



DESIGN REQUIREMENTS

COMMISSIONING

GENERAL INFORMATION

- 1.1 Columbia University is committed to commissioning major renovation and new building construction projects. This section will establish the minimum commissioning guidelines and expectations of the Commissioning Agent for work performed at the University, as well as inform the Architect/Engineer of their responsibilities with the commissioning process. Unless specifically indicated otherwise, these guidelines are not intended to restrict or replace professional judgment or to limit or supersede contractual obligations.
- 1.2 The commissioning process generally begins during Design Development and continues on through occupancy. The process is split into design-phase and construction-phase activities.
- 1.3 Commissioning focuses on the Mechanical, **Electrical and Plumbing** (MEP) aspects of a project. Architectural work is generally not commissioned, except where it interacts with MEP systems.
- 1.4 The commissioning process is performed by a commissioning team. During the design phase the commissioning team will include the University Commissioning Engineer, Commissioning Agent, University Project Manager, Architect and MEP Engineer(s) and the Construction Manager / General Contractor (if selected). The construction phase commissioning team adds the Construction Manager / General Contractor (if not included previously), Sub-Contractors and Testing and Balancing Vendors. The commissioning team and its activities are coordinated by the University Commissioning Engineer who will be the primary point of contact between the relevant parties.
- 1.5 Commissioning is a systematic process of insuring that the building systems and equipment operate and perform according to the owner's project requirements and operational needs. The commissioning process oversees, verifies and documents that the facility and its systems and equipment are planned, designed, installed, tested, operated and maintained as required to meet the owners functional intent and project contract documents. The commissioning process is not intended to replace good engineering judgment or supersede the authority of the Architect/Engineer team. The commissioning process also does not relieve the contractor of providing a finished and fully functional product.



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1.6 Applicable Codes and Standards

- a. The commissioning process is governed by ASHRAE Guideline 0-2005 – The Commissioning Process. The commissioning agent may follow other, more stringent requirements, though this will require the approval of the Project Management Team.
- b. The University has made a concerted effort to achieve LEED recognition on its projects, so the requirements set forth by the USGBC LEED Program are to be followed. All major renovation and new construction projects will require the EA Credit 3: Enhanced Commissioning.

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2.1 The following are the design phase expectations and responsibilities for each commissioning team member / group:

- a. Architect/Engineer Team:
 1. Develop and provide the Commissioning Team the Basis of Design (BoD) for the project MEP systems. Respond to any questions from the commissioning team pertaining to the BoD.
 2. Meet with the commissioning team to discuss and coordinate review of the design documents as well as the commissioning plan (to be developed by the commissioning agent).
 3. Incorporate the commissioning specifications and any commissioning specific information into the design documents and specifications. Coordinate with the commissioning agent regarding Specification Section numbers.
 4. Incorporate and respond to design review comments provided by the commissioning agent and University Facilities staff. These comments will be consolidated to avoid multiple responses from the Architect/ Engineer team.
 5. Meet with the commissioning team as required to discuss comments developed during the design review. These meetings may be incorporated with the scheduled project meetings if desired by the Architect/ Engineer or Project Management team.
 6. Develop Owner's Project Requirements (OPR) documentation.
- b. Commissioning Agent:
 1. Participate in design review meetings on an as-needed basis.

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2. Review all MEP drawings and specifications related to the building and thermal power process systems. These reviews are for checking the completeness and adherence to the original design intent (BoD).
 3. Review contract documents to assure complete coordination among the various disciplines, as well as how they relate to construction sequences, materials storage, site and building access and equipment maintenance access.
 4. Develop and maintain a Design Deficiency Report detailing issues generated through the review process from both the commissioning agent and Columbia University Operations. Consolidate comments into a single report and submit to the Architect/Engineer team for incorporation into the design / construction documents. Verify comments have been incorporated.
 5. Develop the Commissioning Plan and necessary functional performance tests, procedures and specifications that will be provided to the Architect/Engineer team for incorporation into the contract documents. The Commissioning Plan should describe the systems scheduled for commissioning, the nature of the testing to be performed, those personnel of the Commissioning Team / Contractor / Sub-Contractor(s) required to be in attendance, the documentation of these efforts that will be required (pre-functional and functional checklists) and who is responsible for this documentation.
 6. Outline test plans for each system and piece of equipment to be commissioned. Include manpower requirements for construction trades where applicable.
 7. Produce a commissioning schedule to be incorporated into the overall project schedule. Include time for both equipment and systems testing (where applicable).
 8. Review the specifications and develop a document submission list to assure that the University receives all necessary documentation from the Contractor, that clear procedures are established for the commissioning process, that any special equipment or instrumentation needed for obtaining measurements during performance testing is included and that there is a well-defined training program to assure that the University's building operation personnel receive adequate training for the proper operation of the new equipment and systems.
- c. University Commissioning Engineer:
1. Ensure that the Project Management team has the latest revision of the University Design Standards and any relevant bulletins at the onset of the project. If a Design Standard Bulletin is released during the course of Schematic or Design Document development, ensure that any changes are incorporated into the project design. If a Design Standard Bulletin is released during Construction Document development,



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- discuss with the Project Management team to determine if the change can be incorporated into the design.
 - 2. Distribute submittals to University Facilities personnel for their review and comment.
 - 3. Coordinate the activities of the Commissioning Agent and ensure that design reviews and comments are completed in a timely manner. Ensure that University Facilities comments are included in the submittal review comments.
 - 4. Ensure that the Design Deficiency Report developed by the Commissioning Agent is reviewed and responded to by the Architect/Engineer team. Track any open items on the report and ensure they are addressed by the Architect/Engineer team.
 - 5. Present any Variance Requests to the relevant University Facilities Operations groups and acquire their consent to use non-approved equipment / variances to the Design Standards.
- d. Project Management Team:
- 1. Formally transmit the University Design Standards to the Architect/Engineer team.
 - 2. Provide the required number of submittals to the University Commissioning Engineer so they can be distributed to the relevant operations personnel and commissioning agent.
 - 3. Organize meetings to discuss cost or schedule impacts of comments developed during the document review process. Work with the Architect/Engineer team and Commissioning team to resolve issues that arise during the design process.

CONSTRUCTION REQUIREMENTS

3.1 Construction Phase Commissioning

a. Bid Phase

1. Commissioning Agent

- a) The commissioning agent is to chair a post-bid award meeting with MEP and specialty trades to define what is involved in commissioning, review of the sequence and schedule of this work and an explanation of its importance to the project. Include anticipated manpower requirements and timeframes for the commissioning work.

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b. Construction Phase

1. Commissioning Agent

- a) Coordinate the commissioning and start-up work with the Contractor and engineer of record, ensure that the commissioning and start-up activities are accounted for in the master project schedule. Review and update the commissioning schedule and submit corrections to the Construction Manager / General Contractor for inclusion in the overall project schedule.
- b) Update the commissioning plan to include all equipment and systems developed during the design phase. Develop project specific plans and tests as required with input from the Construction Manager and Architect/Engineer team. Submit to the Construction Manager.
- c) Perform site visits as required to ensure construction is ongoing per the construction documents and that the commissioning schedule is on target. Document any deficiencies noted between field conditions and the construction documents during these walkthroughs.
- d) Develop and maintain a construction deficiency report which will be submitted to the engineer of record for correction. Verify corrections have been made as required.
- e) Conduct periodic commissioning team meetings. These meetings should occur at least monthly during the construction phase and weekly during the actual commissioning phase.
- f) Attend project construction meetings at times sufficient to advise the commissioning team on critical path milestone dates. Advise the Owner on any issues regarding or affecting commissioning that develop in these meetings.
- g) Review equipment documentation submitted by the Contractor during the submittal process. From this information develop detailed start-up procedures. Consolidate comments with University Operations personnel and submit to engineer of record for correction.
- h) Review the start-up plans, equipment and component test procedures with the Construction Manager and Owner to ensure all systems receive proper start-up and commissioning.
- i) Review pre-functional tests and checklists prepared by the Construction Manager.

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- j) Witness the testing of equipment (pre-functional and functional) to ensure that the equipment is properly installed and ready for functional performance testing. Provide start-up documentation to measure set-points and record positions of valves / dampers / etc.
 - k) Coordinate with the engineer of record, Project Management team, Construction Manager and sub-contractors on the implantation of the plans and keep the Owner informed of any changes to the plans that result from coordination with the Construction Manager.
 - l) Prior to equipment and system start-up, gather and review the current control sequences and interlocks and work with the Construction Manager and engineer of record until sufficient clarity has been obtained, in writing to be able to write detailed testing procedures.
 - m) Review testing, adjusting and balancing (TAB) plan once submitted. Provide comments to engineer of record. Witness the actual TAB work and verify measurements as required.
2. Architect/Engineer Team
- a) Assist Commissioning Agent and Construction Manager in the development of project specific testing requirements for equipment and systems.
 - b) Review construction deficiency report developed by Commissioning Agent and include relevant items in engineering punchlists.
 - c) Incorporate commissioning and University Operations comments to submittals.
 - d) Coordinate with commissioning team regarding start-up plans and documentation. Ensure control sequences and interlocks are developed sufficiently to ensure detailed testing procedures can be developed.
3. University Commissioning Engineer
- a) Attend project construction meetings and report operational concerns to affected University Operations departments. Work with Project Management team to seek resolution to issues raised during these meetings.
 - b) Distribute submittals to University Facilities personnel for their review and comment.
 - c) Coordinate all comments to submittals from University Operations personnel and submit to commissioning agent for inclusion in comments forwarded to engineer of record.

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- d) Perform periodic walkthroughs of the construction site. Coordinate with commissioning agent and provide comments to be included in construction deficiency report.
- e) Witness hydrostatic tests of piping and ductwork pressure tests.
- 4. Project Management Team
 - a) Provide the required number of submittals to the University Commissioning Engineer so they can be distributed to the relevant operations personnel and commissioning agent.
 - b) Organize meetings to discuss cost or schedule impacts of comments developed from the construction deficiency report. Work with the Architect/Engineer team and Commissioning team to resolve issues that arise during the construction process.
- c. Commissioning Phase
 - 1. Commissioning Agent
 - a) Plan and conduct meeting(s) to outline the scope of commissioning. This meeting should include the Construction Manager, sub-contractors, engineer of record, Project Management team and University Commissioning Engineer.
 - b) Verify all prepared checklist and protocols from the Original Equipment Manufacturers and the sub-contractors for start-up of systems. Integrate this documentation into the Commissioning Plan.
 - c) Verify with the engineer of record and the Owner that all equipment and systems have been properly installed and that all equipment and systems are working in conformance with the requirements of the design and construction documents.
 - d) Perform commissioning of each piece of equipment and its associated system.
 - e) Identify deficiencies discovered during the commissioning process and make corrective recommendations. Maintain a master deficiency and resolution log, as well as a separate testing record. Integrate log with comments from University Operations personnel. Provide to the engineer of record and Owner written progress reports and test results with recommended actions.
 - f) Review completed as-built records, including operation and maintenance manuals prepared by equipment manufacturers, fabricators or installers for inclusion in the Owner's Manual. Once these documents have been completely assembled,

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review with the Owner. Provide two complete master sets permanently bound in a manner approved by the Owner.

- g) Review all equipment warranties and advise the Owner of compliance with the specifications.
 - h) Verify the accuracy and completeness of final testing, adjusting and balancing (TAB) reports.
 - i) Observe environmental performance testing, and testing of environmental monitoring systems by others. Include other Owner-contracted tests or tests by manufacturer's personnel over which the commissioning agent may not have direct control. Document and include the results of these tests in the Commissioning Record in the O&M Manuals.
 - j) Coordinate with the Construction Manager and participate in Operations and Maintenance staff training. Include any vendors and sub-contractors necessary. Verify to Owner that this training has been satisfactorily completed.
 - k) Oversee continuing adjustment, optimization and modification of all systems to meet specified operating and regulatory requirements. Advise the Owner on a regular basis on the status of this process.
 - l) Ensure that all tools, lubricants, miscellaneous start-up consumables and attic stock are provided for the project equipment. Verify that these are stored in an acceptable manner until use.
 - m) Coordinate with engineer of record, Construction Manager, sub-contractors and all regulatory agencies to ensure all local, State and Federal requirements have been satisfied.
 - n) Provide a final commissioning report stating that all systems / sub-systems, components and major equipment meet the specifications and design intent of the project and has been installed properly. For each commissioned piece of equipment and system state that it has been installed correctly, is operating in a satisfactory manner and that University personnel have been trained on its use and maintenance. The report shall include an executive summary, list of participants and roles, brief systems description, an overview of commissioning and testing scope and a general description of testing and verification methods.
2. University Commissioning Engineer
- a) Provide Construction Manager and Project Management team copies of any deficiencies developed during the commissioning process. Track and ensure that these items are resolved.

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- b) Attend commissioning meetings and forward any issues to the appropriate University Operations personnel or departments. Ensure responses are forwarded to the Project Management team and Construction Manager.
- 3. Project Management Team
 - a) Organize meetings to discuss cost or schedule impacts of comments developed from the commissioning deficiency report. Work with the Construction Manager and Commissioning team to resolve issues that arise during the commissioning process.
- d. Off-Season Commissioning Phase
 - 1. All Parties
 - a) Four to six months after the initial commissioning of the systems has been completed, return to the site and perform commissioning of the off season equipment mode (heating if in Winter, cooling if in Summer). The commissioning process will follow the steps listed above in Section 3.1.c. - Commissioning Phase.
 - e. Post Commissioning Performance Verification
 - 1. Commissioning Agent
 - a) Two months prior to the end of the warranty period, review with the Owner and the University Operations personnel the operation of the systems and equipment and the condition of any outstanding issues related to the performance of the warranted equipment and systems. The Commissioning Agent should provide assistance to the University Operations personnel in developing reports, documents and requests for services to manufacturers to remedy outstanding warranty problems. Once deficiencies have been corrected the Commissioning Agent is to provide oversight on any final testing required and document the results in the Commissioning Record.
- 3.2 Equipment and Systems to be Commissioned
 - a. The following lists systems and equipment that are to be commissioned as part of the construction process. Not all systems or equipment will be present for each job, nor is this list meant to include all possible equipment. Where additional equipment not listed is specified or included as part of the project, it will be detailed specifically in the RFP documents to the Commissioning Agent.
 - b. The systems and equipment listed below provides a guide for design and construction review for the Commissioning Agent. The Commissioning Agent shall review each of

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these systems and pieces of equipment for accessibility and maintainability and conformance with the CU Specifications where applicable, as part of the review process.

c. List of Systems and associated equipment:

1. High and Low Pressure Steam Systems

a) Boilers

- 1) Stacks (forced or induced draft)
- 2) Burners and Controls
- 3) Accessibility and Maintainability

b) Piping

- 1) Conformance to piping guidelines
- 2) Slope and Pitch
- 3) Insulation
- 4) Expansion Loops

c) Heat Exchangers

- 1) Heat Transfer Performance
- 2) Installation and location of Meters and Gauges
- 3) Accessibility and Maintainability

d) Traps

- 1) Accessibility and Maintainability

e) Pressure Reducing Stations

- 1) Accessibility and Maintainability

2. Condensate Systems

a) Receivers & Pumps

- 1) Accessibility and Maintainability
- 2) Installation and location of Meters and Gauges

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- b) Piping
 - 1) Conformance to piping guidelines
 - 2) Slope and Pitch
 - 3) Insulation
- c) Controls
- 3. Chilled Water Systems
 - a) Chillers
 - 1) Performance – Full and Part Load
 - 2) Installation and location of Meters and Gauges
 - 3) Accessibility and Maintainability
 - b) Pumps
 - 1) Performance
 - 2) Installation and location of Meters and Gauges
 - 3) Accessibility and Maintainability
 - c) Piping
 - 1) Conformance to piping guidelines
 - 2) Slope and Pitch
 - 3) Insulation
 - d) Controls
 - e) Water Treatment
- 4. Condenser Water System
 - a) Cooling Towers
 - 1) Performance – Full and Part Load
 - 2) Installation and location of Meters and Gauges
 - 3) Accessibility and Maintainability

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- b) Pumps
 - 1) Performance
 - 2) Installation and location of Meters and Gauges
 - 3) Accessibility and Maintainability
- c) Sand Filtration
 - 1) Performance – Full and Part Load
 - 2) Installation and location of Meters and Gauges
 - 3) Accessibility and Maintainability
- d) Piping
 - 1) Conformance to piping guidelines
 - 2) Slope and Pitch
- e) Controls
- f) Water Treatment
- 5. HVAC Systems
 - a) AHUs (Packaged and Custom)
 - 1) Conformance to specifications
 - 2) Performance
 - 3) Accessibility and Maintainability
 - 4) VFD Selection (as applicable)
 - 5) Insulation / Noise Attenuation
 - 6) Piping and connections
 - 7) Integration with BMS
 - b) Fans
 - 1) Conformance to specifications
 - 2) Performance

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- 3) Accessibility and Maintainability
- 4) VFD Selection (as applicable)
- 5) Insulation / Noise Attenuation
- 6) Integration with BMS
- c) Air Terminal Units / VAV Boxes
 - 1) Conformance to specifications
 - 2) Performance
 - 3) Accessibility and Maintainability
 - 4) Insulation / Noise Attenuation
 - 5) Integration with BMS
- d) Fan Coil Units
 - 1) Conformance to specifications
 - 2) Performance
 - 3) Accessibility and Maintainability
 - 4) Insulation / Noise Attenuation
 - 5) Integration with BMS
- e) Split Air Conditioning Units
- f) Smoke Purge System
 - 1) Fire Dampers
 - 2) Fan Operation
 - 3) Integration with BMS / Fire System
- g) Free Cooling / Winter Operation
 - 1) Heat Exchanger Performance
 - 2) Pumping Capacity / VFD

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- 3) Accessibility and Maintainability
 - 4) Integration with BMS
 - h) Humidification
- 6. Plumbing Systems
 - a) Domestic Water Systems
 - 1) Domestic Water Booster Pumps
 - 2) Hot Water Booster / Circulation Pumps
 - 3) Backflow Preventers
 - b) Sewage Systems
 - 1) Sewage Ejector Pumps
- 7. Fire Protection Systems
 - a) Fire Pump
 - 1) Performance
 - 2) Installation and location of Meters and Gauges
 - 3) Accessibility and Maintainability
- 8. Electrical Systems
 - a) Main Electrical Switchgear and Distribution Panels
 - b) Building Grounding Network
 - c) Lighting and Emergency Lighting
 - d) GFCI outlets
 - e) Variable Frequency Drives
 - f) Fire Alarm
 - 1) Damper Operation
 - 2) Smoke Purge System Operation
 - 3) Equipment Coordination



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9. Emergency / Standby Power Systems
 - a) Switchgear and Distribution Panels
 - b) Automatic Transfer Switches
 - c) Generator
 - 1) Enclosure
 - 2) Fuel Oil Storage
 - 3) Fuel Oil Pump Set and Piping
 - 4) Paralleling Gear / Controller
 - 5) Exhaust Flue / Stack
10. BMS Instrumentation and Controls Systems
 - a) Hardware and Software
 - b) Point to Point
 - c) Equipment Integration and Systems Testing
 - d) Documentation / Graphics
11. Compressed Air Systems
 - a) Air Compressors
 - 1) Performance
 - 2) Installation and location of Meters and Gauges
 - 3) Accessibility and Maintainability
 - 4) Integration with BMS
 - b) Pressure Reducing Stations
 - 1) Accessibility and Maintainability
 - c) Valves and Specialties
 - 1) Performance
 - 2) Accessibility and Maintainability



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d) Air Dryers / Oil Separators

- 1) Performance
- 2) Installation and location of Meters and Gauges
- 3) Accessibility and Maintainability

12. Specialty Systems (to be detailed in RFP documents if required)

- a) Air Pollution Controls
- b) Clean Steam
- c) Co-Generation Systems
- d) Compressed Air Systems (Including Lab Bottled Gases)
- e) Heat Tracing
- f) Laboratory Hoods / Exhaust Systems
- g) Uninterruptable Power Supplies (UPS)

3.3 Minimal Functional Check and Performance Test Requirements for Selected Equipment and Systems

a. Functional Checks

Functional Checks are to be conducted on components and controls to ensure they function as intended. For example, Functional Checks will prove proper operation of dampers, economizer modes, valve operation, scheduling, etc., as commended by the building automation system. The checks also prove proper operation of safety devices, limits and interlocks. Instrumentation calibration checks shall be performed during this phase.

1. Control Systems (BMS)

- a) The control system shall be comprehensively functionally checked to verify that all control loops are stable, all modes and sequences work correctly, main programming is completed and operator interface shows correct equipment and control points. Instrumentation calibration shall be verified to insure the operator interface displays the actual device value. The Commissioning Agent shall use their own instrumentation, in the field, to do this.
- b) Upon substantial completion of the Controls System, a full point to point check shall be performed. This shall be witnessed by the Commissioning Agent.

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2. VAV Boxes

Functional checks on the terminal air boxes (SAV, VAV, EAV) shall included (at a minimum) verification of damper operation, flow meter calibration and confirmation of correct min/max airflow for each box using the Commissioning Agent firm's own in-house NIST calibrated equipment and technicians. The functional check shall also verify that proper temperature set points are maintained.

b. 72 Hour Trending of Room Temperature and Humidity

Trending of these parameters over time shall be performed to verify conditions are achieved within the design criteria ranges. Calibrated portable data loggers shall be utilized, along with the trending capabilities by the building automation system. The Commissioning Agent shall provide trending documentation that indicates space conditions were maintained during occupied and unoccupied periods.

c. Performance Tests

Performance tests shall be conducted to verify catalog capacity in field installed conditions and in field ambient conditions. These tests shall be conducted using the Commissioning Agent firm's own in-house NIST calibrated testing and measuring equipment and the firm's own trained personnel.

1. Centrifugal Chillers

Performance testing on chillers shall assure that the installed unit(s) meet the efficiency and capacity standards called out in the specifications. Each chiller shall be tested in accordance with the guidelines presented in the ARI (Air-Conditioning and Refrigeration Institute) Standard 550 - Water Chilling Packages Using the Vapor Compression Cycle. The units will be tested at design conditions (chilled and condenser water flows and inlet water temperatures). The chiller shall be tested at 100%, 75% and 50% of maximum design rating as well as minimum load. "False loading" of the chiller(s) to obtain the desired test points shall be done if weather conditions does not permit. The results of the testing should include (at a minimum):

- a) Determination of the unit's maximum load capability (tons)
- b) Efficiency (kW/ton) across its operating range
- c) Proper operation at minimum load (verify that the chiller does not surge)
- d) Proper stable control and load response
- e) Proper temperature "approaches" to ensure clean heat exchangers, proper refrigerant charge, no air in the machine, etc.)

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- f) Identification of any chiller and system deficiencies

2. Cooling Tower

Cooling Tower performance testing shall be conducted according to the guidelines presented by the CTI (Cooling Tower Institute). Performance Testing shall verify that the cooling tower maximum capacity, and proper temperature ranges are met. The data collection points shall include (at a minimum):

- a) Condenser water flow
- b) Power input to the tower fans
- c) Condenser water temperature in and out of the cooling tower
- d) Outside air temperature and humidity (several points around the cooling tower)
- e) Make up water flow and temperature

Tower performance testing will be conducted at or near a peak design day in the summer.

3. Water Circulation Pump Testing

Individual pump performance tests shall be conducted on the chilled water, condenser water and heating hot water pumps. Data shall be recorded for at least three test points per pump. Pump head shall be varied via throttling of the isolation valve on the discharge of each pump. Test points to be recorded include (at a minimum):

- a) Suction Pressure
- b) Discharge pressure
- c) Pump flow in gpm with an ultrasonic flow meter or differential pressure reading across a flow measuring device
- d) Pump / motor speed
- e) Motor amperage, voltage, power and power factor

Utilizing the test data, pump performance shall be calculated for comparison with design. Operating points will be plotted vs. the pump's design curve (flow versus head) for comparison.

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4. Heat Exchangers

The heat transfer performance of the hot water heat exchangers shall be verified through measurement of flow rates and temperatures over a fixed period of time. In addition pressure drop performance is to be verified during this testing.

5. Air Handling Units

Performance testing of the AHU's shall include the following parameters:

- a) Temperatures before and after coils to check capacity
- b) Coil temperatures at several locations in order to check for stratification
- c) Airflow traverse readings of the AHU
- d) Fan total static pressure
- e) Static pressure profile of the AHU
- f) Power readings on the fan motor
- g) Fan and motor RPM readings
- h) Water pressure drops across the heating and cooling coils

The Commissioning Agent shall provide the following analysis on the system in order to properly evaluate the air handler performance:

- a) The total heat transfer of the cooling and heating coils versus rated values
- b) The GPM/ton of cooling performed in order to evaluate heat transfer effectiveness of the system
- c) Comparison of fan performance to the fan specifications
- d) Comparison of cooling coil water and airside pressure drop readings to rated values
- e) Comparison of fan speed and power draw to rated values

6. Boiler Performance Testing

Boiler performance will be verified in accordance with ASME Power Test Code 4.1 for Boiler Performance Testing. The performance testing is to be performed over the boiler's full load range. Data recorded during the testing includes (at a minimum):

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- a) Boiler efficiency
- b) Ambient temperature
- c) Stack temperature, O₂, CO₂, CO, combustibles, excess air, NO, NO₂, NO_x and SO₂
- d) The performance test shall also verify minimum load capability to ensure proper burner turndown ratio is achieved.

3.4 Sampling Percentages for Typical Mechanical Equipment

- a. The following table lists the typical requested sampling / testing percentages for equipment.

Component	Sampling Percentage
Boilers	100%
Chillers	100%
Cooling Towers	100%
Heat Exchangers	100%
Pumps (hot water / chilled water)	100%
Air Handling Units (central station / roof top)	100%
CAV / VAV Boxes	20% - Not Less Than 10 Units *
Fan Coil Units	20% - Not Less Than 10 Units *
Unit Ventilators	20% - Not Less Than 10 Units *
Unit Heaters	20% - Not Less Than 10 Units *
Terminal Balancing Check	20% - Not Less Than 10 Units *
Exhaust Fans	20% / 100% for Life Safety related equipment (fume hoods / fume exhaust) *
Hydronic Terminal Units	20% - Not Less Than 10 Units *
Building Management System	20% of Point Addresses *
Occupancy Sensors	20% - Not Less Than 10 Units *

- * Failure of more than 5% of tested units will require 100% testing, at cost to the Contractor.

REFERENCE

- 4.1 The applicable CSI Specification Section is 23 08 00.