Intended audience
 - .3 Location of training
 - .4 Objectives
 - .5 Subjects covered (description, duration of discussion, special methods, etc.)

- .6 Duration of training on each subject
- .7 Instructor for each subject
- .8 Methods (classroom lecture, video, Site walk-through, actual operational demonstrations, written handouts, etc.)
- .9 Instructor and qualifications
- .5 For the primary HVAC equipment, the controls Subcontractor shall provide a short discussion of the control of the equipment during the mechanical or electrical training conducted by others.
- .6 The CA develops an overall training plan and coordinates and schedules, with the Region, the overall training for the commissioned systems. The CA develops criteria for determining that the training was satisfactorily completed, including attending some of the training, etc. The CA recommends approval of the training to the Region using a standard form. The Region will also sign the approval form.
- .7 The Mechanical and Electrical Design Engineer who are G. Bruce Stratton Architects' subconsultants shall at the first training session present the overall system design concept and the design concept of each equipment section. This presentation shall include a review of all systems using the simplified system schematics (one-line drawings) including chilled water systems, heating systems, air distribution system, control system strategies, electrical distribution, fire systems, etc.

3.9 Deferred Testing

- .1 Unforeseen Deferred Tests: If any check or test cannot be completed due to the building structure, required occupancy condition or other deficiency, execution of test sheets and functional testing may be delayed upon approval of the Region. These tests will be conducted in the same manner as the seasonal tests as soon as possible. Services of necessary parties will be negotiated.
- .2 Seasonal Testing During the warranty period, seasonal testing (tests delayed until weather conditions are closer to the system's design) shall be completed as part of this contract. The CA shall coordinate this activity. Tests will be executed, documented and deficiencies corrected by the appropriate Subs, with facilities staff and the CA witnessing. Any final adjustments to the O&M manuals and as-builts due to the testing will be made.

3.10 WRITTEN WORK PRODUCTS

- .1 The commissioning process generates a number of written work products described in various parts of the Specifications. The Commissioning Plan lists all the formal written work products, describes briefly their contents, who is responsible to create them, their due dates, who receives and approves them and the location of the specification to create them. In summary, the written products are:

<u>Product</u>	<u>Developed By</u>
1. Final commissioning plan	CA
2. Commissioning Meeting Minutes	CA
3. Commissioning Schedule	CA with GC
4. Equipment documentation submittals	Subs
5. Sequence clarifications	Subs and A/E as needed
6. Pre-functional test sheets	CA
7. Startup and initial checkout plan	Subs and CA (compilation of existing documents)
8. Startup and initial checkout forms filled out	Subs

9.	Final TAB report	TAB Subcontractor
10.	Issues log (deficiencies)	CA
11.	Commissioning Progress Record	CA
12.	Functional test forms	CA
13.	Filled out functional tests	CA
14.	O&M manuals	Subs
15.	Final Commissioning Documentation	CA
16.	Overall training plan	CA
17.	Specific training agendas	Subs
18.	Final commissioning report	CA
19.	Misc. approvals	CA

END OF SECTION

DIVISION 21, 22, 23, 25 - MECHANICAL

21 00 00	CONTENTS
01 91 00	COMMISSIONING REQUIREMENTS
21 08 00	FIRE SUPPRESSION SYSTEM COMMISSIONING
21 13 13	SPRINKLER SYSTEMS
22 08 00	PLUMBING SYSTEM COMMISSIONING
22 11 10	PLUMBING PIPING
22 42 01	PLUMBING SPECIALTIES
22 42 03	PLUMBING FIXTURES
23 03 13	ELECTRIC MOTORS
23 05 01	ELECTRIC WIRING FOR MECHANICAL
23 05 10	HYDRONIC PIPING
23 05 14	MOTOR STARTERS
23 05 15	HYDRONIC SPECIALTIES
23 05 20	HORIZONTAL FAN COIL UNITS
23 05 29	SUPPORTS & ANCHORS
23 05 48	VIBRATION ISOLATION
23 05 53	MECHANICAL IDENTIFICATION
23 05 93	TESTING ADJUSTING BALANCING COMMISSIONING
23 07 13	DUCT INSULATION
23 07 15	INSULATION SCHEDULES
23 07 20	PIPING INSULATION
23 08 00	HVAC SYSTEM COMMISSIONING
23 31 10	LOW PRESSURE DUCTWORK
23 33 00	DUCTWORK ACCESSORIES
23 33 14	BALANCING DAMPERS
23 33 16	FIRE-DAMPERS
23 33 46	FLEXIBLE DUCTWORK
23 33 53	ACOUSTIC DUCT LINING
23 34 00	Fans
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23 82 36	Finned Tube Radiation
25 00 00	CONTROLS
25 08 00	INTEGRATED AUTOMATION COMMISSIONING

PART 1 – GENERAL

1.1 General

- .1 The purpose of this section is to specify responsibilities in the commissioning process for the work of Division 21.
- .2 The systems to be commissioned are listed in Section 01 91 00, subsection 1.9. The abbreviations and definitions used in Section 01 91 00 apply to this Section 21 08 00 – Fire Suppression System Commissioning.
- .3 Commissioning shall take into account the requirements under Division 21 to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirements and coordination are detailed in Section 01 91 00. For the purposes of completing work under Division 21, the Contractor shall be familiar with all parts of Section 01 91 00 and the commissioning plan issued by the CA and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.2 Responsibilities

- .1 Fire Suppression Subcontractor: The responsibilities of the Contractor and its Fire Suppression Subcontractor, during construction and acceptance phases in addition to those listed above are (all references apply to commissioned equipment only) are as follows:
 - .1 Documentation of all procedures performed shall be provided and forwarded to the Consultant. Written documentation must contain recorded test values of all tests performed per the individual product specification.
 - .2 The start-up service company shall be present during energization of the plumbing equipment. Jobsite and equipment access must be provided by the Fire Suppression Subcontractor.
 - .3 Supply a power source, specified by the start-up service company, for on-site test equipment.
 - .4 Attend all factory witness testing required within the respective specification sections. The Contractor shall include all related costs in the total Contract Price submitted with its bid.
 - .5 Perform tests using qualified personnel. Provide necessary instruments and equipment.
 - .6 The Contractor shall include the cost of commissioning in the total Contract Price, submitted with its bid..
 - .7 The Contractor shall ensure it complies with the requirements of GC -10 Subcontractors and ensures that the Fire Suppression Subcontractor complies with the Contract requirements for submittal data, O&M data and training.
 - .8 Attend a commissioning scoping meeting and other necessary meetings scheduled by the CA to facilitate the Cx process.
 - .9 Provide normal cut sheets and Shop Drawing submittals to the CA of commissioned equipment. Provide additional requested documentation, prior to normal O&M manual submittals, to the CA for development of pre-functional and functional testing procedures.
 - .1 Include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Agent.

- .2 The Commissioning Agent may request further documentation necessary for the commissioning process. This data request may be made prior to normal submittals.
- .10 Provide a copy of the O&M manuals submittals of commissioned equipment, through normal channels, to the CA for review.
- .11 Assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
- .12 Provide assistance to the CA in preparation of the specific functional performance test procedures specified in Division 21. Subs shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
- .13 Develop a full start-up and checkout plan using manufacturer's start-up procedures and the pre- functional test sheets from the CA. Submit manufacturer's detailed start-up procedures and the full start-up plan and procedures and other requested equipment documentation to CA for review.
- .14 During the startup and checkout process, execute and document the mechanical-related portions of the pre-functional test sheets provided by the CA for all commissioned equipment.
- .15 Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CA.
- .16 Provide skilled technicians to execute starting of equipment and to execute the functional performance tests. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving.
- .17 Perform functional performance testing under the direction of the CA for specified equipment in Section 01 91 00, subsection 1.9. Assist the CA in interpreting the monitoring data, as necessary.
- .18 Correct deficiencies (differences between specified and observed performance) as interpreted by the CA, PM and A/E and retest the equipment.
- .19 Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
- .20 During construction, maintain as-built red-line drawings for all Drawings and final CAD as-builts for contractor-generated coordination drawings. Update after completion of commissioning (excluding deferred testing). Prepare red-line as-built drawings for all drawings and final as-builts for contractor-generated coordination drawings
- .21 Provide training of the Owner's operating personnel as specified in the Contract Documents.
- .22 Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.
- .23 Execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.
- .24 Correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.
- .25 Assist and cooperate with the Mechanical and TAB Subcontractor and CA by:
- .1 Putting all equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
 - .2 List and clearly identify on the as-built drawings the locations of equipment.
 - .3 Prepare a preliminary schedule for Division 21 equipment start-up, as well as TAB start and completion for use by the CA. Update the schedule as appropriate.

- .4 Notify the PM/GC or CA depending on protocol, when pipe testing, flushing, cleaning, start-up of each piece of equipment and TAB will occur. Be responsible to notify the PM/GC or CA, ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed, and that CA has the scheduling information needed to efficiently execute the commissioning process.

PART 2- PRODUCTS

- .1 NOT USED

PART 3- EXECUTION

3.1 Submittals

- .1 Provide submittal documentation relative to commissioning under Division 21 to the CA as requested by the CA. Refer to Section 01 91 00 Part 3.3 for additional Section 21 requirements.

3.2 Start-up of Equipment

- .1 Follow the start-up and initial checkout procedures listed in the Responsibilities list in this section and in 01 91 00. Ensure the start-up responsibility under Division 21 is met and complete systems and sub-systems so they are fully functional, meeting the design objectives of the Contract Documents. The commissioning procedures and functional testing do not relieve or lessen this responsibility or shift that responsibility partially to the commissioning agent or Owner.
- .2 Functional testing is intended to begin upon completion of a system. Functional testing may proceed prior to the completion of systems or sub-systems at the discretion of the CA and CM. Beginning system testing before full completion does not relieve the Contractor from fully completing the system, including all pre functional checklists as soon as possible.
- .3 Prior to the start-up of equipment under Division 21 the Contractor shall arrange to have the manufacturer of all major equipment inspect the installation to ensure their equipment has been installed in accordance with their recommendations.
- .4 The manufacturer shall submit a written report of their findings.
- .5 Upon confirmation that the equipment has been installed in accordance with the Manufacturers Recommendations the equipment may be started.
- .6 All equipment shall be started by the manufacturer's representative.

3.3 Pre-Functional Test Sheets

- .1 Pre-functional test sheets contain items to be performed under Division 21. On each checklist, a column is provided that is to be completed by the Contractor assigning responsibility for that line item to a trade. Those executing the test sheets are only responsible to perform items that apply to the specific application at hand. These test sheets do not take the place of the manufacturer's recommended checkout and start-up procedures or report. Some checklist procedures may be redundant in relation to checkout procedures that will be documented on typical factory field checkout sheets. Double documenting may be required in those cases.
- .2 Refer to Section 01 91 00 for additional requirements regarding pre-functional test sheets, startup and initial checkout.

3.4 Operations and Maintenance Manuals

- .1 Compile and prepare documentation for all equipment and systems covered in Division 21 and deliver to the GC for inclusion in the O&M manuals
- .2 The CA shall receive a copy of the O&M manuals for review.

3.5 Training of Owner Personnel

- .1 The GC shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed. Refer to Section 01 91 00 for additional details.
- .2 The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment. Refer to Section 01 91 00 for additional details.
- .3 Fire Suppression Contractor. The Contractor shall ensure the Fire Suppression Subcontractor meets the following training responsibilities:
 - .1 Provide the CA with a training plan two weeks before the planned training according to the outline described in Section 01 91 00, Part 3.8.
 - .2 Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of commissioned fire suppression equipment
 - .3 Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including start-up, shutdown, fire/smoke alarm, power failure, etc.
 - .4 During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
 - .5 Ensure the appropriate trade or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment is required. More than one party may be required to execute the training.
 - .6 The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
 - .7 Training shall include:
 - .1 Use of the printed installation, operation and maintenance instruction material included in the O&M manuals.
 - .2 A review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.
 - .3 Discussion of relevant health and safety issues and concerns.
 - .4 Discussion of warranties and guarantees.
 - .5 Common troubleshooting problems and solutions.
 - .6 Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.

- .7 Discussion of any peculiarities of equipment installation or operation.
- .8 Hands-on training shall include start-up, operation in all modes possible, including manual, shut- down and any emergency procedures and preventative maintenance for all pieces of equipment.
- .9 Ensure the Fire Suppression Subcontractor fully explains and demonstrates the operation, function and overrides of any local packaged controls, not controlled by the central control system.
- .10 Training shall occur after functional testing is complete, unless approved otherwise by the Project Manager.

3.6 Deferred Testing

- .1 Refer to Section 01 91 00, Part 3.9 for requirements of deferred testing.

3.7 WRITTEN WORK PRODUCTS

- .1 Written work products under Division 21 shall consist of the start-up and initial checkout plan as described in Section 01 91 00, as well as completed start-up, initial checkout and pre-functional test sheets.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide a complete automatic sprinkler system, including all necessary labour services, products, materials and equipment as shown on the Drawings and as specified herein. Products, materials and equipment shall include, but not necessarily be limited to, the following:
 - .1 Piping and fittings.
 - .2 Valves.
 - .3 Hydraulic piping design and calculations.
 - .4 Sprinkler heads.
 - .5 Sprinkler cabinets.
 - .6 Supervisory devices.
 - .7 Hydrant water flow tests required for hydraulic design.

1.2 REFERENCE STANDARDS

- .1 Provide all work in accordance with the latest requirements of NFPA 13, local codes and all authorities having jurisdiction.
- .2 Provide materials that are ULC listed and approved.

1.3 SUBMITTALS

- .1 Prior to installation, submit minimum ten (10) copies of the working drawings, hydraulic design and calculations to all authorities having jurisdiction. All hydraulic design and calculations shall be sealed by a professional engineer. Assume any additional costs that may be incurred to modify or complete the system should the authorities having jurisdiction require changes. Any and all costs pertaining to approval shall be borne by the Contractor.
- .2 Submit Drawings to the Consultant after review by all authorities having jurisdiction including comments received.
- .3 Provide shop drawings for all sprinkler hardware including heads, alarm valves and trim, valves.

1.4 SAMPLES

- .1 Provide samples of each type of sprinkler head and accompanying escutcheons.
- .2 Provide samples of sprinkler head guards.

PART 2 - PRODUCTS

2.1 PIPE AND FITTINGS

- .1 Provide pipe and fittings of good quality consistent with the respective manufacturer, devoid of any defects and compatible with required system working pressure.
- .2 All sprinkler piping shall be rigid black steel pipe, including piping connections to sprinkler heads. Flexible sprinkler drops are not permitted on sprinkler head connections.
- .3 Pipe sizes up to 150 mm (6") shall be Schedule 40 black steel pipe conforming to ASTM standards. Thin wall piping conforming to ASTM standards is acceptable when used with rolled groove fittings for plain end pipe.
- .4 Pipe sizes 200 mm (8") and over shall be Schedule 30 black steel pipe conforming to ASTM standards.
- .5 Connections shall be screwed for piping 65 mm (2-1/2") and under. Connections for piping over 65 mm (2-1/2") may be screwed, welded (when approved by local authorities) or joined by means of Victaulic couplings (when approved by local authorities and performed to NFPA and IAO standards).
- .6 Victaulic types fittings shall only be used where piping is accessible.

2.2 SPRINKLER HEADS

- .1 Provide ULC approved sprinkler heads:
 - .1 In finished ceilings, unless otherwise indicated, chrome plated semi-recessed liquid filled pendant heads with chrome plated or painted escutcheons.
 - .2 In finished ceilings, where specifically indicated, fully recessed sprinkler heads (flush type) with painted or stainless steel coverplates.
 - .3 In unfinished areas, (such as mechanical rooms, garage, etc.) pendant or upright bronze sprinkler heads.
- .2 Provide wire guards to protect sprinkler heads in all mechanical, electrical and elevator machine rooms, and in any area where heads may be damaged.
- .3 Provide high temperature sprinkler heads in electric rooms, elevator machine rooms, diesel generator rooms, boiler rooms, and in all locations where sprinkler heads are located close to heating coils, unit heaters, high-intensity lighting or other hot equipment.
- .4 Provide a metal cabinet with spare sprinkler heads of each type, 5 spare wrenches, keys and labels. Locate the cabinet in an accessible location in the 4th floor mechanical room.
- .5 Rooms or spaces having dropped ceilings that are open to the surrounding areas shall have sprinkler coverage provided both above and below the dropped ceiling as required by NFPA 13. The Drawings indicate only the sprinkler heads to be installed below the dropped ceiling areas. Provide sprinkler coverage above the dropped ceilings in accordance with NFPA 13.

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Piping and Fittings
 - .1 Install piping and fittings, including all necessary hangers and supports, in accordance with NFPA and IAO regulations, codes and all authorities having jurisdiction.
 - .2 Flush the piping system until all foreign material has been removed. Provide a certificate stating that

proper flushing has been performed.

- .3 Provide a system test for two (2) hours at 1780 kPa (250 psi) without any pressure loss. If leaks occur, they shall be repaired and the system retested. Provide a certificate stating that the hydrostatic test has been carried out to the satisfaction of all authorities having jurisdiction.
- .4 In areas with floating ceilings or with ceiling projections, sprinkler piping shall be concealed behind adjacent walls, ceiling spaces, structural elements, etc. so as not to be visible. All piping drops for these areas shall be concealed in such a manner. Horizontal piping serving sprinkler heads shall be installed at low level as close to the top of the floating ceiling or ceiling projection as possible so as not to be visible.

3.2 PERMITS AND INSPECTIONS

- .1 Apply and pay for all necessary permits and inspections required by authorities having jurisdiction.

3.3 HYDRAULIC DESIGN CRITERIA

- .1 Provide hydraulically designed system in accordance with NFPA 13 standards.
- .2 Provide the hydraulic design and piping calculations necessary for a complete sprinkler system.
- .3 Hazard classification shall be to NFPA 13 (IAO G13) standards:
 - .1 Office areas - light hazard.
- .4 Provide and install the required number of sprinkler heads and all necessary components as approved by all codes and all governing authorities.

END OF SECTION

PART 1 – GENERAL

1.1 General

- .1 The purpose of this section is to specify Division 22 responsibilities in the commissioning process.
- .2 The systems to be commissioned are listed in Section 01 91 00.1.9.
- .3 Commissioning requires the participation of Division 22 to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirements and coordination are detailed in Section 01 91 00. Division 22 shall be familiar with all parts of Section 01 91 00 and the commissioning plan issued by the CA and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.2 Responsibilities

- .1 Plumbing Contractor: The responsibilities of the Plumbing Contractor, during construction and acceptance phases in addition to those listed above are (all references apply to commissioned equipment only):
 - .1 Documentation of all procedures performed shall be provided and forwarded to the Consultant. Written documentation must contain recorded test values of all tests performed per the individual product specification.
 - .2 The start-up service company shall be present during energization of the plumbing equipment. Site and equipment access must be provided by the plumbing Subcontractor.
 - .3 The Contractor shall supply a power source, specified by the start-up service company, for on-Site test equipment.
 - .4 The plumbing Subcontractor is to attend all factory witness testing required within the respective Specification sections. The Contractor is responsible to cover all their costs and include them in their bid.
 - .5 Perform tests using qualified personnel. Provide necessary instruments and equipment.
 - .6 Include the cost of commissioning in the Contract Price, if not yet included.
 - .7 In each purchase order or subcontract written, include requirements for submittal data, Operating and Maintenance (O&M) data and training.
 - .8 Attend a commissioning scoping meeting and other necessary meetings scheduled by the CA to facilitate the Cx process.
 - .9 Contractor shall provide normal cut sheets and Shop Drawing submittals to the CA of commissioned equipment. Provide additional requested documentation, prior to normal O&M manual submittals, to the CA for development of pre-functional and functional testing procedures.
 - .1 Typically this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Agent.
 - .2 The Commissioning Agent may request further documentation necessary for the commissioning process. This data request may be made prior to normal submittals.

- .10 Provide a copy of the O&M manuals submittals of commissioned equipment, through normal channels, to the CA for review.
- .11 Contractors shall assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the Specifications, control Drawings or equipment documentation is not sufficient for writing detailed testing procedures.
- .12 Provide assistance to the CA in preparation of the specific functional performance test procedures specified in Section 22. Subcontractors shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
- .13 Develop a full start-up and checkout plan using manufacturer's start-up procedures and the pre- functional test sheets from the CA. Submit manufacturer's detailed start-up procedures and the full start-up plan and procedures and other requested equipment documentation to CA for review.
- .14 During the startup and checkout process, execute and document the mechanical-related portions of the pre-functional test sheets provided by the CA for all commissioned equipment.
- .15 Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CA.
- .16 Provide skilled technicians to execute starting of equipment and to execute the functional performance tests. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving.
- .17 Perform functional performance testing under the direction of the CA for specified equipment in Section 01 91 00, subsection 1.9. Assist the CA in interpreting the monitoring data, as necessary.
- .18 Correct deficiencies (differences between specified and observed performance) as interpreted by the CA, PM and A/E and retest the equipment.
- .19 Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
- .20 During construction, maintain as-built red-line Drawings for all Drawings and final CAD as-builts for Contractor-generated coordination Drawings. Update after completion of commissioning (excluding deferred testing). Prepare red-line as-built Drawings for all Drawings and final as-builts for Contractor-generated coordination Drawings
- .21 Provide training of the Owner's operating personnel as specified in Section 25 00 00.
- .22 Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.
- .23 Execute seasonal or deferred functional performance testing, witnessed by the CA, according to the Specifications.
- .24 Correct deficiencies and make necessary adjustments to O&M manuals and as-built Drawings for applicable issues identified in any seasonal testing.
- .25 Assist and cooperate with the mechanical and Testing, Adjusting Balancing (TAB) Subcontractor and CA by:
 - .1 Putting all equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
 - .2 Providing temperature and pressure taps according to the Contract Documents for TAB and commissioning testing.

- .26 Install a Pressure Transducer (P/T) plug at each water sensor which is an input point to the control system.
- .27 List and clearly identify on the as-built Drawings the locations of applicable sensors and meters
- .28 Prepare a preliminary schedule, in conjunction with Division 25 Subcontractors for Division 22 pipe system testing, flushing and cleaning, equipment start-up and TAB start and completion for use by the CA. Update the schedule as appropriate.
- .29 Notify the PM/GC or CA depending on protocol, when pipe system testing, flushing, cleaning, start-up of each piece of equipment and TAB will occur. Be responsible to notify the PM/GC or CA, ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed, and that the CA has the scheduling information needed to efficiently execute the commissioning process.

PART 2 - PRODUCTS

- .1 NOT USED

PART 3 - EXECUTION

3.1 Submittals

- .1 The Contractor shall ensure that Section 22 Subcontractors provide submittal documentation relative to commissioning to the CA as requested by the CA. Refer to Section 01 91 00 Part 3.3 for additional Section 22 requirements.

3.2 Start-up of Equipment

- .1 The plumbing Subcontractors shall follow the start-up and initial checkout procedures listed in the Responsibilities list in this section and in 01 91 00. Division 22 has start-up responsibility and is required to complete systems and sub-systems so they are fully functional, meeting the design objectives of the Contract Documents. The commissioning procedures and functional testing do not relieve or lessen this responsibility or shift that responsibility partially to the commissioning agent or Owner.
- .2 Functional testing is intended to begin upon completion of a system. Functional testing may proceed prior to the completion of systems or sub-systems at the discretion of the CA and CM. Beginning system testing before full completion does not relieve the Contractor from fully completing the system, including all pre functional checklists as soon as possible.
- .3 Prior to the start-up of equipment the Division 22 Contractor shall arrange to have the manufacturer of all major equipment inspect the installation to ensure their equipment has been installed in accordance with their recommendations.
- .4 The Supplier shall submit a written report of their findings.
- .5 Upon confirmation that the equipment has been installed in accordance with the manufacturer's recommendations the equipment may be started.
- .6 All equipment shall be started by the manufacturer's representative.

3.3 Pre-Functional Test Sheets

- .1 Pre-functional test sheets contain items for Section 22 Subcontractors to perform. On each checklist, a column is provided that is to be completed by the Contractor assigning responsibility for that line item to a trade. Those executing the test sheets are only responsible to perform items that apply to the specific application at hand. These test sheets do not take the place of the manufacturer's recommended checkout and start-up procedures or report. Some checklist procedures may be redundant in relation to checkout procedures that will be documented on typical factory field checkout sheets. Double documenting may be required in those cases.
- .2 Refer to Section 01 91 00 for additional requirements regarding pre-functional test sheets, startup and initial checkout. Items that do not apply should be noted along with the reasons on the form. If this form is not used for documenting, one of similar rigor and clarity shall be used pending approval from the CA. Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their Subcontractors are completed and checked off. "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = Architect/Engineer, All = all Contractors, CA = Commissioning Agent, CC = Controls Contractor, EC = Electrical Contractor, PM/GC = General Contractor, MC = Mechanical Contractor, SC = Sheet Metal Contractor, TAB = Test and Balance Contractor.

3.4 Operations and Maintenance Manuals

- .1 The Contractor shall ensure that Section 22 Subcontractors compile and prepare documentation for all equipment and systems covered in Section 22 and deliver to the Contractor for inclusion in the O&M manuals.
- .2 The CA shall receive a copy of the O&M manuals for review.

3.5 Training of Owner Personnel

- .1 The Contractor shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed. Refer to Section 01 91 00 for additional details.
- .2 The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment. Refer to Section 01 91 00 for additional details.
- .3 Mechanical Contractor. The mechanical contractor shall have the following training responsibilities:
 - .1 Provide the CA with a training plan two weeks before the planned training according to the outline described in Section 01 91 00, Part 3.8.
 - .2 Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of HVAC equipment including, but not limited to, pumps, boilers, furnaces, chillers, heat rejection equipment, air conditioning units, air handling units, fans, terminal units, controls and water treatment systems, etc.
 - .3 Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including start-up, shutdown, fire/smoke alarm, power failure, etc.
 - .4 During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.

- .5 The appropriate trade or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment is required. More than one party may be required to execute the training.
- .6 The controls Subcontractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
- .7 The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
- .8 Training shall include:
 - .1 Use of the printed installation, operation and maintenance instruction material included in the O&M manuals.
 - .2 A review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.
 - .3 Discussion of relevant health and safety issues and concerns.
 - .4 Discussion of warranties and guarantees.
 - .5 Common troubleshooting problems and solutions.
 - .6 Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.
 - .7 Discussion of any peculiarities of equipment installation or operation.
- .9 The format and training agenda in The HVAC Commissioning Process, ASHRAE Guideline 1- 1989R, 1996 is recommended.
- .10 Classroom sessions shall include the use of overhead projections, slides, video/audio-taped material as might be appropriate.
- .11 Hands-on training shall include start-up, operation in all modes possible, including manual, shut- down and any emergency procedures and preventative maintenance for all pieces of equipment.
- .12 The mechanical Subcontractor shall fully explain and demonstrate the operation, function and overrides of any local packaged controls, not controlled by the central control system.
- .13 Training shall occur after functional testing is complete, unless approved otherwise by the Consultant.

3.6 Deferred Testing

- .1 Refer to Section 01 91 00, Part 3.9 for requirements of deferred testing.

3.7 WRITTEN WORK PRODUCTS

- .1 The Contractor shall ensure that written work products of Section 22 Subcontractors consist of the start-up and initial checkout plan as described in Section 01 91 00, as well as completed start-up, initial checkout and pre-functional test sheets.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide complete plumbing and drainage systems, including all necessary labour, services, Products, materials and equipment as shown on the Drawings and listed in the schedules as specified herein. Products, materials and equipment shall include, but not necessarily be limited to, the following:
 - .1 Piping and fittings.
 - .2 Valves.

1.2 REFERENCE STANDARDS

- .1 Provide all Work in accordance with the latest edition of the Ontario Plumbing Code and the requirements of all local Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector, etc., and all applicable by-laws.

1.3 SUBMITTALS

- .1 Submit Shop Drawings for each type of valve in accordance with Section 21 05 01.
- .2 Submit Shop Drawings for grooved mechanical couplings and fittings in accordance with Section 21 05 01.
- .3 Provide valve charts for inclusion in Operating and Maintenance Manuals in accordance with Section 21 05 01.

PART 2 - PRODUCTS

2.1 PLUMBING PIPING AND FITTINGS

- .1 Provide pipe and fittings of good quality devoid of any defects and compatible with required system working pressure.
 - 1 Domestic Water Piping
 - 1 Above Ground - 100 mm (4") and smaller.
 - 1 Type 'L' hard copper pipe with wrought copper fittings and silver solder joints.
 - 2 Sanitary Drain and Vent Piping.
 - 1 Above Ground - 65 mm (2-1/2") and smaller.
 - 1 Drain, Waste, Vent ("DWV") copper with drainage fittings and 60/40 lead/tin solder joints.
 - 2 Plastic drain, waste and vent piping is acceptable for use above grade provided it meets the minimum requirements for flame spread (25) and smoke developed (50) classifications as required by the Ontario Building Code (i.e. IPEX XFR or Equivalent).
 - 2 Above Ground - 75 mm (3") and larger.
 - 1 CSA class 4000 cast iron soil piping and drainage fittings.

- 2 Plastic drain, waste and vent piping is acceptable for use above grade provided it meets the minimum requirements for flame spread (25) and smoke developed (50) classifications as required by the Ontario Building Code (i.e. IPEX XFR or Equivalent).

2.2 VALVES

- .1 Provide valves that are compatible with the piping and service required.
- .2 Valves of each type shall be the product of one manufacturer.

2.3 WATER HAMMER ARRESTORS (SHOCK STOPS)

- .1 Provide pre-charged hard drawn copper shock absorber with brass piston, Ethylene Propylene Diene Monomer ("EPDM") O-ring seals and make IPS (Iron Pipe Size) connection.
- .2 Suitable for pressures up to 150 psi, and temperatures to 180 F.
- .3 Unit sizing as per manufacturers instructions. Confirm following sizing table with manufacturer, use manufacturers sizing guidelines.

FIXTURE UNITS	ARRESTOR SIZING
1-11	CONNECTION: ½", HEIGHT: 5" DIAMETER: 1-7/16"
12-32	CONNECTION: ¾", HEIGHT: 7" DIAMETER: 1-7/16"
33-60	CONNECTION: 1", HEIGHT: , 7-3/8" DIAMETER: 2-3/16"
61-113	CONNECTION: 1-1/4", HEIGHT: 10-13/16" DIAMETER: 2-11/16"
114-154	CONNECTION: 1-1/2", HEIGHT: 1-1/2" DIAMETER: 3-5/16"
155-330	CONNECTION: 2", HEIGHT: 14-7/8" DIAMETER: 3-5/16"

2.4 PLUMBING VALVE SCHEDULE

PLUMBING VALVE SCHEDULE				
SYSTEM	PIPING	TYPE	SYSTEMS 50 MM (2") AND SMALLER	SYSTEMS 65 MM (2-1/2") AND LARGER
Domestic	Copper	Gate	Bronze, soldered, solid wedge disc, NRS, 200 psi CWP. (1324) Kitz #64	Iron body, flanged, solid wedge disc, O.S.&Y. bronze trim, RS 200 psi CWP. (465-1/2) Kitz#72 Toyo #421A
Domestic	Copper	Globe	Bronze, soldered, renewable teflon disc, 200 psi CWP. (1310) Kitz#10 Toyo #222	Iron body, flanged O.S.&Y., bronze trim, 200 psi CWP. (351) Kitz #76 Toyo#400A
Domestic	Copper	Ball (*)	Kitz#69AMLL Toyo#5049S MAS B3ZSS * Note Lock and Lever	2-1/2" and 3" same as 2" and smaller but 400 psi CWP.
Domestic	Copper	Butterfly (Lug Wafer Type)	Note: Butterfly valves shall be lugged type, cast Iron or Ductile iron body, Aluminum bronze disc, EPDM liner, stainless steel stem. Valves shall have bubble tight shutoff to 200psi when downstream flange is removed (Full dead-end service valves. 150mm (6") smaller shall have lever operator. Valves 200mm (8") & Larger shall have manual gear operator.	Iron body, flanged, anti-friction coated ductile iron disc, 416 stainless steel stem, EPDM seat, 150 psi CWP. 4" & Less: lock lever handles. 6" & greater: gear operator with handwheel (55-D4E) Kitz 6122EL (Lever) Kitz 6122EG (Gear) Toyo 918BESL (Lever) Toyo 918BESG (Gear) Demco NE Series 22XX5-1145351(285PSIG)
Domestic	Copper	Check	Bronze, soldered, swing, Y pattern 200 psi CWP. Kitz#30.	2-1/2" and 3" same as 2" and smaller. Kitz#30.
NOTES: 1. (*) For drain valves, provide complete with hose end adaptor, cap and chain. 2. Valves based on Crane Manufacturer ☐ RS = Rising Stem ☐ NRS = Non-Rising Stem				

PART 3 – EXECUTION

3.1 TESTING OF DOMESTIC WATER PIPING SYSTEMS

- .1 When piping system installation is complete, pressure test all domestic water piping systems as required by the Ontario Building Code.
- .2 Provide water pressure test or air pressure test. Water pressure testing shall confirm that piping systems withstand a water pressure of minimum 1000 kPa (145 psi) for minimum 1 hour with no loss of pressure. Air pressure testing shall confirm that piping system withstands an air pressure of minimum 700 kPa (102 psi) for minimum 2 hour with no drop in air pressure.

3.2 DISINFECTION OF DOMESTIC WATER PIPING SYSTEM

- .1 Prior to starting Work, verify system is complete, flushed and clean. Ensure PH of water to be treated is between 7.4 and 7.6 by adding alkali (caustic soda or soda ash) or acid (hydrochloric).
- .2 Inject disinfectant, free chlorine in liquid, powder, tablet or gas form, throughout system to obtain 50 to 80 mg/l residual.
- .3 Bleed water from outlets to ensure distribution and test for disinfectant residual at minimum 15 percent of outlets. Maintain disinfectant in system for 24 hours. If final disinfectant residual tests less than 25 mg/L, repeat treatment.
- .4 Flush disinfectant from system until residual equal to that of incoming water or 1.0 mg/L. Take samples no sooner than 24 hours after flushing, from 5 percent of outlets and from water entry, and analyze.

3.2 INSTALLATION

.1 Piping and Fittings

- 1 Install piping such that uniform grade is maintained. Install piping with ends aligned and carefully abutted. Install pipe joints in accordance with the recommendations of the respective manufacturer.
- 2 Ensure that the piping is protected at all times from movement, etc. Ensure piping is kept clean at all times and cap ends during periods when work is stopped.
- 3 Install piping to conform to building planes. Run parallel to walls and structural components. Conserve headroom at all times and co-ordinate the piping installation with the Work of other Subcontractors and Divisions.
- 4 Install flanges or unions to isolate each piece of equipment.
- 5 Provide the necessary chemicals, equipment and labour to clean and disinfect the system to the requirements of all Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector, etc.

.2 Valves

- 1 Install valves at each piece of equipment, plumbing fixture, at the base of each riser and at any main branch of the piping system.

.3 Water Hammer Arrestors

- 1 Install arrestors concealed inside partitions.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide complete plumbing and drainage systems, including all necessary labour, services, products, materials and equipment as shown on the Drawings, listed in the equipment schedules on the mechanical Drawings and as specified herein. Products, materials and equipment shall include, but not necessarily be limited to, the following:
 - .1 Floor drains;
 - .2 Cleanouts;
 - .3 Miscellaneous plumbing specialties.

1.2 REFERENCE STANDARDS

- .1 Provide all Work in accordance with the latest edition of the Ontario Building Code and the requirements of all local Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector, etc., and all applicable by-laws.

PART 2 - PRODUCTS

2.2 FLOOR AND ROOF DRAINS

- .1 Provide all floor drains necessary for a complete installation.
- .2 Refer to equipment schedules for details.

2.3 CLEANOUTS AND MISCELLANEOUS

- .1 Provide all cleanouts and miscellaneous items necessary for a complete installation.
- .2 Refer to equipment schedules for details.

2.4 THERMOSTATIC MIXING VALVES

- .1 Complete with check valve, volume control shut-off valve and stem thermometer on outlet, strainer stop check on inlet, mounted in lockable cabinet of 1.5 mm prime coated steel.

2.5 TRAP SEAL PRIMERS

- 1. Provide trap seal primers for all floor drains including all necessary piping and appurtenances and connect to nearest available domestic cold water supply in accordance with local Authority standards, including but not limited to standards of the plans examiner, building inspector, etc.

PART 3 – EXECUTION

3.1 INSTALLATION

.1 Floor and Roof Drains

- 1 Install floor drains as required by the Ontario Building Code (“OBC”) and as detailed on the Drawings.
- 2 Install roof drains as required by OBC and as detailed on the Drawings.

.2 Cleanouts and Miscellaneous

- 1 Install cleanouts in sanitary and storm drainage piping as required by OBC and all Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector, etc.
- 2 Install cleanouts at the base of all stacks and at each major change of direction on horizontal pipe runs.
- 3 Install backflow preventors on all domestic water connections to non-potable water systems. Pipe all relief ports to nearest funnel floor drain.

.3 Trap Primers

- 1 Install in accordance with manufacturers’ recommendations.
- 2 Connect to nearest available domestic cold water supply in accordance with local Authority standards, including but not limited to standards of the plans examiner, building inspector, etc.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide plumbing fixtures and trim as listed in the equipment schedules where shown on the Drawings.

1.2 REFERENCE STANDARDS

- .1 Perform all Work in accordance with the latest edition of the Ontario Building Code and the requirements of all local Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector, etc., and all applicable by-laws.

PART 2 - PRODUCTS

2.1 PLUMBING FIXTURES AND TRIM

- .1 Provide all plumbing fixtures and trim, including traps, wastes, water connections, etc. necessary for a complete and functional installation.
- .2 Plumbing fixtures and trim shall be Products of one manufacturer unless otherwise noted in the Contract Documents or approved by the Consultant.
- .3 Plumbing fixtures shall be white unless otherwise noted in the Contract Documents.
- .4 All plumbing fixtures and trim shall conform to the latest CSA standards.
- .5 Refer to equipment schedules for details.

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Install new plumbing fixtures and trim. Finished surfaces shall be clean, smooth and bright, and guaranteed not to change colour nor to scale. Imperfections of any kind shall be sufficient reason for rejection by the Consultant and an acceptable replacement shall be installed at no extra cost to the Owner.
- .2 Provide cast brass, chrome plated escutcheon plates with set screws on all water and drain pipes passing through walls, floors and partitions.
- .3 Plumbing fixture mounting heights to comply with NBCC and CSA B651 Standards.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide electric motors for all mechanical equipment as specified herein.
- .2 Provide three phase high efficiency motors where the motor is 0.75 kW (1.0 HP) or greater in size.

1.2 SUBMITTALS

- .1 Provide a list of all three phase motors in the Operating and Maintenance Manuals including the following data for each motor.
 - .1 Size (HP)
 - .2 Voltage and Phase
 - .3 Speed (RPM)
 - .4 Efficiency (%)
 - .5 Manufacturer
 - .6 Serial Number
 - .7 NEMA frame size

PART 2 - PRODUCTS

2.1 GENERAL

- .1 All motors up to 0.37 kW (1/2 hp) shall be 120V single phase.
- .2 All motors 0.56 kW (3/4 hp) and larger shall be three phase as indicated in the EQUIPMENT SCHEDULES provided on the Drawings.
- .3 Motors shall be selected to match the equipment to which they are connected. Motors shall be sized for continuous operation without exceeding the nameplate full load rating, exclusive of service factor.
- .4 All motors shall be provided with factory installed nameplates indicating all technical data.

2.2 HIGH EFFICIENCY ELECTRIC MOTORS

- .1 Provide high efficiency motors which exceed the efficiencies specified in the NEMA Premium Efficiency Requirements.
- .2 Motors for use with variable frequency drives shall have minimum Class F insulation, rated for inverter duty.

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Dry out motor if dampness is present in accordance with manufacturer's recommendations.
- .2 Install motor so that undue stress is not placed on motor bearings by drive mechanism. Use only lifting facilities provided.
- .3 Provide liquid tight polyvinyl chloride (PVC) jacketed flexible conduit between motor and rigid conduit.
- .4 Make flexible conduit long enough to permit movement of motor over entire length of slide rails.
- .5 Check for correct direction of rotation, with motor uncoupled from driven equipment.
- .6 Align and couple motor to driven equipment in accordance with manufacturers' instructions.
- .7 Provide unfused lockable disconnect switch for each motor located in accordance with the Electrical Safety Code (CSA C-22.1)

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Division 26 ELECTRICAL includes the provision of power wiring from motor starters to motors.
- .2 Division 26 ELECTRICAL includes the provision of power wiring from electrical panels or splitters to loose motor starters.
- .3 Division 26 ELECTRICAL includes the provision of power wiring from electrical panels or splitters to packaged control panels.
- .4 Division 23 CONTROLS includes the provision of interlock wiring between motor starters.
- .5 Division 23 CONTROLS includes the provision of control wiring from motor starters to remote control devices.
- .6 Division 23 CONTROLS includes the provision of control wiring from packaged control panels to remote control devices.
- .7 Division 23 CONTROLS includes the provision of control wiring for fire alarm fan shutdown from loose fan motor starters to fan shutdown relay in the nearest motor control centre.

PART 2 - PRODUCTS

2.1 GENERAL

- .1 Provide all wiring materials in accordance with the requirements of Division 26.
- .1 Wiring materials include, but are not limited to, conduit, wire, outlet boxes and wiring devices.

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Install all wiring in accordance with the requirements of the Electrical Safety Code (CSA C-22.1).
- .2 Install all control wiring in conduit. Conceal conduit where possible if not already placed in poured concrete.
- .3 The work of Division 26 ELECTRICAL includes provision of unfused disconnect switches for all motors supplied under this Division and where required by the Electrical Safety Code (CSA C-22.1).

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide complete systems, including all necessary labour, services, products, materials and equipment as shown on the Drawings, listed in the Schedules below, and as specified in the Contract Documents. Products shall include, but not necessarily be limited to, the following:
 - .1 Pipe and fittings.
 - .2 Valves

1.2 WORK PROVIDED BY OTHERS

- .1 Automatic control valves shall be supplied under Section 25 00 00 Controls and installed as part of the work of this Section.
- .2 Thermowells shall be supplied under Section 25 00 00 Controls and installed as part of the work of this Section.

1.3 REFERENCE STANDARDS

- .1 Provide all work in accordance with the latest applicable codes of CSA and ASTM and the requirements of all local Authorities Having Jurisdiction, including plans examiner, building inspector, and all applicable by-laws.

PART 2 - PRODUCTS

2.1 PIPING AND FITTINGS

- .1 Provide pipe and fittings of good quality devoid of any defects and in compliance with the latest ASTM regulations and standards.
- .2 Heating Water
 - 1 Schedule 40 black steel.
 - 2 Type 'L' copper.
- .3 Condensate Drains
 - 1 DWV copper.
- .4 Refer to Schedules below for fittings and methods of joining.

2.2 VALVES

- .1 Provide valves that are compatible with the piping and service required.
- .2 Valves of each type shall be the product of one manufacturer.

.3 Refer to Schedules below and to Section 23 05 15 for details.

2.3 THERMOWELLS

.1 Install thermowells supplied by controls Subcontractor where applicable. Coordinate locations with control Subcontractor.

2.4 HVAC VALVE SCHEDULE

SYSTEM	PIPING	TYPE	SYSTEMS 50 MM (2") AND SMALLER	SYSTEMS 65 MM (2-1/2") AND LARGER
		Swing Check	Bronze, threaded, swing disc, Y pattern, 200 psi CWP. Similar to Crane #37, Kitz #22, Toyo #236 or Equivalent	
		Silent Check		Install at discharge of pumps in vertical pipes. Cast iron body, wafer type, 316 SS disc and seat, BUNH-N ring and teflon spacer, Class 125. Similar to Grinnell or Equivalent.
		Circuit Balancing Valve (CBV)	Bronze copper alloy construction, threaded, teflon disc ring, 'Y' globe style, c/w hand wheel, division ring scale, drain connection & balancing connector ports with square knob shut-offs. Armstrong CBV I.	Cast iron construction, flanged teflon disc ring, 'Y' globe style c/w hand wheel, division ring scale, balancing connector ports with square knob shut-offs. Armstrong CBV II or Equivalent.
		Eccentric Plug		Cast iron construction, flanged or Victaulic, gear operator with handwheel. Similar to DeZurik Series 100 or Equivalent.
		Angle type combination shut off, balancing and check valve.		Install at discharge of vertical inline pumps. Flanged cast iron body, bronze disc and seat, SS stem and SS spring, multiple turn. Armstrong FTA or Equivalent.
NOTES:				
SS	Stainless Steel	RS	Rising Stem	NRS Non-Rising Stem

2.5 PIPE JOINTS AND FITTINGS SCHEDULE

PIPE JOINTS AND FITTINGS					
MATERIAL	TYPE			FLANGED	UNIONS
	MECHANICAL	SCREWED	WELDED		
Steel	Provide long radius elbow, malleable iron steel or ductile iron with wall thickness compatible with pipe. Victaulic fitting suitable for groove end pipe for chilled, condensor, glycol and hot water system.	Screwed permitted for all systems 50 mm (2") and under.	Weld all pipe sizes and provide long radius elbows and forged steel fittings of the same weight as the pipe being joined. Provide welding tees threadoletts and weldoletts on branch connections.	Weld neck or slip on with raised face.	Cast iron with ground joint.
Copper	Cast brass or streamline wrought copper. Provide dielectric fittings when connecting to steel pipe. Braze copper pipe and joints with 95/5 tine/antimony for water systems. For non-pressure drain systems solder with 50/50 tin/lead.			Cast brass or streamline wrought copper. Provide dielectric isolator when connecting to steel.	Cast iron with ground joint. Provide dielectric isolator when connecting to copper.

PART 3 - EXECUTION

3.1 INSTALLATION

.1 Piping and Fittings

- 1 Install piping with ends aligned and carefully abutted. Install pipe joints and fittings in accordance with the recommendations of the respective manufacturer, compatible with the operating pressure of the piping system and in conformance with the latest ANSI standards.
- 2 Ensure that the piping is protected at all times from movement, etc. Ensure piping is kept clean at all times and cap ends during periods when work is stopped.
- 3 Ensure that piping is cut true, reamed and cleaned before installation.
- 4 Ensure that piping and fittings are cleaned, bevelled, aligned and spaced prior to welding.
- 5 Install piping to conform to building planes. Run parallel to walls and structural components. Conserve headroom at all times and co-ordinate the piping installation with the work of other Subcontractor and Divisions.
- 6 Install flanges or unions at all connections to equipment. Ensure that all piping, fittings, valves and

cleanout devices are accessible.

- 7 Install a minimum of three (3) elbows at all branch connections or provide a flexible connection.
- 8 Upfeed branches for heating by means of 45 degree to vertical, then grade up to riser or rise up vertically. Downfeed branches for heating by means of 45degree to vertical, then grade down to vertical drop or drop down vertically.
- 9 Minimum grade for heating mains and branch supply: 1:50 up in direction of flow and on the return mains and branches grade 1:50 down in direction of flow.
- 10 Install drain connections as required. Pipe discharge from safety valves, relief valves, overflows, etc., to nearest funnel floor drain.
- 11 Provide drains at all low points in piping systems terminating with a plugged gate valve.
- 12 Risers shall be valved where they connect to the mains, and in addition supply and install 20 mm (3/4") drain valves with hose end at the base of all risers.
- .13 Provide the necessary chemicals, equipment and labour to clean and disinfect the system to the requirements of all Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector.
- .14 Victaulic pipe fittings shall not be permitted in inaccessible spaces.
- .2 Valves
 - 1 Install valves at each piece of equipment and where noted on the Drawings.

3.2 WELDING

- .1 All welding shall be performed by a certified welder holding a current certificate for the class of pipe to be welded.
- .2 Provide all welding and fabrication in accordance with current CSA standards and all Authorities Having Jurisdiction.
- .3 Provide adequate fire protection during welding or cutting procedures. Provide welder with a fully charged 10 lb CO² fire extinguisher for emergency use.
- .4 Provide York Region project manager a minimum advance notice of three Working Days prior to welding activities to ensure by-pass of existing smoke detectors prior to welding.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 The Contractor shall supply and install all motor starters for all motors supplied under this Division.
- .2 The Contractor shall supply and install all variable speed drives for motors supplied under this Division.

1.2 SUBMITTALS

- .1 Submit Shop Drawings for all variable speed drives in accordance with Section 21 05 01 and including individual schematic wiring diagrams for each starter, including the following data:
 - .1 EEMAC starter size.
 - .2 Fuse sizes.
 - .3 Control transformer size.
 - .4 Terminations for remote devices.
 - .5 Interlocking.
 - .6 Identification of all control components.
- .2 Submit revised updated shop drawings for inclusion in the project Operating and Maintenance Manuals.

PART 2 - PRODUCTS

2.1 GENERAL

- .1 All starters shall be provided by the same manufacturer.
- .2 Identify all starters with lamacoid nameplates indicating equipment designation and service.

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Install starters, connect wiring as required.
- .2 Ensure correct fuses and overload heater elements are installed.

3.2 TESTING

- .1 Field test all starter's after completion of the wiring to verify correct operation.

END OF SECTION

PART 1 - GENERAL

1.1 SHOP DRAWINGS

- .1 Submit Shop Drawings in accordance with Section 21 05 01.
- .2 Indicate on manufacturer's catalogue literature: expansion tanks, air vents, separators, valves, strainers, and flow meters.

1.2 MAINTENANCE DATA

- .1 Provide maintenance data for incorporation into Operation and Maintenance Manuals.

PART 2 - PRODUCTS

2.1 AUTOMATIC AIR VENT

- .1 Standard float vent with brass body and NPS 1/8 connection and rated at 690 kPa (100 psi) working pressure.
- .2 Industrial float vent with cast iron body and NPS 1/2 connection and rated at 860 kPa (125 psi) working pressure.
- .3 Float: solid material suitable for 115 degrees C (240 degrees F) working temperature.

2.2 PIPE LINE STRAINER

- .1 NPS 1/2 - 2: bronze body, screwed connections.
- .2 NPS 2-1/2 - 12: cast steel body, flanged connections.
- .3 Size: as indicated on the Drawings.
- .4 Blowdown connection: NPS 1.
- .5 Screen: stainless steel with perforation size of 1.6 mm (1/16") to 75 mm (3") and 3.2 mm (1/8") for 100 mm (4") and larger.
- .6 Working pressure: 860 kPa (125 psi).

2.3 CIRCUIT BALANCING VALVES (CBV'S)

- .1 Each valve shall have two 1\4" NPT brass metering ports with check valves and gasketed caps located on both sides of valve seat. Two additional 1/4" NPT connections with brass plugs are to be provided on the opposite side of the metering ports for use as drain connections. Drain connections and metering ports are to be interchangeable to allow for measurement flexibility when valves are installed in tight locations.
- .2 Valves are to be of the "Y" pattern, modified, equal percentage globe style and shall provide the following three functions:
 - 1 Precise flow measurement.
 - 2 Precision flow balancing.

- 3 Positive drip tight shut off.
- .3 Valve shall provide multi-turn, 360° adjustment with a micrometer type indicator located on valve handwheel. Valve handwheel shall have hidden memory feature, which will provide a means for locking the valve position after the system is balanced. 90° turn adjustable valves are not acceptable.
- .4 Valve body for 1/2" - 2" valves shall be bronze with ultra-high strength engineered resin plug. The plug shall have precision-contoured channels to distribute flow uniformly across valve seat. Bronze stem and high strength resin handwheel and sleeve. Valves shall have a minimum of four full 360° handwheel turns.
- .5 Valve body for 2-1/2" - 12" valves shall be ductile iron with industrial standard grooved ends. Valve stem and plug disc shall be bronze with handwheel with multi-turn handwheel adjustments. Flange adapters shall be supplied, to prevent rotation.
- .6 The valve shall be installed with flow in the direction of the arrow on the valve body and installed at least five pipe diameters downstream from any fitting, and at least ten pipe diameters downstream from any pump. Two pipe diameters downstream from the CBV shall be free of any fittings. Mounting of valve in piping must prevent sediment build-up in metering ports.
- .7 Each valve shall be furnished with a pre-formed recoverable PVC insulation jacket to meet all required codes, including the Ontario Building Code, with a flame spread rating of 50 or less. Provide mineral fiberglass insulation to meet ASHRAE 90.1-1989 specifications in operating conditions with maximum Fluid Design Operating Temperature Range of 141-200°F and Mean Rating Temperature of 125°F.

PART 3 - EXECUTION

3.1 GENERAL

- .1 Install according to piping layout. Pipe drains and blow off connections to nearest drain.
- .2 Maintain proper clearance around equipment to permit performance of service maintenance. Check final location with the Consultant if different from that indicated on the Drawings prior to installation.
- .3 Should deviations beyond allowable clearances arise, request and follow the Consultant's instructions.
- .4 Refer to manufacturer's installation drawings.
- .5 Check that all openings for appurtenances and equipment operating weight conform to shop drawings.
- .6 If accessories and/or ancillaries are received knocked down, check assembly with the Consultant.

3.2 STRAINERS

- .1 Install in horizontal or down flow lines.
- .2 Ensure adequate clearance for removal of basket.
- .3 Install ahead of each pump (except vertical inline pumps), automatic control valve (larger than 3/4") and as indicated on the Drawings.

3.3 AIR VENTS

- .1 Install at high points of systems.
- .2 Pipe overflow to nearest drain.

- .3 On large-capacity air vent, install gate valve upstream of air vent.

END OF SECTION

PART 1 - GENERAL

2.1 WORK INCLUDED

- .1 Provide direct drive or belt drive horizontal fan coil units, where indicated on the Drawings, and of the types and performance as listed in the Schedules on the Drawings.
- .2 Fan coils to be complete with Minimum Efficiency Reporting Value ("MERV") 13 filters, internal condensate drain, and overflow drain.

2.2 SUBMITTALS

- .1 Submit Shop Drawings for each fan coil unit in accordance with Section 23 05 10 and including the following data:
 - 1 Fan performance at the specified external static pressure at all three speeds.
 - 2 Heating and cooling coil performance at the specified entering air and water conditions at all three speeds.
 - 3 Sound power levels at all three speeds.
- .2 Provide data for inclusion in the Operating and Maintenance Manuals in accordance with Section 23 05 10.

2.3 MANUFACTURER CERTIFICATION

- .1 Provide manufacturer certification of the installation in accordance with Section 23 05 10.

2.4 MANUFACTURER WARRANTY

- .1 Mechanical contractor to provide **(2) two year warranty** for all fan coil units from manufacturer from the date of substantial completion of the project. Date of substantial completion can be found in the Front End of the York Region Tender Documents.

PART 2 - PRODUCTS

2.1 GENERAL

- .1 Fan coil units shall be rated in accordance with the Air Conditioning and Refrigeration Institute ARI standards as a complete package.
- .2 Deliver units to the construction site completely assembled and in one piece. Protect casings from damage and cover all pipe and duct connections.
- .3 For direct drive units, provide unit mounted speed switch and electrical connection box, all factory wired with "OFF" position suitable for use as a disconnect switch.

2.2 CASING

- .1 Construct unit casing of 1.02 mm (20 gauge) galvanized steel, reinforced for rigidity.
- .2 Provide insulated return air plenum designed for rear air inlet including filter mounting.
- .3 Provide access to fans, motor and filter to permit removal with units installed.
- .4 Insulate entire casing, including return air plenum with minimum 12 mm (1/2") thick glass fibre insulation with neoprene coating.

2.3 DRAIN PAN

- .1 Provide insulated galvanized steel drain pan under the entire coil section and extending on the connection side sufficiently to permit control valves and return water piping to be mounted above.
- .2 Drain pan shall be double wall construction with insulation between inner and outer pans.
- .3 Provide copper drain connection at low end, and overflow drain.
- .4 Provide insulation on drain pan to comply with NFPA-90A.

2.4 FANS

- .1 Provide fans with forward curved, double width wheels, stable pressure curve and low sound power levels.

2.5 FILTER

- .1 Provide MERV13 filters mounted in return air plenum.
- .2 Filter sizes have been standardized for York Region stocking of replacement filters. Provide filter sizes as indicated in the HORIZONTAL FAN COIL UNIT SCHEDULE.

2.6 WATER COILS

- .1 Coils shall be aluminum fin mechanically bonded to copper tubing rated at 1725 kPa (250 psig) working pressure. Fit return connections with manual air vent.

2.7 MOTOR (DIRECT DRIVE UNITS)

- .1 Motors shall be Electronically Commutated Motor ("ECM") type with bronze sleeve type bearings and oil reservoirs directly connected to fan wheels. Motors shall have integral overload protection and the capability of starting at 78% of rated voltage and operating at 90% of rated voltage at a temperature of 10°C (50°F).

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Install fan coil units in accordance with the manufacturer's installation instructions.
- .2 Support units from the slab with steel hanger rods and neoprene vibration isolators. Adjust mounts so that drain pan slopes to the condensate drain.
- .3 Insulate piping up tight to coils including control valves, and securely fasten insulation to casing.
- .4 Do not obstruct access to unit for service or filter replacement.
- .5 Direct power connection to fan coil units provided as part of the work of the electrical Subcontractor unless otherwise indicated.
- .6 Check all units for excessive vibration.
- .7 Provide isolation ball valves and unions on chilled and heating water supply and return piping. Mount control valves over drain pan.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide complete systems, including all necessary labour, services, products, materials and equipment as shown on the Drawings, listed in the Schedule below and as specified herein.
- .2 Provide and set all sleeves and anchors required to accommodate the work of Division 21, 22 and 23.
- .3 Read and be governed by the requirements of Section 23 05 48 - Vibration Isolation.

1.2 REFERENCE STANDARDS

- .1 Provide all work in accordance with the latest CSA and ASTM requirements and other applicable codes and the requirements of all local Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector, etc.

PART 2 - PRODUCTS

2.1 PIPE AND EQUIPMENT SUPPORTS

- .1 Provide all necessary supports, hangers, racks, stands, pads and platforms required to adequately support the piping system and associated equipment from the structure.
- .2 Design bases and supports to carry loads safely under all conditions.
- .3 Provide all roof curbs and sleepers for roof mounted equipment. Curbs and sleepers shall be set in place prior to insulation of roof to allow for water proofing and flashing. Provide all necessary concrete or wood shims as required to ensure horizontal installation on sloping roof.
- .4 Provide all necessary inserts or beam clamps to connect hanger rods to the structure.
- .5 Refer to Schedule below for details of pipe hangers.
- .6 Provide angle iron wall brackets with specified hanger to support horizontal piping from wall.
- .7 For risers passing through floors, provide riser clamps (similar to Grinnell Fig. 261).

2.2 ANCHORS AND GUIDES

- .1 Provide anchors and guides of structural steel as required.
- .2 Provide Grinnell Fig. 257 pipe slide assemblies for horizontal pipes or Equivalent.
- .3 Provide Flexonics or Equivalent alignment guides for vertical pipes. For pipes 100 mm (4") and smaller, provide guides at every floor or 3 m (10 ft). For pipes larger than 100 mm (4"), provide guides at every second floor or 8 m (25 ft).

2.3 PIPE SLEEVES

- .1 Provide pipe sleeves for all penetrations through floors and walls. The work of this Division shall include setting of all required anchors and sleeves to accommodate the work of this Division.
- .2 Provide Schedule 40 steel pipe for exterior and interior walls above grade and extra heavy cast iron for exterior walls

below grade and waterproofed walls.

- .3 Provide extra heavy cast iron or Drain Waste Vent (DWV) copper for waterproof floors. Provide a sleeve extension of 100 mm (4") above finished floor.

2.4 CEILING, WALL AND FLOOR PLATES

- .1 Provide, at floors and ceilings, for insulated and uninsulated pipe stamped steel, chrome plated split type, spring loaded with locking screws and concealed hinge.
- .2 Provide at walls for uninsulated pipe stamped steel, chrome plated split type, spring loaded with locking screws and concealed hinge. Provide at walls for insulated pipe flat seamed 1 mm (18 gauge) galvanized steel band fitted over insulation and 50 mm (2") outside pipe sleeve.

2.5 FLASHING AND COUNTER FLASHING

- .1 Provide flashing and counter flashing for all ducts, pipes, etc., passing through walls, waterproof floors and roofs.

2.6 PIPING EXPANSION

- .1 Provide and install piping with all necessary expansion loops, offsets, guides, joints, anchors, etc., as may be required.
- .2 Provide expansion joints in steel pipes 50 mm (2") and smaller Equivalent to Flexonics 2-ply stainless steel bellows, internal guides with male ends. Provide in steel pipes 65 mm (2-1/2") and larger 304 stainless steel bellows and all accessories.
- .3 Provide expansion joints in copper pipes, Flexonics or Equivalent 2-ply bronze bellows and all accessories.

2.7 PIPE HANGERS AND SPACING SCHEDULE

NOTES:

1. Hanger rods shall be cadmium plated continuous thread with locking nuts (Grinnell Fig. 146 or Equivalent).
2. Provide oversized hangers and galvanized steel insulation protection (Grinnell Fig. 167 or Equivalent) for insulated cold piping.
3. Provide insulation protection saddles (Grinnell Fig. 160 or Equivalent) under all insulated piping supported on roller or trapeze hangers.
4. Provide plastic coated hangers where hangers are in direct contact with copper pipes.

PIPE HANGERS AND SPACING SCHEDULE				
HANGER	PIPE SIZE	ROD DIAMETER	HANGER SPACING	
			Copper Pipe	Steel Pipe
Adjustable Ring Type (Grinnell Fig. 269 or)	12 mm and 20 mm ½" and ¾"	10 mm 3/8"	1.5 m 5'	1.5 m 5'
	25 mm 1"	10 mm 3/8"	1.8 m 6'	2.1 m 7'
Adjustable Clevis Type (Grinnell Fig. 260 or 65)	32 mm 1-1/4"	10 mm 3/8"	1.8 m 6'	2.1 m 7'
	40 mm and 50 mm 1-1/2" and 2"	10 mm 3/8"	2.4 m 8'	2.7 m 9'
	65 mm and 75 mm 2-1/2" and 3"	12 mm 1/2"	3.7 m 12'	4.3 m 14'
For uninsulated piping and insulated cold piping: Adjustable Clevis Type (Grinnell Fig. 260) For insulated hot piping: Roller Type (Grinnell Fig. 171)	100 mm and 125 mm 4" and 5"	5/8" 15 mm	N/A	5.2 m 17'
	150 mm 6"	19 mm 3/4"	N/A	5.2 m 17'
	200 mm and 250 mm 8" and 10"	22 mm 7/8"	N/A	5.8 m 19'
	300 mm 12"	22 mm 7/8"	N/A	7 m 23'

PART 3 - EXECUTION

3.1 INSTALLATION

.1 Pipe and Equipment Supports

- .1 Provide housekeeping pads 100 mm (4") high from finished floor, extending 100 mm (4") beyond equipment and provide chamfered edges. Provide and install all required hold-down bolts.
- .2 Provide support of all suspended equipment from the bottom of the equipment.
- .3 All hanger rods shall be vertical, without bends or offsets.
- .4 Supply all necessary templates, anchor bolts, inserts and location drawings for the equipment supplied. Supervise the work of installation of the bases.

.2 Flashing and Counter Flashing

- .1 Flashing

- .1 Provide flashings for mechanical penetration through roof.
- .2 Counter Flashing
 - .1 Provide flashings for mechanical penetration through roof.
- .3 Anchors and Guides
 - .1 Install guides adjacent to loops and expansion joints and adhere to manufacturer's recommendations.
 - .2 Install a minimum of two (2) guides on each side of loop or expansion joint.
- .4 Pipe Sleeves
 - .1 Provide and seal walls which separate areas of different air pressure with permanently resilient silicone base sealing compound.
 - .2 Install sleeves concentric with pipe and size sleeves to permit continuity and integrity of insulation through sleeves where required.
 - .3 Install watertight concrete curb 100 mm (4") high and extend 100 mm (4") beyond pipe at all sleeves extending through floor.
 - .4 Install sleeves 25 mm (1") beyond the exterior face of wall.
 - .5 Provide packing of loose fibreglass insulation for all sleeves between pipe and sleeve or insulation and sleeve, and seal both sides.
 - .6 Provide and seal sleeves with silicone base fire stop system equal to the fire rating of the wall approved by local inspector enforcing the Ontario Building Code.
 - .7 Seal all vertical sleeves through roofs, mechanical rooms and floors with permanently resilient waterproof silicone base sealing compound.
- .5 Piping Expansion
 - .1 Install expansion loops, offsets, guides, joints, etc., so piping will not be overstressed during expansion and contraction.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide vibration isolation and accessories to achieve the following sound levels:
 - .1 Office Areas: Noise Criteria ("NC") 35.
- .2 Refer to Vibration Isolation Schedule below for specific requirements of mechanical equipment.
- .3 Provide spring hangers for piping as specified herein.

1.2 SHOP DRAWINGS

- .1 Submit Shop Drawings in accordance with Section 21 05 01.
- .2 Provide separate Shop Drawings for each isolated system complete with performance and Product data.

PART 2 - PRODUCTS

2.1 ELASTOMERIC PADS

- .1 Type P1 - neoprene waffle or ribbed; 9 mm (3/8") minimum thickness; 50 durometer; maximum loading 350 kPa (50 psi).
- .2 Type P2 - rubber waffle or ribbed; 9 mm (3/8") minimum thickness; 30 durometer natural rubber; maximum loading 415 kPa (60 psi).
- .3 Type P3 - neoprene-steel-neoprene; 9 mm (3/8") minimum thickness neoprene bonded to 1.71 mm (14 gauge) steel plate; 50 durometer neoprene, waffle or ribbed; holes sleeved with isolation washers; maximum loading 350 kPa (50 psi).
- .4 Type P4 - rubber-steel-rubber; 9 mm (3/8") minimum thickness rubber bonded to 1.71 mm (14 gauge) steel plate; 30 durometer natural rubber, waffle or ribbed; holes sleeved with isolation washers; maximum loading 415 kPa (60 psi).

2.2 ELASTOMERIC MOUNTS

- .1 Type M1 - colour coded; neoprene in shear; maximum durometer of 60; threaded insert and two bolt-down holes; ribbed top and bottom surfaces.

2.3 ISOLATOR SPRINGS

- .1 Design stable springs so that ratio of lateral to axial stiffness is equal to or greater than 1.2 times the ratio of static deflection to working height. Select for 50% travel beyond rated load. Units shall be complete with levelling devices.
- .2 Ratio of height when loaded to diameter of spring shall be between 0.8 and 1.0.
- .3 Cadmium plated for all installations.
- .4 Colour code springs.

2.4 SPRING MOUNT

- .1 Zinc or cadmium plated hardware; housings coated with rust resistant paint.

- .2 Type M2 - stable open spring; support on bonded 6 mm (1/4") minimum thick ribbed neoprene or rubber friction and acoustic pad.
- .3 Type M3 - stable open spring; 6 mm (1/4") minimum thick ribbed neoprene or rubber friction and acoustic pad, bonded under isolator and on isolator top plate; levelling bolt for rigidly mounting to equipment.
- .4 Type M4 - restrained stable open spring: supported on bonded 6 mm (1/4") minimum thick ribbed neoprene or rubber friction and acoustic pad; built-in resilient limit stops, removable spacer plates.
- .5 Type M5 - enclosed spring mounts with snubbers for isolation up to 950 kg (430 lbs) maximum.
- .6 Performance as indicated on the Equipment Schedules provided on the Drawings.

2.5 HANGERS

- .1 Colour coded springs, rust resistant, painted box type hangers. Arrange to permit hanger box or rod to move through a 30 degree arc without metal to metal contact.
- .2 Type H1 - neoprene - in-shear, molded with rod isolation bushing which passes through hanger box.
- .3 Type H2 - stable spring, elastomeric washer, cup with molded isolation bushing which passes through hanger box.
- .4 Type H3 - stable spring, elastomeric element, cup with molded isolation bushing which passes through hanger box.
- .5 Type H4 - stable spring, elastomeric element with precompression washer and nut with deflection indicator.
- .6 Performance as indicated.

2.6 ACOUSTIC BARRIERS FOR ANCHORS AND GUIDES

- .1 Acoustic barriers: between pipe and support, consisting of 25 mm (1") minimum thickness heavy duty duck and neoprene isolation material.

2.7 HORIZONTAL THRUST RESTRAINT

- .1 Spring and elastomeric element housed in box frame; assembly complete with rods and angle brackets for equipment and ductwork attachment; provision for adjustment to limit maximum start and stop movement to 9 mm (3/8").
- .2 Arrange restraints symmetrically on either side of unit and attach at centre line of thrust.

2.8 VIBRATION ISOLATION SCHEDULE

VIBRATION ISOLATION SCHEDULE					
EQUIPMENT	BASE		ISOLATOR		REMARKS
	TYPE	THICKNESS mm (in)	TYPE	THICKNESS mm (in)	
Cabinet Fans	N/A	N/A	H2	25.4 (1)	
Vertical In-Line Pumps	N/A	N/A	P3	3.8 (0.15)	
Boilers	N/A	N/A	P3	3.8 (0.15)	

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Install vibration isolation equipment in accordance with manufacturer's instructions and adjust mountings to level equipment.
- .2 Ensure piping, ducting and electrical connections to isolated equipment do not reduce system flexibility and that piping and ducting passage through walls and floors does not transmit vibrations.
- .3 Unless indicated otherwise in the Contract Documents, support piping connected to isolated equipment with spring mounts or spring hangers with 25 mm (1") minimum static deflection as follows:
 - .1 Up to Nominal Pipe Size ("NPS") 4: first 3 points of support.
 - .2 NPS 5 to NPS 8: first 4 points of support.
 - .3 NPS 10 and over: first 6 points of support.
 - .4 First point of support shall have a static deflection of twice deflection of isolated equipment, but not more than 50 mm (2").
- .4 Where isolation is bolted to floor, avoid short circuiting of sound pads by using vibration isolation rubber washers.

Block and shim level all bases so that ductwork and piping connections can be made to a rigid system at the operating level, before isolator adjustment is made. Ensure that there is no physical contact between isolated equipment and building structure.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide a complete system of identification.

1.2 EQUIPMENT

.1 Manufacturer's Nameplates

- .1 Provide metal nameplates on each piece of equipment, mechanically fastened with raised or recessed letters.
- .2 Provide Underwriters' Laboratories and CSA registration plates, as required by respective agency.
- .3 Manufacturer's nameplate to indicate size, equipment model, manufacturer's name, serial number, voltage, cycle, phase and power of motors.
- .4 Locate nameplates so that they are easily read. Do not insulate or paint over plates.

.2 System Nameplates

- .1 Provide laminated plastic plates with black face and white centre of minimum size 90 X 40 X 2.5 mm (3-1/2" X 1-1/2" X 1/8") nominal thickness, engraved with 6 mm (1/4") high lettering. Use 25 mm (1") lettering for major equipment.
- .2 Fasten nameplates securely in conspicuous place. Where nameplates cannot be mounted on cool surface, provide standoffs.
- .3 Identify equipment designation and number.
- .4 Submit list of nameplates to the Consultant for review prior to engraving.

1.3 PIPING

- .1 Identify medium in piping with markers showing name and service, including temperature, pressure and directional flow arrows in accordance with CGSB 24-GP-3a.
- .2 Conform to CGSB 1-GP-12c.Colour Coding System Schedule for new buildings.
- .3 Primary colour paint to conform to CGSB 1-GP-60M.
- .4 Manufactured pipe markers and colour bands:
- .1 Plastic coated cloth material with protective overcoating and waterproof contact adhesive undercoating, suitable for continuous operating temperature of 150 degrees C (302 degrees F) and intermittent temperature of 200 degrees C (392 degrees F). Apply to prepared surfaces.
- .2 50 mm (2") wide tape single wrap around pipe or pipe covering with ends overlapping one pipe diameter but not less than 25 mm (1") for colour bands.
- .3 Block capital letters 50 mm (2") high for pipes of 75 mm (3") nominal and larger outside diameter (including insulation) and not less than 20 mm (3/4") high for smaller diameters.
- .4 Direction arrows 150 mm (6") long by 50 mm (2") wide for piping of 75 mm (3") nominal or larger outside diameter including insulation, and 100 mm (4") long by 20 mm (3/4") wide for smaller diameters. Use double headed arrows where direction of flow is reversible.
- .5 Waterproof and heat resistant plastic marker tags for pipes and tubing 20 mm (3/4") nominal and smaller.
- .6 Black pipe marker letters and direction arrows, white on red background for fire protection markers.

- .5 Identify piping with full description of medium using only abbreviations indicated in the Legend on the Drawings.
- .6 Location
 - .1 Locate markers and classifying colours on piping systems so they can be seen from floor or platform.
 - .2 On each piping run at least once in each room.
 - .3 Maximum 15 m (50') between identifications in open areas.
 - .4 Both sides where piping passes through walls, partitions and floors.
 - .5 At point of entry and leaving, where piping is concealed in pipe chase or other confined space, and at each access opening.
 - .6 At start and end points of runs and at each piece of equipment.
 - .7 At major manual and automatic valves immediately upstream of valves.
 - .8 Identify branch, equipment or building served after valve.
- 1.4 DUCTWORK
 - .1 Use 50 mm (2") high black stencilled letters (eg. "Supply Air", "Return Air", "Sanitary Exhaust", "General Exhaust") with directional flow arrow.
 - .2 Maintain maximum 15 m (50') distance between markings.
 - .3 Identify ducts on each side of dividing walls or partitions and beside each access door.
 - .4 Stencil over final finish only.
- 1.5 VALVES AND CONTROLLERS
 - .1 Provide brass tags with 12 mm (1/2") stamped code lettering and numbers filled with black paint, secured with non-ferrous chains or "S" hooks for valves and operating controllers except at plumbing fixtures and radiation and except in plain sight of equipment they serve.
 - .2 Provide the Consultant with six identification flow diagrams of approved size for each system. Include tag schedule, designating number, service, function, and location of each tagged item and normal operating position of valves.
 - .3 Install where directed by the Consultant one copy of flow diagram and valve schedule mounted in glazed frame. Provide one copy in each operating and maintenance manual.
 - .4 Consecutively number valves in systems.
- 1.6 FAN COIL UNITS
 - .1 Provide label of t-bar at locations of ceiling mounted fan coil units to indicate fan coil location for filter and valve maintenance.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide testing, adjusting, balancing (TAB) and commissioning of all systems. Commissioning shall include putting into service, adjusting, calibrating and verifying all systems.
- .2 Provide the services of an independent balancing company, acceptable to the Consultant, to test, balance and adjust the air and water systems.
- .3 Comply with all applicable ASHRAE HVAC Systems and Applications, Testing, Adjusting and Balancing and Associated Air Balance Council (AABC) Standards.
- .4 Provide one (1) copy of the balancing report to the Consultant for review. Rebalance any systems which are not operating as intended following remedial work directed by the Consultant. Include all revisions in the final balancing report. Submit three (3) copies of the final report to the Consultant.
- .5 Provide one (1) copy of the balancing report to the Commissioning Agent for review. Rebalance any systems which are not operating as intended following remedial work directed by the Commissioning Agent. Include all revisions in the final balancing report. Submit one (1) copy of the final report to the Commissioning Agent.
- .6 Notify Commissioning Agent 14 Working Days prior to start of TAB to allow for Commissioning Agent to witness TAB procedures and testing.
- .7 Prior to commencing the work, identify all deficiencies in the mechanical systems which will affect the performance or accuracy of the work. Balance systems as they are available to meet the schedule for project completion.

PART 3 – EXECUTION

2.1 FLUID SYSTEMS

- .1 Test all fluid systems as follows:
 - 1 Plumbing systems to the Ontario Building Code ("OBC") requirements.
 - 2 Fire protection systems to OBC requirements.
 - 3 All systems not covered by OBC to 150% of working pressure, but not less than 1035 kPa (150 psig) or the maximum working pressure of expansion joints or isolators, for 24 hours.
- .2 Provide balancing and adjusting of all hydronic systems to achieve specified flow rates to within 5% of design flow rates.
- .3 Provide data in the balancing report which indicates flow rates, motor data, operating curves, operating temperatures and operating pressures for all pumps, coils and heat exchangers.
- .4 Mark balancing valves indicating the balanced position.
- .5 Verify operation of all control valves including perimeter heating.

2.2 AIR SYSTEMS

- .1 Provide balancing and adjusting of all air systems to achieve specified design values ($\pm 5\%$).
- .2 Provide data in the balancing report which indicates air volumes at each outlet, static pressures, fan data, motor data and coil data.

- .3 Provide duct traverse readings for each air handling unit and fan (with ducted connections and exceeding 1000 cfm).
- .4 Identify pressure drop across filters for all air handling units.
- .5 Adjust the air pattern for all diffusers as indicated on the Drawings or as directed by the Consultant.
- .6 Verify the operation of all control devices.

2.3 EQUIPMENT

- .1 Provide balancing, testing and adjusting of all equipment.
- .2 Include the following data in the balancing report:
 - 1 Electrical characteristics.
 - 2 Flow rates (air).
 - 3 Operating pressures and pressure drops.
 - 4 Operating efficiencies.

2.4 REPORTS

- .1 Submit all reports and forms to the Consultant for approval prior to any testing, balancing and adjusting. The forms shall be modified if they are not acceptable to the Consultant.
- .2 Submit all reports and forms to the Commissioning Agent for approval prior to any testing, balancing and adjusting. The forms shall be modified if they are not acceptable to the Commissioning Agent.
- .3 Provide all data required for evaluation of the work of this Section.
- .4 Provide schematic drawings of each system indicating points at which readings have been obtained.

2.5 DEMONSTRATION

- .1 Provide the demonstration of all systems and equipment, including complete documentation of the operating procedures of each system or piece of equipment. The time allotted for demonstration shall be adequate for the complexity of the systems and shall be acceptable to the Consultant.

2.6 TRIAL USAGE

- .1 Provide operation of all systems for purposes of demonstration and training of operating personnel. Trial usage does not constitute acceptance by the Owner.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide all thermal insulation and accessories for ducting of the types and thicknesses indicated in the Insulation Schedule contained in Section 23 07 15.
- .2 All rigid supply air ductwork from fan coil units shall be insulated.

1.2 REFERENCE STANDARDS

- .1 Meet the requirements of NFPA 90A. Maximum flame spread rating of 25 and maximum smoke developed rating of 50 in accordance with NFPA 255 and CAN4-S102 for all components of insulation system. Materials shall be tested in accordance with ASTM C411-82.

1.3 SAMPLES SUBMITTALS

- .1 Submit for the Consultant's approval, a complete assembly of each type of insulation system, insulation, coating and adhesive proposed. Mount samples on 12 mm (1/2") plywood board. Label each sample indicating type.

1.4 DEFINITIONS

- .1 For purposes of this Section:
 - .1 "CONCEALED" shall mean insulated mechanical services and equipment in suspended ceilings and non-accessible chases and furred spaces.
 - .2 "EXPOSED" shall mean "not concealed" as defined herein.

PART 2 - PRODUCTS

2.1 D-1 MINERAL FIBRE BLANKET 20 degrees C TO 65 degrees C (68 degrees F TO 150 degrees F)

- .1 Material:
 - .1 CGSB 51-GP-11M mineral fibre blanket.

2.2 D-2 MINERAL FIBRE BLANKET WITH VAPOUR BARRIER -40 degrees C TO 65 degrees C (-40 degrees F TO 150 degrees F)

- .1 Material:
 - .1 CGSB 51-GP-11M mineral fibre blanket: CGSB 51-GP-52M for vapour barrier.

2.3 D-3 MINERAL FIBRE RIGID 20 degrees C TO 65 degrees C (68 degrees F TO 150 degrees F)

- .1 Material:
 - .1 CGSB 51-GP-10M, rigid mineral fibre board.

2.4 D-4 MINERAL FIBRE RIGID WITH VAPOUR BARRIER TO 65 degrees C (150 degrees F)

.1 Material:

- .1 CGSB 51-GP-10M, rigid mineral fibre board: CGSB 51-GP-52M vapour barrier jacket and facing material.

2.5 FASTENINGS

- .1 Tape: self-adhesive, 100 mm (4") wide.

- .2 Contact adhesive: quick-setting.

- .3 Lap seal adhesive: quick-setting for joints and lap sealing of vapour barriers.

- .4 For canvas:

- .1 Washable adhesive for cementing canvas lagging cloth to duct insulation.

- .5 Pins:

- .1 Weld pins 4 mm (1/8") in diameter, with 35 mm (1.5") diameter head for installation through the insulation. Length to suit thickness of insulation.

- .2 Weld pins 2 mm (1/16") in diameter, for installation prior to applying insulation. Length to suit thickness of insulation. Nylon retain clips 32 mm (1.5") square.

2.6 JACKETS

- .1 Canvas:

- .1 Apply in exposed areas: ULC listed plain weave, cotton fabric at 220 g/sq. m (6.5 oz./sq. yd).

PART 3 - EXECUTION

3.1 APPLICATION

- .1 Apply insulation after required tests have been completed and approved by the Consultant. Insulation and surfaces shall be clean and dry when installed and during application of any finish. Apply insulation materials, accessories and finishes to manufacturer's recommendations and as specified in the Contract Documents.

- .2 Vapour barriers and insulation to be unbroken over full length of duct or surface, without penetration for hangers, standing duct seams and without interruption at sleeves.

- .3 Use stand-offs for all duct-mounted control accessories.

- .4 Apply 1.0 mm (18 gauge) thick galvanized sheet metal corners to all ductwork in mechanical rooms.

3.2 INSTALLATION

- .1 General

- .1 Adhere and seal vapour barrier using vapour seal adhesives.

- .2 Stagger longitudinal and horizontal joints on multi-layered insulation.
- .2 Mechanical Fastenings
 - .1 On rectangular ducts, use 50% coverage of insulating cement and weld pins at not more than 200 mm (8") centres, but not less than two (2) rows per side and bottom.
- .3 Apply canvas jacket in all exposed areas.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- 1 Provide all thermal insulation and accessories for ducting, piping, and equipment of the types and thicknesses indicated in the following Insulation Schedule.
- .2 Refer to Specification Sections 23 07 13, 23 07 20, 23 05 14, and 23 05 15 for additional details.
- .3 Increase thickness of piping insulation to 50 mm (2") where piping over 50 mm (2") is electrically traced.

INSULATION SCHEDULE			
ITEM	TYPE	THICKNESS mm (in)	COMMENTS
Domestic Cold Water	P-2	25 (1)	
Domestic Hot Water Supply and Recirculating (2"Ø and Below)	P-1	25 (1)	
Domestic Hot Water Supply and Recirculating (Above 2"Ø)	P-1	40 (1-1/2)	
Chilled Water Supply and Return	P-2	40 (1-1/2)	
Heating Water Supply and Return	P-1	40 (1-1/2)	
Condensate Drains from Cooling Coils	P-2	25 (1)	
Supply Air Duct - Round	D-2	25 (1)	All rigid supply air ductwork within concealed ceiling spaces and shafts
Supply Air Duct - Rectangular	D-2	25 (1)	All rigid supply air ductwork within concealed ceiling spaces and shafts

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide all thermal insulation and accessories for piping.
- .2 Refer to the Insulation Schedule (Section 23 07 15) for piping to be insulated, insulation type and thickness.
- .3 Insulate all associated fittings and valves.

1.2 REFERENCE STANDARDS

- .1 Meet the requirements of NFPA 90A-1985. Maximum flame spread rating of 25 and maximum smoke developed rating of 50 in accordance with NFPA 255 and CAN4-S102 for all components of insulation system. Materials tested in accordance with ASTM C411.

1.3 SAMPLES

- .1 Submit for the Consultant's approval a complete assembly of each type of insulation system, insulation coating and adhesive proposed. Mount samples on minimum 12 mm (1/2") plywood board. Label each sample indicating type.

1.4 DEFINITIONS

- .1 For purposes of this section:
 - .1 "CONCEALED" shall mean insulated mechanical services and equipment in suspended ceilings and non-accessible chases and furred spaces.
 - .2 "EXPOSED" shall mean "not concealed" as defined herein.

PART 2 - PRODUCTS

2.1 P-1 FORMED MINERAL FIBRE TO 200 degrees C (392 degrees F)

- .1 Material:
 - .1 CGSB 51-GP-9M, rigid mineral fibre sleeving for piping.

2.2 P-2 FORMED MINERAL FIBRE WITH VAPOUR BARRIER TO 85 degrees C (185 degrees F)

- .1 Material:
 - .1 CGSB 51-GP-9M, rigid mineral fibre sleeving for piping and CGSB 51-GP-52M, vapour barrier jacket and facing material.

2.3 P-3 FLEXIBLE MINERAL FIBRE WITH VAPOUR BARRIER TO 85 degrees C (185 degrees F)

.1 Material:

- .1 CGSB 51-GP-11M, mineral fibre blanket for piping and CGSB 51-GP-52M vapour barrier jacket and facing material.

2.4 P-4 FLEXIBLE ELASTOMERIC -40 degrees C TO 100 degrees C (-40 degrees F TO 212 degrees F)

.1 Material:

- .1 CAN2-51.40-M80 Aug-83, flexible elastomeric unicellular sheet and pipe covering.

2.5 FIRE RATED THERMAL PIPE INSULATION

- .1 Equivalent to "Instant Firestop Inc." type "PI".

- .2 ULC listed as a component of a fire stop system complete with vapour barrier jacket.

2.6 FASTENINGS

- .1 For insulation systems P-1, P-2, P-3:

- .1 Tape: self-adhesive.

- .2 Lap seal adhesive: quick-setting for joints and lap sealing of vapour barriers.

- .2 For insulation system P-4 and underside of roof drain body:

- .1 Contact adhesive: quick-setting for seams and joints.

- .2 Tape: self-adhesive Polyvinyl Chloride (PVC).

- .3 For canvas:

- .1 Washable adhesive for cementing canvas lagging cloth to piping insulation.

2.7 INSULATION CEMENT

- .1 To CGSB 51-GP-6M.

2.8 JACKETS

- .1 PVC

- .1 Apply in accordance with CGSB 51-GP-53M only when specified.

- .1 0.38 mm (28 gauge) thick minimum.

- .2 Fitting covers, one piece premoulded to match.

- .3 Fastenings standard to manufacturer.

PART 3 - EXECUTION

3.1 APPLICATION

- .1 Apply insulation after required tests have been completed and approved by the Consultant. Insulation and surfaces shall be clean and dry when installed and during application of any finish. Apply insulation materials, accessories and finishes in accordance with manufacturer's recommendations and as specified in the Contract Documents.
- .2 On piping with insulation and vapour barrier, install high density insulation under hanger shield. Maintain integrity of vapour barrier over full length of pipe without interruption at sleeves, fittings and supports.
- .3 On piping with insulation and vapour barrier that passes through a fire separation (wall, floor slab, etc.), provide fire rated thermal insulation to maintain continuity of vapour barrier and insulation without violating the integrity of the fire separation. Fire rated insulation shall be installed as part of a ULC listed fire stop system to provide the same rating as the fire separation.
- .4 Apply PVC jacket to all exposed piping insulation located indoors unless otherwise indicated in the Contract Documents. PVC jacket is not required for chrome plated sections of water and drain piping, only for non-chrome plated piping sections.

3.2 INSTALLATION

- .1 Preformed: sectional up to NPS 12, sectional or curved segmented greater than NPS 12.
- .2 Multi-layered: staggered butt joint construction.
- .3 Vertical pipe greater than NPS 3: insulation supports welded or bolted to pipe directly above lowest pipe fitting. Thereafter, locate on 4.5 m (15') centres.
- .4 Expansion joints: terminate single layer and each layer of multiple layers in straight cut. Leave space of 25 mm (1") between terminations. Pack void tightly with mineral fibre. Protect joints with stainless steel or aluminum sleeves.
- .5 Terminate insulation with insulation cement.
- .6 Bevel away for studs and nuts to permit their removal without damage to insulation, and seal with insulating cement.
- .7 Insulation is not required for chrome plated piping, valves and fittings.
- .8 Provide removable sections of insulation for fittings or devices requiring routine maintenance such as strainers.

3.3 FASTENINGS

- .1 Secure pipe insulation by tape at each end and centre of section, but not greater than 900 mm (36") on centres.

END OF SECTION

PART 1 – GENERAL

1.1 General

- .1 The purpose of this section is to specify responsibilities in the commissioning process for the work of Division 23.
- .2 The systems to be commissioned are listed in Section 01 91 00, subsection.1.9. The abbreviations and definitions used in Section 01 91 00 apply to this Section 23 08 00 – HVAC System Commissioning.
- .3 Commissioning shall take into account the requirements under Division 23 to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirements and coordination are detailed in Section 01 91 00. For the purposes of completing work under Division 23, the Contractor shall be familiar with all parts of Section 01 91 00 and the commissioning plan issued by the CA and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.2 Responsibilities

- .1 Mechanical Subcontractor. The responsibilities of the Contractor and its HVAC Subcontractor, during construction and acceptance phases in addition to those listed above are (all references apply to commissioned equipment only):
 - .1 Documentation of all procedures performed shall be provided and forwarded to the Consultant. Written documentation must contain recorded test values of all mechanical tests performed per the individual product specification.
 - .2 The start-up service company shall be present during energization of the mechanical equipment. Jobsite and equipment access must be provided by the Mechanical Subcontractor.
 - .3 Supply a power source, specified by the start-up service company, for on-site test equipment.
 - .4 Attend all factory witness testing required within the respective specification sections. The Contractor shall include all related costs in the total Contract Price submitted with its bid.
 - .5 Perform tests using qualified personnel. Provide necessary instruments and equipment.
 - .6 The Contractor shall Include the cost of commissioning in the total Contract Price, submitted with its bid..
 - .7 The Contractor shall ensure it complies with the requirements of GC -10 Subcontractors and ensures that the Mechanical Subcontractor complies with the Contract requirements for submittal data, O&M data and training.
 - .8 Attend a commissioning scoping meeting and other necessary meetings scheduled by the CA to facilitate the Cx process.
 - .9 Provide normal cut sheets and shop drawing submittals to the CA of commissioned equipment. Provide additional requested documentation, prior to normal O&M manual submittals, to the CA for development of pre-functional and functional testing procedures.
 - .1 Include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, fan curves, full factory testing reports, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Agent.

- .2 The Commissioning Agent may request further documentation necessary for the commissioning process. This data request may be made prior to normal submittals.
- .10 Provide a copy of the O&M manuals submittals of commissioned equipment, through normal channels, to the CA for review.
- .11 Assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
- .12 Provide assistance to the CA in preparation of the specific functional performance test procedures specified in Division 23. Subs shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
- .13 Develop a full start-up and checkout plan using manufacturer's start-up procedures and the pre- functional test sheets from the CA. Submit manufacturer's detailed start-up procedures and the full start-up plan and procedures and other requested equipment documentation to CA for review.
- .14 During the start-up and checkout process, execute and document the mechanical-related portions of the pre-functional test sheets provided by the CA for all commissioned equipment.
- .15 Perform and clearly document all completed start-up and system operational checkout procedures, providing a copy to the CA.
- .16 Provide skilled technicians to execute starting of equipment and to execute the functional performance tests. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving.
- .17 Perform functional performance testing under the direction of the CA for specified equipment in Section 01 91 00, subsection 1.9. Assist the CA in interpreting the monitoring data, as necessary.
- .18 Correct deficiencies (differences between specified and observed performance) as interpreted by the CA, PM and A/E and retest the equipment.
- .19 Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
- .20 During construction, maintain as-built red-line drawings for all drawings and final CAD as-builts for contractor-generated coordination drawings. Update after completion of commissioning (excluding deferred testing). Prepare red-line as-built drawings for all drawings and final as-builts for contractor-generated coordination drawings.
- .21 Provide training of the Owner's operating personnel as specified in the Contract Documents.
- .22 Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.
- .23 Execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.
- .24 Correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.
- .25 Assist and cooperate with the TAB Subcontractor and CA by:
- .1 Putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
- .2 Including cost of sheaves and belts that may be required by TAB.

- .3 Providing test holes in ducts and plenums where directed by TAB to allow air measurements and air balancing. Providing an approved plug.
- .4 Providing temperature and pressure taps according to the Construction Documents for TAB and commissioning testing.
- .26 Install a Pressure Transducer (P/T) plug at each water sensor which is an input point to the control system.
- .27 List and clearly identify on the as-built drawings the locations of all air-flow stations.
- .28 Prepare a preliminary schedule for pipe to be installed under Division 23 and duct system testing, flushing and cleaning, equipment start-up and TAB start and completion for use by the CA. Update the schedule as appropriate.
- .29 Notify the PM/GC or CA depending on protocol, when pipe and duct system testing, flushing, cleaning, start-up of each piece of equipment and TAB will occur. Be responsible to notify the PM/GC or CA, ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed, and that the CA has the scheduling information needed to efficiently execute the commissioning process.
- .2 TAB Subcontractor: The duties of the TAB Subcontractor, in addition to those listed in 1.2.1 are:
 - .1 Six weeks prior to starting TAB, submit to the PM/GC the qualifications of the site technician for the project, including the name of the contractors and facility managers of recent projects the technician on which was lead. The Owner will approve the site technician's qualifications for this project.
 - .2 Submit the outline of the TAB plan and approach for each system and component to the CA, PM/GC and the Controls Subcontractor six weeks prior to starting the TAB. This plan will be developed after the TAB has some familiarity with the control system. The submitted plan will include:
 - .1 Certification that the TAB Subcontractor has reviewed the construction documents and the systems with the design engineers and contractors to sufficiently understand the design intent for each system.
 - .2 An explanation of the intended use of the building control system. The Controls Subcontractor will comment on feasibility of the plan.
 - .3 All field checkout sheets and logs to be used that list each piece of equipment to be tested, adjusted and balanced with the data cells to be gathered for each.
 - .4 Discussion of what notations and markings will be made on the duct and piping drawings during the process.
 - .5 Final test report forms to be used.
 - .6 Detailed step-by-step procedures for TAB work for each system and issue: terminal flow calibration (for each terminal type), diffuser proportioning, branch / submain proportioning, total flow calculations, rechecking, diversity issues, expected problems and solutions, etc. Criteria for using air flow strengtheners or relocating flow stations and sensors will be discussed. Provide the analogous explanations for the water side.
 - .7 List of all air flow, water flow, sound level, system capacity and efficiency measurements to be performed and a description of specific test procedures, parameters, formulas to be used.

- .8 Details of how total flow will be determined (Air: sum of terminal flows via BAS calibrated readings or via hood readings of all terminals, supply (SA) and return air (RA) pilot traverse, SA or RA flow stations. Water: pump curves, circuit setter, flow station, ultrasonic, etc.).
- .9 The identification and types of measurement instruments to be used and their most recent calibration date.
- .10 Specific procedures that will ensure that both air and water side are operating at the lowest possible pressures and provide methods to verify this.
- .11 Confirmation that TAB understands the outside air ventilation criteria under all conditions.
- .12 Details of whether and how minimum outside air cfm will be verified and set and for what level (total building, zone, etc.).
- .13 Details of how building static and exhaust fan / relief damper capacity will be checked.
- .14 Proposed selection points for sound measurements and sound measurement methods.
- .15 Details of methods for making any specified coil or other system plant capacity measurements.
- .16 Details of any TAB work to be done in phases (by floor, etc.), or of areas to be built out later.
- .17 Details regarding specified deferred or seasonal TAB work.
- .18 Details of any specified false loading of systems to complete TAB work.
- .19 Details of all exhaust fan balancing and capacity verifications, including any required room pressure differentials.
- .20 Details of any required interstitial cavity differential pressure measurements and calculations.
- .21 Plan for hand-written field technician logs of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests (scope and frequency).
- .22 Plan for formal progress reports (scope and frequency).
- .23 Plan for formal deficiency reports (scope, frequency and distribution).
- .3 A running log of events and issues shall be kept by the TAB field technicians. Submit hand-written reports of discrepancies, deficient or uncompleted work by others under this Contract, contract interpretation requests and lists of completed tests to the CA and PM/GC at least twice a week.
- .4 Communicate in writing to the Controls Subcontractor all setpoint and parameter changes made, or problems and discrepancies identified during TAB which affect the control system setup and operation.
- .5 Provide a draft TAB report within 10 Working Days of completion of commissioning. A copy will be provided to the CA. The report will contain a full explanation of the methodology, assumptions and the results in a clear format with designations of all uncommon abbreviations and column headings. The report should follow the latest and most rigorous reporting recommendations by AABC, NEBB.
- .6 Provide the CA with any requested data, gathered, but not shown on the draft reports.
- .7 Provide a final TAB report for the CA with details, as in the draft.
- .8 Conduct functional performance tests and checks on the original TAB as specified for TAB in Section 23 05 93.

PART 2- PRODUCTS

- .1 NOT USED

PART 3- EXECUTION

3.1 Submittals

- .1 Provide submittal documentation relative to commissioning to the CA as requested by the CA. Refer to Section 01 91 00 Part 3.3 for additional Section 23 requirements.

3.2 Start-up of Equipment

- .1 Follow the start-up and initial checkout procedures listed in the Responsibilities list in this section and in 01 91 00. Ensure the start-up responsibility under Division 23 is met and complete systems and sub- systems so they are fully functional, meeting the design objectives of the Contract Documents. The commissioning procedures and functional testing do not relieve or lessen this responsibility or shift that responsibility partially to the commissioning agent or Owner.
- .2 Functional testing is intended to begin upon completion of a system. Functional testing may proceed prior to the completion of systems or sub-systems at the discretion of the CA and CM. Beginning system testing before full completion does not relieve the Contractor from fully completing the system, including all pre functional checklists as soon as possible.
- .3 Prior to the start-up of equipment under Division 23 the Contractor shall arrange to have the manufacturer of all major equipment inspect the installation to ensure their equipment has been installed in accordance with their recommendations.
- .4 The supplier shall submit a written report of their findings.
- .5 Upon confirmation that the equipment has been installed in accordance with the Manufacturers Recommendations the equipment may be started.
- .6 All equipment shall be started by the manufacturer's representative.

3.3 Pre-Functional Test Sheets

- .1 Pre-functional test sheets contain items to be performed under Division 23. On each checklist, a column is provided that is to be completed by the contractor assigning responsibility for that line item to a trade. Those executing the test sheets are only responsible to perform items that apply to the specific application at hand. These test sheets do not take the place of the manufacturer's recommended checkout and start- up procedures or report. Some checklist procedures may be redundant in relation to checkout procedures that will be documented on typical factory field checkout sheets. Double documenting may be required in those cases.

- .2 Refer to Section 01 91 00 for additional requirements regarding pre-functional test sheets, start-up and initial checkout. Items that do not apply should be noted along with the reasons on the checklist. If this checklist is not used for documenting, one of similar rigor and clarity shall be used pending approval from the CA. Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off. "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E
= Architect/Engineer, All = Contractor including all Subcontractors, CA = Commissioning Agent, CC = Controls Subcontractor, EC = Electrical Subcontractor, PM/GC = General Contractor, MC = Mechanical Subcontractor, SC = Sheet Metal Subcontractor, TAB = Test and Balance Subcontractor.

3.4 Operations and Maintenance Manuals

- .1 Compile and prepare documentation for all equipment and systems covered in Division 23 and deliver to the GC for inclusion in the O&M manuals
- .2 The CA shall receive a copy of the O&M manuals for review.

3.5 Training of Owner Personnel

- .1 The GC shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed. Refer to Section 01 91 00 for additional details.
- .2 The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment. Refer to Section 01 91 00 for additional details.
- .3 Mechanical Subcontractor. The mechanical contractor shall have the following training responsibilities:
- .1 Provide the CA with a training plan two weeks before the planned training according to the outline described in Section 01 91 00, Part 3.8.
- .2 Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of HVAC equipment including, but not limited to, pumps, boilers, furnaces, chillers, heat rejection equipment, air conditioning units, air handling units, fans, terminal units, controls and water treatment systems, etc.
- .3 Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including start-up, shutdown, fire/smoke alarm, power failure, etc.
- .4 During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
- .5 Ensure the appropriate trade or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment is required. More than one party may be required to execute the training.
- .6 The controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
- .7 The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.

- .8 Training shall include:
 - .1 Use of the printed installation, operation and maintenance instruction material included in the O&M manuals.
 - .2 A review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.
 - .3 Discussion of relevant health and safety issues and concerns.
 - .4 Discussion of warranties and guarantees.
 - .5 Common troubleshooting problems and solutions.
 - .6 Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.
 - .7 Discussion of any peculiarities of equipment installation or operation.
- .9 The format and training agenda in The HVAC Commissioning Process, ASHRAE Guideline 0- 2005 is recommended.
- .10 Classroom sessions shall include the use of overhead projections, slides, video/audio-taped material as might be appropriate.
- .11 Hands-on training shall include start-up, operation in all modes possible, including manual, shut- down and any emergency procedures and preventative maintenance for all pieces of equipment.
- .12 The mechanical contractor shall fully explain and demonstrate the operation, function and overrides of any local packaged controls, not controlled by the central control system.
- .13 Training shall occur after functional testing is complete, unless approved otherwise by the Project Manager.

3.6 Deferred Testing

- .1 Refer to Section 01 91 00, Part 3.9 for requirements of deferred testing.

3.7 WRITTEN WORK PRODUCTS

- .1 Written work products under Division 23 shall consist of the start-up and initial checkout plan as described in Section 01 91 00, as well as completed start-up, initial checkout and pre-functional test sheets.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide all low pressure ductwork and accessories as shown on the Drawings.

PART 2 - PRODUCTS

2.1 CLASSIFICATION

.1 Ductwork

Class	Maximum Pressure Pa ("Water Gauge)	Maximum Velocity Class m/s (fpm)	Seal
I	500 (2)	12.5 (2500)	A
II	250 (1)	12.5 (2500)	B
III	125 (0.5)	10.0 (2000)	C

.2 Seals

- 1 Class A: seams, joints and connections made airtight with sealing compound and tape.
- 2 Class B: seams, joints and connections made airtight with sealing compound.
- 3 Class C: transverse joints and connections made airtight with sealing compound. Longitudinal seams unsealed.

2.2 SEALANT AND TAPE

- .1 Sealant: oil resistant, polymer type flame resistant high velocity duct sealing compound. Temperature range of -30 degrees C to 93 degrees C (-22 degrees F to 200 degrees F).
- .2 Tape: polyvinyl treated, open weave glass fibre tape, 50 mm (2") wide.

2.3 DUCT LEAKAGE

- .1 Class I: 0.50% of total system design flow at 500 Pa (2" W.G.).
- .2 Class II: 1.00% of total system design flow at 250 Pa (1" W.G.).
- .3 Class III: 1.50% of total system design flow at 125 Pa (1/2" W.G.).
- .4 Class IV: 5.00% of total system design flow at 125 Pa (1/2" W.G.).

2.4 FITTINGS

- .1 Fabrication: to SMACNA standards
- .2 Radius elbows: standard radius or short radius with single thickness turning vanes.

- .3 Square elbows: to 400 mm (16") with single thickness vanes.
- .4 Square elbows: over 400 mm (16") with double thickness vanes.
- .5 Main supply duct branches with or without splitter damper. If splitter damper is not used, provide branch and main duct balancing dampers.
- .6 Sub-branch duct with 45 degree entry and balancing damper on branch, or sub-branch duct with square connection, volume extractor and branch duct balancing damper.
- .7 Transitions:
 - 1 Diverging: 20 degree maximum included angle.
 - 2 Converging: 30 degree maximum included angle.
- .8 Offsets: square elbows or radius elbows as indicated on the Drawings.
- .9 Obstruction deflectors: maintain full cross-sectional area. Maximum included angles for transitions.

2.5 GALVANIZED STEEL

- .1 Lock forming quality: to ASTM A525M-80, Z90 zinc coating.
- .2 Thickness: to ASHRAE and SMACNA.
- .3 Fabrication: to ASHRAE and SMACNA.
- .4 Joints: to ASHRAE and SMACNA or proprietary manufactured duct joint. Proprietary manufactured flanged duct joint shall be considered to be a Class A seal.
- .5 All round exposed ductwork shall be of spiral wound manufacture.

2.6 HANGERS AND SUPPORTS

- .1 Strap hangers: of same material as duct, but next sheet metal thickness heavier than duct.
- .2 Hanger configuration: to ASHRAE and SMACNA. Maximum size duct supported by strap hanger: 500 mm (20").
- .3 Hangers: galvanized steel angle with galvanized steel rods to ASHRAE and SMACNA, In accordance with the following table:

Duct Size mm (")	Angle Size mm (")	Rod Size mm (")
up to 750 (30)	25 x 25 x 3 (1 x 1 x 1/8)	6 (1/4)
751 (30) to 1050 (42)	40 x 40 x 3 (1.5 x 1.5 x 1/8)	6 (1/4)
1051 (42) to 1500 (60)	40 x 40 x 3 (1.5 x 1.5 x 1/8)	10 (3/8)
1501 (60) to 2100 (84)	50 x 50 x 3 (2 x 2 x 1/8)	10 (3/8)
2101 (84) to 2400 (96)	50 x 50 x 5 (2 x 2 x 3/16)	10 (3/8)
2401 (96) and over	50 x 50 x 6 (2 x 2 x 1/4)	10 (3/8)

- .4 Upper hanger attachments:
 - 0.1 For concrete: manufactured concrete inserts.

PART 3 - EXECUTION

3.1 GENERAL

- .1 Install ducts in accordance with ASHRAE and SMACNA.
- .2 Provide all duct supports in accordance with SMACNA standards. Maximum duct sag shall be limited to ½ inch per foot.
- .3 All HVAC ductwork and equipment, including existing equipment, shall be protected from exposure to moisture and from collecting dust, debris, odours and other contaminants while demolition and construction activities are ongoing.
- .4 The ends of all ductwork and openings in HVAC equipment are to be sealed tightly, whether they are installed or being stored prior to installation. All ductwork and equipment that is waiting to be installed must be kept off the floor a minimum of 75 mm.
- .5 Provide adequate access into ductwork for cleaning purposes.
- .6 Immediately after installation, the open ends of return and exhaust ductwork shall be sealed with 6-mil plastic.
- .7 HVAC equipment and ductwork left in place during demolition and construction shall be wrapped in 6-mil plastic sheeting.
- .8 Do not break continuity of insulation vapour barrier with hangers or rods. Insulate strap hangers 100 mm (4") beyond insulated duct.
- .9 Support risers in accordance with ASHRAE and SMACNA, or as indicated on the Drawings.
- .4 Unless otherwise indicated on the Drawings, ductwork shall be constructed of galvanized steel.
- .5 All supply and exhaust ductwork shall be Seal Class C. All other ductwork shall be Class I, Class II or Class III as required.

3.2 HANGERS

- .1 Strap hangers: install in accordance with SMACNA.
- .2 Angle hangers: complete with locking nuts and washers.
- .3 Hanger spacing as follows:

Duct Size mm (")	Spacing mm (")
to 1500 (60)	3000 (10)
1501 (60) and over	2500 (8)

3.4 SEALING AND TAPING

- .1 Apply sealant to outside of joint in accordance with manufacturer's recommendations.
- .2 Bed tape in sealant and recoat with minimum of one (1) red coat of sealant in accordance with manufacturer's recommendations.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide all duct accessories.

1.2 CERTIFICATION OF RATINGS

- .1 Catalogue or published ratings shall be those obtained from tests carried out by manufacturer or independent testing agency signifying adherence to codes and standards.

PART 2 - PRODUCTS

2.1 FLEXIBLE CONNECTIONS

- .1 Frame: galvanized sheet metal frame 1.5 mm (16 gauge) thick with fabric clenched by means of double locked seams.
- .2 Material: Fire resistant, self-extinguishing, neoprene coated glass fabric, temperature rated at -40°C to 90°C (-40°F to 194°F), density of 1.3 kg.sq. m (25 lbs/sq.ft).

2.2 SEALANT AND TAPE

- .1 Sealant: oil resistant, polymer type flame resistant high velocity duct sealing compound. Temperature range of -30°C to 93°C (-22°F to 200°F).
- .2 Tape: polyvinyl treated, open weave fibre glass tape, 50 mm (2") wide.

2.3 ACCESS DOORS

- .1 General
 - 1 Non-insulated sandwich construction of same material as duct, one sheet metal thickness heavier, minimum 0.6 mm (24 gauge) thick, complete with sheet metal angle frame.
 - 2 Insulated sandwich construction of same material as duct, one sheet metal thickness heavier, minimum 0.6 mm (24 gauge) thick, complete with sheet metal angle frame and 25 mm (1") thick rigid glass fibre insulation.
- .2 Gaskets: neoprene or foam rubber.
- .3 Hardware:
 - 1 Up to 300 mm x 300 mm (12" x 12"): two (2) sash locks.
 - 2 301 mm to 450 mm (12" to 18"): four (4) sash locks.
 - 3 451 mm to 1000 mm (18" to 40"): piano hinge and minimum two (2) sash locks.
 - 4 Doors greater than 1000 mm (40"): piano hinge and two (2) handles operable from both sides.

2.4 TURNING VANES

- .1 Factory or shop fabricated, single or double thickness in accordance with the recommendations of SMACNA.

2.5 INSTRUMENT TEST PORTS

- .1 1.6 mm (14 gauge) thick steel zinc plated after manufacture.
- .2 Cam lock handles with neoprene expansion plug and handle chain.
- .3 28 mm (1") minimum inside diameter. Length to suit insulation thickness.
- .4 Neoprene mounting gasket.

2.6 BACK DRAFT DAMPERS

- .1 Automatic gravity operated, multi leaf, aluminum construction with nylon bearings, and centre pivoted.

PART 3 - EXECUTION

3.1 INSTALLATION

.1 Flexible Connections

1 Install in following locations:

- 1 Inlets to supply air units, except where units are internally isolated.
- 2 Outlets from supply air units except where units are internally isolated.
- 3 Inlets and outlets of fans.
- 4 As indicated on the Drawings.

2 Length of connection: 150 mm (6").

3 Minimum distance between metal parts when system in operation: 75 mm (3").

4 Install in accordance with recommendations of SMACNA.

.2 Sealants and tapes

1 Apply sealant in accordance with recommendations of SMACNA and the manufacturer.

2 Bed tape in sealant and recoat with minimum of one coat of sealant in accordance with the manufacturer's recommendations.

.3 Access doors

1 Size:

- 1 760 mm x 1500 mm (30" x 60") for person size entry.
- 2 600 mm x 1200 mm (24" x 48") for servicing entry.
- 3 300 mm x 300 mm (12" x 12") for viewing.
- 4 As indicated on the Drawings.

2 Location

- 1 At fire and smoke dampers.
 - 2 At control dampers.
 - 3 At devices requiring maintenance.
 - 4 At locations required by the Ontario Building Code.
 - 5 As indicated on the Drawings.
- .4 Instrument Test Ports
- 1 General
 - 1 For traverse readings, install in accordance with recommendations of SMACNA.
 - 2 For temperature readings, install in accordance with recommendations of SMACNA.
 - 3 Install in accordance with manufacturer's instructions.
 - 2 Locations
 - 1 Traverse:
 - 1 At ducted inlets to roof and wall exhausters.
 - 2 At inlets and outlets of other fan systems.
 - 3 At main and sub-main ducts.
 - 4 As indicated or required for full, accurate readings.
 - 2 Temperature:
 - 1 At outside air intakes.
 - 2 At mixed air locations.
 - 3 At inlet and outlet of coils.
 - 4 Downstream of junctions of two converging air streams of different temperatures.
 - 5 As indicated on the Drawings or required for all necessary readings.
- .5 Turning vanes
- 1 Install in accordance with recommendations of SMACNA.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide all balancing dampers and accessories.

PART 2 - PRODUCTS

2.1 SPLITTER DAMPERS

- .1 Of same material as duct but one sheet metal thickness heavier, with appropriate stiffening.
- .2 Double thickness construction, airfoil blade profile.
- .3 Size and configuration to recommendations of SMACNA.
- .4 Control rod with locking device.
- .5 Bend end of rod to prevent end from entering duct.
- .6 Pivot: piano hinge.

2.2 SINGLE BLADE DAMPERS

- .1 Of same material as duct. V-groove stiffened.
- .2 Size and configuration to recommendations of SMACNA, except maximum height 250 mm (10").
- .3 Locking quadrant, with shaft extension to accommodate insulation thickness.
- .4 Inside and outside bronze end bearings.

2.3 MULTI-BLADED DAMPERS

- .1 Factory manufactured of material compatible with duct.
- .2 Opposed blade: configuration, metal thickness and construction to recommendations of SMACNA.
- .3 Maximum blade height: 100 mm (4").
- .4 Bearings: pin in bronze bushings.
- .5 Linkage: shaft extension with locking quadrant.
- .6 Channel frame material of same material as duct, complete with angle stop.

2.4 DIVERTING DAMPERS

- .1 Adjustable, curved vanes mounted in supporting frame.
- .2 All aluminum construction.

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Install where indicated on the Drawings and as required to completely balance the air systems.
- .2 Install in accordance with recommendations of SMACNA and in accordance with manufacturer's instructions.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide all fire dampers and accessories.

1.2 SUBMITTALS

- .1 Submit Shop Drawings for each type of fire damper in accordance with Section 21 05 01.
- .2 Provide data for inclusion in the Operating and Maintenance Manuals in accordance with Section 21 05 01.

1.3 CERTIFICATION OF RATINGS

- .1 Catalogue or published ratings shall be those obtained from tests carried out by the manufacturer or those ordered by the manufacturer from an independent testing agency signifying adherence to applicable codes and standards.

PART 2 - PRODUCTS

2.1 FIRE DAMPERS

- .1 Fire dampers shall be listed and bear label of ULC and shall meet requirements of Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector, etc.
- .2 Mild steel, factory fabricated for fire rating requirement to maintain integrity of fire wall and/or fire separation.
- .3 Top hinged: offset single damper, round or square; multi-blade hinged or interlocking type; roll door type; guillotine type; sized to maintain full duct cross section.
- .4 Fusible link actuated, weighted to close and lock in closed position when released or having negator-spring-closing operator for multi-leaf type or roll door type in horizontal position with vertical air flow.
- .5 Frame and 40 mm x 40 mm x 3 mm (1.5" x 1.5" x 1/8") angle iron on full perimeter of frame on both sides of fire wall and/or fire wall being pierced.
- .6 All fire dampers shall be type 'B' fire dampers to maintain full duct cross sectional area when open.

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Install fire dampers in accordance with NFPA 90A.
- .2 Maintain integrity of fire wall and/or fire separation.
- .3 After completion and prior to concealment, obtain approvals of complete installation from the Consultant and Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector, etc.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide all flexible ductwork.

1.2 REFERENCE STANDARDS

- .1 Comply with the requirements of:
 - .1 ULC S110M for fire tests for air ducts.
 - .2 UL 181 for factory made air ducts and connectors.
 - .3 NFPA 90A for installation of air conditioning and ventilating systems.
 - .4 NFPA 90B for installation of warm air heating and air conditioning systems.
 - .5 SMACNA for flexible duct installation and duct support standards.

1.3 CERTIFICATION OF RATINGS

- .1 Catalogue or published data ratings shall be those obtained from tests carried out by manufacturer or independent testing agency signifying adherence to applicable codes and standards.

1.4 SAMPLES

- .1 Submit samples with Product data of each different type of flexible duct being used.

PART 2 - PRODUCTS

2.1 GENERAL

- .1 Factory fabricated.
- .2 Pressure drop coefficients listed below are based on sheet metal duct pressure drop coefficient of 1.00.
- .3 Flame spread rating not to exceed 25. Smoke developed rating not to exceed 50.

2.2 METALLIC - UNINSULATED

- .1 Spiral wound flexible aluminum.
- .2 Performance:
 - .1 Minimum working pressure: 2.5 kPa (10" WG)
 - .2 Maximum pressure drop coefficient : 3.

2.3 METALLIC - INSULATED

- .1 Spiral wound flexible aluminum with factory applied flexible glass fibre thermal insulation with vapour barrier and vinyl jacket.
- .2 Performance:
 - .1 Minimum working pressure: 2.5 kPa (10" WG).
 - .2 Maximum pressure drop coefficient : 3.
 - .3 Thermal loss/gain: 22 W/sq.m degree C (4 BTU/hr./sq.ft degree F).

2.4 METALLIC – ACOUSTIC FLEX

- .1 Spiral wound perforated flexible aluminum with factory applied flexible glass fibre insulation and flame retardant non-toxic polyethylene vapour barrier.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

- .1 Provide acoustic metallic flexible duct in all areas unless otherwise indicated on the Drawings.
- .2 Provide minimum three (3) screws or stainless steel worm drive clamps to fasten flexible ducts to diffusers or rigid ductwork. Completely seal connections with tape.
- .3 Attach flexible ductwork to fan coil unit supply air ductwork with pressure clamps. Fastening with tie-wraps is not acceptable.
- .4 Support in accordance with SMACNA.
- .5 Maximum length of flexible duct: 1.9 m (6 ft).

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide all acoustic duct lining and accessories.

1.2 REFERENCE STANDARDS

- .1 Carry out work in accordance with recommendations of ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers).

PART 2 - PRODUCTS

2.1 DUCT LINER

- .1 General
 - .1 Fibrous glass duct liner density 22 kg/cu. m (1.5 lb/cu.ft): one side coated with black neoprene.
 - .2 Flame spread rating shall not exceed 25. Smoke development rating shall not exceed 50.
- .2 Rigid
 - .1 25 mm (1") thick, to CGSB 51-GP-10M fibrous glass rigid board duct liner. For ductwork located outdoors, increase thickness to 50mm (2").
 - .2 Use on all flat surfaces.
- .3 Flexible
 - .1 25 mm (1") thick, to CGSB 51-GP-11M+Amdt-Apr-78, fibrous glass blanket duct liner. For ductwork located outdoors, increase thickness to 50mm (2").
 - .2 Use on round or oval surfaces.

2.2 ADHESIVE

- .1 Flame spread rating shall not exceed 25. Smoke development rating shall not exceed 50. Temperature range – 30 degrees C to 93 degrees C (-22 degrees F to 200 degrees F). Meet requirements of NFPA 90A.

2.3 FASTENERS

- .1 Weld pins 2.0 mm (0.8") diameter, length to suit thickness of insulation. Metal retaining clips, 32 mm (1-1/4") square.

2.4 JOINT TAPE

- .1 Poly-vinyl treated open weave fibre glass membrane 50 mm (2") wide.

2.5 SEALER

- .1 Flame spread rating shall not exceed 25. Smoke development rating shall not exceed 50. Temperature range - 68 degrees C to 93 degrees C (-90 degrees F to 200 degrees F). Meet requirements of NFPA 90A-1996.

PART 3 - EXECUTION

3.1 GENERAL

- .1 Line inside of ducts where indicated on the Drawings or in Schedules provided on the Drawings.
- .2 Duct dimensions shown on the Drawings are clear inside. Increase actual duct dimensions accordingly to maintain clear dimensions indicated on Drawings.
- .3 Manufacture duct in lengths to accommodate installation of duct liner.

3.2 DUCT LINER

- .1 Install in accordance with manufacturer's recommendations, recommendations of SMACNA, and as follows:
 - 1 Fasten to interior sheet metal surface with 100% coverage of adhesive.
 - 2 In addition to adhesive, install weld pins at one pin per 2 sq. m (20 sq. ft) of liner, but not less than one row per side.

3.3 JOINTS

- .1 Seal all joints, exposed edges, weld pin and clip penetrations and all damaged areas of liner with joint tape. Badly damaged areas of lining shall be replaced at discretion of the Consultant.
- .4 Seal joint tape in accordance with manufacturer's recommendations, recommendations of SMACNA, and as follows:
 - 1 Bed tape in sealer.
 - 2 Apply two coats of sealer over tape.
- .5 Protect leading and trailing edges with sheet metal edging.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide fans and accessories where indicated on the Drawings and of the types and performance as listed in the Schedules.

1.2 SUBMITTALS

- .1 Submit shop drawings for each fan in accordance with Section 15010 and including the following:
 - .1 Certified fan curves and sound power data for 75%, 100% and 125% of rated speed.
 - .2 For variable volume systems, also provide data at 30% and 50%.
- .2 Provide data for inclusion in the operating and Maintenance Manuals in accordance with Section 15010.

1.3 MANUFACTURED ITEMS

- .1 Catalogued or published ratings shall be those obtained from tests carried out by manufacturer or those provided by an independent testing agency signifying adherence to codes and standards in force.
- .2 Provide confirmation of testing.

PART 2 - PRODUCTS

2.1 FANS - GENERAL

- .1 Capacity, total and static pressure, revolutions per minute, power, model, size and sound power levels: as indicated.
- .2 Sound ratings: comply with AMCA 301-76 tested to AMCA 300-67. Unit shall bear AMCA certified sound rating seal.
- .3 Fans: statically and dynamically balanced, constructed in conformity with AMCA 99-83.
- .4 Ratings: based on tests performed in accordance with AMCA 210-74, and ASHRAE 51-85. Unit shall bear AMCA certified rating seal, except for propeller fans smaller than 300 mm (12") diameter. Fans shall have non-overloading characteristics.

- .5 Bearings: heavy duty, split pillow-block, flange mounted, grease lubricated ball or roller bearings of self-aligning type with oil retaining, dust excluding seals and a certified minimum rated life of 100,000 hours in accordance with AFBMA I-10 life standard. Bearings to be rated and selected in accordance with AFBMA 9 and AFBMA 11.
- .6 Motors: sizes as indicated or specified.
- .7 Provide motors capable of accelerating to operating speed in 15 seconds without motor overload. For starting times over 10 seconds, or fan motors 30 hp or over, provide thermistors in motors.
- .8 Accessories and hardware: V-belt drives, adjustable motor bases, belt guards, coupling guards and hinged fan inlet and outlet safety screens for exposed inlets or outlets.
- .9 Belt guards on exposed belts.
- .10 Factory primed exterior and factory primed and enameled interior before assembly in colour standard to manufacturer.
- .11 Scroll drains: where indicated.
- .12 Balanced sheaves to 15 hp, fixed sheaves above.
- .13 Provide an additional set of sheaves as required for balancing.
- .14 Fans serving a smoke exhaust function shall have bearings, belts and drives outside the air stream wherever possible. Otherwise, bearings, belts and drives shall be shielded.
- .15 V-belt drive shall be capable of transmitting 150% of fan motor horsepower.
- .16 Extend lubrication services to outside the casing.

2.2 CENTRIFUGAL FANS

- .1 Fan wheels
 - .1 Welded steel construction.
 - .2 Maximum operating speed of centrifugal fans shall not be more than 40% of first critical speed.
 - .3 Airfoil, forward curved, backward inclined blades as indicated.
- .2 Housings
 - .1 Form volute with inlet cones, fabricated steel for wheels 300 mm (12") or greater, cold rolled steel for smaller wheels, braced and with welded supports. Convertible discharge up to 675 mm (27") wheels, fixed discharge for larger.
 - .2 For horizontally and vertically split housings, provide flanges on each section for

bolting together, with gaskets of non-oxidizing non-flammable material.

- .3 Provide airtight access doors with handles.
- .4 Provide 10 mm (3/4") drain plug.

2.3 CABINET FANS

- .1 Single or multiple wheels with DWDI centrifugal fans in factory fabricated casing complete with motor, V-belt drive and guard inside or outside casing.
- .2 Fabricate casing of zinc coated or phosphate treated steel of 1.5 mm (16 gauge) thickness reinforced and braced for rigidity. Provide removable panels for access to internal parts. Uncoated steel parts shall be painted over with corrosion resistant paint to CGSB 1-GP-181M+Amdt-Mar-78. Finish inside and out, over prime coat, with rust resistant baked on enamel. Internally line cabinet with 25 mm (1") thick rigid acoustic insulation.

2.4 UTILITY SETS

- .1 Characteristics and construction: as for centrifugal fans.
- .2 Preassemble single width centrifugal fan with removable protective hood with vents, and automatic back draft dampers and bird screens.
- .3 Provide belt driven sets with adjustable motor bed plate and variable pitch driver sheave.

2.5 AXIAL FLOW FANS

- .1 Fabricate casings of welded steel with welded motor support, hinged or bolted access plates, streamlined inlet cone and discharge bell sections and integral silencer casing, external silencer.
- .2 Provide floor-mounted units with reinforced legs. Provide ceiling-suspended units with support brackets welded to side of casing.
- .3 Direct drive
 - .1 Adjustable blade wheels: totally enclosed, air over motors.
 - .2 Diameter of wheel hub: at least equal to that of motor frame.
 - .3 Adjust blades for varying range of volume and pressure. Hubs shall facilitate indexing of blade angle. Provide automatic adjustment stops to avoid overloading motor. Provide easy access to fan wheel.
- .4 Belt drive
 - .1 Drive adjustable blades by externally mounted motors through V-belt drive. Provide

- internal belt fairing, external belt guards and adjustable motor mounts.
- .2 Adjust blades for varying range of volume and pressure. Hubs shall facilitate indexing of blade angle. Provide automatic adjustment stops to avoid overloading motor. Provide easy access to fan wheel.
- .5 Provide remote control actuator for hub pitch control, with maximum flow with no signal.
- .6 Provide companion flanges of same gauge as fan flanges.

2.6 TUBULAR CENTRIFUGAL FANS

- .1 Characteristics and construction: as for centrifugal fan wheels, with axial flow construction and direct drive motor.
- .2 Provide AMCA arrangements 1 or 9 as indicated with stiffened flanges, smooth rounded inlets and stationary guide vanes.

2.7 PROPELLER FANS

- .1 Fabricate multi-bladed propellers of sheet steel or airfoil shape within bell mouth entrance on integral mounts, with grease lubricated ball bearings suited for operating in any position, direct or belt driven, complete with motor as indicated.
- .2 Provide blade guards, bird screen and automatic back draft dampers on discharge, with gasketed edges.
 - .1 ECM motor set for use with 2 speeds.
 - .2 Wall sleeve, fan guard and other accessories as listed on the schedule.

PART 3 - EXECUTION

3.1 FAN INSTALLATION

- .1 Install fans as indicated, complete with resilient mountings and flexible electric leads.
- .2 Install fans with 100 mm (4") flexible connection on inlet ductwork and on discharge ductwork. Ensure metal bands of connectors are parallel with minimum 25 mm (1") flex between ductwork and fan during running.
- .3 Install fan restraining snubbers as indicated. Flexible connections shall not be in tension during running.

- .4 Provide sheaves and belts required for final air balance.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide all grilles, registers, diffusers and accessories.
- .2 Grilles, registers and diffusers shall be the product of one manufacturer.

1.2 SHOP DRAWINGS AND PRODUCT DATA

- .1 Submit Shop Drawings in accordance with Section 21 05 01.

1.3 SAMPLES

- .1 Samples are required for each type of grille, register and diffuser.

1.4 CERTIFICATION OF RATINGS

- .1 Catalogued or published ratings shall be those obtained from tests carried out by manufacturer or those ordered by the manufacturer from independent testing agency indicating adherence to ASHRAE and SMACNA codes and standards.

PART 2 - PRODUCTS

2.1 GENERAL

- .1 Provide standard product to meet capacity, throw, noise level, throat and outlet velocity.
- .2 Where grilles, registers and diffusers penetrate fire walls and fire partitions, provide approved steel sleeve secured to structure in accordance with NFPA 90A.
- .3 Frames:
 - .1 Steel: prime coated cold rolled steel with exposed welded joints and mitred corners.
 - .2 Aluminum: extruded satin finish with mechanical fasteners and mitred corners.
 - .3 Provide full perimeter gaskets.
 - .4 Provide plaster frames as plaster stops where set into plaster or gypsum board.
 - .5 Provide concealed fasteners and operators.
- .4 Sizes and capacities as indicated in Schedules provided on the Drawings.
- .5 Floor grilles to be capable of supporting 90 kg (200 lbs) point load weight between supports with negligible deflection.

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Install in accordance with manufacturer's instructions.
- .2 Install with flat head cadmium plated screws in countersunk holes where fastenings are visible.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

- .1 Provide fin tube radiation of the capacities shown on the Drawings.
- .2 Provide enclosures as specified herein, including all supports and accessories.

1.2 SUBMITTALS

- .1 Provide shop drawings in accordance with Section 15010 and including construction details of radiation enclosure at mullions, columns and corners.

PART 2 - PRODUCTS

2.1 HEATING ELEMENT

- .1 Provide heating element of 20 mm (3/4") seamless copper tubing with 100 mm (4") x 100 mm (4") aluminum fins mechanically bonded to the tubing.
- .2 Heating capacities shall be the net capacity after correction for enclosure effect, water velocity and entering air and water temperature.
- .3 Select heating elements based on entering air temperature of 21 °C (70 °F) and average water temperature of 76 °C (170 °F).

2.2 ENCLOSURES

- .1 Enclosures shall be constructed of minimum 16 gauge cold rolled steel and finished with a prime coat of paint.
- .2 Enclosures shall be of a flush mullion design with the panels between the mullions removable for access to the heating elements, piping and controls.
- .3 Provide punched grilles on the top of the enclosure unless otherwise indicated.
- .4 Enclosures shall be continuous or column to column as indicated. Field measure enclosure length.
- .5 Provide factory installed gusset plates to maintain enclosure shape during shipment and installation.
- .6 Provide telescoping end pieces at all intersections with drywall surfaces.

- .7 Enclosure shall be firmly supported at the top by a continuous joggle strip mounted to the horizontal window mullion.
- .8 Refer to the Drawings for enclosure details.

2.3 EXTRUDED ALUMINUM ENCLOSURE

- .1 Where indicated, provide extruded aluminum integral outlet grille and formed aluminum top.
- .2 Finish aluminum to match mullions of glazing system.
- .3 Provide extruded aluminum mullion pieces with alignment pins.
- .4 Front cover of enclosure shall be suspended from aluminum top and fastened at mullion sections. Re-inforce removable panels for rigidity.

2.4 SLOPING TOP ENCLOSURES (TYPE A)

- .1 Enclosures shall be constructed of minimum 16 gauge cold rolled steel and finished with a prime coat of paint.
- .2 Enclosures shall be 450 mm high with 2 rows of heating elements installed at 150 mm centres complete with wall brackets, joggle strips, end caps and 150 x 150 hinged access door for valve service.
- .3 Provide punched grilles on the sloping top of the enclosure unless otherwise indicated.

2.5 ELEMENT BRACKETS

- .1 Element brackets shall consist of a steel cradle mounted on ball or roller bearings to allow free and quiet element expansion.
- .2 Provide sufficient number of brackets to adequately support heating element.

2.6 HOT WATER PANEL RADIATORS

- .1 Radiators shall be manufactured of cold rolled low carbon steel, fully welded and consisting of header pipes at each end, connected by flat oval water tubes, 1.22mm wall thickness.
- .2 Radiator header pipes shall be square 2.77mm min. wall thickness and include all necessary supply, return and air vent connections, internal baffling, 19mm piping connections.

- .3 Radiators shall be phosphatized and primed with flat white baked enamel and finish painted with a gloss baked enamel, for a total paint thickness of 2. to 3 mils. Colour of finish paint shall be selected from optional colours by Architect prior to ordering.
- .4 Provide all necessary wall mounting brackets. End caps shall be provided to provide a continuous wall to wall appearance. End caps shall be field measured prior to manufacturing.
- .5 Provide horizontal piping connections where radiators terminate at columns or partition walls. Provide vertical piping connections with vertical pipe covers where radiators terminate at doorways.
- .6 Provide radiator lockshield valves (Overtop Combi4) with proportional presetting to allow isolating, fitting and drainage without alternation of the presetting.

PART 3 - EXECUTION

3.1 INSTALLATION

- .1 Support enclosures from the horizontal window mullion and from the vertical mullions.
- .2 Do not penetrate wall vapour barrier during installation of heating elements or enclosure.
- .3 Ensure that enclosures are level and aligned with the windows.
- .4 Install isolating ball valves, manual air vent and pneumatic control valves on each heating element as indicated on the Drawings.
- .5 Co-ordinate installation of mock-up sections with other Trades.

END OF SECTION

PART 1 - GENERAL

1.1 WORK INCLUDED

This document outlines the minimum equipment and performance standards for a completely interoperable Building Automation System (BAS).

The work shall include design, supply, installation, and commissioning a complete microprocessor based automatic control system to achieve the performance specified in the following Sections.

- .3 The BAS shall be supplied and installed by a controls vendor familiar with the system installed at base building by Delta Controls.

The BAS shall be capable of total integration of facility infrastructure systems with user access to all system data, either locally over a secure Intranet within the building or by remote access by a standard Web Browser over the Internet.

The entire BAS shall be peer-to-peer networked, stand-alone, distributed control in accordance with American National Standards Institute/American Society of Heating, Refrigerating and Air Conditioning Engineers (ANSI/ASHRAE) Standard 135-2004, BACnet – A Data Communication Protocol for Building Automation and Control Networks.

All labour, material, equipment and software not specifically referred to herein or on the plans, but is required to meet the functional intent, shall be provided without additional cost to the Owner.

- .1 The Contractor shall ensure that the BAS Subcontractor will provide the necessary engineering, installation, supervision, commissioning and programming for a complete and fully operational system. The Contractor will provide as many trips to the job site for installation, supervision, and commissioning as are necessary to complete the project to the satisfaction of the Consultant and/or project supervisor.

The Contractor shall ensure that the BAS Subcontractor will specifically read all mechanical and electrical Drawings, specifications, and addenda and determine the controls work provided by other forces under the Contract, including the mechanical Subcontractor, and the electrical Subcontractor. The Contractor shall ensure the controls Subcontractor has the expertise to coordinate the work of other Subcontractors (electrical, mechanical, general trades, etc.) and to make a completely coordinated Building Automation Control System (BAS) for the mechanical systems.

- .2 The BAS shall be compatible with future control Products for 10 years or more.

- .3 Ensure compliance with all applicable codes and requirements of Authorities Having Jurisdiction, including but not limited to plans examiner, building inspector, etc.

Ensure the system shall be installed by trade certified electricians regularly employed by the BAS Subcontractor. The system shall be tested and calibrated by factory certified technicians qualified for this type of work and in the regular employment of the BAS Subcontractor or its exclusive factory authorized installing contracting field office representative. The installing office shall have a minimum of five years of installation experience with the manufacturer. Ensure supervision, calibration and commissioning of the system shall be by the BAS Subcontractor.

- .4 Refer to the instructions to bidders for the bidders' meeting scheduled prior to the tender closing date to become familiar with field conditions and existing equipment.

1.2 SCOPE

- .1 Preparation of control Shop Drawings for review and approval. See Section 1.3 Submittals.
- .2 Supply and install a network of Building Automation Control System (BAS) panels and field devices.
- .3 Supply and install customized graphics software as specified.

- .4 Install, wire and label all BAS control system components.
- .5 Calibrate and commission the installed control system.
- .6 Provide maintenance manuals and as-built drawings.
- .7 Provide customized training for operations, maintenance and technical staff.
- .8 Provide complete point-to-point commissioning testing, and submit commissioning report to Commissioning Agent and Consultant prior to Commissioning Functional Testing.
- .9 Provide complete updating of existing graphical user interface to indicate all new control point and equipment locations. Graphical interface shall include floor plans with actual locations of wallfin radiators, control valves, temperature sensors, fan coil units, etc.

3.2 SUBMITTALS

- .1 Submit Shop Drawings in accordance with Section 21 05 01 and include the following:
 - Control Schematics.
 - Detailed sequence of operation for each control schematic or controlled system.
 - System Architecture indicating the proposed interconnection and location of all BAS
 - Panels, network connections and key peripheral devices (workstations, modems, printers, repeaters, etc.)
 - BAS Points List indicating the panel Identification (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). Terminal
 - Identification for all control wiring shall be shown on the shop drawings.
 - Wiring diagrams including complete power system, interlocks, control and data
 - Communications.
 - Hard copy graphical depiction of the application control programs.
 - Manufacturers' data / specification sheets for all material supplied.
- .2 Provide data for inclusion in the Operating and Maintenance Manuals in accordance with Section 21 05 01.

3.3 TRAINING

- .1 Training and technical support shall be provided to the Owner's designated representative which will cover the complete operation of the Building Control System ("BCS") and the software procedures to allow the user to add, modify or create points, Direct Digital Control ("DDC") loops or energy management programmes.
- .2 The duration of the training and technical support period shall be not less than eight (8) hours, conducted during normal working hours (i.e. 8.00 a.m. to 4.30 p.m., Monday through Friday). The instruction shall consist of both hands-on and classroom training.

3.4 MANUFACTURER CERTIFICATION

- .1 Provide manufacturer certification of the installation in accordance with Section 21 05 01

PART 2 - PRODUCTS

2.1 AUTOMATIC CONTROL VALVES AND OPERATORS

- .1 All characteristics of control valves shall be suitable for the required operation.
- .2 Straight through water valves shall be single seated with equal percentage flow characteristics.

- .3 Three-way mixing valves shall be linear for each port giving constant total flow.
- .4 All valves shall have stainless steel stems and spring loaded teflon cone packing.
- .5 Valves 50 mm (2") and smaller shall have screwed bodies. Valves 65 mm (2-1/2") and larger shall have flanged cast iron bodies.
- .6 The maximum pressure drop across any control valves shall not exceed 21 kPa (3 psi) unless specified otherwise in the Contract Documents.
- .7 Valve to have the following characteristics based on application:

Application	Valve Type (≤2")	Valve Type (2"+)	Spring Return	Control Signal
Fan Coil Unit (FCU) Cooling Coil	Globe or Characterized ball	Globe	No	Modulation
Radiator Heating Valve	Globe or Characterized ball	Globe	Yes	Modulation

2.2 THERMOWELLS

- .1 Thermowells shall be installed under section 23 05 10. Coordinate the requirements of this Section fully with section 23 05 10 and provide all required locations of thermowells for installation. The Contractor shall be responsible for all costs associated with providing thermowells due to information not being provided in advance of piping installation.

2.3 FIELD SENSORS AND CONTROL DEVICES

- .1 Each control unit shall be directly connected to point devices as specified by the input/output summary and control drawings.
- .2 Temperature Sensors
 - .1 All mixed air sensors shall be thermistor type with a 25 ft. averaging element. Accuracy of the thermistor shall be +/- 0.2°C over a range of 0 to 100°C. Sensor utilizing discreet sensor distribution over the length are not acceptable.
 - .2 All supply and return air sensors shall be thermistor type with nominal value of 10kOhm @ 25 degrees C. The sensor probe shall have a minimum length of 8". The accuracy of the sensor shall be +/- 0.2°C over a range of 0 to 100°C.

Temperature sensors utilized for wall mounting in occupied spaces will be mounted in a white plastic enclosure. The size of the enclosure will not exceed 127 mm Width x 83 mm Height x 25 mm Diameter. The sensor will have a set-point and override push button. The sensor will have a service port to connect a laptop computer. The range shall be 4 to 37°C.
 - .3 All liquid immersed sensors shall be thermistor type with nominal value of 10kOhm @ 25C. Strap-on temperature sensors are not acceptable. Each sensor shall be provided with a well suitable for the working temperature and pressure of the fluid. The accuracy of the sensor shall be +/- 0.2°C over a range of 20 to 80°C, 0 to 100°C or 50 to 150°C to suit application. Provide brass wells for copper pipe and stainless-steel wells for steel pipe.
 - .4 Outdoor air sensors shall be the thermistor type with nominal value of 10kOhm @ 25C mounted in a weatherproof enclosure. The accuracy of the sensor shall be +/- 0.2°C over a range of -40 to 60°C.
- .3 Room Multi-Sensor Hub
 - 1. The Sensor hub shall measure space temperature at the occupant location and height within the room. Alternatively, provide multiple pendant mounted temperature sensors in each room in addition

to the wall-mounted temperature sensors shown. The sensor array shall measure or sense:

- a. The average space temperature at 5' above the finished floor in an area 10' in diameter
 - b. Relative humidity in the room
 - c. Dry bulb temperature in the air surrounding the Sensor Hub
 - d. Motion in the space using passive infrared sensing
 - e. Sound levels in room
 - f. Lighting intensity
2. Based on measured and sensed conditions, the Sensor Hub will provide the following:
 - a. Aggregate value for space temperature based on analytics and fusion of multiple sensors to within +/- 0.5 C accuracy
 - b. Aggregate values for room occupancy based on analytics and fusion of multiple sensors
 - c. Light intensity in foot-candles or lux
 - d. Light color in Red, Green, Blue (RGB) values or in degrees Kelvin (color temperature)
 3. The sensor hub shall include an EnOcean or Equivalent access point in rooms as per the Drawings
 4. The audio information shall not be recorded or stored in any way.

2.4 PANELS

- .1 Control panels shall be sprinkler resistant cabinets with all steel construction. Cabinets shall have hinged door with lock. All cabinet locks shall be common keyed.
- .2 Panels shall be wall mounted and shall be located in mechanical and electrical rooms.
- .3 Locate all control components except control units within control panels.
- .4 Each enclosure housing electronic equipment shall have a standard duplex AC power receptacle located within the enclosure to provide power for test equipment.
 - .1 All wiring internal to panel shall be in conduit or other plastic raceway.
 - .2 All field wiring shall terminate at a terminal strip. Wiring from terminal strip to controller shall be numbered and colour coded.

2.5 SYSTEM ARCHITECTURE AND COMMUNICATIONS

- .1 The BCS shall consist of intelligent microprocessor based control units interconnected by local area networks.
- .2 The system shall include three types of control units:
 - .1 Network control unit.
 - .2 System control unit.
 - .3 Terminal control unit.
 - .4 Integrated Room control unit
- .3 Systems utilizing control units incorporating functionality of more than one type are acceptable provided that all capabilities and flexibility specified in the Contract Documents are maintained.
- .4 Interface with and connect all new graphics, monitoring and control functions to the existing personal computer (PC) system central supervisory workstations.
- .5 Each Network, System, and Integrated Room control unit shall communicate by BACnet ethernet and/or BACnet IP protocols via ethernet port(s)

- .6 Each Network, System, and Terminal control units shall have capability to communicate by BACnet MS/TP via a RS-485 port
- .7 Operator interface to the system shall be through the PC workstations and each network control unit. All of these locations shall provide access to the complete system.

2.6 CONTROL UNITS - GENERAL

- .1 Each control unit shall be capable of full operation either as a completely independent unit or as part of the building-wide control system. All units shall contain the necessary equipment for direct interface to the sensors and actuators connected to it. Provide the necessary quantity of control units to accomplish the requirements of this Specification.
- .2 Controllers shall be loaded to a maximum of 90%. 10% of inputs and outputs shall remain unused for future expansion.
- .3 Each control unit shall include its own microprocessor controller, power supply, input/output modules, termination modules and real time clock/calendar.
- .4 Each control unit shall be capable of direct interface to a variety of industry standard sensors and input devices.
 - .1 It shall be possible for each control unit to monitor the following types of inputs:
 - .1 Analog Inputs (AI)
 - .1 4 - 20 mA
 - .2 Thermistors
 - .3 0 - 10 VDC
 - .2 Digital Inputs (DI)
 - .2 The control unit shall directly control electronic actuators and control devices. Each control unit shall be capable of providing the following control outputs:
 - .1 Digital Output (DO),
 - .2 Analog Outputs (AO)
 - .1 0 - 10 VDC
 - .3 Each digital output shall have an associated LED mounted within the control unit enclosure to indicate whether the DO relay is in the energized or de-energized position.
- .5 Any point connected to the control unit shall be assignable to any energy management programme in a networked system.
- .6 It shall be possible to fully create, modify or remove control algorithms within a specific control unit while it is operating and performing other control functions.
- .7 The control unit shall contain all software necessary to maintain control of and monitor all points physically connected to it.
- .8 Operating System
 - .1 A real time operating system shall be provided which shall include software to operate, manage and communicate to all peripheral devices.

- .2 Upon restoration of power, the operating system software shall ensure that the control unit resumes full operation without operator intervention. The control unit shall automatically reset its clock such that the proper operation of any time dependent function will occur without manual reset. All monitored functions shall be updated.
- .3 Should a loss of power exceed battery back-up, the operating system software shall be able to restore the most current versions of all energy management control programmes, direct digital control programmes, data base parameters, and all other data and programmes stored in the RAM of each control unit by downloading from the central computer system.
- .4 The operating system shall include self diagnostic software that shall continuously monitor the operation of the control unit. A control unit that is malfunctioning shall annunciate throughout the system indicating the nature of the malfunction and the control unit affected.
- .5 Point Database
 - .1 The control unit software shall have the capability to define each point in the point database and be capable of providing on-line access to the point data base, and on-line editing of the point data base while the system is functioning.
 - .2 Each point shall have an alphanumeric acronym assigned to it by which it may be referenced for use in any software module or applications programme in the system.
 - .3 The user editing capabilities of the point database shall be totally accomplished from any operator communication device.
 - .4 The operator, without assist from the BAS Subcontractor shall be able to add, delete and modify all points within the point database.
- .6 Direct Digital Control (DDC) Software
 - .1 The control unit shall contain DDC software that can be assigned to every analog or digital output point.
 - .2 The DDC software shall have the capability to be linked to any event or energy management programmes.
 - .3 The DDC software shall contain all the control functions required to perform the specified sequence of operation, including but not limited to the following:
 - .1 Proportional, integral and derivative control.
 - .2 On-Off dead band or floating control.
 - .3 Sequencing and cascading.
 - .4 Interlocks.
 - .5 Calculations.
 - .6 Boolean algebra statements.
 - .7 Time delays.
 - .4 All DDC functions shall be written in an English language format using a BASIC type software language.
 - .5 The building operator shall have the capability of adjusting any DDC parameters while the control unit is online.
- .9 All controllers shall be capable of operation in any environment that ranges from 32°F to 122°F, with 0% to 90% Relative Humidity ("RH"). The controllers should meet industry standards UL-864 and IEEE-472, if application

requires as such as determined by the Consultant.

.10 Input/Output Support

- .1 Digital to analog and analog to digital conversion precision within the controller shall provide a minimum of 10 bits accuracy.

2.7 NETWORK CONTROL UNITS

- .1 Provide network control units in each mechanical room and as necessary to provide a complete communications system.
- .2 The Network control unit shall have a BACnet Ethernet and BACnet IP communication port for communication with Controllers and Operator Workstations at 10 Mbauds, minimum. The Ethernet port must conform to ISO 8802.3. Communication media shall be 10BaseT. Each Controller shall have diagnostic LEDs for the Ethernet communication port. Each Controller shall be addressable via "DIP SWITCH".
- .3 The Network control shall support two MS/TP (RS485) BACnet communication ports for communication with terminal control units. These networks shall operate at 76800 bauds. The network speed shall be adjustable from 9600 to 76800 bauds. Each Controller shall have diagnostic LEDs for the MS/TP (RS485) communication port.
- .4 The network control unit shall support up to 99 terminal control units.
- .5 Network control unit shall permit up to 255 points to be shared between control units.
- .6 Provide preprogrammed energy management software that requires only operator configuration for the following:
 - .1 Time of day scheduling complete with holidays.
 - .2 Duty cycling with temperature compensation.
 - .3 Start/Stop optimization.
 - .4 Electrical demand limiting.
- .7 Provide rechargeable battery backup or super capacitor to maintain program entries, clock and all stored data for minimum seventy-two (72) hours. On restoration of power, Network Control Units shall load its program from built-in flash drive, if battery/capacitor backup has failed.
- .8 The controller shall be BTL listed.
- .9 Operator/System Communication
 - .1 Each control unit shall contain all software necessary for operator/system communication. This software shall permit full operator communication including as a minimum:
 - .1 Obtaining information about the performance of the system.
 - .2 Allowing the operator to add, modify or delete point data or programs.
 - .3 Diagnosing system malfunctions.
 - .4 Execution of Report Software as defined in this Specification.
 - .5 Execution of Alarm and Monitoring Software as defined in this Specification.
 - .6 Execution of User Programming Software, Energy Management and Direct Digital Control Software as defined in this Specification.
 - .2 Provide five-level password protection:
 - .1 Level One: Data Access and Display

- .2 Level Two: Level One plus Operator Overrides
- .3 Level Three: Level Two plus Database Modification
- .4 Level Four: Level Three plus Database Generation
- .5 Level Five: Level Four plus Password Add/Modification
- .3 It shall be possible for passwords to be defined by the system manager while the system is on-line and fully operational.
- .4 All operator communication shall be by full English language commands and prompts.
- .10 Monitoring and Control
 - .1 The operator shall be able to obtain information on all the system functions including point status or value, runtimes, setpoints, energy management parameters, and database elements. All information displayed shall use full English words and numerical values in floating point notation.
 - .2 Upon selection of any command point, the operator may change the point's binary state (START/STOP/AUTO) by actuating a single dedicated function key on the keyboard. Failure of the command to execute, as detected by a proof of operation status input, shall result in an alarm condition providing that no higher priority control action is in progress superseding the manual command. All manual, program or event commands competing for control of a start/stop binary point shall be prioritized with the highest level taking control until released to the next lower command state. Provide sixteen (16) priority levels which may be displayed with their current status for each logical two (2) or three (3) state command point in the system. Setpoints for analog control points and Proportional, Integral, Derivative ("PID") loops shall be changed by selecting the point (and its setpoint entry element) and typing in its new setpoint value for manual setpoint control.
 - .3 All start/stop and status points shall accumulate runtime.
- .11 Report Software
 - .1 Provide software to produce reports in pre-defined format. All of the reports and logs specified in this Section shall be provided in a "ready to use" state. Documentation for operator use of these reports shall include specific examples of how to institute and interpret the reports.
 - .2 The functional operation of the control unit shall not be affected by report display or printing.
 - .3 All reports and logs shall include the date and time of report initiation, the name of the report, and row and column headings with all units clearly labelled.
 - .4 All reports and logs shall be attainable on a per point basis or on a user defined group of points. Groups of points shall be logically combined without regard to the hardware physical location.
 - .5 As a minimum, the following control unit report summaries shall be provided:
 - .1 All point summary.
 - .2 Group summary.
 - .3 Status summary.
 - .4 Alarm summary.
 - .5 Analog alarm limit summary.
 - .6 Locked out points summary.
 - .7 Message summary.

- .8 DC programme listing.
- .9 Historical trend report.
- .10 Totalization report.

2.8 SYSTEM CONTROL UNITS

- .1 Provide standalone system control units as required to implement the specified control functions. Provide one system control unit for each supply air system and each water system.
- .2 All input/output points associated with a physical system shall be directly connected to the system control unit. Provide control units with input/output configurations to meet specific application requirements.
- .3 System control units shall be fully user programmable via the associated network control unit.
- .4 The system control unit shall have a BACnet Ethernet and BACnet IP communication port for communication with Controllers and Operator Workstations at 10 Mbauds. The Ethernet port must conform to ISO 8802.3. Communication media shall be 10BaseT. Each Controller shall have diagnostic LEDs for the Ethernet communication port. Each Controller shall be addressable via "DIP SWITCH".
- .5 Each System control unit shall include an integral real time clock/calendar.
- .6 Provide rechargeable battery backup or super capacitor to maintain program entries, clock and all stored data for minimum seventy-two (72) hours. On restoration of power, System control units shall load its program from built-in flash drive, if battery/capacitor backup has failed.
- .7 Provide the following software capabilities for each system control unit:
 - .1 Proportional, Integral, Derivative (PID) control.
 - .2 Temperature compensated duty cycling.
 - .3 Self-diagnostics.
 - .4 Start/Stop optimization.
 - .5 Programmable logic control.
 - .6 Enthalpy control.
 - .7 Time of day scheduling.
 - .8 Power failure restart.
 - .9 User defined programming.
- .8 Provide lockable metal enclosure suitable for wall mounting or locate within control panels.
- .9 Controller shall support the use of a user friendly handheld or panel mounted interface unit. This unit will display a graphic of the system being controlled, store alarms, and have audible/visual alarm indicator. Provide display unit as noted on points listed.
- .10 The controller shall be BTL listed.

2.9 TERMINAL CONTROL UNITS

- .1 Provide standalone application specific control units for all terminal units where indicated in the Contract Documents.

- .2 Terminal control units shall include preprogrammed control sequences requiring only configuration or be fully programmable based on application. The database shall be maintained in non-volatile Flash drive memory.
- .3 Provide the following software capabilities for each terminal control unit:
 - .1 PID space temperature control.
 - .2 Self-diagnostics.
 - .3 Power failure restart.
- .4 Provide outputs for damper operator, control valves and fan control as required for each application. Where necessary, provide control relays to interface between control units and fan circuit.
- .5 Provide local communication jack at controller.
- .6 The terminal control shall support a MS/TP (RS485) communication port. These networks shall operate at 76800 bauds. The network speed shall be adjustable from 9600 to 76800 bauds. Each controller shall have diagnostic LEDs for the MS/TP (RS485) communication port.
- .7 Provide rechargeable battery backup or super capacitor to maintain program entries, clock and all stored data for minimum seventy-two (72) hours. On restoration of power, System control units shall load its program from built-in flash drive, if battery/capacitor backup has failed.
- .8 The controller shall be BTL listed.

2.10 INTEGRATED ROOM CONTROL UNITS

- .1 Provide standalone programmable control units as required to implement the specified control functions.
- .2 All input/output points associated with a physical system shall be directly connected to the programmable control unit. Provide control units with input/output configurations to meet specific application requirements.
- .3 Programmable control units shall be fully user programmable via the associated network control unit.
- .4 The controller shall be a Deutsche Institut für Normung (DIN) rail mounted, BTL listed BACnet Rev 14 or greater Advanced Application Controller.
- .5 The controller must have dual port Ethernet that allows 'daisy chained' network connectivity.
- .6 The controller shall be expandable to include the modules that are needed for the automation of the space.
- .7 Controller universal I/O shall be fully software configured and defined as either input or output, and shall support input types of 10K, 0-5V, 0-10V, or 4-20mA, and outputs of 0-10V sourcing or 1-10V sinking current modes, so as to include support for control of dimmable lighting ballasts.
- .8 Each programmable control unit shall include an integral real time clock/calendar.
- .9 Provide rechargeable battery backup or super capacitor to maintain program entries, clock and all stored data for minimum seventy-two (72) hours. On restoration of power, System control units shall load its program from built-in flash drive, if battery/capacitor backup has failed.
- .10 Provide the following software capabilities for each programmable control unit:
 - .1 PID control.
 - .2 Temperature compensated duty cycling.
 - .3 Self-diagnostics.
 - .4 Start/Stop optimization.

- .5 Programmable logic control.
- .6 Enthalpy control.
- .7 Time of day scheduling.
- .8 Power failure restart.
- .9 User defined programming.
- .11 Provide lockable metal enclosure suitable for wall mounting or locate within control panels.
- .12 Controller shall support the use of a user friendly handheld or panel mounted interface unit. This unit will display a graphic of the system being controlled, store alarms, and have audible/visual alarm indicator. Provide display unit as noted on points listed.

2.11 CENTRAL COMPUTER SYSTEM HARDWARE

- .1 Terminal unit controllers shall support the use of a user friendly handheld or panel mounted interface unit. This unit shall directly connect to the controller through the room sensor jack, or directly at the controller's communications jack. Provide one handheld display and instruct building maintenance on use.

PART 3 - EXECUTION

3.1 POWER AND CONTROL WIRING

- .1 Provide all necessary conduit, fittings and wire to provide a complete control system described in this Specification. Power and Control wiring shall be installed in EMT conduit. Plenum cable is not acceptable.
- .2 Provide power to control panels from the nearest electrical panel. 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.

3.2 IDENTIFICATION

- .1 Provide engraved lamacoid nameplate clearly indicating the service and designation for the following devices. The nameplate for any device being controlled by the Energy Management Control System ("EMCS") shall also include the EMCS point name and the designation of the control panel which serves the device.
- .1 Duct and pipe mounted sensors.
- .2 Electronic control panels.
- .3 Manual switches.
- .4 Thermostats in unfinished areas.
- .5 Control valves.
- .6 Damper operators.
- .2 All wiring shall be identified with permanent numbered wire markers cross referenced to wiring diagrams.

3.3 CONTROL UNITS

- .1 Locate control units to be accessible for service and replacement.
- .2 Provide power from nearest electrical panel. Provide all transformers necessary to power control units, actuators and other system components.
- .3 Network Control Units
- .4 Locate network control units within spaces shown on the Drawings. Confirm exact location with Consultant.
- .5 Mount units with operator interface at level convenient for viewing and operation.
- .6 Programmable Control Units
- .7 Locate programmable control units adjacent to equipment served.
- .8 Programmable control units shall not be mounted on mechanical or electrical equipment.
- .9 The Contractor shall co-ordinate with heat pump manufacturer and provide commissioning.

3.4 PROGRAMMING

- .1 Provide all programming necessary for a fully functioning system.
- .2 The control strategy for each system shall be performed by software within the control unit. Refer to the Control Drawings for the sequence of operation for each system.
- .3 Tune each temperature control loop to provide control within $\pm 1^{\circ}\text{F}$ unless otherwise indicated in the Contract Documents.
- .4 Provide time schedules for all start/stop points.
- .5 Provide high and low limit alarms on all analog input points.
- .6 Program the level of annunciation for each alarm to the requirements of the Owner
- .1 Local to specific network control unit(s).
- .2 PC Workstations.

3.5 DEMONSTRATION AND TESTING

- .1 Submit a schedule of testing for each system, sample checklist and description of tests for review by the Consultant.
- .2 Provide detailed testing of each system prior to review by the Consultant. Submit a checklist, by system, indicating that all connected points and programming have been verified as specified herein.
- .3 The BCS will not be considered substantially complete until all specified points are connected to the system and testing has been completed.
- .4 All digital input alarm points (eg. high level, low pressure, etc.) shall be tested by physically simulating an alarm condition.
- .5 Start/stop points shall be verified by physical inspection.
- .6 All temperature, humidity and pressure sensors shall be calibrated using accurate electronic testing equipment as a reference.

- .7 All control loops and programmed sequences of operation shall be verified by simulating conditions for each mode of operation.
- .8 Provide demonstration of each system to the Consultant and the Owner when testing is completed. The purpose of this demonstration is to verify that testing has been successfully completed.

3.6 OWNER'S INSTRUCTION

- .1 Provide instruction to the Owner's representatives with respect to operation and maintenance of the BCS. This is not part of training as specified below.
- .2 Explain the operation of each device including normal operating conditions, emergency procedures and maintenance requirements.
- .3 Indicate, by physical inspection, the location of all control devices within mechanical and other service rooms.
- .4 Demonstrate procedures for adjusting and calibrating thermostats, controllers and sensors. Demonstrate all manual override capabilities of the system.

3.7 POINT-TO-POINT COMMISSIONING

- .1 Provide complete point-to-point commissioning testing, and submit commissioning report to Commissioning Agent and Consultant prior to Commissioning Functional Testing.

END OF SECTION

PART 1 – GENERAL

1.1 General

- .1 The purpose of this section is to specify Division 25 responsibilities in the commissioning process for the work of Division 23.
- .2 The systems to be commissioned are listed in Section 01 91 00 subsection 1.9. The abbreviations and definitions used in Section 01 91 00 apply to this Section 23 08 00 – HVAC System Commissioning.
- .3 Commissioning shall take into account the requirements under Division 25 to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirements and coordination are detailed in Section 01 91 00. For the purposes of completing work under Division 25 shall be familiar with all parts of Section 01 91 00 and the commissioning plan issued by the CA and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.2 Responsibilities

- .1 Controls Subcontractor. The responsibilities of the Contractor and its Controls Subcontractor, during construction and acceptance phases in addition to those listed above are (all references apply to commissioned equipment only):
 - .1 Sequences of Operation Submittals. The Controls Contractor's submittals of control drawings shall include complete detailed sequences of operation for each piece of equipment, regardless of the completeness and clarity of the sequences in the specifications. They shall include:
 - .1 An overview narrative of the system (1 or 2 paragraphs) generally describing its purpose, components and function.
 - .2 All interactions and interlocks with other systems.
 - .3 Detailed delineation of control between any packaged controls and the BAS, listing what points the BAS monitors only and what BAS points are control points and are adjustable.
 - .4 Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included but will generally require additional narrative).
 - .5 Start-up sequences.
 - .6 Warm-up mode sequences.
 - .7 Normal operating mode sequences.
 - .8 Unoccupied mode sequences.
 - .9 Shutdown sequences.
 - .10 Capacity control sequences and equipment staging.
 - .11 Temperature and pressure control: setbacks, setups, resets, etc.
 - .12 Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.
 - .13 Effects of power or equipment failure with all standby component functions.
 - .14 Sequences for all alarms and emergency shut downs.
 - .15 Seasonal operational differences and recommendations.

- .16 Initial setpoints and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.
- .17 Schedules, if known.
- .18 To facilitate referencing in testing procedures, all sequences shall be written in concise statements.
- .2 Control Drawings Submittal
 - .1 The control drawings shall have a key to all abbreviations.
 - .2 The control drawings shall contain graphic schematic depictions of the systems and each component (i.e. sensors, dampers, coils, valves, etc.)
 - .3 The schematics will include the system and component layout of any equipment that the control system monitors, enables or controls, even if the equipment is primarily controlled by packaged or integral controls.
 - .4 Provide a full points list with at least the following included for each point:
 - .1 Controlled system
 - .2 Point abbreviation
 - .3 Point description
 - .4 Display unit
 - .5 Control point or setpoint (Yes / No)
 - .6 Monitoring point (Yes / No)
 - .7 Intermediate point (Yes / No)
 - .8 Calculated point (Yes / No)
 - .9 Key:
 - Point Description: DB temp, airflow, etc.
 - Control or Setpoint: Point that controls equipment and can have its setpoint changed (OSA, SAT, etc.)
 - Intermediate Point: Point whose value is used to make a calculation which then controls equipment (space temperatures that are averaged to a virtual point to control reset).
 - Monitoring Point: Point that does not control or contribute to the control of equipment, but is used for operation, maintenance, or performance verification.
 - Calculated Point: "Virtual" point generated from calculations of other point values.
- .3 As-Built Controls Package - An updated as-built version of the Controls Drawings and Sequence of Operation, which is to include all items identified above, shall be provided to the CA and included in the final controls O&M manual submittal.
- .4 Assist in TAB Work- Ensure the Controls Subcontractor shall assist in the TAB work through the following:

- .1 Meet with the TAB Subcontractor prior to beginning TAB and review the TAB plan to determine the capabilities of the control system toward completing TAB. Provide the TAB Subcontractor any needed unique instruments for setting terminal unit boxes and instruct the TAB Contractor in their use (handheld control system interface for use around the building during TAB, etc.).
- .2 For a given area, have all required prefunctional checklists, calibrations, startup and selected functional tests of the system completed and approved by the CA prior to TAB.
- .3 Provide a qualified technician with minimum 5 years of verifiable controls installation and programming experience to operate the controls to assist the TAB contractor in performing TAB, or provide sufficient training for TAB to operate the system without assistance.
- .5 Required assistance to the CA - Assist and cooperate with the CA in the following manner:
 - .1 Using a skilled technician who is familiar with the building, execute the functional testing of the all equipment specified in Section 01 91 00 under direction of the CA. Provide two-way radios during the testing.
 - .2 Execute all control system trend logs specified in Section 01 91 00.
 - .3 Written Plan – Ensure the Controls Subcontractor shall prepare a written plan indicating in a step-by-step manner, the procedures that will be followed to test, checkout and adjust the control system prior to functional performance testing, according to the process in Section 01 91 00. At minimum, the plan shall include the following for each type of equipment controlled by the automatic controls:
 - .1 System name.
 - .2 List of devices.
 - .3 Step-by-step procedures for testing each controller after installation, including:
 - .1 Process of verifying proper hardware and wiring installation.
 - .2 Process of downloading programs to local controllers and verifying that they are addressed correctly.
 - .3 Process of performing operational checks of each controlled component.
 - .4 Plan and process for calibrating valve and damper actuators and all sensors.
 - .5 A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.
 - .4 A copy of the log and field checkout sheets that will document the process. This log must include a place for initial and final read values during calibration of each point and clearly indicate when a sensor or controller has “passed” and is operating within the contract parameters.
 - .5 A description of the instrumentation required for testing.
 - .6 Indicate what tests on what systems should be completed prior to TAB using the control system for TAB work. Coordinate with the CA and TAB Subcontractor for this determination.
 - .6 Checkout Certification - Provide a signed and dated certification report to the CA and PM/GC upon completion of the checkout of each controlled device, equipment and system prior to functional testing. This report shall serve as confirmation that all system programming is complete in accordance to the Contract Documents, with the exception functional testing requirements. The checkout report shall also include complete point-to-point verification and sequence of operations verification checklists.

- .7 List and clearly identify on the as-built duct and piping drawings the locations of all static and differential pressure sensors (air, water and building pressure).

PART 2- PRODUCTS

- .1 NOT USED

PART 3- EXECUTION

3.1 Submittals

- .1 Provide submittal documentation relative to commissioning to the CA as requested by the CA. Refer to Section 01 91 00 Part 3.3 for additional Section 25 requirements.

3.2 Start-up of Equipment

- .1 Follow the start-up and initial checkout procedures listed in the Responsibilities list in this section and in Section 01 91 00, Part 3.4. Ensure the start-up responsibility under Division 21 is met has start-up responsibility and is required to complete systems and sub-systems so they are fully functional, meeting the design objectives of the Contract Documents. The commissioning procedures and functional testing do not relieve or lessen this responsibility or shift that responsibility partially to the CA or Owner.
- .2 Functional testing is intended to begin upon completion of a system. Functional testing may proceed prior to the completion of systems or sub-systems at the discretion of the CA and CM. Beginning system testing before full completion does not relieve the Contractor from fully completing the system, including all pre functional checklists as soon as possible.
- .3 Prior to the start-up of equipment under Division 21 the Contractor shall arrange to have the manufacturer of all major equipment inspect the installation to ensure their equipment has been installed in accordance with their recommendations.
- .4 The manufacturer shall submit a written report of their findings.
- .5 Upon confirmation that the equipment has been installed in accordance with the Manufacturers Recommendations the equipment may be started.
- .6 All equipment shall be started by the manufacturer's representative.

3.3 Pre-Functional Test Sheets

- .1 Pre-functional test sheets contain items to be performed under Division 25. On each checklist, a column is provided that is to be completed by the contractor assigning responsibility for that line item to a trade. Those executing the test sheets are only responsible to perform items that apply to the specific application at hand. These test sheets do not take the place of the manufacturer's recommended checkout and start-up procedures or report. Some checklist procedures may be redundant in relation to checkout procedures that will be documented on typical factory field checkout sheets. Double documenting may be required in those cases.

- .2 Refer to Section 01 91 00 for additional requirements regarding pre-functional test sheets, startup and initial checkout. Items that do not apply should be noted along with the reasons on the checklist. If this checklist is not used for documenting, one of similar rigor and clarity shall be used pending approval from the CA. Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off. "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item.

A/E= Architect/Engineer, All = Contractor including all Subcontractors, CA = Commissioning Agent, CC = Controls Subcontractor, EC = Electrical Subcontractor, PM/GC = General Contractor, MC = Mechanical Subcontractor, SC = Sheet Metal Subcontractor, TAB = Test and Balance Subcontractor.

3.4 Operations and Maintenance Manuals

- .1 Compile and prepare documentation for all equipment and systems covered in Division 25 and deliver to the GC for inclusion in the O&M manuals
- .2 The CA shall receive a copy of the O&M manuals for review.

3.5 Training of Owner Personnel

- .1 The GC shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed. Refer to Section 01 91 00 for additional details.
- .2 The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment. Refer to Section 01 91 00 for additional details.
- .3 Controls Subcontractor. The controls contractor shall have the following training responsibilities:
 - .1 Provide the CA with a training plan two weeks before the planned training according to the outline described in Section 01 91 00, Part 3.8.
 - .2 Provide designated Owner personnel with comprehensive training in the understanding of the systems and the operation and maintenance of the BAS system.
 - .3 Training shall start with classroom sessions, if necessary, followed by hands on training on the BAS, which shall illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure, etc.
 - .4 During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
 - .5 The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
 - .6 Training shall include:
 - .1 Use the printed installation, operation and maintenance instruction material included in the O&M manuals.
 - .2 Include a review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.
 - .3 Discuss relevant health and safety issues and concerns.
 - .4 Discuss warranties and guarantees.
 - .5 Cover common troubleshooting problems and solutions.

- .6 Explain information included in the O&M manuals and the location of all plans and manuals in the facility.
- .7 Discuss any peculiarities of equipment installation or operation.
- .8 Classroom sessions shall include the use of overhead projections, slides, video and audio taped material as might be appropriate.
- .7 Hands-on training shall include start-up, operation in all modes possible, including manual, shut- down and any emergency procedures and maintenance of all pieces of equipment.
- .8 Ensure the Controls Subcontractor shall fully explain and demonstrate the operation, function and overrides of any local packaged controls, not controlled by the central control system.
- .9 Training shall occur after functional testing is complete, unless approved otherwise by the Project Manager.

3.6 Deferred Testing

- .1 Refer to Section 01 91 00, Part 3.9 for requirements of deferred testing.

3.7 WRITTEN WORK PRODUCTS

- .1 Written work products under Division 25 shall consist of the start-up and initial checkout plan as described in Section 01 91 00, as well as completed start-up, initial checkout and pre-functional test sheets.

END OF SECTION