

## **PART 1 – GENERAL**

### **1.1 DEFINITIONS**

- 1.1.1 Validate: for tests and demonstrations: to witness and validate successful performance demonstration or record deficiencies; to validate after correction successful demonstration; these validations of the tests become references for the Consultant's certification.
- 1.1.2 Certify: for documents including as-built drawings: Review for accuracy and completeness or record deficiencies.
- 1.1.3 Witness: The Commissioning Authority will observe as required and record summary of test results.
- 1.1.4 BAS: Building Automation System for controls.
- 1.1.5 TAB: Testing and Balancing for system verification.
- 1.1.6 Commissioning Authority: Commissioning authority in charge of the commissioning process and recommends final acceptance.
- 1.1.7 Independent Third Party Agent: Independent agent specialized in installation and testing of the system and retained by the Contractor or Owner.

### **1.2 REFERENCES**

- 1.2.1 Section 01 91 13 - Facility Commissioning - General
- 1.2.2 NFPA 13-2003 - Installation of Sprinkler Systems
- 1.2.3 LEED Canada NC v2009 - Green Building Rating System Reference Guide
- 1.2.4 National Building Code - Latest version of National Building Code
- 1.2.5 NECB 2011 - National Energy Code of Canada for Buildings

### **1.3 DOCUMENTS**

- 1.3.1 In case of discrepancies or conflicts between documents, documents will be governed in the order specified in Division 1.

### **1.4 COMMISSIONING OBJECTIVES**

- 1.4.1 Objectives of commissioning process are:
  - 1.4.1.1 to support quality management through monitoring and checking of installation;

- 1.4.1.2 to verify system performance through functional performance testing of completed installation;
- 1.4.1.3 to move completed facility from “static completion” state to optimal “dynamic” operating state;
- 1.4.1.4 to transfer facility from Contractor to Owner in such a manner that provision of a quality facility to Owner has been assured.
- 1.4.1.5 to optimize operating and maintenance through delivery of comprehensive quality training and instruction to Owner’s operating personnel.
- 1.4.1.6 to assure provision of accurate and useful historical records, such as, as-builts drawings, test certificates, etc. to Owner. Such records provide important data for operating and maintaining systems as well as for future system testing, maintenance or renovations and to trouble shoot and repair the components of systems.
- 1.4.1.7 to extend commissioning activities into operational phase in order to verify performance levels under a range of operating conditions; such as change of seasons. This process will help to avoid unforeseen or hidden operating and maintenance expenses that may develop later on.
- 1.4.1.8 monitor operation, performance and maintenance programs; optimize system’s performance under normal operating conditions, reasonable possible operating conditions (equipment failure, partial system failure, etc.), partial occupancy, and full occupancy, under the direction and review of Commissioning Authority. This phase lasts throughout warranty period. It may, however, involve activities to ensure completion of:
  - 1.4.1.8.1 system debugging and optimization.
  - 1.4.1.8.2 completion of training and instruction for operating and maintenance personnel.
  - 1.4.1.8.3 completion of all commissioning activities on defective, seasonally-sensitive systems, for varying modes and periodic simulated emergency conditions.
- 1.4.1.9 commissioning shall be considered complete when all of the objectives of the commissioning process, as specified herein, have been achieved.

**1.5 COMMISSIONING MEETINGS, SCHEDULING, AND REPORTING**

- 1.5.1 Contractor shall include the commissioning plan in their construction schedule and shall schedule for all tests and equipment start-up in the construction schedule.
- 1.5.2 Commissioning meetings shall be scheduled as required. The meetings shall address commissioning related responsibilities as well as all specified testing, documentation,

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O&M manuals, training, and post construction requirements. The testing schedules and results of all tests shall be reviewed at the meetings.

- 1.5.3 Where construction may be completed in phases, allow for the frequency of meetings to correspond to the varying stages of construction of each phase.
- 1.5.4 The Contractor shall attend commissioning meetings at regular intervals, as called by the Commissioning Authority.
- 1.5.5 The Contractor shall schedule work to include specified Commissioning related tasks. Cooperate with the Owner's Commissioning Authority, and coordinate subtrades as required, to successfully demonstrate and verify commissioning related testing and verifications.
- 1.5.6 The Contractor shall schedule work to include specified Commissioning related testing prior to Owner's demonstration and Owner's training.
- 1.5.7 Testing forms and reports associated with the mechanical systems shall be directed to the Owner, to the Consultant, and to the Commissioning Authority.
- 1.5.8 The forms and reports to be provided shall include:
  - 1.5.8.1 shop drawings, issued and accepted;
  - 1.5.8.2 equipment testing and verification forms;
  - 1.5.8.3 reports resulting from testing and verification;
  - 1.5.8.4 testing schedule.

## 1.6 WARRANTY

- 1.6.1 Involvement of Commissioning Authority does not void any guarantees or warranties nor does it relieve Contractor of any contractual responsibilities.

## 1.7 RESPONSIBILITIES OF COMMISSIONING AUTHORITY

- 1.7.1 Responsibilities of Commissioning Authority are as follows:
  - 1.7.1.1 Design Phase:
    - 1.7.1.1.1 participate in design team meetings. Obtain Owner's requirements and Consultant's philosophy and intent and expected system performance. This will form the basics of the testing and commissioning documents.
    - 1.7.1.1.2 provide input and feedback to design team with emphasis on testing and verification, Functional Performance Testing, operation and maintenance of the proposed system and equipment.

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1.7.1.1.3 provide commissioning document to form part of the Bid documents.

### 1.7.1.2 Bid Phase:

1.7.1.2.1 review Bid documents, design Drawings and specifications.

1.7.1.2.2 review Contract Documents to ensure the documents have included all the required testing and commissioning requirements.

1.7.1.2.3 provide commissioning related comments for incorporation in Contract Documents.

1.7.1.2.4 participate in Bid review meetings to ensure Bidders are aware of testing and commissioning requirements.

### 1.7.1.3 Construction Phase:

1.7.1.3.1 review Contractor's approved shop drawing submission for commissioning related issues.

1.7.1.3.2 review Contractor's commissioning plan and schedule to ensure commissioning conforms to Contract requirements and there is ample time in the schedule to complete all commissioning activities;

1.7.1.3.3 monitor, check and inspect the installation throughout the construction stages.

1.7.1.3.4 supervise the commissioning, including scheduling.

1.7.1.3.5 issue deficiencies reports noting any issues that may have an impact on the commissioning of the equipment or system.

1.7.1.3.6 attend construction site meetings as required to discuss commissioning related items and any impact on Project schedule.

1.7.1.3.7 set-up and chair commissioning meetings.

1.7.1.3.8 witness and validate tests; note deficiencies and issue progress reports.

1.7.1.3.9 work with the project team to expeditiously resolve any problems that may arise due to site conditions.

1.7.1.3.10 prepare Systems Operation Manual.

1.7.1.3.11 coordinate with Owner, training and instructions provided by Contractors, manufacturers and Suppliers.

### 1.7.1.4 Post-Construction Phase:

- 1.7.1.4.1 prepare final report on commissioning, identifying any deficiencies that may be outstanding.
- 1.7.1.4.2 recommendation of any additional training and/or instruction of operating and maintenance personnel deemed necessary over and above that already provided.
- 1.7.1.4.3 complete system checks with Contractor:
  - 1.7.1.4.3.1 once during the first month of building operation as required.
  - 1.7.1.4.3.2 once during the third month of building operation as required.
  - 1.7.1.4.3.3 once between the fourth and tenth months in a season opposite to the first or third month visit.

## **1.8 RESPONSIBILITIES OF OWNER**

1.8.1 Responsibilities of Owner are as follows:

- 1.8.1.1 to provide operating personnel to attend training and instruction regarding specific components, equipment and systems.
- 1.8.1.2 to retain the services of independent third parties for system verification and certification as required in the document or by applicable codes.
- 1.8.1.3 to observe on-site installation, start-up and testing equipment and systems.

## **1.9 RESPONSIBILITIES OF CONSULTANT**

1.9.1 Responsibilities of Consultant are as follows:

- 1.9.1.1 review Contractor's shop drawings submission to verify general conformance with contract documents;
- 1.9.1.2 periodically observe the installation throughout the construction stages to determine that the installation generally conforms to the requirements of the contract documents and issue field observation reports;
- 1.9.1.3 review operating and maintenance manuals, balancing and test reports and as-builts for completeness;
- 1.9.1.4 witness selected tests; note deficiencies and provide field observation reports;
- 1.9.1.5 assist Commissioning Authority and Contractors with any design related issues found during the commissioning process.

## **1.10 RESPONSIBILITIES OF CONTRACTOR**

1.10.1 Responsibilities of Contractor are as follows:

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### 1.10.1.1 Construction Phase:

- 1.10.1.1.1 to manage and ensure entire installation comply with requirements of the Contract Documents;
- 1.10.1.1.2 submit shop drawings complete with Contractor's Stamp of Review;
- 1.10.1.1.3 submit working detail (interference or installation) drawings, as required;
- 1.10.1.1.4 complete data test forms provided by the Commissioning Authority;
- 1.10.1.1.5 complete University FAMIS New Equipment forms and EQU Stickers, tags, and chains placement;
- 1.10.1.1.6 submit installation method statement. This generally includes:
  - 1.10.1.1.6.1 method of equipment delivery to the installation location on site;
  - 1.10.1.1.6.2 prerequisite preparation for delivery, such as completion of the factory testing and the completion of site work to accept this equipment;
  - 1.10.1.1.6.3 installation method and sequences of installing the equipment and the associated connections to the equipment;
- 1.10.1.1.7 submit an installation schedule. This schedule shall include:
  - 1.10.1.1.7.1 time schedule of each activity, with lead and lag time allowed and indicated;
  - 1.10.1.1.7.2 shop drawings and working detail drawings submission;
  - 1.10.1.1.7.3 major equipment delivery and factory testing date
  - 1.10.1.1.7.4 coordinated installation activities and sequences in compliance with the Construction Manager's project schedule and other trade's installation schedule;
  - 1.10.1.1.7.5 schedule of commissioning activities of the systems and major equipment;
- 1.10.1.1.8 submit a commissioning schedule. This schedule shall include:
  - 1.10.1.1.8.1 time schedule for system and equipment commissioning which are in compliance with the timing and sequences of installation schedule stated above. In this schedule allow for additional time for testing and commissioning, such that re-test of the equipment can be performed in a timely manner if required without impacting the overall project schedule or cause delay to Project completion;

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- 1.10.1.1.8.2 dates for completion of required factory tests prior to equipment delivery to the site shall be indicated in the schedule;
  - 1.10.1.1.8.3 prepare and submit commissioning activities method statements for review and approval;
  - 1.10.1.1.8.4 prepare and submit commissioning activities records or report forms for review and approval;
  - 1.10.1.1.9 attend progress and commissioning meetings;
  - 1.10.1.1.10 promptly rectify or replace reported deficiencies and defects;
  - 1.10.1.1.11 where required by codes and/or specification, retain manufacturers and/or independent third parties to provide service for testing and certification of the systems and training of Owner's personnel;
  - 1.10.1.1.12 provide training and instruction to the Owner's operating personnel;
  - 1.10.1.1.13 perform commissioning activities of equipment and systems to the satisfaction of the Consultant and Commissioning Authority as stated in approved schedule and method described above. Commissioning activities will be witness by the Commissioning Authority as required. Contractor or his retained agents shall also record procedure and finding in approved test and record forms. Submit test and record forms with the signature of the tester for review and approval to the Consultant and Commissioning Authority;
  - 1.10.1.1.14 pay for and be responsible for all inspections required by codes, specification and Authorities having Jurisdiction. Obtain and submit all Certificate of Approval for such inspections and verifications;
  - 1.10.1.1.15 submit for review as-builts drawings including those for location of control devices and wiring and operating and maintenance manuals for each equipment as per the specification requirements;
  - 1.10.1.1.16 provide Operating and Maintenance Manuals for review by the Consultant and Commissioning Authority with all the commissioning activity results and reports incorporated;
  - 1.10.1.1.17 obtain, issue and assign warranties for equipment and systems to the Owner;
  - 1.10.1.1.18 provision of all necessary test equipment shall be the responsibility of the contractor. Provide recently validated calibration certificate for all equipment to be used for verification prior to functional performance testing commencement.
- 1.10.1.2 Post-Construction Phase:

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- 1.10.1.2.1 optimize operation according to occupant's needs, using the System Operation Manual developed by the Commissioning Authority, as reference points;
  - 1.10.1.2.2 complete all commissioning procedures and activities and performance verification procedures which were delayed or not concluded during the commissioning phase;
  - 1.10.1.2.3 complete system checks:
    - 1.10.1.2.3.1 once during the first month of building operation;
    - 1.10.1.2.3.2 once during the third month of building operation;
    - 1.10.1.2.3.3 once between the fourth and tenth months in a season opposite to the first or third month visit;
  - 1.10.1.2.4 complete rectification of all deficiencies revealed by these checks. Equipment manufacturers involved in commissioning shall participate in systems checks.
  - 1.10.1.2.5 revise all "as-built" and operating and maintenance documents to reflect all changes, modifications, revisions and adjustment upon completion of commissioning;
  - 1.10.1.2.6 schedule a question and answer session for the operating and maintenance personnel 3 months after handover of the facility to the Owner. The duration of this session or sessions will be dictated by the number of questions or concerns that shall be addressed.

## **1.11 COMMISSIONING INVOLVEMENT**

- 1.11.1 Commissioning Authority shall direct, witness and validate as required; and Contractor and/or his Suppliers or retained Independent Third Party Agents shall perform the following:
  - 1.11.1.1 check and ensure installation of systems and equipment to ensure installations are completed and in a proper and safe state ready for functional performance testing;
  - 1.11.1.2 Start-up: run the systems and equipment to verify their operation, direction, and installation prior to testing and verification;
  - 1.11.1.3 Testing/Verification: run and test the systems and equipment through their design parameters to verify their capabilities in performance, sequencing, safety protection and alarms annunciation;
  - 1.11.1.4 Testing/Verification: run and test the systems and equipment through actual or simulated normal and reasonable possible situations to verify their capabilities in performance, sequencing, safety protection and alarms annunciation;



1.11.1.5 ensure deficiencies and defects found are rectified and replaced and the systems and equipment re-tested as required;

1.11.1.6 arrange and provide demonstration and training of Owners' personnel;

1.11.1.7 issue Operating and Maintenance Manuals for systems and equipment;

## **1.12 SYSTEMS TO BE COMMISSIONED**

1.12.1 Mechanical systems shall include but not limited to following:

1.12.1.1 Plumbing and drainage;

1.12.1.2 Domestic hot and cold water systems;

1.12.1.3 Hydronic heating;

1.12.1.4 chemical treatment of systems;

1.12.1.5 distribution systems, circulators, variable speed drives;

1.12.1.6 chilled water systems;

1.12.1.7 compressed air, and nitrogen system;

1.12.1.8 air distribution and exhaust systems;

1.12.1.9 heating, ventilation, and air conditioning (HVAC) systems;

1.12.1.10 testing, adjusting and balancing;

1.12.1.11 steam and condensate systems,

1.12.1.12 building automation system (controls);

1.12.1.13 Integrated systems controls;

1.12.1.14 fire protection systems and sprinkler system.

## **1.13 TESTING EQUIPMENT**

1.13.1 Contractor and manufacturer shall provide all instrumentation and test equipment necessary to conduct the tests specified during the commissioning process. Contractor shall submit a list of equipment to be used and copies of latest equipment calibration certificates to the Commissioning Authority and Consultant for approval.

1.13.2 Mechanical Testing Equipment:

1.13.2.1 Following equipment shall be provided but not limited to:

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- 1.13.2.1.1 pressure measurements: manometers, pressure gauges, digital pressure readers, pressure trending devices;
  - 1.13.2.1.2 temperature measurements: thermometers, digital thermometers, thermocouples, temperature trending devices;
  - 1.13.2.1.3 velocity measurement: pitot tube, propeller or revolving vane manometer, thermo anemometers, hot wire anemometers;
  - 1.13.2.1.4 volume or mass flow measurement: ultrasonic flow meter, venturi, nozzle and orifice flowmeter, positive displacement meter;
  - 1.13.2.1.5 rotative speed: tachometer;
  - 1.13.2.1.6 combustion analysis: flue gas analysis;
  - 1.13.2.1.7 sound measurement: electronic sound level meter for acoustic measurement with octave band analysis;
  - 1.13.2.1.8 vibration measurement: accelerometer;
  - 1.13.2.1.9 recording: chart recorder;
  - 1.13.2.1.10 electrical measurements: voltmeter, ammeter and wattmeter;
  - 1.13.2.1.11 Any other equipment specified by the manufacturer to perform required testing and verification.

#### **1.14 EXTENT OF FUNCTIONAL PERFORMANCE TESTING**

1.14.1 Functional Performance Testing sampling rates include but not limited to the following:

- 1.14.1.1 Major Systems - 100% sample rate:
  - 1.14.1.1.1 Chillers / Heat Pumps systems
  - 1.14.1.1.2 Boilers systems
  - 1.14.1.1.3 Air Handling Units systems
  - 1.14.1.1.4 Heat Exchangers systems
  - 1.14.1.1.5 Pumps
  - 1.14.1.1.6 Domestic Hot Water Tanks
  - 1.14.1.1.7 Compressed air systems
  - 1.14.1.1.8 Utility meters

1.14.1.2 Minor System - 25% sample rate

1.14.1.2.1 Exhaust Fans

1.14.1.2.2 Plumbing fixtures

1.14.1.2.3 Compressed air drops.

1.14.1.2.4 Energy Meters

1.14.1.3 Terminal Systems - 15% sample rate:

1.14.1.3.1 Air Terminal units

1.14.1.3.2 General space temperature sensor control

1.14.1.3.3 Terminal dampers and valves

1.14.1.3.4 Plumbing devices

1.14.1.4 Balancing of System - 10% sampling rates

**1.15 DOCUMENTATION**

1.15.1 Contractor shall record test results and procedures on approved record forms and submit the forms together with copies of test certificates to Consultant and Commissioning Authority for review and approval.

1.15.2 When results are validated, Commissioning Authority shall incorporate those records in his System Operation Manual. He shall also make entry of those test results into appropriate sections of the Operation and Maintenance Manual as reference for future system/equipment performance tests.

**1.16 COMMISSIONING PROCESS**

1.16.1 Commissioning Authority: to perform and complete all work as specified in the "GENERAL" Section of this specification "Responsibilities of Commissioning Authority".

1.16.2 Contractors: To perform and complete all works as specified in the "GENERAL" Section of this specification "Responsibilities of Contractor". In general, it shall include complete activation of all systems; calibration, test, and verification of performance of all components, equipment and systems; verification of performance of all systems through all specified modes of control and sequence of operation along with simulated reasonable operational situations; rectification of deficiencies; recording of test results for submission; demonstration, instruction and training of Owner's operating and maintenance personnel; follow-up during first year of operation for fine tuning and building service monitoring.

1.16.3 Equipment verification: Contractor shall complete the equipment verification forms for each piece of equipment. Forms shall be submitted to the Commissioning Authority for

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inclusion in the final commissioning report. Equipment data shall include, but is not limited to:

- 1.16.3.1 manufacturer's name, address and telephone number;
  - 1.16.3.2 distributors' name, address and telephone number;
  - 1.16.3.3 make, model number and serial number;
  - 1.16.3.4 pumps – type, RPM, impeller sizes, rated flow;
  - 1.16.3.5 fans – belt type and size, sheave type and size;
  - 1.16.3.6 electrical – volts, amps, fuse size, overload size;
  - 1.16.3.7 equipment enclosure type;
  - 1.16.3.8 switchboard, panel board – volt, rated current, number of phase and fault rating;
  - 1.16.3.9 any other special characteristics.
- 1.16.4 Pre-requisites to Functional Performance Testing (FPT) for a System/Assembly in order of required completion:
- 1.16.4.1 Prefunctional / FAMIS forms, EQU stickers, tags, and chains are complete;
  - 1.16.4.2 Static Installation Completed
  - 1.16.4.3 Mechanical Contractor Testing and Verification
  - 1.16.4.4 Testing Adjusting and Balancing of Air and Water
  - 1.16.4.5 Controls Point to Point Complete
  - 1.16.4.6 Controls Sequence of operation complete
  - 1.16.4.7 Controls Testing and Verification
  - 1.16.4.8 Controls Graphics complete
  - 1.16.4.9 BMS Integration (BacNet etc) complete
  - 1.16.4.10 Mechanical Inspection Deficiencies complete
  - 1.16.4.11 The contractor is to perform a dry run of the Functional Performance Testing prior to the start of FPT by the Commissioning Authority.
- 1.16.5 Functional Performance Testing by the Commissioning Authority:

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- 1.16.5.1 It is expected that once the contractor has performed a dry run of the Functional Performance Test (FPT) and is satisfied that the system is working properly; the contractor will invite the Commissioning Authority to the Functional Performance Testing.
  - 1.16.5.2 During the Functional Performance Testing; minor issues (that can be resolved in 15 – 30 minutes) will be tolerated to an extent depending on the importance/severity of the issue. Once two minor issues have been encountered; testing may be suspended (and re-scheduled) at the Commissioning Authority's discretion.
  - 1.16.5.3 If the first Functional Performance Test fails, the Owner will pay for a second test. If the test fails thereafter, the cost of re-testing(s) will be the contractor's.
  - 1.16.5.4 Any System/Assembly that is microprocessor based, and includes any customized programming/software is required to pass functional performance testing without any failure. Partial functional performance testing is not acceptable. Should any aspect of the functional performance test fail, defects shall be corrected and the entire test shall be repeated.

#### **1.17 TESTING FOR MECHANICAL SYSTEMS**

1.17.1 The following is a list of tests to be performed, but not limited to:

1.17.1.1 Plumbing and Drainage System Testing:

- 1.17.1.1.1 Plumbing and drainage system shall be tested in accordance with the National Building Code of Canada and Municipal Regulations.
- 1.17.1.1.2 Contractor shall notify Building Inspector when systems are available for testing. Contractor shall document all tests performed and shall arrange for Building Inspector to sign for tests completed. Forward forms to Consultant and Commissioning Authority for review.
- 1.17.1.1.3 When the plumbing system has been completed take a sample of the drinking water, in the presence of the Consultant. Forward the sample to a testing laboratory which shall be approved by the Consultant. Forward the test results to the Consultant and Commissioning Authority. Include for all cost of water analysis.
- 1.17.1.1.4 Also perform hydrostatic pressure test and system flush and disinfection for domestic hot and cold water systems as per the specification.

1.17.1.2 Water Treatment Systems:

- 1.17.1.2.1 Contractor shall employ a Chemical Treatment Specialist who shall assist the Contractor with selection of the chemical treatment system, inspect the installation and test the system. Specialist shall complete manufacturers' testing forms and submit a report to the Consultant.

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- 1.17.1.2.2 Specialist shall assist Contractor to clean all piping systems. Specialist shall take samples and repeat the cleaning process if specification requirements are not met.
- 1.17.1.2.3 Specialist shall assist Contractor and add chemical immediately after the cleaning process for each system for protection. The specialist shall take samples and repeat the process until specification requirements are met.
- 1.17.1.3 Fire Protection System and Smoke Control and Evacuation System:
- 1.17.1.3.1 Contractor shall hydrostatically test the systems as per the specifications and NFPA requirements to meet all certifications. The test shall be witnessed. Provide a copy of the report in NFPA 13 reporting format for all such test to the Commissioning Authority.
- 1.17.1.3.2 Contractor to perform flow, alarm, drain flow and supervision as required.
- 1.17.1.3.3 Coordinate interfacing with fire alarm control panel installation specified under Division 28. Perform test include smoke control and evacuation as required by this specification, National Building Code and its Supplementary Guidelines and Authorities having Jurisdiction.
- 1.17.1.3.4 Obtain approval certificates from Authorities having Jurisdiction and submit copies of the certificates to the Commissioning Authority for review.
- 1.17.1.3.5 Upon receiving the required documentation, provide resources to conduct testing as outlined in specification Section 01 91 13 subsection 1.19 Integrated Systems Testing.
- 1.17.1.4 Contractor's testing of piping systems (applicable to hydronic circulation, domestic hot and cold water, steam and condensate)
- 1.17.1.4.1 Test all piping systems in accordance with all applicable Plumbing Codes and CSA B139.
- 1.17.1.4.2 All other systems not covered by Codes noted above shall be tested and proven tight over a period of 24 hours by a hydrostatic test. Remove fixtures, appliances, devices, vents and gauges and temporarily plug connections as required. Provide temporary by-pass when required. Protect equipment not capable of withstanding test pressure during testing.
- 1.17.1.4.3 Test pressure for steam and water systems (chilled water, heating, domestic cold and hot water) shall be:
- 1.17.1.4.3.1 1-1/2 times the system working pressure but not less than 100 psig for a minimum of 4 hours;
- 1.17.1.4.3.2 test pressure shall be limited to the maximum working pressure of expansion joints and vibration isolators.

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- 1.17.1.4.4 Repair any leaks or defects and repeat the tests to the satisfaction of the Consultant.
  - 1.17.1.4.5 After completion of the testing, rough balance the water systems and ensure all coils, converters, etc., are operating approximately to the design conditions to ensure freezing conditions will not occur anywhere. Adjust the circuits by means of the balancing valves.
  - 1.17.1.4.6 Where multiple branch, domestic hot recirculation or drinking fountain chilled water lines are installed, the flow in these shall be balanced to ensure hot or chilled water, as applicable, at all fixtures.
  - 1.17.1.4.7 All tests for the systems shall be witnessed. Complete the testing forms and forward copies of the tests reports to the Consultant and Commissioning Authority.
  - 1.17.1.4.8 Coordinate with TAB Contractor to ensure all necessary valves required for balancing the system are installed.
  - 1.17.1.4.9 Notify Consultant and Commissioning Authority in writing that this coordination has taken place before installation begins. If Contractor fails to coordinate with TAB Contractor and if failure to co-ordinate results in being unable to balance the systems, the cost of any changes required shall be paid for by Contractor at no cost to Owner.
  - 1.17.1.4.10 Ensure all cooling coil drain pans drain freely and that no standing water remains.
  - 1.17.1.4.11 Ensure access is provided to all valves and equipment that requires servicing.
  - 1.17.1.4.12 Contractor is responsible for all equipment operating to design conditions and shall trim impellers, etc., to provide the required conditions, but is not responsible for the final balancing of the system, which shall be carried out by TAB Contractor. Final verification of balancing to be coordinated by the TAB Contractor and witnessed/verified by the Commissioning Authority.
  - 1.17.1.4.13 Contractor shall make available staff at no extra cost to Owner, as required by TAB Contractor, to correct any deficiencies in the mechanical systems which prevent TAB Contractor from balancing the system.
  - 1.17.1.4.14 Contractor shall provide copies of all shop drawings requested by TAB Contractor.
  - 1.17.1.5 The Independent Testing, Adjusting, and Balancing Contractor's balancing of water and glycol hydronic systems:
    - 1.17.1.5.1 Contractor shall co-ordinate with TAB Contractor and provide assistance during balancing process.

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- 1.17.1.5.2 Balancing shall not begin until all point to point and BAS component testing has been satisfactorily completed.
  - 1.17.1.5.3 TAB Contractor shall balance the entire water system to ensure all equipment and systems are operating to design conditions. Adjust the circuits by means of the balancing valves and record the balance positions.
  - 1.17.1.5.4 Each pump shall be checked for design, working and shut-off head conditions. Any pump that varies by more than 10% from the design conditions shall have the impeller trimmed or pump changed until design conditions have been met. Contractor shall pay for impeller trimming.
  - 1.17.1.5.5 Flow through all heat exchangers and other such equipment shall be balanced to ensure that the pressure drop through the equipment is within 10% of manufacturer's design conditions.
  - 1.17.1.5.6 Initial balancing of coils shall be used to ensure that the pressure drops are within 10% of manufacturers' design conditions. When both the air and water systems are fully operational, entering air and water, and leaving air and water readings shall be taken as close as possible to the peak design conditions to ensure the coil performance meets the design conditions. Coil water working conditions shall only be taken in conjunction with the air flow working conditions for the coil.
  - 1.17.1.5.7 Adjust bleed-off from evaporative condensers, spray coils and similar equipment to prevent lime deposits. Record bleed-off rate.
  - 1.17.1.5.8 TAB Contractor shall co-ordinate with Contractor to ensure all necessary devices and valves for control and balancing are installed in all necessary locations. Notify Consultant and Commissioning Authority in writing that this co-ordination has taken place. Include in this letter any recommendations made regarding valves, locations, installation, etc. If TAB Contractor fails to coordinate with Contractor and if failure to co-ordinate results in being unable to balance the systems, the cost of any changes required shall be paid for by TAB Contractor at no cost to Owner.
  - 1.17.1.5.9 TAB Contractor shall not disconnect any direct digital control (DDC) device after it has been calibrated. BAS Contractor shall make all necessary adjustments through the control system as requested by TAB Contractor. If TAB Contractor fails to co-ordinate with BAS Contractor and if failure to co-ordinate results in any cost, the cost of any change required shall be paid for by TAB Contractor at no cost to Owner.
  - 1.17.1.5.10 TAB Contractor shall coordinate with the BAS Contractor and receive instruction regarding set-up, calibration and operation of the DDC as it applies to the TAB Contractor work. The BAS Contractor shall provide the TAB Contractor with a portable operator's terminal for this work.



- 1.17.1.5.11 TAB Contractor is responsible for balancing the systems to obtain the design conditions and shall repeat the balancing until the required conditions have been met.
  - 1.17.1.5.12 At time of final inspection, recheck, in presence of Consultant and Commissioning Authority, random selections of data recorded in the certified report. Points or areas of recheck shall be selected by Consultant/Commissioning Authority and shall be up to a maximum of 50% of the report data.
  - 1.17.1.5.13 A measured deviation of more than 10% between the verification reading and the reported data will be considered as failing the verification procedure.
  - 1.17.1.5.14 A failure of more than 10% of the selected verification readings will be considered unacceptable and will result in rejection of the report.
  - 1.17.1.5.15 In the event the report is rejected, rebalance all systems, submit new certified reports and perform a re-inspection, all at no additional cost to Owner.
  - 1.17.1.5.16 Following final acceptance of the certified reports by Consultant, permanently mark the settings of all valves and other adjustable devices so that balance set position can be restored if distributed at any time. For circuit balancing valves, record the valve position by the number of turns registered on the valve and lock the valve into that position. Do not mark such devices until after final acceptance.
  - 1.17.1.5.17 Submit 1 Hard copy in a binder and 1 PDF on a USB drive of the final testing and balancing reports to Consultant. Reports shall be complete with index pages and index tabs and certified by TAB Contractor. Any diagram or single line representation of a mechanical system specifically prepared for this project shall be prepared using a CAD system and shall be acceptable to Consultant.
  - 1.17.1.5.18 Submit a copy of the consultant's reviewed report to Commissioning Authority for further review.
  - 1.17.1.5.19 Include in the water balancing report: Types, serial numbers, dates, and calibration of all instruments used in balancing report.
- 1.17.1.6 Contractor's Testing of Air Distribution Systems:
- 1.17.1.6.1 Contractor shall test for air leakage in accordance with SMACNA Manuals and Standards, all ductwork with the exception of ductwork downstream of variable air volume boxes or other pressure reducing devices. Seal ducts at all equipment connections and pressurize with a smaller blower. Test methods and results shall be in compliance with HVAC air duct leakage test manuals of SMACNA. In addition, seal any leaks. Test system as a whole or in parts, provided all ductwork is accessible for inspection at the time of test. Provide blower, calibrated orifice tube and all test equipment. (The inlet opening of the test blower shall be blocked off before the test blower is

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started. The inlet opening shall then be opened slowly to prevent over-pressurizing the system). Refer to the specifications for the criteria for leakage evaluation and for the definition of acceptable test results.

- 1.17.1.6.2 Refer to specification Section related to Ductwork and Specialties for pressure ratings and testing requirements of ductwork and systems.
- 1.17.1.6.3 Entire system shall be tested for noise, tightness of joints and proper functioning of the system. Noise tests shall be made under minimum system pressure drop conditions (highest air velocities and clean filter conditions). This section shall make all necessary alterations and repeat the tests until satisfactory operation is achieved.
- 1.17.1.6.4 All tests shall be performed in presence of Consultant. Complete the testing forms and forward to Consultant and Commissioning Authority.
- 1.17.1.6.5 Adjust minimum outside air controller and adjust return air and exhaust air damper linkages to approximately design air quantities, for both maximum and minimum conditions where required, to ensure freezing conditions will not occur.
- 1.17.1.6.6 Coordinate with TAB Contractor to ensure all necessary manual dampers and splitter dampers for balancing the system are installed. Notify Consultant in writing that this co-ordination has taken place before installation begins. If this Contractor fails to coordinate with TAB Contractor and if failure to co-ordinate results in being unable to balance the systems, the cost of any changes required shall be paid for by Contractor at no cost to Owner.
- 1.17.1.6.7 The testing equipment shall be itemized in the test reports and shall be approved by the Consultant before any tests are undertaken. Calibration of the test equipment must be submitted, confirmed, and approved by the Consultant before any tests are undertaken.
- 1.17.1.6.8 Ensure access is provided to all fire dampers and equipment that require servicing. Fire damper operation to be verified by the Commissioning Authority with, and coordinated by, the Contractor.
- 1.17.1.6.9 Contractor is responsible for all equipment operating to design conditions and shall change fan sheaves, etc., to provide the required conditions, but is not responsible for the final balancing of the system.
- 1.17.1.6.10 Contractor shall make available staff, as required by TAB Contractor, to correct any deficiencies in mechanical systems which prevent TAB Contractor from balancing system.
- 1.17.1.6.11 Contractor shall provide copies of all shop drawings requested by TAB Contractor.

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1.17.1.6.12 Contractor shall provide access ports for balancing as requested by TAB Contractor.

1.17.1.7 The Independent Testing and Balancing Contractor's balancing of air systems:

1.17.1.7.1 Contractor shall co-ordinate with TAB Contractor and provide assistance during the balancing process.

1.17.1.7.2 Balancing shall not begin until all point to point and BAS component testing has been satisfactorily completed.

1.17.1.7.3 TAB Contractor shall balance the entire air systems including air volumes and control settings under maximum system pressure drop conditions (filter at replacement condition).

1.17.1.7.4 TAB Contractor shall take air measurements, make final adjustments and report upon the air volume at each variable volume box, diffuser, register and grille. Measure the static pressure upstream and downstream of the fan, the fan speed and the motor current.

1.17.1.7.5 Measure the return and supply air flow when mixing dampers are set for full outside air and minimum outside air position.

1.17.1.7.6 Set the minimum position for the mixing dampers. Coordinate with BAS Contractor.

1.17.1.7.7 Contractor shall provide new filters, when the final balancing has been completed.

1.17.1.7.8 Air volumes measured by TAB Contractor shall be within +5% of those shown on Drawings for diffusers, grilles, registers, variable air volume boxes and fans, at both maximum and minimum volumes shown.

1.17.1.7.9 Duct traverse readings shall be taken through access ports. The access ports shall be Duro Dyne IP-1 or IP-2 air tight type. Duct tape is not acceptable.

1.17.1.7.10 The insulation or vapour barrier shall be repaired in an approved manner, if damaged.

1.17.1.7.11 For variable air volume boxes, TAB Contractor shall verify the minimum and maximum air volumes after the VAV boxes are commissioned by the BAS Contractor.

1.17.1.7.12 In all cases where measurements by TAB Contractor show failure to comply with the drawings and specifications, Contractor at no cost to Owner shall change fan sheaves, etc., as required, and new balancing measurements shall be taken, and a report issued, by TAB Contractor.

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- 1.17.1.7.13 Ensure all thermostats and controls are set to give the specified conditions and include settings in the report.
- 1.17.1.7.14 Adjust each supply outlet to provide proper throw and distribution in accordance with architectural requirements.
- 1.17.1.7.15 Fans on all systems shall be set-up to give the minimum discharge pressure required to overcome the resistance of the box, discharge ductwork and diffusers.
- 1.17.1.7.16 Coordinate with Contractor to ensure that all necessary manual and splitter dampers for balancing are installed in all necessary locations. Notify Consultant in writing that this co-ordination has taken place. Include in this letter any recommendations made regarding dampers, locations, installation, etc. If TAB Contractor fails to co-ordinate with Contractor and if failure to co-ordinate results in being unable to balance the systems, the cost of any changes required shall be paid for by TAB Contractor at no cost to Owner.
- 1.17.1.7.17 TAB Contractor shall not disconnect any control device after it has been calibrated. BAS Contractor shall make all necessary adjustments through Building Automation and Controls Systems as requested by TAB Contractor. If TAB Contractor fails to co-ordinate with BAS Contractor and if failure to co-ordinate results in any cost, the cost of any change required shall be paid for by TAB Contractor at no cost to Owner.
- 1.17.1.7.18 TAB Contractor shall co-ordinate with BAS Contractor and receive instruction regarding set-up, calibration and operation of the DDC as it applies to TAB Contractor work. BAS Contractor shall provide, TAB Contractor, with a portable operator's terminal for this work.
- 1.17.1.7.19 TAB Contractor is responsible for balancing the systems to obtain the design conditions and shall repeat the balancing until the required conditions have been met.
- 1.17.1.7.20 At the time of final inspection, recheck in the presence of Consultant and Commissioning Authority random selections of air quantities and fan data recorded in the certified report. Points or areas for recheck would be selected by Consultant/Commissioning Authority and shall be a maximum of up to 50% of the report data.
- 1.17.1.7.21 At the time of verification measure space temperature and relative humidity in a representative number of rooms to verify performance. Tabulate these results and include in certified report as an appendix.
- 1.17.1.7.22 A measured flow deviation of more than 10% between the verification reading and the reported data will be considered as failing the verification procedure.
- 1.17.1.7.23 A failure of more than 10% of the selected verification readings will be considered unacceptable and will result in rejection of the report.

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- 1.17.1.7.24 In the event the report is rejected, rebalance all systems, submit new certified reports and re-inspect, all at no additional cost to Owner.
- 1.17.1.7.25 Following final acceptance of the certified report by Consultant, permanently mark the settings of all dampers, splitters and other adjustable devices so balance set position can be restored if distributed at any time. Do not mark such devices until after final acceptance.
- 1.17.1.7.26 Submit one Searchable PDF copy of the final testing and balancing report to Consultant. Reports shall be complete with index pages and index tabs and certified by TAB Contractor. Any diagram or single line representation of a mechanical system specifically prepared for this project shall be prepared using a CAD system and shall be acceptable to Consultant.
- 1.17.1.7.27 Submit a copy of the report to Commissioning Authority for review.
- 1.17.1.7.28 Include in balancing report:
- 1.17.1.7.28.1 types, serial numbers and dates of calibration of all instruments used in balancing report;
  - 1.17.1.7.28.2 equipment data, manufacturer and model size, arrangement discharge and class, motor type, horse power, voltage, phase, cycles and full load amps. Location and local identification data;
  - 1.17.1.7.28.3 fan design data, total volume flow rate, static pressure, motor type, RPM, volts, full load amps and outside air flow rate;
  - 1.17.1.7.28.4 a complete system schematic with design and actual flow rates at each outlet or inlet. Show room numbers and floors. Duct air quantities: for mains, branches and maximum and minimum for outside air and exhausts, duct size, pressure readings, average velocity, duct recorded flow rates, duct design flow rates. Air inlet and outlets, supply or exhaust outlet identification. Location and number designation;
  - 1.17.1.7.28.5 Manufacturers' catalogue identification and type, of air inlets and outlets application factors, designated area, design and recorded velocities, design and recorded air flow rates, deflector vane of diffusion cone settings.
- 1.17.1.8 Testing of HVAC and Specialties Equipment and Systems:
- 1.17.1.8.1 General:
    - 1.17.1.8.1.1 Contractor shall prepare and submit for approval, Commissioning Plan and schedule which includes:
      - 1.17.1.8.1.1.1 detailed schedule for all individual testing activity. The detail shall include the steps to be taken sequentially and indicate which conditions should be observed and recorded;

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- 1.17.1.8.1.1.2 the status of systems to be able to perform tests;
  - 1.17.1.8.1.1.3 required testing equipment;
  - 1.17.1.8.1.1.4 Manufacturers' commissioning activity time for all systems and equipment;
  - 1.17.1.8.1.1.5 required time for remedial works if necessary;
  - 1.17.1.8.1.1.6 staged start-up and commissioning activities of the systems.
  - 1.17.1.8.1.2 Start-up and test procedures must be consistent with manufacturer's recommendations contained in the Operating and Maintenance Manual.
  - 1.17.1.8.1.3 The start-up report shall record all observations made during the start-up procedures including problems and their resolutions.
  - 1.17.1.8.1.4 Contractor shall retain the services of the manufacturer's technicians to test the equipment and associated systems. Technician shall record the results of the tests on the testing forms. The tests shall be witnessed by Consultant. When tests have been completed satisfactorily the technician and witnessing authority shall sign the forms. A copy of the forms shall be forwarded to the Consultant and Commissioning Authority. The original shall be inserted into the Systems Operation Manual.
  - 1.17.1.8.1.5 Should equipment or systems fail a test, the test shall be repeated after repairs or adjustments have been made. The additional tests shall be witnessed by the Consultant and the Commissioning Authority.
  - 1.17.1.8.1.6 Tests which have not been witnessed shall not be accepted and shall be repeated.
  - 1.17.1.8.1.7 Equipment and systems to be tested shall include but not limited to the following wherever applicable:
    - 1.17.1.8.1.7.1 chilled water system;
    - 1.17.1.8.1.7.2 heating system;
    - 1.17.1.8.1.7.3 air handling systems;
    - 1.17.1.8.1.7.4 humidification systems;
    - 1.17.1.8.1.7.5 Building Automation and Controls Systems;
    - 1.17.1.8.1.7.6 Steam system;
  - 1.17.1.9 Air Handling Systems:

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- 1.17.1.9.1 Air handling units shall be inspected and tested by manufacturer's technician. Technician shall enter the test results on forms provided by manufacturer. The Consultant shall witness the final operational test.
- 1.17.1.9.2 Technician shall verify that the air handling units have been installed according to manufacturer's recommendations, shop drawings and the specification.
- 1.17.1.9.3 Tests shall include verification of electrical power, electrical interlocks, safeties, control, DX compressor, condenser, heating burner and plenum/coils, fans, ductwork, dampers and fire dampers.
- 1.17.1.9.4 Technician shall start-up the air handling unit and monitor the operation for a minimum of 4 hours of running time after all tests have been completed. Technician shall revisit the site after 1 month of operation and monitor the operation of the system for a minimum period of 4 hours running time. Technician shall issue a report to Consultant after each visit.
- 1.17.1.9.5 Air handling unit manufacturer shall co-ordinate with BAS Contractor to provide the necessary interface to the Building Automation and Controls Systems. Technician shall witness the Building Automation and Controls Systems testing procedure for the air handling unit and sign the testing forms.
- 1.17.1.9.6 Contractor shall rectify any deficiencies identified by TAB Contractor.
- 1.17.1.10 Humidification System:
- 1.17.1.10.1 Humidifiers shall be inspected and tested by manufacturer's technician. Technician shall enter the test results on the forms provided by manufacturer. Consultant shall witness the final operational test.
- 1.17.1.10.2 Technician shall verify humidifiers have been installed according to manufacturer's recommendations, shop drawings and the specification.
- 1.17.1.10.3 Tests include verification of safeties and control, drains, steam piping and insulation, steam nozzles and distribution.
- 1.17.1.10.4 Technician shall start-up the humidifiers, record and monitor their operation for a minimum of 4 hours running time after the tests have been completed. Technician shall revisit the site after 1 month of operation and monitor the operation of the humidifiers for a minimum period of 4 hours running time. Reports shall be forwarded to Consultant after each visit.
- 1.17.1.10.5 Manufacturer shall co-ordinate with BAS Contractor to provide necessary interface to the Building Automation and Controls Systems. Technician shall witness the Building Automation and Controls Systems testing procedure and control of the humidifiers.
- 1.17.1.11 Chilled Water System:

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- 1.17.1.11.1 The chillers and pumps shall be inspected and tested by the Manufacturers' Technician. The Technician shall enter the test results on forms provided by manufacturer. Consultant shall witness the final operational test.
- 1.17.1.11.2 Technician shall verify chillers have been installed according to manufacturer's recommendations, shop drawings and the specification.
- 1.17.1.11.3 Tests include verification of electrical power, electrical interlocks, safeties, equipment performance and controls.
- 1.17.1.11.4 Technician shall start-up the chillers and monitor the operation for a minimum of 4 hours of running time after all tests have been completed. Technician shall revisit the site after 1 month of operation and monitor the operation of the system for a minimum period of 4 hours running time. Technician shall issue a report to Consultant after each visit.
- Chillers manufacturer shall co-ordinate with BAS Contractor to provide the necessary interface to the Building Automation and Controls Systems. Technician shall witness the Building Automation and Controls Systems testing procedure for the chillers and sign the testing forms
- 1.17.1.12 Heating Systems:
- 1.17.1.12.1 Heat exchangers, pumps and distribution piping shall be inspected and tested by manufacturer's technician. Technician shall enter the test results on forms provided by manufacturer. Consultant and Commissioning Authority shall witness the final operational test.
- 1.17.1.12.2 Technician shall verify heat exchangers and pumps have been installed according to manufacturer's recommendations, shop drawings and the specification.
- 1.17.1.12.3 Tests shall include verification of safeties and controls.
- 1.17.1.13 Building Automation and Controls Systems:
- 1.17.1.13.1 The Building Automation and Controls Systems shall be fully tested and verified by manufacturer's technician to operate in the manner defined by the specifications prior to Functional Performance Testing.
- 1.17.1.13.2 BAS Contractor shall provide a print-out of general and critical alarm lists and all points connected to the Building Automation and Controls Systems. The all point log shall be sub-divided into points per system. One report shall be taken prior to the acceptance test.
- 1.17.1.13.3 BAS Contractor shall provide an operating terminal and sufficient training and instruction to TAB Contractor which will allow them to set-up and balance the water and air systems.



- 1.17.1.13.4 A point-to-point testing shall be done by BAS Contractor. This test shall include, but is not limited to:
- 1.17.1.13.4.1 ensuring that wiring is accurately connected to appropriate terminals;
  - 1.17.1.13.4.2 checking the function of each control and controlled device (such as the beginning, end and extent of actuator travel);
  - 1.17.1.13.4.3 connection integrity between actuator and device;
  - 1.17.1.13.4.4 calibration of sensors;
  - 1.17.1.13.4.5 output from sensors;
  - 1.17.1.13.4.6 operation of relays;
  - 1.17.1.13.4.7 data/information integrity at console;
  - 1.17.1.13.4.8 remote reset integrity from console to field device;
  - 1.17.1.13.4.9 interfacing with other systems such as life safety monitoring system.
  - 1.17.1.13.4.10 BAS contractor in conjunction with the mechanical contractor shall create simulated design load conditions for control verification tests.
- 1.17.1.13.5 Testing procedure shall include but is not limited to:
- 1.17.1.13.5.1 check and verify that each input point is reporting to the Building Automation and Controls Systems panels and workstations in the normal state and change or state;
  - 1.17.1.13.5.2 create false alarms at each point and provide a print-out of the test;
  - 1.17.1.13.5.3 command each output point, via the workstation and verify the action at the device;
  - 1.17.1.13.5.4 verify that each time of day and optimum start program is operational in software and at the device;
  - 1.17.1.13.5.5 verify that each program is operational in software and at the device(s);
  - 1.17.1.13.5.6 verify that each system graphic is dynamically updating;
  - 1.17.1.13.5.7 test each DDC loop and verify that it is controlling in a stable manner. Create set point changes on output points. False loads shall be introduced to observe the control loops response. Program trend logs at the Building Automation and Controls Systems for a minimum of 30 minutes per control loop with a sampling time of 30 seconds. Provide a print-out of the results. Tune each DDC loop prior to acceptance test.

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Check each loop again, once during the heating and once during the cooling season and re-tune where necessary;

- 1.17.1.13.5.8 verify that each report type is functional;
- 1.17.1.13.5.9 verify that each global program that controls more than 1 system is operating;
- 1.17.1.13.5.10 verify that all safeties are operating (ie. firestats);
- 1.17.1.13.5.11 verify valve and damper actuation;
- 1.17.1.13.5.12 verification of the minimum and maximum settings on VAV boxes;
- 1.17.1.13.5.13 verify the calibration of each analog input point.
- 1.17.1.13.6 Any sensor disconnected from the input terminal after completion of the performance test shall be retested.
- 1.17.1.13.7 BAS Contractor shall provide a "signed-off" copy of the results of all tests to the Consultant. Acceptance test will not begin until the tests have been reviewed and accepted. Consultant and Commissioning Authority shall witness these tests.
- 1.17.1.13.8 Provide the calibration procedure for each analog sensor. Physically check the calibration of each analog sensor type using a calibrated instrument prior to testing.
- 1.17.1.13.9 When all tests have been completed BAS Contractor shall request the acceptance test procedure shall begin. Consultant shall verify the installation is complete and all tests have been performed and have been successful. BAS Contractor shall then initiate the acceptance test.
- 1.17.1.13.10 The acceptance test period shall be 21 Days. BAS Contractor shall log into the system each morning, Monday to Friday, review the Building Automation and Controls Systems operation, trend and alarm logs identifying the root cause of all problems experienced by the system. During the first 14 Days of the acceptance test, any operational or equipment failures shall be corrected and the acceptance test shall continue from the date the failure has been corrected. During the last 7 Days of testing, no major failures of any kind will be accepted, or the last 7 Days shall be repeated.
- 1.17.1.13.11 During the acceptance test Contractor shall print out 1 "all-points" log per day. The logs shall be issued to Consultant for review.
- 1.17.1.13.12 BAS Contractor shall set up trend logs and group logs which shall be stored on hard disk for review by Consultant.

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1.17.1.13.13 System shall not be accepted or considered substantially complete until all tests are completed and approved.

1.17.1.13.14 BAS Contractor shall provide a minimum of 2 weeks notice to Consultant prior to testing date.

1.17.1.13.15 BAS Contractor shall revisit the site during the first year of operation to review the performance of the Building Automation and Controls Systems. The review shall include DDC loop tuning, sensor calibration, programs, communication, DDC panels, workstations and the operational logs. The visits shall be a minimum of 4 hours each visit. The visits shall be:

1.17.1.13.15.1 beginning of cooling season;

1.17.1.13.15.2 during the cooling season;

1.17.1.13.15.3 beginning of heating season;

1.17.1.13.15.4 during the heating season.

1.17.1.14 Steam:

1.17.1.14.1 Contractor shall have all steam devices such as steam traps, steam trap monitors, vacuum breakers, pressure reducing valve, safety relief valve, steam relief valves and steam separators, etc. installation inspected and tested by manufacturer. Manufacturers shall complete the testing forms and submit a report to Consultant.

1.17.1.14.2 Contractor shall have all steam to steam generator, heat exchanger, condensate receivers, tanks and pumps, etc. installation inspected and tested by the manufacturer. Manufacturers shall complete the testing forms and submit a report to Consultant.

## **1.18 OPERATING AND MAINTENANCE MANUAL**

1.18.1 Contractor shall prepare and submit the Operating and Maintenance Manual to Consultant and Commissioning Authority 6 weeks prior to beginning of training.

1.18.2 The O&M manual to be in searchable PDF format on CD, DVD or USB drive.

1.18.3 Each Mechanical Operations and Maintenance manual shall be organized as per section 01 78 00 Closeout Submittals.

1.18.4 Contractor shall re-submit the manual should the Consultant or Commissioning Authority find deficiencies. Training shall not begin until the manual has been accepted by the Consultant.

1.18.5 Operating procedures shall be the recommended manufacturer's operating procedures for the equipment.

- 1.18.6 Maintenance procedures shall include Scope of Work, frequency of activity, parts required and necessary documentation.
- 1.18.7 Spare parts list shall be manufacturer's recommended list for maintenance purposes.
- 1.18.8 Trouble shooting guide shall be manufacturer's recommendation for equipment.
- 1.18.9 Equipment list shall include make, model, serial number, electrical characteristics, RPM, pump impeller sizes, fan belt and sheave sizes.
- 1.18.10 Operating and Maintenance Manual shall be submitted to the Owner in searchable PDF format.
- 1.18.11 The Operating and Maintenance Manual will be used by the maintenance personnel to assist them in the daily operation of the systems.

#### **1.19 SYSTEMS OPERATION MANUAL**

- 1.19.1 Systems Operation Manual shall be prepared by Commissioning Authority using data collected by Contractor and test results.
- 1.19.2 The content and format of the SOM to be as per the university's document "Systems Operation Manual Creation Process and Expected Contents".
- 1.19.3 Commissioning Authority shall provide a copy of the Systems Operation Manual to the University.

#### **1.20 OPERATOR TRAINING AND INSTRUCTIONS**

- 1.20.1 Contractor and equipment manufacturers shall provide operator training for each mechanical system and equipment.
- 1.20.2 The training and instruction shall be provided by qualified technicians and shall be conducted in a classroom setting at the equipment or system.
- 1.20.3 Owner Training Pre-requisites:
  - 1.20.3.1 O&M manual(s) been reviewed and approved by the engineers.
  - 1.20.3.2 For the system/assembly that training will occur on:
    - 1.20.3.2.1 TAB has been 100% completed, with no remaining deficiencies
    - 1.20.3.2.2 Contractor Testing and Verification has been 100% completed, with no remaining deficiencies
    - 1.20.3.2.3 Functional Performance Testing has been 100% completed, with no remaining deficiencies, or items on the Commissioning Issues Log.

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- 1.20.3.3 Two weeks in advance of the scheduled training date, the following to be submitted to the owner for review:
- 1.20.3.3.1 An Agenda
  - 1.20.3.3.2 A Trainor's bio
  - 1.20.3.3.3 Training materials specific to the Agenda have been provided in electronic form for review and approval.
- 1.20.3.4 The owner reserves the right to reject the Trainor, or modify the agenda, if either are found to be unacceptable.
- 1.20.4 Each session shall be structured to cover:
- 1.20.4.1 the Operating and Maintenance Manual;
  - 1.20.4.2 operating procedures;
  - 1.20.4.3 maintenance procedures;
  - 1.20.4.4 trouble-shooting procedures;
  - 1.20.4.5 manufacturer's or service representative's name, address and phone number.
- 1.20.5 Contractor shall prepare a detailed training and instruction plan. This plan shall include the outline of all sessions and identification of the training presenters.
- 1.20.6 Provide course documentation for up to 6 people.
- 1.20.7 The sessions may be videotaped by the owner as required.
- 1.20.8 Training and instruction shall be provided for the following systems wherever applicable:

<b>SYSTEM</b>	<b>MINIMUM TRAINING DURATION</b>
Air Handling Units	1 hour per unit
Humidification System	2 hours
Life Safety & Fire Protection Systems	2 hours
Heating and Chilled Water Systems	2 hours
Water Treatment Systems	2 hours
Building Automation and Controls Systems	16 hours

- 1.20.9 The minimum training and instruction for the Building Automation and Controls Systems shall be 16 hours. The training shall include:

- 1.20.9.1 a two phased approach as outlined in section 25 01 12;
  - 1.20.9.2 a walk-through of the installation for all maintenance personnel to review the installation and equipment;
  - 1.20.9.3 operation of the central computer;
  - 1.20.9.4 operation of portable terminals;
  - 1.20.9.5 control sequences;
  - 1.20.9.6 report set-up and generation;
  - 1.20.9.7 managing the system;
  - 1.20.9.8 maintenance requirements.
- 1.20.10 Training and instruction requirement for the mechanical system shall include a walk-through of building by Contractor. During the walk-through the Contractor shall:
- 1.20.10.1 identify equipment;
  - 1.20.10.2 identify starters associated with equipment;
  - 1.20.10.3 identify valves and balancing dampers;
  - 1.20.10.4 identify access doors;
  - 1.20.10.5 review general maintenance of equipment;
  - 1.20.10.6 review drain points in pipework systems;
  - 1.20.10.7 identify maintenance items.
- 1.20.11 Should any deficiencies be discovered during training; the session will be re-scheduled
- 1.20.12 When each session has been completed, the Commissioning Authority shall sign to certify completion.

## **1.21 SYSTEMS DEMONSTRATION AND TURNOVER**

- 1.21.1 System demonstration and turnover to the Owner shall occur when:
- 1.21.1.1 the installation is complete;
  - 1.21.1.2 acceptance test conducted by the Consultant has been successfully completed;
  - 1.21.1.3 Commissioning Authority Functional Performance Testing (FPT) and verification has been successfully complete;

- 1.21.1.4 training and instruction has been completed;
- 1.21.1.5 Operating and Maintenance Manuals have been accepted;
- 1.21.1.6 shop drawings have been updated;
- 1.21.1.7 as-built drawings have been completed.

1.21.2 Systems demonstration shall be conducted by Contractor and manufacturers. The demonstration shall cover all operation and maintenance requirements and a physical demonstration of equipment installation and operation.

## **1.22 TESTING FORMS**

1.22.1 Contractor and manufacturers shall provide information required to complete forms listed in this Section and any other additional data sheets not included in this specification, but required for the mechanical and electrical systems of this Project. All forms to be supplied by Commissioning Authority.

1.22.2 Mechanical testing and verification forms to be completed are as follows wherever applicable, but not limited to:

- 1.22.2.1 drainage testing form;
- 1.22.2.2 equipment test form;
- 1.22.2.3 piping pressure test form;
- 1.22.2.4 chemical treatment data sheet;
- 1.22.2.5 air handling unit data sheet;
- 1.22.2.6 chiller data sheet;
- 1.22.2.7 coil data sheet;
- 1.22.2.8 controller device data sheet;
- 1.22.2.9 fan coil data sheet;
- 1.22.2.10 damper data sheet;
- 1.22.2.11 fan data sheet;
- 1.22.2.12 filter data sheet;
- 1.22.2.13 heat exchanger data sheet;
- 1.22.2.14 humidifier data sheet;

1.22.2.15 pump data sheet;

1.22.2.16 radiation data sheet;

1.22.2.17 domestic hot water tank;

1.22.2.18 condensate receiver and pump data sheet;

1.22.2.19 unit heaters - hot water data sheet;

### **1.23 EQUIPMENT AND SYSTEM WARRANTIES**

1.23.1 Equipment and system warranties shall be as defined in Division 1.

1.23.2 Contractor shall fill-out the warranty form listing the equipment and systems and the start and finishing dates for warranty.

1.23.3 Refer to Division 1 and all Mechanical and Electrical divisions of the specification for the requirements during the warranty period.

1.23.4 Contractor shall re-visit the building during the warranty period with Consultant, Commissioning Authority and Owner. During these visits the performance of the system shall be reviewed. These visits shall occur:

1.23.4.1 once during the first month of building operation;

1.23.4.2 once during the third month of building operation;

1.23.4.3 once between fourth and tenth month in a session opposite to the first- and third-month visits.

1.23.4.4 During these three visits, any outstanding seasonal testing that was not conducted during Functional Performance Testing to be conducted.

1.23.5 The Owner shall organize these visits.

1.23.6 At these meetings Owner, Consultants, and Commissioning Authority shall review the performance of the systems. If the performance is satisfactory then no further action required. If unsatisfactory then Contractor will be instructed to correct deficiencies, at his cost, to the satisfaction of Consultant.

**END OF SECTION**