TABLE OF CONTENTS

IV. TRAINING

Project Commissioning Program
Executive Summary

The Commissioning Program establishes an in-depth and active participation in the architectural, mechanical and electrical portions of the project work, scrutinizing the details of the installation, start-up, and acceptance. Commissioning of the building systems engages a comprehensive examination of the many components acting and working together in concert in order to support the environmental requirements of the building's operation. This Plan has been formulated to develop and implement that process of examination and has been divided into **"Three"** segments to illustrate a level of detail for the application of specifics for that process.

Commissioning (Cx) is a quality assurance program necessitating an attitude and an approach that is fundamental and an essential element of any project process throughout its extent. Each commissioned project benefits from that element. The completion of the commissioned project and the successful execution of the commissioning procedures represent the achievement of goals not just for the owner but the accomplishment of vested interests by the design and build teams as well. The **Introduction** section of this Plan describes the roles, responsibilities, and schedule needed to attain those goals for this facility, by the project team members.

The commissioning process coordinates and organizes several parts of the quality assurance program for each of the facility's significant systems. The final and expected value of implementing such a program should be defined in the Project Commissioning Plan. The realization of successfully implementing the CX Plan is to ensure not only that the facility performs responsively, operating efficiently and effectively, but assures each of the owner's expectations for the project will be met.

The acceptance testing portion of this Plan establishes a process for achieving, verifying, and documenting that the performance of the building project and its systems meet the intent of the design as well as the owner's and occupants' project goals and objectives. This portion yields the cumulative results obtained from the continuity of reliability verified through all the phases of the design, construction, installation, and start up. The Commissioning Program for this Project includes, as a result, a formal scrutiny of evaluations, inspections and reviews intent on ensuring an extra level of confidence in the performance and quality of the facility being built, prior to its being operated and occupied.
This results in an extensive interaction of the commissioning team, especially during testing. The results of that interaction will be exchanged among the team members utilizing electronic media as a working platform. The media will represent the forms developed to register and document performance. The procedures and methodology of the commissioning verification activities supporting those forms and defining the level of reliability to be verified are illustrated in the **Testing** section of this plan.

The mechanical and electrical systems on any project represent the heart of the systems essential to continued successful facility operational performance. The building envelope and building conveyance systems are essential to the useful occupancy of the facility, itself. The **Training** section establishes the format and organization of the owner's operational education for the building systems as well as the evaluation of those systems' continued performance through a then extended period of use, following construction.

Introduction Section
The description of the work, the members of the team, their roles and responsibilities, and the procedures to interact are all laid out in this section with an accompanying schedule for the implementation of the commissioning process. (The schedule for the training is yet to be developed and will be completed as part of the Final Commissioning Plan.) This section also contains the installation Quality Control program of the General Contractor. The commissioning work in the Plan intends to measure system performance following the successful installation of each of its components. Commissioning builds on QC.

Testing Section
The entire project team contributed to this section. The procedures were derived from the specifications, national standards, and historical experience. (Some specific input from individual trades was not as yet available, but is forthcoming and will replace procedures currently included for such areas as low voltage, controls, auxiliary chillers, etc.) As a result there are a variety of formats used following the trade associations or industry standards adopted and included for the project. In some cases forms are used in which a number of blank spaces remain. These are intended to be reviewed and modified by the team members, collectively, and changed prior to the Final Plan in order to suit the specific dynamics encountered by individual systems on this project.

Training Section
The requirements of the specifications and the Scope of Commissioning Work (contained in this Plan section) set the stage for the format and organization of the training sessions for each system. From a structural context they will all be pretty much the same. That is to say, each will be planned in accordance with other interacting and inter-dependent systems to afford the greatest possible success in achieving a useful schedule for attendees. Each will be have an agenda tailored to attaining the maximum understanding possible for their audiences. And finally each will have a record of what had transpired and who was able to attend.

Following a successful conclusion of the systems verification, acceptance, and training the owner should expect to live with and operate a facility that meets its operational needs for the building systems' intended life, exercising re-commissioning only as a periodic, preventative maintenance element. The value of commissioning cannot be understated. In fact that value should simultaneously act as the objective to be attained and the measure of the success achieved.

ASHRAE prefaces its Commissioning Guideline with the following:

Due to the integration and interdependency of facility systems, a performance deficiency in one system can result in less than optimal performance by other systems. Implementing the Commissioning Process is intended to reduce the project capital cost through the first year of operation and also reduce the life-cycle cost of the facility. Using this integrated process results in a fully functional, fine-tuned facility, with complete documentation of its systems and assemblies and trained operating and maintenance personnel. **Pg. 3 ASHRAE Guideline 0-2005, ISSN 1049-894X**

We, the commissioning team, should expect to deliver no less than these achievements to the Owner for the delivery of this project.

THIS PAGE IS INTENTIONALLY LEFT BLANK

PROJECT DIRECTORY

Team Member	Co. & Contact Names	Voice, office, cell, fax, email, address
Owner (OR) Owners Rep.		
Construction Dir.		
Owner – Engineering Operations Director		
Construction Manager Senior Project Manager Project Manager		
General Contractor Project Director Project Manager MEP Manager		
Commissioning Authority QA Manager		
Architect Project Manager		
Mechanical Designer/Engineer Project Manager		
Electrical Designer/Engineer Project Manager.		
HVAC Contractor Project Manager		

PROJECT DIRECTORY

Team Member	Co. & Contact Names	Voice, office, cell, fax, email, address
Electrical Contractor Sr. Project Manager		
Electric Infrastructure Contractor		
TAB Agency Project Manager		
Controls Contractor Project Manager		
Plumbing Contractor Project Manager		
Fire Protection Contractor Project Manager		
Pneumatic Tube Contractor Project Manager		

Quality Control Plan

(To be inserted by the General Contractor)

THIS PAGE IS INTENTIONALLY LEFT BLANK

Testing and Training Schedule

(To be inserted by the General Contractor)

THIS PAGE IS INTENTIONALLY LEFT BLANK

Scope of Commissioning Work

Section 01810 General Commissioning Requirements

DESCRIPTION

A. Commissioning. Commissioning is a systematic process of ensuring that all building systems perform interactively according to the design intent and the owner's operational needs. This is achieved by beginning in the design phase and documenting design intent and continuing through construction, acceptance and the warranty period with actual verification of performance. The commissioning process shall encompass and coordinate the traditionally separate functions of system documentation, equipment startup, control system calibration, testing and balancing, performance testing and training of owners operational personnel.

Commissioning during the construction phase is intended to achieve the following specific objectives according to the Contract Documents:

1) Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and to minimum referenced standards and that they receive adequate operational checkout by installing contractors.
2) Verify and document proper performance of equipment and systems.
3) Verify that O&M documentation left on site is complete.
4) Verify that the Owner's operating personnel are adequately trained.
5) Receive and transmit to owner spare parts, materials, etc. as required by the contract documents

The commissioning process does not take away from or reduce the responsibility of the system designers or installing contractors to provide a finished and fully functioning product.

B. The Commissioning process will consist of development, review and approval of the project Commissioning Plan, defining the requirements for Construction Functional Performance Testing; development, review and approval of Construction Checklists; monitoring and documentation of equipment and system Acceptance; and finally monitoring and documentation of Functional Performance Testing.

C. The process of assuring quality and compliance for this project will take place in two ways. **Quality Control** shall implement and **monitor, verify, and accept** the work of the project during the construction **installation**, especially the equipment and the system components. The QC program will coordinate with the Commissioning of this project and dovetail the monitoring and requirements for systems and equipment identified under both programs. The **Commissioning** program will **monitor, verify, and accept** the **operation and the performance** of the equipment and systems. In particular, the operation and performance of the mechanical and electrical systems will only be available for verification and acceptance upon the successful execution of the QC program with regard to their installation. The QC Plan will become, as a result, an integral part of the commissioning plan's prerequisite requirements. It will in effect define the necessary accomplishments that must take place prior to the execution of any commissioning acceptance procedures.

D. Terminology

- Inspector of Record (IOR)
- Owner Representative (OR)
- Quality Control (QC)
- General Contractor's Quality Manager (GCQ)
- Test, Adjust, and Balance (TAB)
- Commissioning Authority (CA)
- Electrical Acceptance Test and Verification (ATV)
- General Contractor (GC)
- Construction Manager (CM)
- Architect and Engineer (A/E)
- Mechanical and Electrical Trades (Trades)
- Owner Furnished, Contractor Installed (OFCI)
- Construction (or Pre-Functional) Check List (CC)
- Functional Performance Test (FPT)
- Building Automation System (BAS)
- Facilities Design and Construction (FD&C)
- Engineering Operations (EO)
- Functional Performance Test (FPT)
- Owner Project Requirements (OPR)
- Basis of Design (BoD)

COORDINATION

A. Commissioning Team. The members of the commissioning team consist of the Commissioning Authority (CA), the Owner's Representative (OR), the General Contractor (GC and GCQ), the Architect and design Engineers (particularly the mechanical and electrical engineers), the Mechanical Contractor (MC), the Electrical Contractor (EC), the TAB representative, the Controls Contractor (CC), the ATV representative, any other installing subcontractors or suppliers of equipment. The Owner's building or plant operator/engineer is also a member of the commissioning team along with the project Inspector of Record (IOR). The commissioning team will coordinate and build the commissioning elements and expectations of the commissioning plan on the successive execution of the installation QC program required as developed by the General Contractor.

B. Management. The CA has been hired by the OR directly. The CA facilitates the commissioning activities of the GC, the Trades, the TAB, the ATV and the reports to the OR. The CA's work is subject to Owners approval. All members work together to fulfill their contracted responsibilities and meet the objectives of the Contract Documents.

1. Duties: The OR has provided a Commissioning Authority for the Project to develop, manage and implement the Commissioning program. The CA is required to conduct the Commissioning scoping meetings, attend all the Coordination and Mutual Understanding Meetings, conduct the Commissioning progress meetings, perform submittal review, ensure testing is performed and prepare the project Commissioning Plan.
2. The CA will also be assisted by and may facilitate the commissioning work of the TAB and ETV agencies.

C. Scheduling. The CA will work with the OR and GC according to established protocols to facilitate the schedule of the commissioning activities. The CA will provide sufficient notice to the OR and GC for scheduling commissioning and training activities. The GC will integrate all commissioning activities into the master schedule. All parties will address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process.

The GC has provided the initial schedule of primary commissioning events at the initial commissioning scoping meetings. The *Commissioning Plan*, developed by the CA shall provide a format for testing and will include this schedule. As construction progresses additional schedule revisions may be developed by the GC and facilitated by the CA.

QUALITY CONTROL PROCESS

A. QC Program

- The QC program consists of a QC Organization, a QC Plan, conducting QC meetings, performing three phases of control, performing submittal review, ensuring testing is performed, and preparing QC certifications and documentation necessary to provide materials, equipment, workmanship, fabrication, construction and operations which comply with the requirements of this Contract. In addition this scope consists of the coordination of the QC program with the Commissioning program.

B. Definitions

- Quality Assurance: The procedures for guarding against defects and deficiencies before and during the execution of the Work. Includes submittals, certifications, and other actions to assure that the proposed products and services will meet the Contract requirements.
- Quality Control: The procedures for evaluating completed activities and elements of the Work for conformance with Contract requirements. Includes testing and inspection.

C. Quality Assurance/Control on Installation

- Monitoring - Monitor quality control over suppliers, manufacturers, products, services, site conditions and workmanship to produce work of the specified quality.
- Compliance - Comply fully with manufacturers' instructions including each step in sequence and comply fully with the contract documents inclusive of the entirety of the design intent.
- Conflicts - Should manufacturers' instructions conflict with the Contract Documents, request clarification from Owner's Representative before proceeding.
- Standards:
    1. Comply with specified standards as a minimum quality for the Work except when more stringent tolerances, code, or specified requirements indicate higher standards or more precise workmanship.
    2. Perform Work by persons qualified to produce workmanship of specified quality.
- Anchorage: Secure products in place with positive anchorage devices designed and sized to withstand stresses, vibration, physical distortion and disfigurement.
- Coordination of all above ceiling work is mandatory prior to any installation. Documentation of such coordination will be required prior to said installation taking place in the specific area concerned.

D. Submittals

- Quality Control Plan: The GC shall submit a Quality Control Plan to the OR and CA within sixty (60) days after receiving their Notice to Proceed. The QC Plan will become the basis for prerequisite accomplishments prior to execution of any Functional Performance Testing. The QC Plan as a result will become an integral part of the overall project Commissioning Plan and shall be included therein as a subsection.
- The Ca is required to review the submittals of all equipment and systems to be commissioned.

E. QC Plan

- Requirements: Provide for approval by Owner's Representative, a QC Plan that covers both on-site and off-site Work, and includes the following:

    1. A chart showing the QC organizational structure and its relationship to the production side of the organization.
    2. Names and qualifications, in resume format, for each person in the QC organization.
    3. Duties, responsibilities and authorities of each person in the QC organization.
    4. Documentation procedures, including proposed report formats for all reports required herein.
    5. A letter signed by an officer of the firm appointing the QC Manager and stating that he/she is responsible for managing and implementing the QC program as described herein, and that the QC Manager reports to an officer of the firm, someone other than Contractor's Project Manager.

Include in this letter the QC Manager's authority to direct the stopping, removal and replacement of non-conforming Work.

6. Procedures for reviewing, approving and managing submittals. Provide the name(s) of the person(s) in the QC organization authorized to review and certify submittals prior to approval.
7. Testing laboratory information requirements (testing by UCLA). Refer to Sections 01452 and 01060.
8. A Testing Plan and Log that includes the tests required, referenced by the specification paragraph number requiring the test, test procedures, the frequency, schedule activity number and the person responsible for each test.
9. Procedures to identify, record, track and complete rework items, including schedule activity numbers.
10. A listing of outside organizations such as, architectural and consulting engineering firms that will be employed by Contractor and a description of the services and resumes of personnel these firms will provide.
11. A list of the definable features of work. A definable feature of work is a task that is separate and distinct from other tasks and requires separate control requirements. As a minimum, unless otherwise approved by Owner's Representative, consider each section of the specifications as a definable feature of work. However, there may be more than one definable feature of work in each section of the specifications.
12. A personnel matrix showing, for each section of the specification, who will review and approve submittals, who will perform and document the three phases of control, and who will perform and document the testing.
13. Provide a breakdown of the inspection of the work into five divisions for each area of project construction within the building (by floor, by compass, or a combination of both). These will be Preliminary, prior to layout and erection of walls; In Wall Rough In, prior to closure of wall cavities; Above Ceiling Construction, (2) coordination prior to work commencement and final prior to closure of ceiling cavities (including all installation tests, pressure tests, continuity tests, etc., etc. as necessary or as required); Finishes Inspection, prior to construction completion; Punch List Execution.
14. Provide procedures for each step of the inspection and installation testing highlighted above including those describing mandatory above ceiling coordination prior to the execution of any above ceiling work.

COMMISSIONING PROCESS

A. Commissioning Plan. The *CA as the designated representative of the OR shall develop the Commissioning Plan*. The OR, GC, TAB and A/E will review this plan and offer any perceived edits to the CA that would more effectively edit the plan to better address the specific needs of this project.

- The commissioning plan shall be developed in two stages. The first stage will be considered as a Draft and will be prepared within 60 days following contract award. This Draft plan will be submitted to the Owner's representative for approval. It will provide guidance in the execution of the commissioning process. Upon approval of the Draft plan, a commissioning scoping meeting will be held within 90 days following contract award. Just after the initial commissioning scoping meeting the CA will update the plan which will then be considered the "final" plan. In all instances the Specifications will take precedence over the Commissioning Plan.

- The Commissioning Plan shall be organized into four sections as follows:

  I. Introduction (Organization and Logistics)
  II. Criteria (OPR, BoD, Spec requirements)
  III. Testing (Construction Checklists and FPT's)
  IV. Training (Planning, Agenda, and Record forms)

- The Commissioning Plan and the Commissioning Process for this project will conform to the current version of the ASHRAE Guideline 0, the National Institute of Building Sciences library of commissioning standards, and the tenets of the Building Commissioning Association.

B. Commissioning Process. The following narrative provides a brief overview of the minimum commissioning tasks necessary during construction and the general order in which they occur.

- Commissioning during construction begins with scoping meetings conducted by the CA where the commissioning process is reviewed with the commissioning team members.
- Additional meetings will be required throughout construction, scheduled by the CA with necessary parties attending, to plan, scope, coordinate, schedule future activities and resolve problems.
- Equipment documentation is submitted to the CA (from the GC and where timing is applicable on this project) during normal submittals, including detailed start-up procedures. CA shall obtain submittals and detailed start up procedures of the OFCI equipment from the Owner.
- In general, the checkout and performance verification proceeds from simple to complex, from component level to equipment to systems and intersystem levels with construction checklists being completed before functional testing. Successful acceptance testing in fact shall be documented only by the completion of the Construction Checklists and the corresponding Functional Performance Tests.
- The Trades, under their own direction, execute and document the Construction checklists and perform startup and initial checkout (Operational Testing). The CA documents that the checklists and startup were completed according to the approved plans. This will include the CA, GCQ, and/ or IOR witnessing start-up of selected equipment. This will occur according to a sequence defined by the Commissioning Plan that will integrate the check, tests, and approval of inter-dependent systems and equipment (one being checked prior to the other relying on the first, etc., ie. controls prior to mechanical equipment.)
- The CA developed specific equipment and system functional performance test procedures according to the requirements of the specifications and included them in the plan herein. The GC, Trades, TAB, A/E, and ATV review the procedures.

- The procedures are executed by the Trades, TAB, and ATV under the management of the GC and documented by the CA.
- The work of the TAB and A/E are considered an integral part of the commissioning process. The GC will coordinate and schedule their work in collaboration with the CA in this regard. The documentation will form an essential part of the overall commissioning documentation.
- The Trades will coordinate with the CA, the TAB, and the ATV for a completely tested and commissioned project.
- Items of non-compliance in material, installation or setup are corrected at the GC's expense and the system retested in accordance with the specification requirements.
- The CA reviews the O&M documentation for completeness.
- Commissioning is completed before Substantial Completion.
- The CA reviews, pre-approves and the GC coordinates with the owner the training provided by the Trades and verifies that it was completed.

RESPONSIBILITIES

A. The responsibilities of various parties in the commissioning process are provided in this section. It is noted that the services for the Owner's Representative, Architect, HVAC mechanical and electrical designers/engineers are not provided for in the general contract. That is, the Contractor is not responsible for providing their services. Their responsibilities are listed here to clarify the commissioning process.

B. <u>All Parties</u>

- Follow the Commissioning Plan as it becomes developed by the CA and approved by the Owner's representative.
- Attend commissioning scoping meeting and additional meetings, as necessary.

C. <u>Architect and Engineer</u>

- o *Construction and Acceptance Phase*
    - Perform normal submittal review, construction observation, as-built drawing preparation, etc., as contracted. One site observation should be completed just prior to system startup.
    - The designers shall assist (along with the contractors) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
    - Attend commissioning scoping meetings and other selected commissioning team meetings.
    - Participate in the resolution of system deficiencies identified during commissioning, according to the contract documents.
    - Review and approve the O&M manuals.

- Review and approve the Contractor's as-built drawings and those provided by the vendor as shop drawings, including but not limited to, for the chilled and hot water, condenser water, domestic water, steam and condensate systems; supply, return and exhaust air systems and emergency power system.
- Provide a presentation of systems' design at one of the training sessions for the Owner's personnel.
- Review and approve the pre-functional checklists for major pieces of equipment for sufficiency prior to their use.
- Review and approve the functional test procedure forms for major pieces of equipment for sufficiency prior to their use.
- Witness testing of selected pieces of equipment and systems.

Warranty Period

1. Participate in the resolution of non-compliance, non-conformance and design deficiencies identified during commissioning during warranty-period commissioning.

D. Commissioning Authority (CA)

The CA is not responsible for design concept, design criteria, design or general construction scheduling, cost estimating, or construction management. The CA will develop the project Commissioning Plan and may assist with problem solving, non-conformance or deficiencies, but ultimately that responsibility of conformance resides with the general contractor and the A/E. The primary role of the CA is to develop and coordinate the execution of a testing plan, observe and document performance that systems are functioning in accordance with the documented Owner's Project Requirements and in accordance with the Contract Documents. The Contractors will provide all tools or the use of tools to start, checkout and functionally test equipment and systems.

Construction and Acceptance Phase

- Coordinates and directs the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consultations with all necessary parties, frequently updated timelines and schedules and technical expertise.
- Coordinate the commissioning work and, with the GC and OR, ensure that commissioning activities are being scheduled into the master schedule.
- Revise, as necessary the project *Commissioning Plan.*
- Plan and conduct a commissioning scoping meeting and other commissioning meetings.
- Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures.
- Before startup, gather and review the current control sequences and interlocks and work with contractors and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.

- Review and approve normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
- Write and distribute Construction Checklists.
- Develop an enhanced start-up and initial systems checkout plan with Trades.
- Perform site visits, as necessary, to observe component and system installations. Attends selected planning and job-site meetings to obtain information on construction progress. CA must participate in the QC preparation phase of systems that will be commissioned. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies.
- Witness all or part of the HVAC piping test and flushing procedure, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. In any case, the CA will be copied on all testing reports. Notify Owner's representative (OR) of any deficiencies in results or procedures.
- Witness with the IOR all or part of any ductwork testing and cleaning procedures, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify the OR of any deficiencies in results or procedures.
- Approve Construction Checklist completion by reviewing construction checklist reports and by selected site observation and spot checking.
- Approve systems startup by reviewing start-up reports and by selected site observation.
- Review TAB and ATV execution plan. Those plans will be formulated to meet the requirements as defined by the specifications.
- Oversee sufficient functional testing of the control system and approve it to be used for TAB, before TAB is executed.
- Approve with the IOR the air and water systems balancing by spot testing, report review, and selected site observation; and with the OR the ATV work by reviewing completed reports and by selected site observation.
- Analyze any functional performance trend logs and monitoring data to verify performance.
- Coordinate, witness and approve with the OR manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved.
- Maintain a master deficiency and resolution log and a separate testing record. Provide the OR with written progress reports and test results with recommended actions.
- Witness with the IOR performance testing of smoke control systems by others and all other owner contracted tests or tests by manufacturer's personnel over which the CA may not have direct control. Document these tests and include this documentation in Commissioning Record in O&M manuals.
- Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.
- Oversee and approve the training of the Owner's operating personnel.

- Compile and maintain a commissioning record and building systems book(s).
- Review and approve the preparation of the O&M manuals.
- Provide a final commissioning report (as described in this section).

E. Owner's Representative (OR)

The representation of the Owner will be will specifically and contractually derived from the Facilities, Design and Construction or Engineering Operations department, but may include the designation of other Facility personnel as determined by FD&C or EO. This will certainly include, but not be limited to, such departments as Engineering Operations. While the term Owner's Representative may be used throughout this Plan to refer to the Project Management of FD&C or EO, other facility personnel may be included or substituted in this role at the discretion of FD&C or EO.

Construction and Acceptance Phase

- Facilitate the coordination of the commissioning work by the CA with the GC.
- Ensure that commissioning activities are being scheduled into the contract schedule and that all the phasing requirements are being accommodated and conformed to.
- Review and assist the coordination of all requested shut downs and tie ins of the mechanical and electrical systems.
- Review and approve all temporary mechanical and electrical routings, valvings, etc. not specifically defined by the design documents.
- Review the coordination of the work of the GC QC Manager and the CA.
- Review and approve, with the A/E, the draft and final project Commissioning Plan. Make comments, edits, etc. as necessary for incorporation of corrections, additions, and deletions into the Final Plan.
- Attend a commissioning scoping meeting and all other commissioning team meetings.
- Verify that all required participants are attending the team meetings.
- Coordinate the involvement of any owner personnel needed at the team meetings.
- Perform the normal review of Contractor submittals.
- Review the re-submittals originally found to be in non-compliance.
- Review and approve the functional performance test procedures submitted by the CA, prior to testing.
- Review and approve resubmitted procedures initially found in to be in non-compliance.
- Provide the sign off for such re-submittals prior to execution of the next related, sequenced commissioning step.
- Observe and witness pre-functional checklists prior to start up.
- Observe and witness startup of equipment prior to functional testing.
- Witness all BAS testing.
- Review commissioning progress and deficiency reports.
- Participate in review and approval of deficiency resolutions.
- Keep the A/E appraised of progress and informed of required approvals as well as requests for their input to design related resolutions.

- Coordinate the resolution for issues of non-compliance and deficiencies identified in all phases of commissioning.
- Review and approve all retesting of systems and equipment.
- Sign-off (final approval), along with the IOR and A/E, on individual commissioning tests as completed and passing.
- Review and approve the completion of the commissioning process.
- Assist the CA and GC in coordinating the training of owner personnel.
- Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training sessions according to the project Commissioning Plan.

F. General Contractor (GC)

Construction and Acceptance Phase

- Facilitate the coordination of the commissioning work by the commissioning team, especially the trades. And with the help of the trades and CA ensure that commissioning activities are being scheduled into the master schedule inclusive of training and post-occupancy activities.
- Include the work of commissioning in the total contract scope as defined by the specifications and the Commissioning Change Order.
- Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CA.
- In each purchase order or subcontract written or modified, include requirements for submittal data, O&M data, commissioning tasks and training.
- Ensure that all Trades execute their commissioning responsibilities according to the Contract Documents and schedule.
- A representative shall attend a commissioning scoping meeting and other necessary meetings scheduled by the CA to facilitate the Commissioning process.
- Coordinate the training of owner personnel.
- Prepare O&M manuals, according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.

Warranty Period

- Correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any testing.

G. Equipment Suppliers

- Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the Owner to keep warranties in force.
- Assist in equipment testing per agreements with Trades.
- Include all special tools and instruments (only available from vendor, specific to a piece of equipment, and inclusive of equipment supplied by the Owner) required

for testing equipment according to these Contract Documents in the base bid price to the Contractor.

- Include all special tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment.
- Through the contractors they supply products to, analyze specified products and verify that the designer has specified the newest most updated equipment reasonable for this project's scope and budget.
- Provide information requested by CA regarding equipment sequence of operation and testing procedures.
- Review test procedures for equipment installed by factory representatives.

DEFINITIONS

Acceptance Phase - phase of construction after startup and initial checkout when functional performance tests, O&M documentation review and training occurs.

Approval - acceptance that a piece of equipment or system has been properly installed and is functioning in the tested modes according to the Contract Documents.

Architect / Engineer (A/E) - the prime consultant (architect) and sub-consultants who comprise the design team, generally the HVAC mechanical designer/engineer and the electrical designer/engineer.

Basis of Design - The basis of design is the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the Owners Project Requirements. The basis of design describes the systems, components, conditions and methods chosen to meet the intent. Some reiterating of the design intent may be included.

Commissioning authority (CA) - an independent agent, not otherwise associated with the A/E team members or the Contractor. The CA witnesses, facilitates, and works with the GCQ who directs and coordinates the day-to-day commissioning activities. The CA does not take an oversight role like the OR. The CA is part of the Construction Manager's (CM) team and shall report directly to the OR.

Commissioning Plan - an overall plan, developed following contract award that provides the structure, schedule and coordination planning for the commissioning process.

Construction Checklist (CC) - a list of items to inspect and elementary component tests to conduct to verify proper installation of equipment, provided by the CA to the GC. Construction Checklists, otherwise known as Pre-functional checklists, are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension, oil levels OK, labels affixed, gages in place, sensors calibrated, etc.). However, some pre-functional checklist items entail simple testing of the function of a component, a piece of equipment or system (such as measuring the voltage imbalance on a three phase pump motor of a chiller system). The word pre-functional refers to before functional testing. Pre-functional checklists augment and are combined with the manufacturer's start-up checklist. Even without a commissioning process, contractors typically perform some, if not many, of the pre-functional checklist items a commissioning authority will recommend. However, few contractors document in writing the execution of these checklist items. Therefore, for most equipment, the contractors execute the checklists on their own. The commissioning authority only requires that the procedures be documented in writing, and does not witness much of the pre-functional check listing, except for larger or more critical pieces of equipment.

Contract Documents - the documents binding on parties involved in the construction of this project (drawings, specifications, change orders, amendments, contracts, etc.).

Contractor - the general contractor or authorized representative.

Control system - the central building energy management control system.

Data logging - monitoring flows, currents, status, pressures, etc. of equipment using the control system.

Deferred Functional Tests - FTs that are performed later, after substantial completion, due to partial occupancy, equipment, seasonal requirements, design or other site conditions that disallow the test from being performed.

Deficiency - a condition in the installation or function of a component, piece of equipment or system that is not in compliance with the Contract Documents (that is, does not perform properly or is not complying with the design intent).

Factory Testing - testing of equipment on-site or at the factory by factory personnel with an Owner's representative present.

Functional Performance Test (FPT) - test of the dynamic function and operation of equipment and systems using manual (direct observation) or monitoring methods. Functional testing is the dynamic testing of systems (rather than just components) under full operation (e.g., the chiller pump is tested interactively with the chiller functions to see if the pump ramps up and down to maintain the differential pressure set point). Systems are tested under various modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, fire alarm, power failure, etc. The systems are run through all the control system's sequences of operation and components are verified to be responding as the sequences state. Traditional air or water test and balancing (TAB) is not functional testing, in the commissioning sense of the word. TAB's primary work is setting up the system flows and pressures as specified, while functional testing is verifying that which has already been set up. The commissioning authority develops the functional test procedures in a sequential written form, coordinates, oversees and documents the actual testing, which is usually performed by the installing contractor or vendor. FTs are performed after pre-functional checklists and startup are complete.

General Contractor (GC) - the prime contractor for this project. Generally refers to all the GC's subcontractors as well. Also referred to as the Contractor, in some contexts.

Indirect Indicators - indicators of a response or condition, such as a reading from a control system screen reporting a damper to be 100% closed.

Manual Test - using hand-held instruments, immediate control system readouts or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the "observation").

Monitoring - the recording of parameters (flow, current, status, pressure, etc.) of equipment operation using data loggers or the trending capabilities of control systems.

Non-Compliance - see Deficiency.

Non-Conformance - see Deficiency.

Over-written Value - writing over a sensor value in the control system to see the response of a system (e.g., changing the outside air temperature value from 50F to 75F to verify economizer operation). See also "Simulated Signal."

Owner-Contracted Tests - tests paid for by the Owner outside the GC's contract and for which the CA does not oversee. These tests will not be repeated during functional tests if properly documented.

Owner's Project Requirements - a dynamic document that provides the explanation of the ideas, concepts and criteria that are considered to be very important to the owner. It is initially the outcome of the programming and conceptual design phases.

Owner's Representative (OR) - The Owner's representative in the day-to-day activities of construction. In general, the Owner's Representative (OR) is an employee or employees of the owner who assist in the overall management of the project including supervising and on-site managing authority over the project's design and construction. This is specifically an employee or employees of FD&C or EO. The GC, A/E, CM, and CA report to the OR. The OR is the on-site representative along with his designees. Engineering Operations personnel will, for example, participate in the commissioning work at the discretion of the OR and may assume or compliment the OR responsibility, again at the sole discretion of the OR.

Phased Commissioning - commissioning that is completed in phases (by floors, for example) due to the size of the structure or other scheduling issues, in order minimize the total construction time.

Sampling. - functionally testing only a fraction of the total number of identical or near identical pieces of equipment.

Seasonal Performance Tests - FT that are deferred until the system(s) will experience conditions closer to their design conditions.

Simulated Condition - condition that is created for the purpose of testing the response of a system (e.g., applying a hair blower to a space sensor to see the response in a VAV box).

Simulated Signal - disconnecting a sensor and using a signal generator to send an amperage, resistance or pressure to the transducer and DDC system to simulate a sensor value.

Specifications - the construction specifications of the Contract Documents.

Startup - the initial starting or activating of dynamic equipment, including executing pre-functional checklists.

Trades - the subcontractors to the GC who provide and install building components and systems.

Test Procedures - the step-by-step process, which must be executed to fulfill the test requirements. The test procedures are developed by the CA with the input of the entire commissioning team.

Test Requirements - requirements specifying what modes and functions, etc. shall be tested. The test requirements are not the detailed test procedures. The test requirements are specified in the Contract Documents and the referenced industry association standards, such as NFPA, or have been developed through the collaboration of the commissioning team.

Trending - monitoring using the building control system.

Vendor - supplier of equipment.

Warranty Period - warranty period for entire project, including equipment components. Warranty begins at Substantial Completion and extends for at least one year, unless specifically noted otherwise in the Contract Documents and accepted submittals.

SYSTEMS TO BE COMMISSIONED

A. The following systems will be commissioned in this project.

Air Distribution System
Air Handling Units
Fan Coil Units
Exhaust Fans
Terminal Units

Chilled Water System
Chiller
Pumps
Piping

Hot Water System
Boiler
Pumps
Piping

Power Distribution System
Motor Control Center
Feeders
Panel boards
Transformers
Grounding
Disconnect Switches

Lighting System
Interior Lighting Control
Exterior Lighting Control

Automation System
Building Automation System

Test and Balance

Fire Suppression System

Low Voltage Systems
Fire Alarm System
Telecom

TEST EQUIPMENT

A. All standard testing equipment required to perform startup and initial checkout and required functional performance testing shall be provided by the Division contractor for the equipment being tested. For example, the mechanical contractor of Division 15 shall ultimately be responsible for all standard testing equipment for the HVAC system and controls system in Division 15, except for equipment specific to and used by TAB in their responsibilities.

B. Special equipment, tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment, according to these Contract Documents shall be included in the base bid price to the Contractor and left on site.

C. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the *Specifications.* If not otherwise noted, the following minimum requirements apply: Temperature sensors and digital thermometers shall have a certified calibration within the past year to an accuracy of 0.5°F and a resolution of + or - 0.1°F. Pressure sensors shall have an accuracy of + or - 2.0% of the value range being measured (not full range of meter) and have been calibrated within the last year. All equipment shall be calibrated according to the manufacturer's recommended intervals and when dropped or damaged. Under no circumstances, however, will this period between calibrations extend longer than six months. Provide the OR with such proof of calibration activity **prior** to report, test, document submission, etc. requiring the use of said testing equipment. Calibration tags shall be affixed or certificates readily available.

MEETINGS

A. Scoping Meeting. Following commencement of construction, the CA has scheduled (with the GC), planned and conducted commissioning scoping meetings with the entire commissioning team in attendance. The Draft Commissioning plan will be distributed to all parties by the CA. Information gathered from subsequent follow up scooping meetings will allow the CA to revise the Draft Commissioning Plan to its "Final" version, which will also be distributed to all parties.

B. Miscellaneous Meetings. Other meetings will be planned and conducted by the CA as construction progresses. These meetings will cover coordination, deficiency resolution and planning issues with particular Trades. The CA will plan these meetings and will minimize unnecessary time being spent by Trades. These meetings will be held monthly, until the final 3 months of construction, as determined by the OR, when they may be held as frequently as one per week.

REPORTING

A. The CA will provide regular reports to the OR with increasing frequency as construction and commissioning progresses. Standard forms are expected to be provided and referenced in the Commissioning Plan.

B. The CA will regularly communicate with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling changes through memos, progress reports, etc.

C. Testing or review approvals and non-conformance and deficiency reports are made regularly with the review and testing as described in later sections.

D. A final commissioning report by the CA will be provided to the OR, focusing on evaluating commissioning process issues and identifying areas where the process could be improved. All acquired documentation, logs, minutes, reports, deficiency lists, communications, findings, unresolved issues, etc., will be compiled in appendices and provided with the summary report. Pre-functional checklists, functional tests and monitoring reports may not be part of the final report, but will be provided electronically.

SUBMITTALS

A. The Commissioning authority will review and approve submittals related to the commissioned equipment for conformance to the Contract Documents as it relates to the commissioning process, to the functional performance of the equipment and adequacy for developing test procedures. This review is intended primarily to aid in the development of functional testing procedures and only secondarily to verify compliance with equipment specifications. The Commissioning authority will notify the OR, IOR or A/E as requested, of items missing or areas that are not in conformance with Contract Documents and which require resubmission.

B. The OR, through the GC and CA, may request an additional operational narrative from the Controls Contractor, depending on the design intent documentation and sequences provided with the Specifications.

C. These submittals to the CA do not constitute compliance for O&M manual documentation. The O&M manuals are the responsibility of the Contractor, though the CA will contribute to their review and approval.

START-UP, CONSTRUCTION CHECKLISTS AND INITIAL CHECKOUT

A. The following procedures apply to all equipment to be commissioned. Some systems that are not comprised so much of actual dynamic machinery, e.g., electrical system power quality, may have more simplified construction checkout, and functional performance testing.

B. General. Construction Checklists are important to ensure that the equipment and systems are hooked up and operational. It ensures that functional performance testing (in-depth system checkout) may proceed without unnecessary delays. Each piece of equipment receives full pre-functional checkout verified upon completion and approval of Construction Checklist. No sampling strategies are used. The Construction checklist for a given equipment or system must be successfully completed prior to formal functional performance testing of that same given equipment or system or any equipment, system or subsystem that interfaces with said equipment or system.

C. Start-up and Initial Checkout Plan. The GC shall assist the trades responsible for startup of any equipment in developing detailed start-up plans for all equipment. The primary role of the GC in this process is to ensure that there is written documentation that each of the manufacturer-recommended procedures have been completed. Parties responsible for Construction Checklists are identified in the commissioning scoping meeting and in the checklist forms. Parties responsible for executing functional performance tests are herein identified as the installing subcontractor of the systems in question, ie. the fire alarm system will be energized and tested by the electrical contractor, the chilled water system will be energized and tested by the mechanical contractor, etc. Until substantial completion is achieved, no one other than the installing contractor (as determined by the General Contractor) shall ever energize and operate any system or equipment under contract. The tests will, however, be witnessed by other parties as designated by the Commissioning Plan.

1. The CA has developed Construction Checklists and procedures for all equipment and systems as designated as being commissioned. These checklists indicate required procedures to be executed as part of startup and initial checkout of the systems and the party responsible for their execution.
2. These checklists and tests are provided by the CA to the Contractor. The Contractor determines which trade is responsible for executing and documenting each of the line item tasks and notes that trade on the form. Each form will have more than one trade responsible for its execution.
3. The subcontractor responsible for the purchase of the equipment develops the full start-up plan by combining (or adding to) the CA's checklists with the manufacturer's detailed start-up and checkout procedures from the O&M manual and the normally used field checkout sheets. The plan will include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan.

   The full start-up plan should consist of:
   a. The CA's construction checklists.
   b. The manufacturer's standard written start-up procedures copied from the installation manuals with check boxes by each procedure and a signature block added by hand at the end.
   c. The manufacturer's normally used field checkout sheets.

4. The subcontractor submits the full startup plan to the GC for review and approval. The GC will share this plan with the CA.
5. The CA reviews the procedures and the format for documenting them, noting any procedures that may need to be added.
6. The full start-up procedures will be provided to the OR for review and approval.

D. Execution of Construction Checklists and Startup.

1. Four weeks prior to startup, the Trades and vendors schedule startup and checkout with the OR, GC and CA. The performance of the Construction Checklists, startup and checkout are directed and executed by the Sub or vendor. When checking off pre-functional checklists, signatures may be required of other Trades for verification of completion of their work.
2. The CA shall observe, at minimum, the procedures for each piece of primary equipment,.
3. For lower-level components of equipment, (e.g., sensors, controllers), the CA shall observe a sampling of the pre-functional and start-up procedures. The sampling procedures are identified in the commissioning plan.
4. The Trades and vendors shall execute startup and provide the CA with a signed and dated copy of the completed Construction Checklists.
5. Only individuals that have direct knowledge and witnessed that a line item task on the pre-functional checklist was actually performed shall initial or check that item off. It is not acceptable for witnessing supervisors to fill out these forms.

E. Deficiencies, Non-Conformance and Approval in Checklists and Startup.

1. The Trades shall clearly list any outstanding items of the initial start-up and pre-functional procedures that were not completed successfully, at the bottom of the procedures form or on an attached sheet. The procedures form and any outstanding deficiencies are provided to the CA within two days of test completion.
2. The CA reviews the report and submits either a non-compliance report or an approval form to the Trade and OR. The CA shall work with the Trades and vendors to correct and retest deficiencies or uncompleted items. The CA will involve the OR and others as necessary. The installing Trades or vendors shall correct all areas that are deficient or incomplete in the checklists and tests in a timely manner, and shall notify the CA as soon as outstanding items have been corrected and resubmit an updated start-up report and a Statement of Correction on the original non-compliance report. When satisfactorily completed, the CA recommends approval of the execution of the checklists and startup of each system to the OR using a standard form.
3. Items left incomplete, which later cause deficiencies or delays during functional testing may result in back charges to the responsible party.

FUNCTIONAL PERFORMANCE TESTING

A. This sub-section applies to all commissioning functional testing for all divisions. Along with the work of the Trades, the CA will have the assistance of several professionals as necessary to cover the extent and quantity of separate specific and unique systems, such as controls, low voltage, HVAC, etc.

B. Objectives and Scope. The objective of functional performance testing is to demonstrate that each system is operating according to the documented Owner's Project Requirements and Contract Documents. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and functioning of the systems.

C. Development of Test Procedures. Before test procedures are finalized, the CA shall obtain all requested documentation and a current list of change orders affecting equipment or systems, including an updated points list, program code, control sequences and parameters. CA shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. Each Sub or vendor responsible to execute a test shall provide limited assistance to the CA in developing the procedures review (answering questions about equipment, operation, sequences, etc.). Prior to execution, the CA shall provide a copy of the test procedures to the Sub(s) who shall review the tests for feasibility, safety, equipment and warranty protection. The CA may submit the tests to the A/E for review, if requested.

D. Test Methods.

1. Functional performance testing and verification may be achieved by manual testing (persons manipulate the equipment and observe performance) or by monitoring the performance and analyzing the results using the control system's trend log capabilities.
2. Setup. Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Sub executing the test shall provide all necessary materials, deficiency resolutions, etc. to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions. At completion of the test, the Sub shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.

E. Coordination and Scheduling. The Trades shall provide sufficient notice to the CA regarding their completion schedule for the Construction Checklists and startup of all equipment and systems. The CA will facilitate the schedule of functional tests through the OR, GC and affected Trades. The CA shall witness and document the functional testing of all equipment and systems. The Trades shall execute the tests.

In general, functional testing is conducted after construction checkout and startup has been satisfactorily completed. The control system is sufficiently tested and approved by the CA before it is used for TAB or to verify performance of other components or systems. The air balancing and water balancing is completed and debugged before functional testing of air-related or water-related equipment or systems. Testing proceeds from components to subsystems to systems. When the proper performance of all interacting individual systems has been achieved, the interface or coordinated responses between systems is checked.

F. Problem Solving. The CA will recommend solutions to problems found, however the burden of responsibility to solve, correct and retest problems is with the GC, Trades and A/E.

DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS

A. Documentation. The CA shall witness and document the results of all functional performance tests using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the OR for review and approval and to the Trades for review. The CA will include the filled out forms in the O&M manuals. All original documents, reports, etc. shall be forwarded to the OR for inclusion in facility archives.

B. Non-Conformance.

1. The CA will record the results of the functional test on the procedure or test form. All deficiencies or non-conformance issues shall be noted and reported to the OR on a standard non-compliance form.
2. Corrections of minor deficiencies identified may be made during the tests at the discretion of the CA. In such cases the deficiency and resolution will be documented on the procedure form.
3. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the CA will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues, unless there is an overriding reason to do so at the request of the OR.
4. As tests progress and a deficiency is identified, the CA and GC discusses the issue with the executing contractor.

   a. When there is no dispute on the deficiency and the Sub accepts responsibility to correct it:

      1) The CA documents the deficiency and the Sub's response and intentions and they go on to another test or sequence. After the day's work, the CA submits the non-compliance reports to the OR for signature. A copy is provided to the Sub and GC. The Sub corrects the deficiency, signs the statement of correction at the bottom of the non-compliance form certifying that the equipment is ready to be retested and sends it back to the CA and GC.
      2) The CA and GC reschedule the test and the test is repeated.

b. If there is a dispute about a deficiency, regarding whether it is a deficiency or who is responsible:

1) The deficiency shall be documented on the non-compliance form with the Sub's response and a copy given to the OR and to the Sub representative assumed to be responsible.
2) Resolutions are made at the lowest management level possible. Other parties are brought into the discussions as needed. Final interpretive authority is with the A/E. Final acceptance authority is with the OR.
3) The CA documents the resolution process.
4) Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency, signs the statement of correction on the non-compliance form and provides it to the CA. The CA reschedules the test and the test is repeated until satisfactory performance is achieved.

5. Cost of Retesting.

a. All testing cost is the responsibility of the GC.
b. For a deficiency identified, not related to any pre-functional checklist or start-up fault and only related to instances where the design had to be changed, the following shall apply: The CA will direct the retesting of the equipment once at no "charge" to the GC for their time. However, the CA's, IOR's, and OR's time for a second retest will be charged to the GC. In all cases the GC is not responsible for the cost of testing or retesting due to design flaws only.
c. The time for the CA, IOR, and OR to direct any retesting required because a specific Construction Checklist or start-up test item, reported to have been successfully completed, but determined during functional testing to be faulty, will be back charged to the GC.

6. The Contractor shall respond in writing to the CA and OR at least as often as commissioning meetings are being scheduled concerning the status of each apparent outstanding discrepancy identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.
7. The CA retains the original non-conformance forms until the end of the project.
8. Any required retesting by any Trade shall not be considered a justified reason for a claim of delay or for a time extension by the GC.

C. <u>Failure Due to Manufacturer Defect.</u> If 10%, or three, whichever is greater, of identical pieces (size alone does not constitute a difference) of equipment fail to perform to the Contract Documents (mechanically or substantively) due to manufacturing defect, not allowing it to meet its submitted performance spec, all identical units may be considered unacceptable by the OR. In such case, the Contractor shall provide the OR with the following:

a. Within one week of notification from the OR, the Contractor or manufacturer's representative shall examine all other identical units making a record of the findings. The findings shall be provided to the OR within two weeks of the original notice.
b. Within two weeks of the original notification, the Contractor or manufacturer shall provide a signed and dated, written explanation of the problem, cause of failures, etc. and all proposed solutions which shall include full equipment submittals. The proposed solutions shall not significantly exceed the specification requirements of the original installation.
c. The OR will determine whether a replacement of all identical units or a repair is acceptable.
d. Two examples of the proposed solution will be installed by the Contractor and the OR will be allowed to test the installations for up to one week, upon which the OR will decide whether to accept the solution.
e. Upon acceptance, the Contractor and/or manufacturer shall replace or repair all identical items, at their expense and extend the warranty accordingly, if the original equipment warranty had begun. The replacement/repair work shall proceed with reasonable speed beginning within one week from when parts can be obtained.

D. Approval. The CA notes each satisfactorily demonstrated function on the test form. Formal approval of the functional test is made by the CA and by the OR and IOR, if necessary. The CA recommends acceptance of each test to the OR using a standard form. The OR gives final approval on each test using the same form, providing a signed copy to the CA and the Contractor.

OPERATION AND MAINTENANCE MANUALS

A. Standard O&M Manuals.

1. The specific content and format requirements for the standard O&M manuals are detailed in the Specifications.

2. A/E Contribution. The A/E will include in the beginning of the O&M manuals a separate section describing the systems including:

   a. The Basis of Design narrative prepared by the A/E and provided as part of the bid documents, updated to as-built status by the A/E.
   b. Simplified professionally drawn single line system diagrams on 8 ½" x 11" or 11" x 17" sheets. These shall include chillers, water system, condenser water system, heating system, supply air systems, exhaust systems etc. These shall show major pieces of equipment such as pumps, chillers, boilers, control valves, expansion tanks, coils, service valves, etc.

3. CA Review and Approval. Prior to substantial completion, the CA shall review the O&M manuals, documentation and redline as-builds *for systems that were*

commissioned to verify compliance with the *Specifications.* The CA will communicate deficiencies in the manuals to the OR, and A/E, as requested. Upon a successful review of the corrections, the CA recommends approval and acceptance of these sections of the O&M manuals to the OR and A/E. The CA also reviews each equipment warranty and verifies that all requirements to keep the warranty valid are clearly stated. This work does not supersede the A/E's review of the O&M manuals according to the A/E's contract.

B. Commissioning Record

1. Final Report Details. The final commissioning report shall include an executive summary, list of participants and roles, brief building description, overview of commissioning and testing scope and a general description of testing and verification methods. For each piece of commissioned equipment, the report should contain the disposition of the commissioning authority regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas:
   1) Equipment meeting the equipment specifications,
   2) Equipment installation,
   3) Functional performance and efficiency,
   4) Equipment documentation and design intent, and
   5) Operator training.

   All outstanding non-compliance items shall be specifically listed. Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc. shall also be listed. Each non-compliance issue shall be referenced to the specific functional test, inspection, trend log, etc. where the deficiency is documented. The functional performance and efficiency section for each piece of equipment shall include a brief description of the verification method used (manual testing, BAS trend logs, data loggers, etc.) and include observations and conclusions from the testing.

2. Other documentation will be retained by the CA, but may be provided to the owner at the OR's request for archive documentation.

TRAINING OF OWNER PERSONNEL

A. The GC will be responsible for training coordination and scheduling and ultimately for ensuring that training is completed. Schedule training to meet the user's needs and within a short time of acceptance.

B. The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment and systems. All training will be in conformance with the requirements of the specifications and all direction contained herein is intended to build on those requirements and supply detail only to the specific activities.

1. The CA shall interview the facility manager and lead engineer to determine the special needs and areas where training will be most valuable. The Owner and CA shall decide how rigorous the training should be for each piece of commissioned equipment as well as for the operation of the commissioned systems. The CA shall communicate the results to the Trades and vendors who have training responsibilities.

2. Each Sub and vendor responsible for training will submit a written training plan and agenda (blank base forms are included herein) to the CA for review and approval prior to training. The plan and agendas will be completed by the GC in their entirety for every system to be commissioned and will cover the following elements:

   a. Equipment (included in training)
   b. Intended audience
   c. Location of training
   d. Objectives
   e. Subjects covered (description, duration of discussion, special methods, etc.)
   f. Duration of training on each subject
   g. Instructor for each subject
   h. Methods (classroom lecture, video, site walk-through, actual operational demonstrations, written handouts, etc.)
   i. Instructor and qualifications

4. For the primary HVAC equipment, the Controls Contractor shall provide a short discussion of the control of the equipment during the mechanical or electrical training conducted by others.

5. The CA develops an overall training plan and coordinates and schedules, with the OR and GC, the overall training for the commissioned systems. The CA develops criteria for determining that the training was satisfactorily completed, including attending some of the training, etc. The CA recommends approval of the training to the OR using a standard form. The OR also signs the approval form.

C. The GC will videotape the training sessions and provide a copy of each tape to the OR.

WRITTEN WORK PRODUCTS

A. The commissioning process generates a number of written work products. The *Commissioning Plan* shall list all the formal written work products, describe briefly their contents, who is responsible to create them, their due dates, who receives and approves them and the location of the specification to create them. In summary, the written products will be:

Product	Developed By
1. Final commissioning plan	CA (with GC, Trades, A/E and OR)
2. Meeting minutes	CA
3. Commissioning schedules	GC with CA and OR
4. Equipment documentation submittals	Trades
5. Sequence clarifications	Trades and A/E as needed
6. Construction checklists	CA
7. Startup and initial checkout plan	GC, Trades and CA (compilation of existing documents)
8. Startup and initial checkout forms filled out	Trades
9. Final TAB report	TAB
10. Issues log (deficiencies)	CA
11. Commissioning Progress Record	CA
12. Deficiency reports	CA
13 Functional test forms	GC
14. Filled out functional tests	GC
15. O&M manuals	Trades
16. Commissioning record book	CA
17. Overall training plan	CA, GC, Trades and OR
18. Specific training agendas	CA, GC, Trades and OR
19. Final commissioning report	CA

Calibration and Loop Check Procedures
Supplement to Section 01810

Application For This Project

The following table lists the control elements and what procedures shall be followed with each. Procedures are explained below the table.

Sensors Field-Installed Temperature, Relative Humidity, Flow And Pressure Sensors and Gages	
Point-to-Point Checkout	Yes (see exceptions below)
Sensor Calibration	Yes (see exceptions below)
Relative Sensor Calibration	Yes (on heating and chilled water plant and built-up air handlers)

Actuators (On All Valves and Dampers)	
Point-to-Point Checkout	Yes
Valve and Damper Stroke Setup and Check	
A. Actuator Arrangement	Yes
B. Spring Returns	Yes (when applicable)
C. EMS Readout and Stroke	Yes
D. Closure for Heating Coil Valves	Yes
E. Closure for Cooling Coil Valves	Yes
Coil Valve Leak Check	Yes for all valves > 15 gpm design
Isolation Valve or System Valve Leak Check	Yes for all valves > 20 gpm design

Yes = perform on all equipment, unless noted otherwise.

Methods and Procedures

Alternate methods may be used, if approved by the Owner or Commissioning Authority beforehand. All test instruments shall have had a certified calibration within the last 12 months. Sensors with wiring and transducers installed *in* the equipment unit at the factory *with* calibration certification provided need not be field calibrated.

All procedures used shall be fully documented on the construction checklists, the forms at the end of this document or other forms approved by the Commissioning Authority, clearly referencing the procedures followed and written documentation of initial, intermediate and final results.

1. Point-to-Point Checkout

Each control point will be verified to be commanding, reporting and controlling according to their intended purpose. Every analog and digital input and output in the central control system shall be verified to be functioning properly. Points within and controlled by packaged equipment controllers do not require a point-to-point checkout except for actuator positions or other points listed in the specifications or manufacturer's start-up and checkout procedures. For each output, commands will be initiated and verified to be functioning by visually observing and documenting the status of the controlled device (e.g., command cooling coil valve to full open, or command heating water pump off). For each input, the system or conditions will be perturbed to initiate the input response being tested and the response in the control system observed and recorded (e.g., high duct static pressure alarm). Sensors and actuators will also be calibrated according to the Sections below.

2. Sensor Calibration Methods

All Sensors. Verify that all sensor locations are appropriate and away from causes of erratic operation (in stratified air flow, touching coils, etc.). Verify that sensors with shielded cable, are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, make sure they are reading within 0.2°F of each other for temperature and within a tolerance equal to 2% of the reading, of each other, for pressure. Tolerances for critical applications may be tighter. Hand-held instrument readings should be taken at five or more locations for mixed air temperatures and three or more locations for hot and cold deck temperatures to ensure a good average value to check against the BAS reading.

A. Sensors Without Transmitters--Standard Application. Make a one-point reading within the normal expected range of operation of the sensor with a calibrated test instrument, having accuracy per table below, within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or BAS) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.

B. Sensors With Transmitters--Standard Application. Make a two point calibration. Check the calibration at a condition near the low end and near the high end of expected operating values (temperature, pressure, etc.) using the procedure in (A). If sensor is not within tolerances, calibrate: Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum expected temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature expected matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or BAS) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.

C. Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors, such as making multiple point readings throughout the expected range of sensor operation. Describe any such methods used on an attached sheet.

D. Terminal Unit Flow Sensors. Flow sensors in air terminal units shall be calibrated during testing, adjusting and balancing using NEBB or AABC approved procedures.

E. Required Instrument Accuracy and Calibration Tolerances--Standard Applications

	Sensor	Required Calibrating Instrument Accuracy (+/-)	Required Calibration Tolerance (+/-)
	Cooling coil, chilled and condenser water temps	1.0F	0.4F
	AHU wet bulb or dewpoint	1.0F	0.4F
	Hot water coil and boiler water temp	1.0F	0.4F
	Outside air, space air, duct air temps	1.0F	0.4F
N/A	Combustion flue temps	2.0F	5.0F
	Relative humidity	2% RH	5% RH
	Watt-hour, voltage & amperage	2% of reading	1% of design
	Pressures, air, water and gas	2% of reading	3% of design
	Building differential pressure	1% of full span	0.01 in. WC
	Variable frequency drive	2 Hz	2 Hz
	Flow rates, water	4% of reading	4% of design
N/A	CO_2 monitor	5% of reading	50 ppm
N/A	CO monitor	3% of span	0.6 ppm / deg C
	Flow rates, air	3% of reading	10% of design[1]
	Air velocity rates	3% of reading	10% of design

[1] Flow rate accuracy for laboratory control will vary with the device and the space pressurization direction to ensure that the maximum allowed error in a worst case scenario will not result in the space requirements being violated.

F. Relative Sensor Calibration. This procedure makes sure that sensors are accurate relative to each other in a given piece of equipment. Sensors calibrated in this way, do not need separate calibration as given in Procedures A-D. For example, for a heating water system all the sensors in the fluid stream would be checked at one time, e.g., boiler entering and leaving temperatures, bypass, building supply and return temperatures. This would include building automation sensors, equipment panel readouts and gages. For an air handler it may include the return air temperature, coil temperatures and supply air temperatures. Calibrating sensors with this method is preferable to calibrating them each separately.

The procedure is as follows. 1) Record all current sensor calibration offsets. 2) Remove all sensor calibration offsets. 3) Put the system in a mode that will offer constant flow of water or air past the sensors, e.g., turn off boilers; turn on pumps, or turn on air handler and close outside air dampers and heating and cooling coil valves, etc. 4) Check with the reference instrument that the temperatures across coils and dampers are equal indicating that there is no leak-by. 5) With the reference instrument record the temperature rise across fans. 6) Use the entering fluid temperature to the system as a reference by inserting a reference measuring instrument there. 7) Compare the sensor readings with the reference reading. Take into account temperature rises across fans and pumps. 8) Install offsets or replace sensors and gages as required so sensor readings, compared to the reference, are within the tolerances given in Section E above. 9) Record all conditions, readings and offsets and submit. 10) Return systems to normal.

3. Valve and Damper Stroke Setup and Check

A. Actuator Arrangement. Verify that the actuator is using its full stroke to move the damper or valve through its full range of motion without sacrificing kinematics. Verify that linked or paired actuators are arranged the same. Verify that the linkages and ball joints are lubricated and that linkage rods are not binding or bent.

B. Spring Returns. For valves and dampers with spring returns, apply or remove power to the actuator and see that it moves to the correct position and that the spring has enough torque to fully close or open valve or damper.

C. EMS Readout and Stroke. For all valve and damper actuator positions checked, verify BAS address and the actual position against the BAS readout and verify that the valve or damper strokes fully and that “normal” position is correct.

Set pumps or fans to normal operating mode. Command valve or damper closed, visually verify that valve or damper is closed and adjust output zero signal as required. Dampers shall be adjusted to provide a tight positive closure. Command valve or damper open, verify position is full open and adjust output signal as required. Command valve or damper to a few intermediate positions. If actual valve or damper position doesn’t reasonably correspond, replace actuator or add pilot positioner (for pneumatics). Remove the control signal to the valve or actuator from the BAS. Observe that the failure mode (current position, open, closed) is as per specifications.

D. Closure for heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Then, for pneumatic actuators only: Set heating setpoint to 20°F below room temperature. Observe the valve close. Override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

E. Closure for cooling coil valves (NC): Set cooling setpoint 20°F above room temperature. Observe the valve close. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. For pneumatic actuators only: Set cooling setpoint to 20°F below room temperature. Observe valve open. Override the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

4. Coil Valve Leak Check

A. Method 1--Water Temperature With 2- or 3-Way Valve. Calibrate water temperature sensors on each side of coil to be within 0.2°F of each other. **Option 1.** Test Across Coil--for valves that are tight against AHU cabinet or valves that are away from the cabinet. Turn off air handler fans, close OSA dampers; keep pump running and valve open. Fix the supply water temperature setpoint. Place one sensor in moving supply water stream P/T plug or use existing thermometer, else strap-on sensor and insulate. Place one sensor on the return side of the coil, but not in the main return stream from other coils, ideally in a P/T plug, or strap-on and insulate. Sensor on the valve side of the coil must be on the far side of the valve from the coil. Verify that temperatures on both sides of the coil read the same. If not the same, record differences and compensate in the next part of the test.

Close the valve by software command. After 10 minutes observe water delta-T across coil or valve. If delta-T is not greater than 2°F, leakage is probably occurring. If leaking, reset valve stroke to close tighter. Repeat test until in compliance.

Method 1, Option 2. Test Just Across Valve—for valves more than 4 feet from the coil. Command the valve closed and measure the temperature difference with one sensor in the moving water stream on one side of the valve and one in the dead water at least 3 ft. from both the valve or the coil if the fan is on, if the fan is not on it can be closer to the coil than 3 ft. After 10 minutes observe water delta T across valve. If it is not greater than 2°F, leakage is probably occurring.

B. Method 2--Air Temperature With 2 or 3-Way Valve. Calibrate air temperature sensors on each side of coil to be within 0.2°F of each other. Change mixed or discharge air setpoint, override values or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance. Water leak-by less than 10% will likely not be detected with this method.

C. Method 3 Coil Drain Down for Terminal Units (not for 3-way valves). Put systems in normal mode. If cooling coil valve, remove all call for cooling or if heating coil valve put system in full cooling. Close isolation valve on supply side of coil, open air bleed cap, open drain-down cock and drain water from coil. Water should stop draining, else there may be a leak through the control valve. Return all to normal when done.

5. Isolation Valve or System Valve Leak Check (for valves not by coils)

A. Method 1--Ultra-sonic flow meter. With full pressure in the system, command valve closed. Use an ultra-sonic flow meter to detect flow or leakage.

-- END OF PROCEDURES--

(See documentation forms on following pages)

Sensor Calibration Documentation (sample form)

Sensor & Location	Loca -tion OK?	**1st** Gage or BAS Value	Instr. Meas'd Value or Visual	**Final** Gage or BAS Value	Pass Y/N?
TEMPERATURES					

Sensor & Location	Loca -tion OK?	**1st** Gage or BAS Value	Instr. Meas'd Value or Visual	**Final** Gage or BAS Value	Pass Y/N?
TEMPERATURES					

Valve and Damper Actuator Check Documentation

VALVES, DAMPERS and STATES							
Proced.#→	3A;B	3C					3D;E
Name and Location	Link-age OK	Initial BAS Value	Initial Visual Observ-ation	Final Visual Observ-ation	OK Y/N ?	Nor-mal OK?	Clos-ure OK?
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					

VALVE LEAK-BY TESTS		
4A; B or C		
Name and Location	State Leak-By method used (4A, B or C) and results, (final dT, etc.)	OK Y/N ?

CCV = cooling coil valve, HCV = heating coil valve, DPR = damper, EA=exhaust or relief air, OA = outdoor air, RA= return air

THIS PAGE IS INTENTIONALLY LEFT BLANK

01810 SUPPLEMENT 3

CHECK AND TESTING RESPONSIBILITY TABLES

A. Summary. In general, the HVAC and control system test procedures are written and their execution directed by the Commissioning Authority. For some electrical equipment and specialized systems, the test responsibility is distributed between the Contractor, the manufacturer's service representative, a certified electrical testing company and the design engineer (A/E). All test procedures are approved by the Commissioning Authority prior to execution.

B. *Construction Checklists* are primarily visual checks / inspections of static conditions, but for some equipment may include initial checkout, calibration and operational checks. *Tests* are executed after the checklists, and include measurements and sequence of operation verifications.

C. Abbreviations: **A/E:** Designer, **CA:** Commissioning Authority, **C:** Contractor (appropriate trade), **CC:** Controls Contractor, **CxC:** Contractor's Commissioning Coordinator, **EC:** Electrical Contractor, **CTC:** Certified Testing Company (provided by the CONTRACTOR), **MC:** Mechanical Contractor, **MSR:** Manufacturer Service Representative, **O:** OWNER, **RA:** Regulatory Authorities, **SI:** Special Inspector (hired directly by the OWNER), **TAB:** Testing, Adjusting and Balancing contractor, **NA:** Not applicable.

D. Column Heading Key:

1. Submittal Review: Review submittals of commissioned equipment for either information to assist in test writing and field verification (designated by an (I) in the table), or for a more thorough review to make comments parallel with the A/E reviews (R).
2. Field Observation: General observation of installation to become familiar with equipment and secondarily to identify problems.
3. Prepare Construction Checklists and/or Startup Plan: The first indicated party is responsible to develop written checks to ensure proper installation and setup ***Spec** indicates that the Construction Checklist is included in the Specifications for this equipment, but needs to be transferred to a formal documentation check sheet form by the indicated party. **NETA** indicates the Visual and Mechanical Inspections *of NETA Acceptance Testing Specifications* will be followed on forms created by the indicated party. A **$** indicates that a checkout and startup plan is also required to be developed by the adjacent indicated party and used by the Contractor. This is a written plan for conducting and documenting installation, startup and checkout and shall include specific startup sequence instructions. The Plan consists of manufacturer installation and start up instructions, vendor field check sheets and the Construction Checklists.
4. Perform and Document Checklists: The first indicated party is responsible to execute the checklists and document each line item. “C” indicates the

Contractor and any trades responsible for installing parts of the equipment (mech., elec., sheet metal, balancing, controls, etc.). The CA spot-witnesses check listing and startup and reviews the completed versions (reports). Any Construction Checklists or Startup Plans developed by the CA are reviewed by the Contractor and visa-versa prior to execution.

5. Prepare Test Procedures: Develop the written step-by-step test procedures and documentation forms for mechanical systems. For electrical component tests these procedures may be more checklist in nature and not include all specific procedural details, though all measurements will be recorded.
6. Review Test Procedures: Review and approve test procedures developed by others.
7. Coordinate, Oversee and Document Tests.
   a. Ensure that tests are scheduled and coordinated with the interfaces to other systems and requirements of the authorities having jurisdiction.
   b. Develop a logical test plan that flows from the component level on the various systems to the integrated testing of the systems that interact.
   c. Direct the order that test procedures are conducted. Coordinate the parties participating in the testing.
   d. Verify that all necessary documentation requirements are met for all parties including but not limited to authorities having jurisdiction, the OWNER and the Commissioning Authority.
   e. Facilitate effective communication and coordination across trades and disciplines as required for successful integrated testing of systems and assemblies.
   f. Witness entire test and fully document on approved forms the methods, procedures and results of each test procedure of all tests.
   g. When a contractor AND a certified testing company (CTC) are listed as responsible for this work for a given piece of equipment, the contractor may conduct and document the inspection-type procedures, but the CTC / MSR shall conduct and document testing requiring the use of measuring instruments.
8. Perform Test: Manipulate equipment or systems or set up and initiate actions on assemblies that demonstrates function and performance.
9. Witness: (See also applicable footnotes.)
   a. Witnessing in this column is to identify parties that are not coordinating, overseeing and documenting tests (Col. 7).
   b. Spot: (S) in the table. Spot witnessing of testing shall include a large enough sample to provide reasonable confidence that the tests were conducted properly. Sampling may be random or focused as determined by the Commissioning Authority. For selected systems such as duct and pipe pressure testing, spot witnessing may only require reviewing means and methods at the beginning of the test and a review of the test report.
   c. All: (A) in the table. Witness the duration of all test procedures performed. Note that for some systems where there is a sampling

strategy, not all systems will be tested, but all that are tested, will be witnessed. Refer to the testing requirements in the referenced Sections for details.

d. Witnessing does not necessarily include documenting of individual test or observation results, but does include recording attendance and general results.

10. Review Test Report: Review the testing documentation. See also applicable footnotes.

E. Check and Testing Responsibility Table

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor. Or Review) [3]	2 Field Observ-ation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Const Check Lists	5 Prepare Test Proced-ures	6 Review Test Proced-ures	7 Coordinate, Oversee & Document Test [4]	8 Perform Test	9 Witness Tests Doc. by Others (Spot or All) [1]	10 Review Test Report [2]
MECHANICAL SYSTEMS (Tests requirements in NEW 01815)											
Chilled Water System	Chillers, pumps, seperators, controls, flushing and pressure testing of piping	R-CA	CA; O	CA; $C	C	CA	MC, CC	CA	MC; CC; MSR	none	O; CA
Heating Water System	Boilers; pumps and controls, flushing and pressure testing of piping	R-CA	CA; O	CA; $C	C	CA	MC, CC	CA	MC; CC; MSR	None	O; CA
Air Handlers	Include min OA, CO2 monitoring	R-CA	CA; O	CA; $C	C	CA	MC, CC	CA	MC, CC, TAB	None	O
Air Terminal Units	All	I-CA	CA; O	CA	C	CA	MC, CC	CA	MC, CC	None	O
Ducting	Ducting and leakage tests	R-CA	CA; O	CA	C	MC	CA	MC	MC	S-CA	CA
Exhaust and Make-up Fans	All	I-CA	CA; O	CA	C	CA	MC, CC	MC	CC	None	O
FCUs	Fans, coils & controls	R-CA	CA; O	CA	C	CA	MC, CC	MC	MC, CC	None	O
Building Automation System	All	R-CA	CA; O	CA; $C	C	CA	CC	CA	CC	None	O
TAB Spot Check	Test and balance work.	R-CA	CA; O	CA; $C	TAB	CA	TAB	CA	TAB	None	O

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor. Or Review) [3]	2 Field Obser v-ation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Const Check Lists	5 Prepare Test Proced-ures	6 Review Test Proced-ures	7 Coordinate, Oversee & Document Test [4]	8 Perform Test	9 Witness Tests Doc. by Others (Spot or All) [1]	10 Review Test Report [2]
Thermal comfort	Temperature and humidity control	R-CA	NA	NA	NA	CA	MC, CC	CA	MC, CC	None	AE; O
Vibration Testing	List equipment…..	I-CA	NA	NA	NA	CTC	AE	CTC	CTC	S-AE	AE; O
Acoustical Testing	List equipment and spaces…..	I-CA	NA	NA	NA	CTC	CA	CTC	CTC	S-CA	CA; O
Fire Smoke Dampers		I-CA	CA; O	CA	C	CA	MC; CC	O; C	C	A-O; S-CA	O; CA, AE
PLUMBING (Test requirements in NEW 01814)											
Domestic Hot Water	Heater, circ pumps, mixing valves	I-CA	CA; O	CA	C	CA	MC	MC	MC	S-O	O; CA
Elevator, Storm, and Sewer Ejector, Booster and Sump Pumps	All	I-CA	CA; O	CA	C	CA	MC	MC	MC	S-O	O; CA
Piping Tests and Cleaning	HVAC & domestic, pipe, vents; drainage	None	O	None	NA	none	NA	MC	MC	S-O	CA
IR control Lavatories	All	I-CA	O	None	NA	CA	MC	MC	MC	S-O	CA; O
FIRE PROTECTION (13916; 13975)											
Fire Protection	Stand pipe, valves; controls	I-CA	O	none	None	C	CA; O	O	C	S-O	AE; O

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor. Or Review) [3]	2 Field Obser v-ation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Const Check Lists	5 Prepare Test Proced-ures	6 Review Test Proced-ures	7 Coordinate, Oversee & Document Test [4]	8 Perform Test	9 Witness Tests Doc. by Others (Spot or All) [1]	10 Review Test Report [2]
ELECTRICAL											
Grounding and Bonding 16060		I-CA	CA; O	*Spec	C	CA	CA, EC, CTC	EC; CTC	EC;CTC	S-CA	O; CA, AE
Wiring and Cable 16120		I-CA	CA; O	*Spec	C	CA	CA, EC, CTC	EC; CTC	EC; CTC	S-CA	O; CA, AE
Wiring Devices 16140	Switches and outlets	I-CA	CA; O	None	NA	CA	CA, EC, CTC	EC; CTC	EC; CTC	S-CA	O; CA, AE
Motor Control Centers 16443		R-CA	CA; O	C-NETA	C	CA	CA, EC, CTC	EC; CTC	EC; MSR	S-CA	O; CA, AE
Grounding 16060		I-CA	CA; O	C-NETA	C	CA	CA, EC, CTC	EC; CTC	EC;CTC	S-CA	O; CA, AE
Transformers 16461		I-CA	CA; O	C-NETA	C	CA	CA, EC, CTC	EC; CTC	EC;CTC	S-CA	O; CA, AE
Panel Boards 16442		I-CA	CA; O	C-NETA	C	CA	CA, EC, CTC	EC; CTC	EC;CTC	S-CA	O; CA, AE
Disconnect Switch 16476 [5]		I-CA	CA; O	C-NETA	C	CA	CA, EC, CTC	EC; CTC	EC;CTC	S-CA	O; CA, AE
VFDs	See Mechanical										

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor. Or Review) [3]	2 Field Obser v-ation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Const Check Lists	5 Prepare Test Proced-ures	6 Review Test Proced-ures	7 Coordinate, Oversee & Document Test [4]	8 Perform Test	9 Witness Tests Doc. by Others (Spot or All) [1]	10 Review Test Report [2]
Exterior Lighting Controls 16521; 01816	Timers, Photo-cells	I-CA	O	CA	C	CA	EC	CA	EC	None	O
Interior Lighting Controls 16511; 01816	Timers, Occupancy sensors, contactors, Dimming Systems	R-CA	CA; O	CA	C	CA	EC	CA	EC	None	AE; O
Fire Alarm 01816.		R-CA	CA; O	None	C	MSR	CA, O, A/E	O, C	MSR	S-CA; A-O	AE; O
SPECIAL SYSTEMS											
Elevators	All. CA tests interlocks to DDC	By Elevator Inspector									
Overhead Coiling Doors	All	I-CA	CA; O	None	NA	C	CA	C; MSR	C; MSR	S-CA; O; AE	CA; O
Security and Entry Systems		By Tenant									
Data / Communications		Raceways by JE Dunn, Cabling to be determined									

Notes:
A blank cell with a – or a "none" indicates this activity is not required.
[1] The Architect or design engineers may witness tests per their scope.
[2] The Architect or design engineers may review completed test procedures if in their scope.

[3] AE reviews all submittals and observes construction according to their contract.
[4] When a contractor AND the CTC are listed as responsible for this work for a given piece of equipment, the contractor may conduct and document the inspection-type procedures, but the CTC / MSR shall conduct and document testing requiring the use of measuring instruments.
[5] Current specification section contains adequate testing requirements.

SECTION 01814
PLUMBING AND FIRE PROTECTION SYSTEMS COMMISSIONING

PART 1 GENERAL

1.1 SUMMARY

A. This section specifies the unique responsibilities that are a part of, or are related to the commissioning process for the plumbing and related systems. Plumbing systems include those listed in Section 01810 as being commissioned.

B. Related sections:
1. 01810 General Commissioning Requirements

PART 2 PRODUCTS

2.1 TEST EQUIPMENT

A. The Contractor shall provide all test equipment necessary to fulfill the testing requirements, except required data loggers will be provided by the Owner or Commissioning Authority.

B. Refer to Section 01810 for additional requirements.

2.2 TEST PORTS

A. In the hydronic system, install a P/T plug at each temperature sensor which is an input point to the control system. Install P/T plugs on each side of each control valve and each coil, if control system sensors are not installed in such locations.

PART 3 EXECUTION

3.1 SUBMITTALS

A. Submittal requirements relative to commissioning are found in this Section and in Sections 01810.

B. Prepare a preliminary schedule for pipe system testing, flushing and cleaning for use by the Commissioning Authority. Update the schedule as appropriate.

3.2 OPERATION AND MAINTENANCE (O&M) MANUALS

A. Refer to Section 01810 for requirements for O&M manuals.

3.3 COMMON RESPONSIBILITIES

A. The general commissioning requirements and coordination are detailed in Section 01810 and apply to special systems. The Contractor shall be familiar with all parts of Section 01810 and the commissioning plan issued by the Commissioning Authority and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

B. The requirements and information in this Section is intended to complement and augment the requirements listed elsewhere in the specification as required to support the commissioning process. It is not the intent to require duplicate efforts. For any requirement in this Section, furnishing a copy of similar or nearly similar documentation or performing a task that is nearly identical to that required herein will likely be satisfactory for compliance with these requirements.

C. Notify the Owner two weeks prior to pipe testing, flushing, cleaning and startup of each piece of equipment (water heaters, solar hot water system, specialty pumps, etc.). Notify the Owner ahead of time when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed and that the CA has the scheduling information needed to efficiently execute the commissioning process.

D. Construction Checklists: The Contractor shall develop and execute construction checklists as noted in the list of commissioned systems in Section 01810, following the process described in Section 01810.

E. Check and testing procedure and startup plan development and execution responsibilities are described in the Check and Testing Responsibility Table in the supplements to Section 01810.

F. Training and Orientation: The Contractor shall follow the facility staff orientation and training requirements as described in Section 01810 and other applicable technical sections.

G. Documentation: The Contractor shall follow the documentation requirements as described in Section 01810 and other applicable technical sections. For any testing that the Commissioning Authority is not present, the Contractor shall fully document all testing procedures and results and submit to the Owner.

H. Acceptance Criteria: All systems and assemblies shall meet the specifications, shall have been installed according to the manufacturer's instructions and shall demonstrate compliance with their intended function.

PART 4 VERIFICATION AND TESTING REQUIREMENTS

4.1 SUMMARY

A. This Part specifies the testing requirements for plumbing and related systems and equipment. From these requirements, the Commissioning Authority will develop step-by-step procedures. The general testing process, requirements and test method definitions are described in Section 01810.

4.2 TESTS

A. Testing is intended to begin upon completion of a system. Testing may proceed prior to the completion of systems or sub-systems at the discretion of the Commissioning Authority and Owner. Beginning system testing before full completion, does not relieve the Contractor from fully completing the system as soon as possible, including all construction checklists and may require retesting portions of the system once all components are fully functioning.

B. Refer to Section 01810 for specific details on non-conformance issues relating to construction checklists and tests. Refer to Section 01810, for common requirements of deferred testing and to articles in this Section.

C. The test procedures for each piece of equipment or system shall contain the following:

1. The Contractors responsible to execute the tests, under the direction of the Commissioning Authority.
2. A list of the integral components being tested.
3. Construction checklists associated with the components.
4. Prerequisites to testing.
5. Functions and modes to be tested.
6. Required conditions of the test for each mode.
7. Special procedures.
8. Required methods of testing.
9. Required monitoring.
10. Acceptance criteria.
11. Sampling strategies allowed.

D. Prerequisites: The applicable generic prerequisite checklist items from the list below shall be listed on each written test form and be completed and checked off by Commissioning Authority prior to or during testing:

1. All related equipment has been started up and start-up reports and construction checklists submitted and approved ready for testing:
2. All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.
3. Vibration control report approved (if required).
4. Testing adjusting and balancing complete and approved for the hydronic and air systems.
5. These test procedures reviewed and approved by installing Contractor.
6. Safeties and operating ranges reviewed by the Commissioning Authority.
7. Test requirements and sequences of operation, schedules and set points attached.
8. Sufficient clearance around equipment for servicing.
9. Record of all values for pre-test setpoints changed to accommodate testing has been made and a check box provided to verify return to original values (control parameters, limits, delays, lockouts, schedules, etc.).
10. Other miscellaneous checks of the construction checklist and start-up reports completed successfully.

E. Monitoring: Monitoring is a method of testing as a stand-alone method or to augment active testing. All systems will rely only on active testing, unless monitoring or trending is explicitly listed. For monitoring required in this Section, the general monitoring guidelines given in Section 01815 apply.

F. At the Commissioning Authority's discretion, if large numbers or repeated deficiencies are encountered, the Contractor shall test and troubleshoot all remaining systems at issue on their own before commissioning with the Commissioning Authority will resume.

G. Sampling for Identical Units: When there are a number of identical units, at the Commissioning Authority’s discretion, some or all procedures of a test for a piece of equipment or assembly may be omitted when these same tests on other pieces of identical equipment or assemblies were conducted without deficiency.

4.3 EQUIPMENT-SPECIFIC TESTING REQUIREMENTS

A. The following paragraphs define the testing requirements for each type of system that is a part of the project. The Commissioning Authority shall use this information to develop specific testing procedures for each of the systems to be commissioned. The Contractor shall be responsible for support, execution and coordination of these tests as described in the project specifications including intersystem tests and interlocks with systems in Divisions besides Division 15.

B. Common Testing Requirements

1. The following requirements apply to plumbing and related systems and control that are to be commissioned when referenced below. Tests shall:
   a. Verify functionality and compliance with intent for each individual sequence module in the sequences of operation. Verify proper operation of all control strategies, energy efficiency and self-diagnostics features by stepping through each sequence and documenting equipment and system performance. Test every step in every written sequence and other significant modes, sequences and operational features not mentioned in written sequences; including startup, normal operation, shutdown, scheduled on and off, unoccupied and manual modes, safeties, limits and alarms and reporting, over-rides, lockouts and power failure.
   b. Verify integrated performance of all components and control system components, including all interlocks and interactions with other equipment and systems.
   c. When applicable, demonstrate a full cycle from off to on and no load to full load and then to no load and off.
   d. Verify time of day schedules and setpoints.
   e. Verify that control system graphics are representative of the systems and that all points and control elements are in the same location on the graphic as they are in the field.
   f. Verify operator control of all commandable control system points including proper access level as agreed to during the controls integration meetings.

C. Common Acceptance Criteria:

1. The following common acceptance criteria apply to all equipment and assemblies:

a. For the conditions, sequences and modes tested, the equipment, integral components and related equipment shall respond to varying loads and changing conditions and parameters appropriately as expected, according to the sequences of operation, as specified, according to acceptable operating practice and the manufacturer's performance specifications.
b. Systems shall accomplish their intended function and performance.
c. Control loops shall be stable under all operating conditions. Control loops shall exhibit a quarter decay ratio type response to a step change or other upset and return to stable operation in a time frame that is reasonable and realistic for the system that they are associated with.
d. All safety trips shall require a manual reset to allow a system restart.
e. Resetting a manual safety shall result in a stable, safe, and predictable return to normal operation by the system.
f. Safety circuits and permissive control circuits shall function in all possible combinations of selector switch positions (hand, auto, inverter, bypass, etc.).
g. Other acceptance criteria is given in the equipment testing requirements articles.
h. Additional acceptance criteria will be developed by the Commissioning Authority when detailed test procedures are developed.

D. Equipment-Specific Testing Requirements

1. Piping Tests and Cleaning:

a. Clean, flush, pressure and leak test and treat according to the specifications and codes. Submit a flushing and cleaning plan. Fully document the results of flushing and cleaning and submit a report for all piping flushing, cleaning, tests and water treatment. The Commissioning Authority spot witnesses the domestic flushing, cleaning, testing and reviews reports. The Commissioning Authority verifies the functioning of any heat tracing.

2. Fire Protection--Standpipes, Fire Pumps and Controls:

a. Apply the applicable common testing requirements and acceptance criteria.

b. Flush and pressure test piping according to NFPA 13; 14. Test all piping, controls, pumps, flow and tamper switches, alarms and reporting according to NFPA 13, 14; 20 and regulatory requirements. Verify that there is adequate proximity to drains for testing.

END OF SECTION

THIS PAGE IS INTENTIONALLY LEFT BLANK

SECTION 01815
MECHANICAL SYSTEMS COMMISSIONING

PART 1 GENERAL

1.1 SUMMARY

A. This section specifies the unique responsibilities that are a part of, or are related to the commissioning process for the mechanical systems. Mechanical systems include those listed in Section 01810 as being commissioned. All statements are the responsibility of the Contractor, unless specifically stated otherwise.

B. Related sections.

1. 01810 General Commissioning Requirements
2. 01811 Special Systems Commissioning
3. 15181 Pipe tests
4. 15815 Duct tests

PART 2 PRODUCTS

2.1 TEST EQUIPMENT

A. The Contractor shall provide all test equipment necessary to fulfill the testing requirements, except required data loggers will be provided by the Owner or Commissioning Authority.

B. Refer to Section 01810 for additional requirements.

2.2 TEST PORTS

A. In the hydronic system, install a P/T plug at each temperature sensor which is an input point to the control system and on each side of each control valve and each side of each coil (right next to the coil).

PART 3 EXECUTION

3.1 SUBMITTALS

A. Additional submittal requirements relative to commissioning are found in this Section and in Sections 01810 and 01816.

B. Piping, Ducting and TAB Schedule. At least four weeks prior to setting the first ductwork, prepare and submit an initial schedule for HVAC pipe and duct system testing, flushing and cleaning, equipment start-up and testing adjusting and balancing start and completion for use by the Commissioning Authority. Keep this schedule updated.

C. Pipe Flushing and Cleaning Plan. Submit a plan of the HVAC flushing, cleaning and pressure testing process at least four weeks prior to execution. The plan shall describe how the flushing and cleaning will be accomplished for this project, including phasing, by floors, by system, etc., explaining how proper velocities will be accomplished (give velocities), how large diameter pipe will be cleaned if target velocities are not practical, what locations will have finer strainers put in place, how delicate equipment or sensors will be isolated or removed, bypasses to be used, etc.

D. Duct Testing Plan. Submit a plan of the HVAC ducting testing at least four weeks prior to execution. Describe how the tests will be accomplished, the exact equipment and documentation forms to be used, including formulas, the strategy for staging the tests and the list of which duct sections of each pressure class will be tested, etc.

3.2 OPERATION AND MAINTENANCE (O&M) MANUALS

A. Refer to Section 01810 and other equipment sections for requirements for O&M manuals.

3.3 COMMON RESPONSIBILITIES APPLICABLE TO ALL MECHANICAL EQUIPMENT

A. The general commissioning requirements and coordination are detailed in Section 01810 and apply to mechanical systems. The Contractor shall be familiar with all parts of Section 01810 and the commissioning plan issued by the Commissioning Authority and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

B. The requirements and information in this Section is intended to complement and augment the requirements listed elsewhere in the specification as required to support the commissioning process. It is not the intent to require duplicate efforts. For any requirement in this Section, furnishing a copy of similar or nearly similar documentation or performing a task that is nearly identical to that required herein will likely be satisfactory for compliance with these requirements, with the approval of the Commissioning Authority.

C. The Contractor shall notify the Owner and Commissioning Authority two weeks prior to pipe and duct system testing, flushing, cleaning, startup of each piece of equipment and TAB. The Contractor shall notify the Owner and Commissioning Authority ahead of time when commissioning activities not yet performed or not yet scheduled will delay construction. The Contractor shall be proactive in seeing that commissioning processes are executed and that the Commissioning Authority has the scheduling information needed to efficiently execute the commissioning process.

D. Construction Checklists. The Contractor shall develop and execute construction checklists as noted in the list of commissioned systems in Section 01810, following the process described in Section 01810.

E. Check and testing procedure and startup plan development and execution responsibilities are described in the Check and Testing Responsibility Table in the supplements to Section 01810.

F. The Contractor shall respond to notices of issues identified during the commissioning process, making required corrections or clarifications and returning prompt notification to the Commissioning Authority according to the process given in Section 01810.

G. When completion of a task or other issue has been identified as holding up any commissioning process, particularly functional testing, the Contractor shall, within two days of notification of the issue, notify the Commissioning Authority in writing providing an expected date of completion. The Contractor shall notify the Commissioning Authority in writing within one day of completion. It is not the responsibility of the Commissioning Authority to obtain this status information through meeting attendance, asking questions or field observation.

H. Training and Orientation. The Contractor shall follow the facility staff orientation and training requirements as described in Section 01820 and other applicable technical sections.

I. Documentation. The Contractor shall follow the documentation requirements as described in Section 01810 and other applicable technical sections. For any testing that the Commissioning Authority is not present, the Contractor shall fully document all testing procedures and results and submit to the Owner.

3.4 CONTROLS REQUIREMENTS

A. The Contractor's commissioning-related responsibilities related to controls in addition to responsibilities listed elsewhere in the specifications are:

1. Submit detailed sequences of operation in a format and rigor as provided in the example provided in Supplement 4 to Section 01810 and other sections of the specifications.
    a. These sequences of operation shall be approved by the Designers and Commissioning Authority prior to programming.
2. Submit a written checkout plan indicating in a step-by-step manner, the procedures that will be followed to test, checkout and adjust the control system prior to testing, according to the process in Section 01810. At minimum, the plan shall include for each type of equipment controlled by the automatic controls:

    a. System name.
    b. List of devices.
    c. Step-by-step procedures for testing each controller after installation, including:
        1) Process of verifying proper hardware and wiring installation.
        2) Process of downloading programs to local controllers and verifying that they are addressed correctly.
        3) Process for performing and documenting point-to-point checkout for each digital and analog input and output.
        4) Process of performing operational checks of each controlled component.
        5) Plan and process for calibrating valve and damper actuators and all sensors.
        6) A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.
    d. A copy of the log and field checkout sheets that will document the process. This log must include a place for initial and final read values during calibration of each point and clearly indicate when a sensor, controller or command has “passed” and is operating within the contract parameters.
    e. A description of the instrumentation required for testing.
    f. Indicate what tests on what systems should be completed prior to TAB using the control system for TAB work. Coordinate with the Commissioning Authority and TAB contractor for this determination.
3. Point-to-point Checkout: Included in the checkout plan will be a point-to-point checkout. Each control point tied to a central control system will be verified to be commanding, reporting and controlling according to its intended purpose. For each output, commands will be initiated and verified to be functioning by visually observing and

documenting the status of the controlled device in the field (e.g., command lights or sound off, command cooling coil valve to full open, or command heating water pump off). For each input, the system or conditions will be perturbed to initiate the input response being tested and the response in the control system observed and recorded (e.g., high duct static pressure alarm).

4. Calibrations: The construction checklists will contain requirements for calibrations. The CONTRACTOR is responsible to calibrate all field-installed sensors and actuators using test and documentation methods given in Calibration and LoopCheck Procedures Supplement in section 01810.
   a. Sensors installed in the unit at the factory with calibration certification provided need not be field calibrated.
   b. Valve leak-by tests shall be conducted by the CONTRACTOR for all control valves with a design flowrate of over 10 gpm when leak-by past the closed position will result in energy waste.
   c. All procedures used shall be fully documented on the construction checklists or other suitable forms, clearly referencing the procedures followed and written documentation of initial, intermediate and final results.
5. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control and virtual points as specified in the Specifications.
6. Provide a signed and dated certification to the Owner and Commissioning Authority upon completion of the checkout of each controlled device, equipment and system prior to functional testing with or for the Commissioning, that all system and sequence programming is complete and has been calibrated, checked out and debugged and is ready for full functional testing demonstration to the Commissioning Authority and Owner.
7. List and clearly identify on the as-built duct and piping drawings the locations of all static and differential pressure sensors (air, water and building pressure).

PART 4 VERIFICATION AND TESTING REQUIREMENTS

3.1 SUMMARY

A. This Part specifies the testing requirements for HVAC and mechanical systems and equipment. From these requirements, the Commissioning Authority or Contractor will develop step-by-step procedures. The general testing process, requirements and test method definitions are described in Section 01810.

3.2 TESTS

A. Testing is intended to begin upon completion of a system. Testing may proceed prior to the completion of systems or sub-systems at the discretion of the Commissioning Authority and Owner. Beginning system testing before full completion, does not relieve the Contractor from fully completing the system as soon as possible, including all construction checklists and may require retesting portions of the system once all components are fully functioning.

B. Refer to Section 01810 for specific details on non-conformance issues relating to construction checklists and tests. Refer to Section 01810, for common requirements of deferred testing and to articles in this Section.

C. The test procedures for each piece of equipment or system shall contain the following:
   1. The Contractors responsible to execute the tests.
   2. A list of the integral components being tested.
   3. Construction checklists associated with the components.
   4. Prerequisites to testing.
   5. Functions and modes to be tested.
   6. Required conditions of the test for each mode.
   7. Special procedures.
   8. Required methods of testing.
   9. Required monitoring.
   10. Acceptance criteria.
   11. Sampling strategies allowed.

D. Prerequisites. The applicable generic prerequisite checklist items from the list below shall be listed on each written test form and be completed and checked off by Commissioning Authority prior to or during testing:
   1. All related equipment has been started up and start-up reports and construction checklists submitted and approved ready for testing:
   2. All control system functions for this and all interlocking systems are programmed and operating per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.
   3. Piping system flushing complete and required report approved.
   4. Water treatment system complete and operational.
   5. Vibration control report approved (if required).

6. Testing adjusting and balancing complete and approved for the hydronic and air systems.
7. These test procedures reviewed and approved by installing Contractor.
8. Safeties and operating ranges reviewed by the Commissioning Authority.
9. Test requirements and sequences of operation, schedules and setpoints attached.
10. False loading equipment, system and procedures ready.
11. Crankcase heaters have been on long enough for immediate startup.
12. Sufficient clearance around equipment for servicing.
13. Record of all values for pre-test setpoints changed to accommodate testing has been made and a check box provided to verify return to original values (control parameters, limits, delays, lockouts, schedules, etc.).
14. Other miscellaneous checks of the construction checklist and start-up reports completed successfully.

E. Monitoring
1. Monitoring is a method of testing as a stand-alone method or to augment active testing. Features and functions not able to be fully or readily verified through active tests shall be verified through BAS trend logs, including, but not limited to, space and discharge air temperature and pressure control, relative humidity control (if required), hydronic loop temperatures, outside air control, optimum start, cycling and staging control and time of day scheduling.
2. All points listed in the required monitoring section of the test requirements of each equipment which are control system monitored points shall be trended by the Contractor from a specific request from the Commissioning Agent. Up to 75% of all real and virtual points in the building automation system may be required to be trended (at different times) at as fine a frequency as two minutes for as long as two weeks. Required points may be specifically listed, but are not limited to those identified in the testing requirements in this section. Retrending may be required, at no additional cost to the Owner, to verify corrections or further diagnose problems.
3. Other points may be monitored by the Commissioning Authority using dataloggers.
4. The Commissioning Authority will analyze the trend data and issue a report of findings.
5. Trend data from the building automation system shall be provided by the CONTRACTOR electronically with the following characteristics:
   a. Data shall be 24 hour continuous, unless specified otherwise.

b. The data shall be provided in files that can be directly used in spreadsheet software.
c. The .CSV file format is preferred.
d. The spreadsheet-ready format file shall have date and time down the left column with at least four columns to the right, each containing the data from a trended point.
e. The Contractor shall provide a description of each point abbreviation being trended, including the units of the value.
f. The time of day schedules associated with all trended equipment shall be provided.
g. When possible, the individual files will group points from the same equipment or system.
h. Data will be gathered in such a manner as to not cause such a drag on the system that some sampling will be missed and trend output will have missing data.
i. Data will be downloaded as needed during the trend to ensure no loss of data.
j. If critical data is missing from the trend output, the Contractor shall be responsible to retrend the points.
k. The Contractor shall notify the Commissioning Authority when they have made any changes or adjustments to the system during the trend period that may cause data interpretation problems.

6. Prior to the actual trend log being started, the Contractor shall provide an electronic file of a sample trend log to the Commissioning Authority to ensure proper formats.
7. Hard copies of monitored data, when requested, must be in columnar format with time down the left column and at east four columns of point values on the same page.
8. Some trending and monitoring may occur during manual testing. Most trending and monitoring will occur after systems have been manually tested and are under normal control. This may be after substantial completion or during occupancy, at the discretion of the Commissioning Authority.

F. At the Commissioning Authority's discretion, if large numbers or repeated deficiencies are encountered, the Contractor shall test and troubleshoot all remaining systems at issue on their own before commissioning with the Commissioning Authority will resume.

G. Sampling for Identical Units. When there are a number of identical units, at the Commissioning Authority’s discretion, some or all procedures of a test for a piece of equipment or assembly may be omitted when these same tests on other pieces of identical equipment or assemblies were conducted without deficiency.

H. Opposite Season Tests. As much testing as possible will occur prior to or during turnover, during which some functions may be tested out of season (heating functions tested during warm weather). However, generally some testing shall occur in both the primary heating and cooling seasons. Specific requirements are given in this section. The Contractor shall return to the site for these tests. The Contractor is responsible for troubleshooting identified deficiencies unless Contractor can demonstrate the problem is due to design.

3.3 SPECIFIC TESTING REQUIREMENTS

A. The following paragraphs define the testing requirements for each type of system or feature that is a part of the project. The Commissioning Authority shall use this information to develop specific testing procedures for each of the systems to be commissioned. The Contractor shall be responsible for support, execution and coordination of these tests as described in the project specifications including intersystem tests and interlocks with systems in Divisions besides Division 15.

B. Common Testing Requirements (applicable to all mechanical equipment)
   1. The following requirements apply to all mechanical and control systems and features that are to be commissioned when referenced below. Tests shall:
      a. Verify functionality and compliance with the design intent for each individual sequence module in the sequences of operation. Verify proper operation of all control strategies, energy efficiency and self-diagnostics features by stepping through each sequence and documenting equipment and system performance. Test every step in every written sequence and other significant modes, sequences and operational features not mentioned in written sequences; including startup, normal operation, shutdown, scheduled on and off, unoccupied and manual modes, safeties, alarms, over-rides, lockouts and power failure.
      b. Verify operation of systems and components that may be impacted during low, normal and high load conditions and during combinations of environmental and interacting equipment conditions that could reasonably exist that could result in adverse system reaction.

c. Verify all alarm and high and low limit functions and messages generated on all points with alarm settings.
d. Verify integrated performance of all components and control system components, including all interlocks and interactions with other equipment and systems.
e. Verify shut down and restart capabilities both for scheduled and unscheduled events (e.g. power failure recovery and normal scheduled start/stop).
f. Verify proper sequencing of heat transfer elements as required to prevent simultaneous heating and cooling.
g. Verify control system stability and tuning by upsetting various control loops under different load conditions and observing the system response.
h. When applicable, demonstrate a full cycle from off to on and no load to full load and then to no load and off.
i. Verify time of day schedules and setpoints.
j. Verify all energy saving control strategies.
k. Verify that control system graphics are representative of the systems and that all points and control elements are in the same location on the graphic as they are in the field.
l. Verify operator control of all commandable control system points including proper access level as agreed to during the controls integration meetings.
m. All testing will be fully documented by the party designated in the Check and Testing Responsibility Table in Section 10810.

C. Common Acceptance Criteria (applicable to all mechanical equipment).
1. The following common acceptance criteria apply to all mechanical equipment, assemblies and features:
a. For the conditions, sequences and modes tested, the equipment, integral components and related equipment shall respond to varying loads and changing conditions and parameters appropriately as expected, according to the sequences of operation, as specified, according to acceptable operating practice and the manufacturer's performance specifications.
b. Systems shall accomplish their intended function and performance (e.g., provide air and water at designated temperature, humidity and flow rate, etc., maintain space conditions (light and air) at specified levels at varying conditions, etc.).
c. Control loops shall be stable under all operating conditions. Control loops shall exhibit a quarter decay ratio type response

to a step change or other upset and return to stable operation in a time frame that is reasonable and realistic for the system that they are associated with.

d. All safety trips shall require a manual reset to allow a system restart.

e. Resetting a manual safety shall result in a stable, safe, and predictable return to normal operation by the system.

f. Safety circuits and permissive control circuits shall function in all possible combinations of selector switch positions (hand, auto, inverter, bypass, etc.).

g. Other acceptance criteria is given in the equipment testing requirements articles.

h. Additional acceptance criteria will be developed by the Commissioning Authority when detailed test procedures are developed.

D. Equipment-Specific Testing Requirements

1. Air Handler Units

a. These requirements apply to all air handlers (constant volume, variable air volume and outside air units) and include all components--fans, ducts, coils, valves, dampers, packaged and central control.

b. Have the vendor's startup technician, the mechanical contractor and controls contractor participate during the first hour of testing. Thereafter, the controls contractor and mechanical contractor shall finish testing with the Commissioning Authority.

c. Apply the applicable common testing requirements and acceptance criteria.

d. Test the functions of the economizer, dampers, cooling and preheat or heating coil and valves, humidifier, dehumidification functions, heat recovery components, outside air control, CO2 control when applicable, staging of heating and cooling, discharge air temperature and duct and underfloor plenum static pressure, fan speed, variable speed drive functions, including hand, off, auto, supply and return fan/exhaust interactions, optimum start, proper temperature difference across coils in heating and cooling mode, smoke damper functions, night high and low limit, alarms, heating/cooling changeover, freeze stat, low temperature operation, verify minimum outdoor air control, mixed air temperature control and sensor calibrations. Verify no simultaneous heating and cooling, no valve leak-by and proper building pressurization control.

e. Test Methods. Utilize active testing for most functions. Utilize trending to verify proper operation of key functions, including all control loops that entail setup and tuning (temperature and pressure controls).

f. Opposite Season Testing. Required.

g. Additional Acceptance Criteria.

   1) Air handler unit with supporting systems shall be able to maintain the supply air temperature within 1.0F either side of the deadband of the current setpoint during stable periods and without excessive hunting (within +/- 4F during staging).

   2) Air handler unit with supporting systems shall be able to maintain the space temperature to within 2F of setpoint during all seasons when design assumptions are not exceeded.

   3) Space relative humidity shall be maintained within +/- 10% RH of setpoint.

2. Variable Frequency Drives (VFD)

   a. VFD's are tested integrally with the equipment they control for their functionality with controlled equipment.

   b. Apply the applicable common testing requirements and acceptance criteria.

   c. Verify that automatic features function regardless of whether inverter mode or bypass mode is selected as long as the drive is in auto. Verify that drive can be run in bypass, that low and high speed limits are set and functioning and that ramping up and down functions are working.

   d. Test Methods. Utilize manual methods.

   e. Sampling Strategy. Test all.

   f. Opposite Season Testing. None required.

3. Terminal Units-Air (including all components).

   a. Apply the applicable common testing requirements and acceptance criteria.

   b. Verify damper and fan sequences during heating, cooling, dead bands, occupied, unoccupied, verify flow, valve stroke, verify by measurement, cooling coil valve and heating coil valve positive shutoff (no leak-thru) and thermostat functions. Verify performance of space temperature control.

c. Test Methods. Utilize active testing for most functions. Utilize trending to further verify proper operation of key functions, including all control loops that entail setup and tuning (temperature and pressure controls).

d. Sampling Strategy. Test 5% of identical type units (four minimum). If 10% of any given function fail, test the failed functions on another 5%. If 10% of second sample fail, contractor shall document retesting of all units.

e. Opposite Season Testing. Not required, unless problems exist, except that space temperatures will be trended in the opposite season.

f. Additional Acceptance Criteria.

    1) Space temperature during occupied modes shall average within +/- 1°F of setpoint and always remain within 1°F of the ends of the deadband without excessive hunting of either the damper or coil valve, or complaints of drafts or stuffiness from occupants.

4. Heating Water System (including all components--boiler, pumps, valves, controls, etc.).

    a. Apply the applicable common testing requirements and acceptance criteria.

    b. Performance Tests Conducted and Documented by Manufacturer's Service Representative.

        1) During start-up, test and document all safeties and other recommended set up and test procedures, per manufacturer's recommendations.

        2) Hydrostatically test assembled boiler and piping in accordance with applicable sections of ASME "Boiler and Pressure Vessel Code."

        3) Perform boiler efficiency tests. Operate boiler and record data when operating at low fire start, 20, 40, 60, 80, 100, 80, 60, 40 and 20 percent of full load. The Contractor shall provide and operate all calorimeter, flue gas analysis equipment necessary to determine the efficiency of the boiler and burner at the various load points. Prepare and submit the ASME combustion efficiency abbreviated form for each boiler test. Prepare and submit boiler efficiency curves from data of test points.

        4) Perform combustion efficiency test. Demonstrate optimum burner performance. Orsat analyzer or portable electronic flue gas analyzer may be used for flue gas

analysis. When burners need readjustment tests shall be repeated.

c. Functional Testing Directed By Commissioning Authority.
   1) Have the vendor's startup technician, the mechanical contractor and controls contractor participate during the first hour of testing. Thereafter, the controls contractor and mechanical contractor shall finish testing with the Commissioning Authority.
   2) Operate boilers, boiler trims, burner and combustion control, gas burner system, including all interlock and indicating functions to demonstrate compliance with specified requirements. During the test, boilers shall be started-up in accordance to manufacturer's recommended start-up instructions. Output capacity shall be increased gradually from low to maximum, then from maximum back to low. The test shall be witnessed and shall include an operational test of each safety device including limit switches, differential pressure switches, relief valves, combustion chamber purge controls, flame safety controls, fuel system safety, power failure safety, and all safety alarms and annunciations. Demonstrate the proper performance of automatic recording and sensing systems.
   3) Fully test primary and secondary loops and on-board control panel functions and features. Test each possible lead boiler as lead boiler, and each pump as lead pump. Test pump lockouts. Test variable speed drive functions, including hand, off, auto. Verify system and zone component sizing by verifying that the design temperature difference between supply and return water is met. Verify that the HW reset parameters and staging parameters are appropriate by examining the HWST and HWRT and the reset and staging parameters. Demonstrate proper functioning of all indicating lights.

d. Phased Testing. The heating water system will be tested in phases (primary plant / loop, secondary loop; entire system) according the plan developed and referenced in Section 01810.
e. Test Methods. Utilize active testing for most functions. Utilize trending to verify proper operation of key functions.
f. Sampling Strategy. Test all units.
g. Opposite Season Testing. Yes, in near design conditions.
h. Additional Acceptance Criteria.

1) Boiler performance criteria (condensing boilers): 94% minimum at 120F entering water and 25% fire and 91% minimum at 120F EWT water and 100% fire.
2) Boiler shall maintain the supply water setpoint to within +/- 3F of setpoint deadband during non-startup periods and without excessive hunting (within +/- 6F during staging).
3) Pumping system and controls shall maintain the current desired pressure setpoint to within an amount equal to 10% of the setpoint value either side of the deadband without excessive hunting.

5. Chilled Water System (including all components--chiller, pumps, cooling tower, piping, valves, controls, etc.).
   a. Apply the applicable common testing requirements and acceptance criteria.
   b. Have the vendor's startup technician, the mechanical contractor and controls contractor participate during the first hour of testing. Thereafter, the controls contractor and mechanical contractor shall finish testing with the Commissioning Authority. Fully test primary and secondary loops and on-board control panel functions and features. Test variable speed drive functions, including hand, off, auto. Test lead lag and standby action of chillers and pumps, refrigerant release, low load operation, pump differential pressure control, heat exchanger functions, verify design supply/return temperature difference and cooling tower and condenser water temperature control functions. Cooling tower functions including sump heater, low and high water alarms and fan vibration control. Demonstrate proper functioning of all indicating lights. For air-cooled water chillers verify proper pressure drop across water-side of air-cooled condenser and sequencing and cycling of condenser fans.
   c. Test Methods. Utilize active testing for most functions. Utilize trending to verify proper operation of key functions, including all control loops that entail setup and tuning (temperature and pressure controls).
   d. Sampling Strategy. Test all units.
   e. Opposite Season Testing. Yes, in near design conditions.
   f. Additional Acceptance Criteria.
      1) Chiller shall maintain the chilled water supply setpoint to within +/- 1.0F of setpoint deadband during stable periods and without excessive hunting (within +/- 3F during staging).

2) Pumping system and controls shall maintain the current desired pressure setpoint to within an amount equal to 10% of the setpoint value either side of the deadband without excessive hunting or for reset pressure, shall reset consistently keep all zones satisfied with minimum pumping pressure.
3) Cooling tower should be able to maintain the current specified setpoint for entering condenser water to within +/- 2F, when outside conditions do not restrict this thermodynamically.

6. Piping (HVAC hydronic, domestic and storm water supply, drainage and venting).
   a. Clean, flush, pressure and leak test and treat according to the specifications and codes. Submit a flushing and cleaning plan. Fully document the results of flushing and cleaning and submit a report for all piping flushing, cleaning, tests and water treatment. The Commissioning Authority spot witnesses the HVAC and domestic flushing, cleaning, testing and reviews reports. The Commissioning Authority verifies the functioning of any heat tracing.

7. Ductwork and Building Plenums.
   a. Duct testing procedures are found in Section 15815.
   b. Clean, pressure and leak test according to the specifications and codes, following methods given in *SMACNA HVAC Air Duct Leakage Test Manual.*
   c. For the ductwork of the first major air handler installed, pressure / leak test all medium pressure ductwork from the air handling unit to terminal units. Other air handler duct systems will be visually inspected, benchmarked off the successful first air handler. Duct sections of other air handlers may be required to be tested, if the Commissioning Authority identifies duct sealing or construction that appears deficient. More stringent requirements elsewhere in the specifications will take precedence.
   d. Contractor to submit a plan of pressure testing and fully document the results and submit a report. The Commissioning Authority spot witnesses portions of this activity.
   e. Any building elements used as supply chases or plenums shall be leak tested by the Contractor with their equipment. The first of multiple plenums shall be pressure tested to establish a benchmark of acceptable joint and penetration construction

sealing. If the first plenum fails, additional plenums shall be tested until one is successful. Thereafter, only construction joinery will be inspected.

f. Acceptance Criteria: Leakage shall not exceed two percent of maximum system air quantity indicated in the schedules. More stringent requirements elsewhere in the specifications will take precedence.

8. Testing, Adjusting and Balancing (TAB) Work.
   a. Commissioning Authority shall review TAB report for anomalies and areas that may be performing marginally.
   b. Contractor shall retest supply, return and exhaust registers and hydronic balancing fittings using the same equipment used to perform the original balancing. If 10% fail, test another 10%. If 10% of second sample fail, contractor shall document retesting of all devices of that type . The retest samples are:
      1) Office and administrative areas supply and return: up to 5%.
      2) General building exhaust: 0%.
      3) Hydronic system: 5% of the water balance fittings.
   c. Air Handlers. On two of the air handlers, repeat minimum outside air quantity tests, if Commissioning Authority temperature difference method testing does not corroborate the balance report values.
   d. Pumps. On 25% of the pumps over 200 gpm (minimum of two), repeat the total flow tests, if the Commissioning Authority's differential pressure readings across the pump correlated to the pump curve do not corroborate the balance report values.
   e. Acceptance Criteria: Readings shall be within 10% of balance report for air and water.

9. Building Automation System (BAS)
   a. A significant part of the BAS testing requirements is the successful completion of the tests of equipment the BAS controls or interlocks with. Integral or stand-alone controls shall be functionally tested with the equipment they are attached to, including any interlocks with other equipment or systems and thus are not covered under the BAS testing requirements, except when interlocked to the BAS.
   b. The CONTRACTOR shall fully demonstrate and test all features, modes, alarms and sequences for equipment and systems that are controlled by the BAS, but do not have explicit testing requirements listed in the specifications.

c. Testing and verification shall occur after the CONTRACTOR has performed their own testing and verifications.
d. Apply the applicable common testing requirements and acceptance criteria.
e. Test to ensure that all functions and features are working properly and according to the specifications, including, but not limited to:
   1) Trending and archiving features and standard trend log library
   2) Monitoring of, and communication with other equipment
   3) Power monitoring
   4) Graphic screens
   5) Access passwords
   6) Battery back-up
   7) Clock operation and setting in field panels and central workstation
   8) Set point changing
   9) Calibrations and air terminal box setup capabilities
   10) Remote monitoring and remote access
   11) Alarming on and off site
      a) Alarms generation, levels and messages
      b) Redailing after "busy", "no answer" or otherwise incomplete calls
   12) Panels' response to LAN communication failures
   13) Self-diagnostics and annunciation of each field panel
   14) Communication Speed. Verify the following maximum annunciation or update times at the operator work station during reasonably heavy network traffic, as agreed upon by the Commissioning Authority in accordance with section 15900.
   15) Loop Response. The Contractor shall supply trend data output in graphical form clearly showing the step response of each DDC loop showing the loop's response to a step change of at least 25% of its full range, sampled at a frequency agreed upon by the Commissioning Authority. The trend data shall show for each loop, the set point, command, actuator position, and controlled variable value. Loops that are hunting (never maintaining within setpoint deadband) or that take longer than three cycles to settle within setpoint deadband (each succeeding amplitude is at least 30% less than the previous) shall be retuned.

16) Shutdown and Restart. Shut the DDC and controlled systems off and then restart. The DDC system shall restart and obtain stable control of systems without safety trips, nuisance alarms, excessive deviations in temperatures or pressures or unspecified manual resets.
17) Verify up to 10% of sensors' and actuators' calibrations. If any device fails, select an additional 10% to check. This may be part of equipment tests.
18) Interlocks with fire, lighting, security, etc.
19) Functionality of the access jacks in field panels
20) Verify that all control and energy efficiency strategies are set up and operating properly, such as optimum start/stop, night low and high limit, night flushing, demand limiting, power monitoring, etc.

f. Test Methods. Utilize active testing for most functions. Provide trends as listed above.

g. Sampling Strategy. Test all, except for calibrations as described above.

h. Opposite Season Testing. Not required other than trend logs as listed above and in specific equipment tests.

i. Fine Tuning. The Contractor shall provide 16 hours of the senior control programmer of this project's time for fine-tuning and implementing features requested by the Owner, not explicitly provided in the specifications. This work shall be done within the warranty period at the request of the Owner and is in addition to time required to handle warranty issues.

END OF SECTION

THIS PAGE IS INTENTIONALLY LEFT BLANK

SECTION 01816
ELECTRICAL SYSTEMS COMMISSIONING

PART 1 GENERAL

1.1 SUMMARY

A. This section specifies the unique responsibilities that are a part of, or are related to the commissioning process for the electrical systems. Electrical systems include those listed in Section 01810 as being commissioned. All statements are the responsibility of the Contractor, unless specifically stated otherwise.

B. Electrical Systems Commissioning consists of static checks of component and system installations and actual testing of equipment conditions and functions.

C. The Commissioning Authority or Owner will review and approve, prior to use, all test procedures and forms used and will witness a varying fraction of the initial checks and testing performed by the Contractor. The Commissioning Authority will review the completed check and test documentation of the Contractor of all checks and tests.

D. Electrical testing requirements are found in various sections in Division 16 and in Division 1 (Sections 01810, 01816). It is not the intent of the commissioning process or these specifications to duplicate efforts or to require the Contractor to perform any check or test twice. All checks and testing by the Contractor is expected to occur once in the normal sequence of installation and checkout, if appropriate coordination has occurred allowing the Owner and the Commissioning Authority to witness installations and initial testing. Identical electrical checks and testing requirements in both Division 1 and Division 16 are referring to the same event.

E. The test requirements listed in this section do not release the Contractor from the obligation to perform all other appropriate, industry standard, manufacturer-recommended or code-required checks and tests.

F. Testing Participants: The work of this section shall be performed by parties identified in the Check and Testing Responsibility Table supplement to Section 01810. All static checks and testing shall be fully documented according to provisions in Section 01810.

G. Related sections:
   1. 01810 General Commissioning Requirements
   2. 01811 Special Systems Commissioning

1.2 QUALITY ASSURANCE

A. Qualifications
   1. The CTC (Certified Electrical Testing Company) performing the work of this section shall be qualified to test electrical equipment and is a NETA (International Electrical Testing Association)-certified testing agency. The CTC shall not be associated with the manufacturer of equipment or systems under test.

B. Test Equipment
   1. The Contractor shall provide all test equipment necessary to fulfill the checks and testing requirements.
   2. Refer to Section 01810 for additional requirements.

PART 2 (NOT USED)

PART 3 EXECUTION

6.1 SUBMITTALS

A. Sixty days before any testing is conducted, submit an overall testing plan and schedule for electrical systems that lists the equipment, modes to be tested, dates of testing and parties conducting the tests. Put these tests into the master construction schedule. Keep this plan and schedule updated.

B. Additional submittal requirements relative to commissioning are found in this Section and in Sections 01810 and 01815.

6.2 COMMON RESPONSIBILITIES

A. The following are responsibilities applicable to all electrical systems being commissioned.

B. The general commissioning requirements and coordination are detailed in Section 01810 and apply to electrical systems. The Contractor shall be familiar with all parts of Section 01810 and the commissioning plan issued by the Commissioning Authority and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

C. The work of this Section shall be performed by a CTC, by the EC (Electrical Contractor), or the MSR (Manufacturer's Service Representative). The Commissioning Authority has some testing responsibilities for some equipment. The specified checks and static tests are conducted by any of the above listed parties, but the tests requiring measurements or special tools or skills are generally conducted only by the CTC. The Check and Testing Responsibility Table, included as a supplement to Section 01810 provides specific allocation of check listing and testing responsibilities. The CTC, EC, and MSR shall document all checks and testing on check and test procedure forms submitted to and approved by the Commissioning Authority prior to testing.

D. The Contractor shall notify the Owner ahead of time when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed and that the CA has the scheduling information needed to efficiently execute the commissioning process.

E. The Contractor shall respond to notices of issues identified during the commissioning process, making required corrections or clarifications and returning prompt notification to the Commissioning Authority according to the process given in Section 01810.

F. When completion of a task or other issue has been identified as holding up any commissioning process, particularly functional testing, the Contractor shall, within two days of notification of the issue, notify the Commissioning Authority in writing providing an expected date of completion. The Contractor shall notify the Commissioning Authority in writing within one day of completion. It is not the responsibility of the Commissioning Authority to obtain this status information through meeting attendance, asking questions or field observation

G. Construction Checklists

H. The Commissioning Authority or Contractor shall develop checklists as assigned in the Check and Testing Responsibility Table supplement to Section 01810, following the process described in Section 01810 and in this Section. At a minimum, for a given piece of equipment, all checks from the inspection checklists in *NETA Acceptance Testing Specifications for Electric Power Distribution Equipment and Systems* shall be included in the electrical checklists. The Contractor shall execute and document all checks.

I. Check and testing procedure and startup plan development and execution responsibilities are described in the Check and Testing Responsibility Table in the supplements to Section 01810.

J. The Contractor shall review design documents, shop drawings and O&M manuals and manufacturer recommended installation and testing procedures of each system installation.

K. The Contractor shall monitor installation to ensure the equipment, configuration and quality of construction meets the design requirements, approved submittals and shop drawings.

L. The Contractor shall develop test procedures and forms and execute and document testing as assigned in the Check and Testing Responsibility Table supplement to Section 01810, according to the requirements of this Section, Section 01810 and other specification sections containing testing requirements.

M. Tests of energized equipment shall be conducted when the equipment is operating at its normal capacity. This may require some tests to be conducted after occupancy.

N. Training and Orientation: The Contractor shall follow the facility staff orientation and training requirements as described in Section 01820 and other applicable technical sections.

O. Operation and Maintenance (O&M) Manuals: Refer to Section 01810 for requirements for O&M manuals.

PART 4 EQUIPMENT-SPECIFIC VERIFICATION AND TESTING REQUIREMENTS

8.1 SUMMARY

A. This Part specifies the check and testing requirements for electrical components and systems. From these requirements, the Commissioning

Authority or Contractor will develop detailed procedures and forms. The general testing process, requirements and test method definitions are described in Section 01810.

8.2 CHECKS AND TESTS

A. “Checks” are intended to begin upon completion of a component or equipment installation. “Testing” generally occurs later when systems are energized or nearing that point. Beginning system testing before full completion does not relieve the Contractor from fully completing the system as soon as possible, including all construction checklists and may require retesting portions of the system once all components are fully functioning.

B. Refer to Section 01810 for specific details on non-conformance issues relating to construction checklists and tests. Refer to Section 01810, for common requirements of deferred testing and to articles in this Section.

C. The check and test procedures and record forms shall contain the following:

1. The Contractors executing the checks or tests.
2. A list of the integral components being inspected and tested, equipment tag numbers, manufacturer, model number, pertinent performance information / rating data.
3. Test equipment used.
4. Construction checklists associated with the components, if any.
5. Any special required conditions of the check or test for each procedure.
6. Items, conditions or functions to be inspected, verified or tested, the checks and testing method given and a place provided with results recorded.
7. Acceptance criteria (attached as a table or as a reference by specific table where the acceptance criteria is found).
8. For each procedure, list the technician performing check or test and company, witnesses of the tests and dates of tests.
9. Sampling strategies used.

D. The test procedures for dynamic equipment like lighting controls, emergency generator or fire alarm shall contain more step-by-step procedures with expected responses similar to the sample test provided as a supplement to Section 01810. The test procedures and forms for more static components like panel boards, switch gear, circuit breakers, transformers, etc., can be more checklist-like in format. For each piece of equipment, checks and test procedures and their documentation record forms may be different documents or combined in the same document, but checks and tests should be grouped.

E. At the Commissioning Authority's discretion, if large numbers or repeated deficiencies are encountered, the Contractor shall test and troubleshoot all remaining systems at issue on their own before commissioning with the Commissioning Authority will resume testing or witnessing.

F. Sampling for Identical Units: When there are a number of identical units, at the Commissioning Authority’s discretion, some or all procedures of a test for a piece of equipment or assembly may be omitted when these same tests on other pieces of identical equipment or assemblies were conducted without deficiency.

8.3 TESTING REQUIREMENTS

A. The following paragraphs define the testing requirements for each type of system or feature that is a part of the project. The Commissioning Authority or Contractor shall use this information to develop specific testing procedures for each of the systems to be commissioned. The Contractor shall be responsible for support, execution and coordination of these tests as described in the project specifications including intersystem tests and interlocks with systems in Divisions besides Division 16.

B. Common Testing Requirements
   1. The following requirements apply to all electrical systems and features that are to be commissioned when referenced below. Tests shall:
      a. Verify functionality and compliance with the design intent for each individual sequence module in the sequences of operation. Verify proper operation of all control strategies, energy efficiency and self-diagnostics features by stepping through each sequence and documenting equipment and system performance. Test every step in every written sequence and other significant modes, sequences and operational features not mentioned in written sequences; including startup, normal operation, shutdown, scheduled on and off, unoccupied and manual modes, safeties, alarms, over-rides, lockouts and power failure.
      b. Verify all alarm and high and low limit functions and messages generated on all points with alarm settings.

c. Verify integrated performance of all components and control system components, including all interlocks and interactions with other equipment and systems.
d. Verify shut down and restart capabilities both for scheduled and unscheduled events (e.g. power failure recovery and normal scheduled start/stop).
e. When applicable, demonstrate a full cycle from off to on and no load to full load and then to no load and off.
f. Verify time of day schedules and setpoints.
g. Verify all energy saving control strategies.
h. Verify that monitoring system graphics are representative of the systems and that all points and control elements are in the same location on the graphic as they are in the field.
i. Verify operator control of all commandable control system points including proper security level access.

C. Common Acceptance Criteria

1. The following common acceptance criteria apply to all mechanical equipment, assemblies and features:
   a. For the conditions, sequences and modes tested the equipment, integral components and related equipment shall respond to varying loads and changing conditions and parameters appropriately as expected, according to the sequences of operation, as specified, according to acceptable operating practice and the manufacturer's performance specifications. Verify that equipment operates within tolerances specified in: governing codes, acceptance criteria contained in the construction documents, manufacturer's literature and according to good operating practice.
   b. Systems shall accomplish their intended function and performance.
   c. All safety trips shall require a manual reset to allow a system restart.
   d. Resetting a manual safety shall result in a stable, safe, and predictable return to normal operation by the system.
   e. Safety circuits and permissive control circuits shall function in all possible combinations of selector switch positions (hand, auto, inverter, bypass, etc.).
   f. Other acceptance criteria are given in the equipment testing requirements articles or referenced standards.
   g. Additional acceptance criteria will be developed by the Commissioning Authority when detailed test procedures are developed.

h. When testing procedures for commissioned equipment are listed in *NETA Acceptance Testing Specifications for Electric Power Distribution Equipment and Systems* the NETA performance criteria shall apply.

D. Equipment-Specific Testing Requirements

1. Interior Lighting Controls:
   a. Apply the applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specification.
   c. Test Methods. Utilize active testing, and trending when available. If able to trend, trend all zones over a week period and follow the trending guidelines in Section 01815 Mechanical Systems Commissioning.
2. Exterior Lighting Controls:
   a. Apply the applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specifications.
   c. Test Methods. Utilize active testing, and trending when available. If able to trend, trend all zones over a week period and follow the trending guidelines in Section 01815 Mechanical Systems Commissioning.
3. Fire Alarm:
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test according to NFPA 72.
   c. Document all test procedures and results. A fire alarms system printout of the test annunciation record is not sufficient documentation.
   d. Verify all fire alarm panel functions, alarms and troubles.
   e. Verify all functions in the Fire Alarm Response Matrix, including remote communications.
   f. Verify resetting of all equipment affected by an alarm.
   g. Sampling Strategy: Verify device functions and annunciations per using the approved sampling rate of the authority having jurisdiction.
4. Wire and Cable:
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specifications.
5. Wiring Devices (switches and outlets):
   a. Apply applicable common testing requirements and acceptance criteria.

   b. Test in accordance with the electrical specifications.
6. Panel Boards:
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specifications.
7. Disconnect Switches:
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specifications.
8. Motor Controllers:
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specifications.
9. Switchgear:
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specifications.
10. Motor Control Centers:
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specifications.
11. Transformers:
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specifications.
12. Grounding and Bonding.
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test a in accordance with the electrical specifications.
13. Grounding
   a. Apply applicable common testing requirements and acceptance criteria.
   b. Test in accordance with the electrical specifications.

END OF SECTION

THIS PAGE IS INTENTIONALLY LEFT BLANK

SECTION 01820
DEMONSTRATION AND TRAINING

PART 1 GENERAL

1.1 SUMMARY

A. The OWNER's facility staff (and occupants and service contractors as needed), shall receive orientation and training on features, systems and equipment in this facility requisite with the complexity and criticality of the system and the OWNER's needs.

1.2 EQUIPMENT-SPECIFIC REQUIREMENTS

A. Additional training requirements may be found in specific equipment sections.

PART 2 PRODUCTS

2.1 VIDEO RECORDING

A. The CONTRACTOR shall video record selected trainings, including audio, according to the following schedule:

1. HVAC and Controls: 8 hours
2. Plumbing: 2 hours
3. Electrical: 6 hours
4. Special: 2 hours

B. Which portions of which training sessions are video recorded shall be at the discretion of the Commissioning Authority and OWNER.

C. An introduction shall be made at the beginning of each recording, identifying what equipment is being illustrated, where it is located and who the trainer is.

D. Recording shall be accomplished with a tripod when possible and performed in an expert manner so that the issue being discussed are clearly illustrated and instructions clearly audible. A high quality camera shall be used and additional light provided if ambient light is insufficient.

E. Media shall be clearly labeled with the equipment, date, trainer and segment duration.

F. Recording shall be in video tape format.

1. For larger equipment, not more than one training session shall be put on a single tape. Not more than three pieces of equipment shall be on any single tape, even if the tape is not filled. Small camera sized tapes are acceptable as the final submittal, if a standard VHS adapter tape is provided.

G. Provide an add alternate price for digital recording.

1. The digital recording shall be bookmarked at each training with an index/table of contents provided and recorded on the CD. The bookmarks will clearly indicate which equipment is being presented and the format will allow search and go-to functions for rapidly locating training segments.

H. An original and one copy of the recordings shall be submitted to the OWNER.

PART 3 EXECUTION

3.1 GENERAL RESPONSIBILITIES

A. The CONTRACTOR shall be responsible for training coordination and scheduling and ultimately for ensuring that training is completed on all equipment per the Specifications.

B. The Commissioning Authority will be responsible for coordinating and approving the content and adequacy of the training of OWNER personnel for commissioned equipment.

1. The Commissioning Authority will develop an overall training plan after meeting with the OWNER and appropriate facility staff to determine needs and areas of emphasis for this project.
2. The Commissioning Authority will develop criteria for determining that the training was satisfactorily completed, including attending some of the training, etc. The Commissioning Authority recommends approval of the training to the OWNER's Project Manager.
3. At one of the training sessions, the Commissioning Authority will present a brief presentation discussing the use of the Systems Manual and the blank functional test forms for re-commissioning equipment.

C. Training shall consist of, as needed and at the discretion of the OWNER and Commissioning Authority, the installing technician, installing

CONTRACTOR and the appropriate trade or manufacturer's representative on each major piece of equipment. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment as installed in this project are required. More than one party will be required to execute the training on primary equipment.

D. The controls CONTRACTOR shall attend and present at sessions in addition to the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.

E. The mechanical and electrical design engineer and Architect, or the Commissioning Authority, may attend the first training session for each of the main or special systems and assemblies and present the overall system design. This presentation will include a review of all systems using the simplified system schematics (one-line drawings).

F. Unless otherwise required or approved, the training shall be given during regular business hours during a regular work week.

3.2 TRAINING AGENDAS

A. For each piece of equipment or system a written training agenda shall be submitted by the CONTRACTOR to the Commissioning Authority for review and approval 2 weeks prior to training. The Commissioning Authority may provide a template for this agenda. The agenda shall cover the following elements:

1. Equipment (included in training).
2. Intended audience.
3. Location of training.
4. Objectives.
5. Subjects covered (description, duration of discussion, special methods, etc.).
6. Duration of training on each subject.
7. Instructor for each subject.
8. Methods (classroom lecture, video, site walk-through, actual operational demonstrations, written handouts, etc.).
9. Instructor and qualifications.

3.3 TRAINING PROCESS AND CONTENT

A. The Training Process Shall:

1. As appropriate, normally start with classroom-type sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure, etc.
2. During any demonstration, should the system fail to perform in accordance with the requirements of the operation and maintenance (O&M) manuals or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
3. Follow the outline in the table of contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.

B. Training Shall Include the Following:

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

3.4 DURATION OF TRAINING

A. The CONTRACTOR shall provide training on each piece of equipment according to the following schedule. The CONTRACTOR shall provide training and orientation for other equipment installed on the project not listed here.

Training Schedule	Hours
Mechanical	
Chilled water system (chiller, cooling tower, piping, pumps)	4
Heating water system (boiler, piping, pumps)	8
Air handlers	12
Air terminal boxes	4
Variable speed drives	3
Fan coil units	2
TAB work	2
Automated Control System	8
Plumbing	
Fire protection	
Electrical	
Wire and cable	w/MMC
Interior lighting controls	2
Exterior lighting controls	w/Above
Transformers	w/MMC
Motor control center	4
Ground fault	w/MMC
Secondary grounding	w/MMC
Fire alarm	4

3.5 SPECIAL RESPONSIBILITIES

A. HVAC Controls: The CONTRACTOR shall have the following special training responsibilities relative to the HVAC control systems:

1. For the primary HVAC equipment, the controls contractor shall provide a short discussion of the control of the equipment during the mechanical or electrical training conducted by others.
2. The standard operating manual for the system and any special training manuals shall be provided for and retained by each trainee. In addition, the system technical manual shall be demonstrated during training. Manuals shall include detailed description of the subject matter for each session. The manuals shall cover all control sequences and have a definitions section that fully describes all relevant words used in the manuals and in all software displays. Manuals will be approved by the Commissioning Authority.
3. The trainings will be tailored to the needs and skill-level of the trainees and be oriented to the specific system installed in this project.
4. The trainers shall be knowledgeable on the system and its use in buildings. For the on-site sessions, the most qualified trainer(s) shall be used. The OWNER shall approve the instructor prior to scheduling the training.
5. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system shall be repaired or adjusted as necessary and the demonstration repeated.
6. There shall be two training sessions:
   a. Training I - Control System: The first training shall be __4 hours in length. This training may be held on-site or in the supplier's facility. If held off-site, the training may occur prior to final completion of the system installation. Upon completion, each trainee, using appropriate documentation, should be able to perform elementary operations and describe general hardware architecture and functionality of the system
   b. Training II - Building Systems: The second session shall be held on-site for a period of _4_ hours of actual hands-on training after the completion of system commissioning. The Controls Contractor shall provide the permanent work station with network connections and the controls operating system installed and functioning for this building in the training room for use by the trainees. The session shall include instruction on:

1) A review of the as-built drawings and O&M manuals, a walk-through of the facility to identify control panels and device locations.
2) Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system, including HVAC systems, lighting controls and any interface with security and communication systems.
3) Security levels, alarms, system start-up, shut-down, power outage and restart routines, changing setpoints and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and set points that if changed will adversely affect energy consumption, energy accounting, procedures for obtaining vendor assistance, etc.
4) All trending and monitoring features (values, change of state, totalization, etc.), including setting up, executing, downloading, viewing both tabular and graphically and printing trends. Trainees will actually set-up trends in the presence of the trainer.
5) Every screen shall be completely discussed, allowing time for questions.
6) Use of keypad or plug-in laptop computer at the zone level.
7) Use of remote access to the system via phone lines or networks.
8) Setting up and changing an air terminal unit controller.
9) Graphics generation.
10) Point database entry and modifications.
11) Understanding DDC field panel operating programming (when applicable).

B. Testing Adjusting and Balancing: The CONTRACTOR shall have the following special training responsibilities relative to the testing, adjusting and balancing (TAB) work:

1. The TAB technician shall meet with facility staff after completion of TAB and instruct them on the following:
   a. Go over the final TAB report, explaining the layout and meanings of each data type.
   b. Discuss any outstanding deficient items in control, ducting or design that may affect the proper delivery of air or water.

c. Identify and discuss any terminal units, duct runs, diffusers, coils, fans and pumps that are close to or are not meeting their design capacity.
d. Discuss any temporary settings and steps to finalize them for any areas that are not finished.
e. Other salient information that may be useful for facility operations, relative to TAB.

END OF SECTION

AIR DISTRIBUTION SYSTEM
Construction Checklist - AIR HANDLER UNIT
Tag No.: ________

Components include: Supply fan w/VFD, Chilled Water Coil, Heating Water Coil, Pre-filter, Extended Filter, HEPA Filter, Outside Air Damper, Return Air Damper and Humidifier
Associated Checklists: Chilled and Heating Water Piping

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested documentation submitted

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
Performance data (pump curves, coil data, etc.)			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents*** ___ ***YES*** ___ ***NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manufacturer	1			
	2			
	3			
Model	1			
	2			
	3			
Serial #	3			
Maximum Airflow (CFM)	1			
	2			
	3			
Minimum Airflow (CFM)	1			
	2			
	3			
Cooling Cap. (GPM/MBH)	1			
	2			
	3			
Heating Cap. (GPM/MBH)	1			
	2			
	3			
Volts/Ph/A	1			
	2			
	3			
Other	1			
	2			
	3			

- ***The equipment installed matches the specifications for given trade*** ___ ***YES*** ___ ***NO***

4. Installation Checks

Check	Name	Contr.	Date
Pre-Installation Check			
The AHU is free of physical damage			
The air openings are sealed with durable plastic			
The water openings are sealed with plastic plugs			
The unit appears to be free of water damage			
All access door latches are operational			
All components are present and in the proper sequence			
Installation and startup manual in checklist envelope			
Unit tag no.s are affixed			
Number of rows in the heating coil, design/actual			
The heating coil surface area is free of damage			
Number of rows in the cooling coil, design/actual			
The cooling coil surface area is free of damage			
Fan horsepower, design/actual			
Fan voltage, design/actual			
Cabinet and General Installation Check			
Location and dimensions of pad or curb verified			
Proper clearances around pad/curb verified			
All shipping and installation materials removed			
Maintenance access acceptable for unit and components			
Dedicated floor drain or roof receptor for condensate			
Casing condition good: no dents or leaks			
Door and door frame gaskets installed access doors close tightly - no leaks			
Flex between duct and unit in good condition			
Vibration isolation equipment installed & released from shipping locks			
Seismic restraints installed at fan and not short circuiting			
Sound attenuation installed			
Thermal insulation properly installed and according to specification			
Instrumentation installed according to specification (thermometers, pressure gages, flow meters, etc.)			
Filters installed and replacement type and efficiency permanently affixed to housing--construction filters removed			
All filter frames are gasketed			
Valves, Piping and Coils Check (see piping checklists)			
Pipe fittings complete and pipes properly supported			

Check	Name	Contr.	Date
Pipes properly labeled			
Pipes properly insulated			
Strainers in place and clean			
Piping system properly flushed			
No leaking apparent around fittings			
All coils are clean and fins are in good condition			
All condensate drain pans clean and slope to drain, per spec			
Valves properly labeled			
Valves installed in proper direction			
Flanges or unions installed for coil removal			
Air vents for each coil installed			
Coil drain valves for each coil installed			
Coils are piped counterflow			
Isolation valves for each coil installed			
Return balancing valve for each coil installed			
Control valve installed			
Concentric reducers installed in piping to and from CV			
Strainer installed upstream of CV			
Coil fins are combed out			
Thermometers and pressure gauges are installed			
Condensate pans are properly installed, trapped and run to drain			
P/T plugs installed per drawings			
Fans and Dampers Check			
Supply fan and motor alignment correct			
Supply fan belt tension & condition good			
Supply fan protective shrouds for belts in place and secure			
Supply fan area clean			
Supply fan and motor properly lubricated			
Return/exhaust fan and motor aligned	NA	NA	NA
Return/exhaust fan belt tension & condition good	NA	NA	NA
Return/exhaust fan protective shrouds for belts in place and secure	NA	NA	NA
Return/exhaust fan area clean	NA	NA	NA
Return/exhaust fan and motor lube lines installed and lubed	NA	NA	NA
All dampers close tightly			
All damper linkages have minimum play			
Ductwork Check (preliminary check)			
Sound attenuators installed			
Duct joint sealant properly installed			

Check	Name	Contr.	Date
Ductwork labeling is affixed with correct flow directions			
No apparent severe duct restrictions			
Turning vanes in square elbows as per drawings			
OSA intakes located away from pollutant sources & exhaust outlets			
Pressure leakage tests completed			
Branch duct control dampers operable			
Ducts cleaned as per specifications			
Balancing dampers installed as per drawings and TAB's site visit			
Electrical Check			
Motors: Premium efficiency verified			
Power disconnects in place and labeled			
All electric connections tight			
Proper grounding installed for components and unit			
Starter overload breakers installed and correct size			
VFD Check			
VFD powered (wired to controlled equipment)			
VFD interlocked to control system			
Drive location not subject to excessive temperatures			
Drive location not subject to excessive moisture or dirt			
Drive size matches motor size			
Internal setting designating the model is correct			
Input of motor FLA represents 100% to 105% of motor FLA rating			
Appropriate Volts vs Hz curve is being used			
Accel and decel times are around 10-50 seconds, except for special applications. Actual decel = ______ Actual accel = _____			
Lower frequency limit at 0 for VAV fans and around 10-30% for chilled water pumps. Actual = _______________			
Upper frequency limit set at 100%, unless explained otherwise			
Unit is programmed with full written programming record on site			
Controls Check			
Control panel accessible and properly labeled			
Temperature sensors properly located, secure and calibrated (RA, OA, CC, HC,SA), OA sensor shielded			
PD gauges are installed and calibrated across filters			
Filter PD measuring device installed and calibrated across filter (magnahelic, inclined manometer, etc.)			
Fan DP sensor installed and calibrated			
Fan pitch controls installed and calibrated	NA	NA	NA
Return Air CO2 sensor installed and calibrated	NA	NA	NA

Check	Name	Contr.	Date
Smoke detectors installed in proper location and functioning			
Dampers installed and calibrated			
Hot / chilled water actuators installed and calibrated			
Duct static pressure sensor installed and calibrated			
Low limit freeze stat sensor located to deal with stratification & bypass			
Safety items installed (freeze, high pressure, motor overload)			
All control devices, pneumatic tubing and wiring complete			
Pilot lights are functioning			
Control system interlocks hooked up and functional			
Communication with central system functioning			
TAB			
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents			
Final			
Smoke and fire dampers installed properly per contract docs (proper location, access doors, appropriate ratings verified)			
Smoke and fire dampers and unpowered TU's are open			
Startup report completed with this checklist attached			
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent			
If unit is started and will be running during construction: have quality filters on RA grilles, etc. to minimize dirt in the ductwork and coils and in any finished areas. Verify moisture migration is not a problem, due to improper pressures between spaces.			

- ***The checklist items of Part 4 are all successfully completed for given trade.___YES ___NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
General			
System clean			
Internal isolators adjusted, fan(s) move(s) freely			
Seismic snubbers do not short out isolators			
Manufacturers checklist completed and attached			
Fan lubricated and aligned			
All filters installed properly (no bypass) and clean			
Terminal Unit dampers manually opened or controllable	NA	NA	NA
Vibration isolation inspection report complete (attach)			

Check	Name	Contr.	Date
VFD verification checklist complete			
Fan motor amps, design / actual			
Fans with 3 phase motors - Phase Checks: (%Imbalance = 100 x (avg. - lowest) / avg.) Record all 3 voltages in cell. Imbalance less than 2%?			
System discharge static pressure, design / actual			
Fan rpm, design / actual			
The VFD properly activates and deactivates the unit			
Unit operates without creating objectionable vibration			
Unit operates without creating objectionable noise			
Controls			
All dampers (OA and RA.) stroke fully without binding and spans calibrated and BAS reading site verified (follow procedure in Calibration and Leak-by Test Procedures).			
Valves stroke fully and easily and spanning is calibrated (follow procedure in Calibration and Leak-by Test Procedures).			
Inlet vanes aligned in housing, actuator spanned, modulate smoothly and proportional to input signal and EMS readout	NA	NA	NA
Cooling sequence of control correct (attached)			
Heating sequence of control correct (attached)			
Warm-up sequence of control correct (attached)			
Cool-down sequence of control correct (attached)			
Economizer sequence of control correct (attached)			
IAQ override sequence of control correct (attached)	NA	NA	NA
Unoccupied sequence of control correct (attached)			
Safety items physically tested (freeze, high pressure, motor overload)			
TAB			
Supply fan rotation correct			
Return/exhaust fan rotation correct	NA	NA	NA
Supply fan motor volts, design / actual			
Return fan motor volts, design / actual	NA	NA	NA
Supply fan motor amps, design / actual			
Return fan motor amps, design / actual	NA	NA	NA
Supply fan speed, design / actual			
Return fan speed, design / actual	NA	NA	NA
Heating coil APD @ full flow, design / actual (inches H2O)			
Heating coil water flow @ full flow, design / actual (GPM)			
Heating coil WPD @ full flow, design / actual (feet head)			
Cooling coil APD @ full flow, design / actual (inches H2O)			
Cooling coil water flow @ full flow, design / actual (GPM)			
Cooling coil WPD @ full flow, design / actual (feet head)			

Check	Name	Contr.	Date
Pre-filter pressure drop, design / actual			
Pre-filter is clean			
Extended filter pressure drop, design / actual			
Extended filter is clean			
HEPA filter pressure drop, design / actual			
HEPA filter is clean			
All access doors properly seal			
Minimum outdoor air is constant at all system flows			

- ***The checklist items of Part 5 are all successfully completed for given trade.___ YES ___ NO***

6. Sensor and Actuator Calibration

All field-installed temperature, relative humidity, CO, CO_2 and pressure sensors and gages, and all actuators (dampers and valves) on this piece of equipment shall be calibrated using the methods and tolerances given in the Calibration and Leak-by Test Procedures document. All test instruments shall have had a certified calibration within the last 12 months: Y/N______. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated.

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
Mixed air temperature sensor					
Pre-filter differential pressure sensor					
Extended filter differential pressure sensor					
Airflow measurement sensor					
Temperature sensor upstream of CC					
Chilled water valve actuator					
Temperature sensor upstream of HC					
Heating water valve actuator					
Temperature sensor upstream of Humidifier					
HEPA filter differential pressure sensor					
Room temp. sensor 1					
Room temp. sensor 2					
Room temp. sensor 3					
Room temp. sensor 4					
Room humidity sensor					
Room pressure sensor					

Gage reading = reading of the permanent gage on the equipment. BAS = building automation system. Instr. = testing instrument. Visual = actual observation. The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the referenced procedures are followed.

- ***All sensors are calibrated within required tolerances..................................___ YES ___ NO***

-- END OF CHECKLIST--

THIS PAGE IS INTENTIONALLY LEFT BLANK

AIR DISTRIBUTION SYSTEM
Functional Performance Test - AIR HANDLING UNIT
Tag No.: ________

Related Tests: Chilled Water and Heating Water System

1. Commissioning Participants:

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	City Inspector	Date
Other	Date	Other	Date

Party filling out this form & witnessing ___________________________ Date of test ______________

2. Prerequisite Checklist

a. The following have been started up and startup reports and construction checklists submitted and approved ready for functional testing:

- __ Chiller
- __ Chilled Water Pumps
- __ Heating Water Piping and Valves
- __ Terminal Unit
- NA Cooling towers
- __ Chilled Water Piping and Valves
- __ Boiler
- __ Heating Water Pumps
- NA Condenser water pumps
- NA Variable speed drives for pumps

b. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

Controls Contractor Signature or Verbal	Date

c. __ Piping system flushing complete and required reports approved.
d. __ Water treatment system complete and operational.
e. __ Vibration control report approved (if required).

f. __ Test and balance (TAB) completed and approved for the hydronic systems and terminal units connected.
g. __ All A/E punchlist items for this equipment corrected.
h. __ These functional test procedures reviewed and approved by installing contractor.
i. __ Safeties and operating ranges reviewed.
j. __ Test requirements and sequences of operation attached.
k. __ Schedules and setpoints attached.
l. __ False loading equipment, system and procedures ready (boilers, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)
m. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
n. __ **Control Program Review.** Review the software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
o. __ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Unit discharge air static pressure		
Unit discharge air temp.		
Unit mixed air temperature		
Supply fan leaving air temperature		
Cooling coil leaving air temperature		
Heating coil leaving air temperature		
Space relative humidity		
Return Air relative humidity		
Static Pressure reset schedule		
Discharge air reset schedule		
Building static pressure.		
Dirty pre-filter differential pressure		
Dirty extended filter differential pressure		
Dirty HEPA filter differential pressure		
Outside Air CFM		

3. Sensor Calibration Checks.

Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during construction check listing.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the construction checklist requirements (__________________________). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
Unit Discharge Air Temperature					
Unit Mixed Air Temperature					
Supply Fan Lvg Air Temperature					
Cooling Coil Lvg Air Temperature					
Heating Coil Lvg Air Temperature					
Unit Discharge Pressure					
Building Static Pressure					
Space Relative Humidity					
RA Relative Humidity					
Dirty Pre-filter Differential Pressure Sensor					
Dirty Extended Filter Differential Pressure Sensor					
Dirty HEPA Filter Differential Pressure Sensor					
Room 1 Temperature Sensor					
Room 2 Temperature Sensor					
Room 3 Temperature Sensor					
Room 4 Temperature Sensor					

[1]Sensor location is appropriate and away from causes of erratic operation.

4. Device Calibration Checks.

The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during construction checklisting and startup.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	**Procedure / State**	**1st** BAS Value	Site Observation	**Final** BAS Reading	Pass Y/N
Cooling Coil Valve (CCV) position or command and stroke*	1. Intermediate positions				
	2. Full open				
	3. Increase pressure (open)				
	4. Closed				
	5. Remove power or air (closed)				
Heating Coil Valve (HCV) position or command and stroke*	1. Intermediate positions				
	2. Full open				
	3. Increase pressure (open)				
	4. Closed				
	5. Remove power or air (closed)				

Device or Actuator & Location	**Procedure / State**	**1st** BAS Value	Site Observation	**Final** BAS Reading	Pass Y/N
Steam Valve (SV) position or command and stroke*	1. Intermediate positions				
	2. Full open				
	3. Increase pressure (open)				
	4. Closed				
	5. Remove power or air (closed)				
Mixed air damper position **	1. Closed				
	2. Full open				
Main OA damper position**	1. Closed				
	2. Full open				
Min. OA damper position**	1. Closed				
	2. Full open				
Variable frequency drive speed (VFD)***	1. Min.: __________%				
	2. Max.: __________%				

* Set pumps to normal mode.

Procedure 1. Command valve to a few intermediate positions. Verify that readings in BAS reasonably correspond to the actual positions. For cooling coil valves (NC): *Procedure 2.* Lower space setpoint to 20F below space temperature. Verify BAS reading says CCV is 100% open. Visually verify valve is 100% open. *Procedure 3.* For pneumatic actuators, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator rating). Verify valve stem & actuator position does not change. Restore to normal. *Procedure 4.* Set space setpoint to 20F above space temperature. Verify BAS reading says CCV is closed. Visually verify valve is closed. *Procedure 5.* Remove control air or electricity from the valve and verify that the valve stem and actuator position do not change.
**1. Command damper closed and verify that damper is shut and BAS reads shut. 2. Do the same, commanding damper fully open.
*** VFD: *Procedure 1.* Manually adjusted to the supply air required, airflow to be monitored through the airflow tracker.

5. Verification of Misc. Construction Checks.

Misc. site checks of the construction checklist and startup reports completed successfully.
Pass? Y / N _______

6. General Conditions of Test

____
____
____

7. Functional Testing Record

Seq. ID From Specs[1]	Mode ID[2]	**Test Procedure**[3] (including special conditions)	Expected Response[4]	Pass Y/N	Note
1.4.A	FAN OFF	Standby Check. With Unit Commanded off by DDCP.	Verify by visual inspection that: Outside Air Damper in AHU-1is Closed Return Air Damper in AHU-1 is Closed Cooling Coil Valve on Cooling Coil of AHU-1 is Closed Heating Coil Valve on Heating Coil of AHU-1 is Closed Steam Control Valve to Humidifier of AHU-1 is Closed		
1.4. B.1	UNIT STARTUP	With Unit Commanded on by DDCP	Outside air damper opens Return air damper opens Supply Fan starts through VFD		
1.4. B.2	FIRE/SMOKE CONDITION	Interfacing with ECMS, simulate a fire mode with the Fire Alarm System	Verify that the fire alarm system sends a signal to the DDCS for the AHU System to return to FAN OFF Status, with Smoke damper closed, OA damper closed, Return damper open and control valves closed.		
1.4. B.3	HEATING CONTROL	Place Unit DDCP into cooling. Overwrite the Room Temperature Sensors to be reading 55 Deg F.	Verify that the Cooling Coil Valve closes and the Heating Coil Valve opens.		
1.4. B.5	COOLING CONTROL	Place Unit DDCP into heating. Overwrite the Room Temperature Sensors to be reading 80 Deg F.	Verify that the Heating Coil Valve closes and the Cooling Coil Valve opens.		
1.4. B.6	HUMIDIFICATION CONTROL	Place Unit DDCP into dehumidification. Overwrite the Return Air Humidity Sensor to be reading 10% RH below the humidity setpoint.	Verify that the Humidification steam valve opens and that the steam generator produces steam and that the Humidification load is satisfied.		
1.4. B.6	DE-HUMIDIFICATION CONTROL	Place Unit DDCP into dehumidification. Overwrite the Return Air Humidity Sensor to be reading 10% RH above the humidity setpoint.	Verify that the Humidification steam valve closes, the steam generator stops and the cooling coil valve opens.		
1.4. B.7	SPACE STATIC PRESSURE	Trend log the supply fan speed and the space static pressure for 24 hrs at 5 min. intervals.	Observe in the trends that the space static pressure is maintained within +/- 0.05" of setpoint without excessive hunting.		
NA	WARM-UP CONTROL	Place Unit DDCP Control Mode into Warm-up. Overwrite RAT Sensor Reading to be 65 Deg. F.	Verify that dampers assume a 100% Return Air Mode with OA damper closed.		
NA	WARM-UP CONTROL	Place Units DDCP Control Mode in Warm-up. Overwrite RAT Sensor Reading to be 72 Deg. F.	Verify that unit returns to Normal Operation Mode		

Seq. ID From Specs[1]	Mode ID[2]	Test Procedure[3] (including special conditions)	Expected Response[4]	Pass Y/N	Note
NA	AHU FILTER DROP	Reset the Filter Differential Pressure to exceed the setting recommended by the filter manufacturer.	Verify that the ECMS reports an alarm.		
		Return all changed control parameters and conditions to their preset values[5]	**Check off in Section 2 above when completed**		

Record Foot Notes
[1]Sequences of operation specified in Contract Documents (attached).
[2]Mode or function ID being tested from testing requirements section of the project Specifications.
[3]Step-by-step procedures for manual testing, trend logging or data-logger monitoring.
[4]Include tolerances for a passing condition.
[5]Record any permanently changed parameter values and submit to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

AIR DISTRIBUTION SYSTEM
Construction Checklist - EXHAUST FANS
Tag No.: ________

Associated checklists: Air Handling Units

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ____.

Approvals This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested documentation submitted

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
Performance data (pump curves, coil data, etc.)			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
All control parameters, deadbands & setpoints			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents*** ***___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manufacturer	1			
	2			
	3			
Model	1			
	2			
	3			
Serial #	3			
Maximum Airflow (CFM)	1			
	2			
	3			
Minimum Airflow (CFM)	1			
	2			
	3			
Total Air PD (In WC)	1			
	2			
	3			
Sound Power Level @ 63, 250, and 1K Hz	1			
	2			
	3			
Other	1			
	2			
	3			

- ***The equipment installed matches the specifications for given trade.........___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Cabinet and General Installation			
Permanent labels affixed			
Casing condition good: no dents, leaks, door gaskets installed			
Mountings checked and shipping bolts removed			
Vibration isolators installed			
Equipment guards installed			
Pulleys aligned			
Belt tension correct			
Plenums clear of debris			
Fans rotate freely			
Fire and balance dampers installed			
Backdraft dampers installed, per drawings, and operate freely			
Duct system complete			
Electrical			
Electrical connnections complete			
Disconnect switch installed			
Overload heaters in place			
Control connections complete			
Operational Checks			
Fan rotation correct			
Electrical interlocks verified			
Any fan status indicators functioning			
No unusual vibration or and noise			
Record full load running amps for each fan. _____rated FL amps x ______srvc factor = _______ (Max amps). Running less than max?			
Check voltage: Rate = ______ Actual = _______ Within 5%?			
The disconnect switch properly operates			
After 24 hours of operation, recheck belt tension and alignment			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

-- END OF CHECKLIST--

THIS PAGE IS INTENTIONALLY LEFT BLANK

AIR DISTRIBUTION SYSTEM
Construction Checklist – FAN COIL UNIT
Tag No.: ________

Components included: Supply fan, cooling coil, pre-filter
Associated Checklists: CHW Piping

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested documentation submitted

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
Performance data (pump curves, coil data, etc.)			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents*** ___ ***YES*** ___ ***NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manufacturer	1			
	2			
	3			
Model	1			
	2			
	3			
Serial #	3			
Maximum Airflow (CFM)	1			
	2			
	3			
Minimum Airflow (CFM)	1			
	2			
	3			
Cooling Cap. (GPM/MBH)	1			
	2			
	3			
Heating Cap. (GPM/MBH)	1			
	2	NA	NA	NA
	3			
Volts/Ph/A	1			
	2			
	3			
Other	1			
	2			
	3			

- ***The equipment installed matches the specifications for given trade*** ___ ***YES*** ___ ***NO***

4. Installation Checks

Check	Name	Contr.	Date
Pre-Installation Check			
The FCU is free of physical damage			
The air openings are sealed with durable plastic			
The water openings are sealed with plastic plugs			
The unit appears to be free of water damage			
All access door/panel latches are operational			
All components are present and in the proper sequence			
Installation and startup manual in checklist envelope			
Unit tag no.s are affixed			
Number of rows in the heating coil, design/actual	NA	NA	NA
The heating coil surface area is free of damage	NA	NA	NA
Number of rows in the cooling coil, design/actual			
The cooling coil surface area is free of damage			
Fan horsepower, design/actual			
Fan voltage, design/actual			
Cabinet and General Installation Check			
Location and dimensions of pad or curb verified			
Proper clearances around pad/curb verified			
All shipping and installation materials removed			
Maintenance access acceptable for unit and components			
Floor drain for condensate identified			
Casing condition good: no dents or leaks			
Door and door frame gaskets installed access doors close tightly - no leaks			
Flex between duct and unit in good condition			
Vibration isolation equipment installed & released from shipping locks			
Seismic restraints installed at fan and not short circuiting			
Sound attenuation installed			
Thermal insulation properly installed and according to specification			
Instrumentation installed according to specification (thermometers, pressure gages, flow meters, etc.)			
Filters installed and replacement type and efficiency permanently affixed to housing--construction filters removed			
Valves, Piping and Coils Check (see piping checklists)			
Pipe fittings complete and pipes properly supported			
Pipes properly labeled			
Pipes properly insulated			
Strainers in place and clean			
Piping system properly flushed			
No leaking apparent around fittings			

Check	Name	Contr.	Date
All coils are clean and fins are in good condition			
All condensate drain pans clean and slope to drain, per spec			
Valves properly labeled			
Valves installed in proper direction			
Flanges or unions installed for fan coil removal			
Air vents for each coil installed			
Coil drain valves for each coil installed			
Coils are piped counterflow			
Isolation valves for each coil installed			
Return balancing valve for each coil installed			
Control valve installed			
Concentric reducers installed in piping to and from CV			
Strainer installed upstream of CV			
Coil fins are combed out			
Thermometers and pressure gauges are installed			
Condensate pans are properly installed, trapped and run to drain			
P/T plugs installed per drawings			
Fans and Dampers Check			
Supply fan and motor alignment correct			
Supply fan belt tension & condition good			
Supply fan protective shrouds for belts in place and secure			
Supply fan area clean			
Supply fan and motor properly lubricated			
All dampers close tightly			
All damper linkages have minimum play			
Ductwork Check (preliminary check)			
Sound attenuators installed			
Duct joint sealant properly installed			
Ductwork labeling is affixed with correct flow directions			
No apparent severe duct restrictions			
Turning vanes in square elbows as per drawings			
OSA intakes located away from pollutant sources & exhaust outlets			
Pressure leakage tests completed			
Branch duct control dampers operable			
Ducts cleaned as per specifications			
Balancing dampers installed as per drawings and TAB's site visit			
Electrical Check			
Motors: Premium efficiency verified			
Power disconnects in place and labeled			
All electric connections tight			
Proper grounding installed for components and unit			

Check	Name	Contr.	Date
Starter overload breakers installed and correct size			
VFD Check			
VFD powered (wired to controlled equipment)	NA	NA	NA
VFD interlocked to control system	NA	NA	NA
Drive location not subject to excessive temperatures	NA	NA	NA
Drive location not subject to excessive moisture or dirt	NA	NA	NA
Drive size matches motor size	NA	NA	NA
Internal setting designating the model is correct	NA	NA	NA
Input of motor FLA represents 100% to 105% of motor FLA rating	NA	NA	NA
Appropriate Volts vs Hz curve is being used	NA	NA	NA
Accel and decel times are around 10-50 seconds, except for special applications. Actual decel = ______ Actual accel = _____	NA	NA	NA
Lower frequency limit at 0 for VAV fans and around 10-30% for chilled water pumps. Actual = _______________	NA	NA	NA
Upper frequency limit set at 100%, unless explained otherwise	NA	NA	NA
Unit is programmed with full written programming record on site	NA	NA	NA
Controls Check			
Control panel accessible and properly labeled			
Temperature sensors properly located, secure and calibrated			
PD gauges are installed and calibrated across filters			
Filter PD measuring device installed and calibrated across filter (magnahelic, inclined manometer, etc.)			
Fan DP sensor installed and calibrated			
Return Air CO2 sensor installed and calibrated	NA	NA	NA
Smoke detector installed in proper location and functioning			
Dampers installed and calibrated			
Chilled water actuator installed and calibrated			
Safety items installed (motor overload)			
All control devices, pneumatic tubing and wiring complete			
Pilot lights are functioning			
Control system interlocks hooked up and functional			
Communication with central system functioning			
TAB			
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents			
Final			
Smoke and fire dampers installed properly per contract docs (proper location, access doors, appropriate ratings verified)			
Smoke and fire dampers are open			
Startup report completed with this checklist attached			

Check	Name	Contr.	Date
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent			
If unit is started and will be running during construction: have quality filters on RA grilles, etc. to minimize dirt in the ductwork and coils and in any finished areas. Verify moisture migration is not a problem, due to improper pressures between spaces.			

- ***The checklist items of Part 4 are all successfully completed for given trade.___YES ___NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
General			
System clean			
Internal isolators adjusted, fan(s) move freely			
Seismic snubbers do not short out isolators			
Manufacturers checklist completed and attached			
Fan lubricated and aligned			
All filters installed properly (no bypass) and clean			
Vibration isolation inspection report complete (attach)			
VFD verification checklist complete	NA	NA	NA
Fan motor amps, design / actual			
Fans with 3 phase motors - Phase Checks: (%Imbalance = 100 x (avg. - lowest) / avg.) Record all 3 voltages in cell. Imbalance less than 2%?			
System discharge static pressure, design / actual			
Fan rpm, design / actual			
The HOA switch properly activates and deactivates the unit			
Unit operates without creating objectionable vibration			
Unit operates without creating objectionable noise			
Controls			
All dampers stroke fully without binding and spans calibrated and BAS reading site verified (follow procedure in Calibration and Leak-by Test Procedures).			
Valves stroke fully and easily and spanning is calibrated (follow procedure in Calibration and Leak-by Test Procedures).			
Cooling sequence of control correct (attached)			
Heating sequence of control correct (attached)	NA	NA	NA
Warm-up sequence of control correct (attached)	NA	NA	NA
Cool-down sequence of control correct (attached)			
Economizer sequence of control correct (attached)	NA	NA	NA
IAQ override sequence of control correct (attached)	NA	NA	NA

Check	Name	Contr.	Date
Unoccupied sequence of control correct (attached)			
Safety items physically tested (freeze, high pressure, motor overload)			
TAB			
Supply fan rotation correct			
Supply fan motor volts, design / actual			
Supply fan motor amps, design / actual			
Supply fan speed, design / actual			
Heating coil APD @ full flow, design / actual (inches H2O)	NA	NA	NA
Heating coil water flow @ full flow, design / actual (GPM)	NA	NA	NA
Heating coil WPD @ full flow, design / actual (feet head)	NA	NA	NA
Cooling coil APD @ full flow, design / actual (inches H2O)			
Cooling coil water flow @ full flow, design / actual (GPM)			
Cooling coil WPD @ full flow, design / actual (feet head)			
Air filter pressure drop, design / actual			
Filter is clean			
All access doors properly seal			
Minimum outdoor air is constant at all system flows			

- ***The checklist items of Part 5 are all successfully completed for given trade.___ YES ___ NO***

6. Sensor and Actuator Calibration

All field-installed temperature, relative humidity, CO, CO_2 and pressure sensors and gages, and all actuators (dampers and valves) on this piece of equipment shall be calibrated using the methods and tolerances given in the Calibration and Leak-by Test Procedures document. All test instruments shall have had a certified calibration within the last 12 months: Y/N______. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated.

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
Chilled water actuator					
Temperature sensor					

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?

Gage reading = reading of the permanent gage on the equipment. BAS = building automation system. Instr. = testing instrument. Visual = actual observation. The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the referenced procedures are followed.

- ***All sensors are calibrated within required tolerances.................................___ YES ___ NO***

-- END OF CHECKLIST--

AIR DISTRIBUTION SYSTEM
Functional Performance Test - FAN COIL UNIT
Tag No.: ________

Related Tests: Chilled Water System

1. Commissioning Participants:

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	City Inspector	Date
Other	Date	Other	Date

Party filling out this form & witnessing ___________________________ Date of test ______________

2. Prerequisite Checklist

a. The following have been started up and startup reports and construction checklists submitted and approved ready for functional testing:

__ Chiller
__ Chilled Water Pumps
__ Heating Water Piping and Valves
__ Terminal Unit
NA Cooling towers
__ Chilled Water Piping and Valves_
__ Boiler
__ Heating Water Pumps
NA Condenser water pumps
NA Variable speed drives for pumps

b. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

Controls Contractor Signature or Verbal ____________________ Date ____________________

c. __ Piping system flushing complete and required reports approved.
d. __ Water treatment system complete and operational.
e. __ Vibration control report approved (if required).
f. __ Test and balance (TAB) completed and approved for the hydronic systems and terminal units connected.

g. __ All A/E punchlist items for this equipment corrected.
h. __ These functional test procedures reviewed and approved by installing contractor.
i. __ Safeties and operating ranges reviewed.
j. __ Test requirements and sequences of operation attached.
k. __ Schedules and setpoints attached.
l. __ False loading equipment, system and procedures ready (boilers, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)
m. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
n. __ **Control Program Review.** Review the software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
o. __ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	**Pre-Test Values**	**Returned to Pre-Test Values** √
Unit discharge differential pressure		
Unit discharge air temp.		
Space temperature		
Space relative humidity		
Dirty pre-filter differential pressure		

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during construction checklisting.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the construction checklist requirements (________________________). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
Unit discharge differential pressure					
Unit Discharge Air Temperature					
Space Temperature Sensor					
Space Relative Humidity					
Dirty Pre-filter Differential Pressure Sensor					

[1]Sensor location is appropriate and away from causes of erratic operation.

4. Device Calibration Checks.

The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during construction checklisting and startup.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	**Procedure / State**	**1st** BAS Value	Site Observation	**Final** BAS Reading	Pass Y/N
Cooling Coil Valve (CCV) position or command and stroke*	1. Intermediate positions				
	2. Full open				
	3. Increase pressure (open)				
	4. Closed				
	5. Remove power or air (closed)				
Electric Reheat Coil	1. Intermediate stages				
	2. On				
	3. Off				
Infrared Humidifier	1. Intermediate settings				
	2. On				
	3. Off				

* Set pumps to normal mode.

Procedure 1. Command valve to a few intermediate positions. Verify that readings in BAS reasonably correspond to the actual positions. For cooling coil valves (NC): *Procedure 2.* Lower space setpoint to 20F below space temperature. Verify BAS reading says CCV is 100% open. Visually verify valve is 100% open. *Procedure 3.* For pneumatic actuators, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator rating). Verify valve stem & actuator position does not change. Restore to normal. *Procedure 4.* Set space setpoint to 20F above space temperature. Verify BAS reading says CCV is closed. Visually verify valve is closed. *Procedure 5.* Remove control air or electricity from the valve and verify that the valve stem and actuator position do not change.

5. Verification of Misc. Construction Checks.

Misc. site checks of the construction checklist and startup reports completed successfully.
Pass? Y / N _______

6. General Conditions of Test

____
____
____

7. Functional Testing Record

Seq. ID From Specs[1]	Mode ID[2]	Test Procedure[3] (including special conditions)	Expected Response[4]	Pass Y/N	Note
1.6.A	FAN OFF	Standby Check. With Unit Commanded off by DDCP.	Verify by visual inspection that: Cooling Coil Valve on Cooling Coil of FCU is Closed Electric Reheat Coil of FCU is Off Infrared Humidifier is off		
1.6.B	UNIT STARTUP	With Unit Commanded on by DDCP	Verify that Supply Fan status through differential pressure sensor		
1.6.C	COOLING CONTROL	Place Unit DDCP into reheat. Overwrite the Room Temperature Sensors to be reading 10 Deg F above room setpoint.	Verify that the Electric Reheat de-energizes and the Cooling Coil Valve opens.		
1.6.D	DE-HUMIDIFICATION CONTROL	Place Unit DDCP into humidification. Overwrite the Space Relative Humidity Sensor to be reading 10% RH above the humidity setpoint.	Verify that the Infrared Humidifier de-energizes and the cooling coil valve opens.		
1.6.D	REHEAT CONTROL	Place Unit DDCP into de-humidification. Overwrite the space Relative Humidity Sensor to a reading 10% RH above the humidity setpoint & drop the room temperature sensor to a reading 10 deg F below the room setpoint.	Verify that the first stage of the Electric reheat coil is energized.		
1.6.E	HUMIDIFICATION CONTROL	Place Unit DDCP into de-humidification. Overwrite the space Humidity Sensor to be reading 10% RH below the humidity setpoint.	Verify that the Infrared Humidifier turns on and modulates the output to maintain the room setpoint.		
1.6.G	FCU FILTER DROP	Reset the Filter Differential Pressure to exceed the setting recommended by the filter manufacturer.	Verify that the ECMS reports an alarm.		
1.6.H	FIRE/SMOKE CONDITION	Interfacing with ECMS, simulate a fire mode with the Fire Alarm System	Verify that the fire alarm system sends a signal to the DDCS for the FCU to stop the supply fan and send a fan shutdown signal to the DDCS, de-energize the infrared humidifier and close chilled water control valve.		
		Return all changed control parameters and conditions to their pre-test values[5]	**Check off in table of Section 2 above when completed**		

Record Foot Notes
[1]Sequences of operation specified in Contract Documents (attached).
[2]Mode or function ID being tested from testing requirements section of the project Specifications.
[3]Step-by-step procedures for manual testing, trend logging or data-logger monitoring.
[4]Include tolerances for a passing condition.
[5]Record any permanently changed parameter values and submit to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

AIR DISTRIBUTION SYSTEM
Construction Checklist – TERMINAL UNITS
Tag No.: ________

Associated checklists: Air Handling Units and Heating Water Piping.

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ____.

Approvals This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested documentation submitted

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
Performance data (pump curves, coil data, etc.)			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
All control parameters, deadbands & setpoints			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manufacturer	1			
	2			
	3			
Model	1			
	2			
	3			
Serial #	3			
Maximum Airflow (CFM)	1			
	2			
	3			
Minimum Airflow (CFM)	1			
	2			
	3			
Inlet Diameter	1			
	2			
	3			
Heating Cap. (GPM/MBH)	1			
	2			
	3			
Total Air PD (In WC)	1			
	2			
	3			
Other	1			
	2			
	3			

4. Installation Checks

Construction checklist items are to be completed on each TU as part of startup & initial checkout, preparatory to functional testing. This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report. The installing contractor's startup and checkout plan shall make reference to Incorporating this checklist or have it attached when submitting the plan to the commissioning agent for approval, prior to execution.

Check	Name	Contr.	Date
Pre Installation Checks			
The terminal unit is free from physical damage			
The air openings in the terminal unit are sealed with durable plastic			
The airflow sensing tubing is plugged			
The enclosure for the local DDC panel is in the proper location			
The grommets for the airflow sensing tube are secure			
Unit tag no.s are affixed			
The manufacturer's ratings are readable			
The manufacturer's ratings are accurate			
General Installation Checks			
Shipping and installation materials removed			
Ducting upstream has been leak and pressure tested, cleaned and approved prior to connecting TU			
Unit, damper and air valve tags affixed			
Model and tag checked against plans and equipment list. Tag or mark affixed.			
Unit secured per manufacturer's recommendations, contract documents and seismic requirements.			
Unit has clear access from below to service and/or remove access panel			
Unit has sufficient clearance to be serviced.			
Inlet conditions OK: Smooth, round, straight duct for at least 3 duct diameters when possible and 2 diameters minimum for velocity pressure sensor and 3 to 5 diameters for single point electronic sensors, OR per manufacturer's recommendation.			
All balancing devices have been provided in compliance with the contract documents.			
Any hot or chilled water piping installation complete with valves tagged. Auto-flow control valves checked to ensure proper model.			
Required pipe cleaning to this unit, pipe flushing and pressure testing has been completed successfully.			
All A/E punch list items related to this TU have been corrected.			
Construction filter has been removed and final filter installed, if applicable.			

Check	Name	Contr.	Date
Control Checks			
Control wiring installation complete and checked to each point			
Software pt. address input into box and checked for all points (zone temp, pressures for flow calcs, damper position, fan status, supply air temp., valve position, etc.)			
Release actuator clutch and verify free damper.			
Controls Software Load. Power up unit and download approved software program.			
Temperature sensor installation complete			
Communication with central system is complete			
Temperature sensor is calibrated			
TAB			
Confirm airflow sensor is calibrated			
Confirm actual maximum airflow (cfm)			
Actual minimum airflow (cfm)			

- ***The checklist items of Part 4 are all successfully completed for given trade. ___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Start air handler fans.			
Override space temp. to be 55F to simulate full heating. Verify that BAS flow sensors read the maximum heating flow and minimum cooling flow for that TU per the TU schedule. Verify proper opening of heating coil valve, if applicable.			
Override space temp. to be 80F to simulate full cooling. Verify that BAS flow sensors read the maximum cooling flow and minimum heating flow for that TU per the TU schedule. Verify by observation, the proper closing of heating coil valve, if applicable. During the above sequencing, if box is fan powered, verify no unusual sound or vibration and verify proper fan staging.			

The checklist items of Part 5 are all successfully completed for given trade. ___ YES ___ NO

6. Sensor and Actuator Calibration

a) Verify that all sensor locations are appropriate and away from causes of erratic operation. Verify that sensors with shielded cable are grounded only at one end.

b) For sensor pairs that are used to determine temperature or pressure differences, make sure they are reading within 0.2F of each other for temperature and within a tolerance equal to 2% of the reading, of each other, for pressure. Critical applications may be tighter.

c) Sensor without Transmitters: Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or BAS is within 0.5F for temps and within 3% of design for pressures of the instrument-measured value. If not, install an offset in the BAS, calibrate or replace sensor.

d) All field-installed temperature, relative humidity, pressure sensors and gages, and all actuators (dampers and valves) on this piece of equipment shall be calibrated using the methods and tolerances given in the Calibration and Leak-by Test Procedures document. All test instruments shall have had a certified calibration within the last 12 months: Y/N______. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated.

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
Flow sensor					
Room temp. sensor					
Htg. valve actuator					

Gage reading = reading of the permanent gage on the equipment. BAS = building automation system. Instr. = testing instrument. Visual = actual observation. The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the referenced procedures are followed.

- ***All sensors are calibrated within required tolerances___ YES ___ NO***

-- END OF CHECKLIST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

AIR DISTRIBUTION SYSTEM
Functional Performance Test - TERMINAL UNITS
Tag No.: ________

Related Tests: Air Handling Units and Heating Water System

1. Commissioning Participants:

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	City Inspector	Date
Other	Date	Other	Date

Party filling out this form & witnessing _________________________ Date of test ________________

2. Test Prerequisites (fill out once, to cover all TU's)

a. The following have been started up and startup reports and construction checklists submitted and approved:
__ All terminal units, except____
__ All air handlers serving terminal units, except ________________________________
__ Hot water pumps

b. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.

______________________________ ______________________________
Controls Contractor Signature or Verbal Date

c. __ Piping system flushing complete, water treatment system complete and required report approved.
d. __ Airside test and balance calibration of BAS readings of TU flows complete (system total flow need not be complete).
e. __ All A/E punch list items for this equipment corrected.
f. __ These functional test procedures reviewed and approved by installing contractor.
g. __ Test requirements and sequences of operation attached.
h. __ Schedules and setpoints attached.

i. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this TU and control system are capable of? If not, list recommendations below.

j. __ The controller & actuator runtime accumulator set to 0 after construction checkout of the entire system.

k. __ Obtain and review the full program of 5% (randomly chosen) of all TU's of each type (parameters & setpoints, etc.). Examine variances. Clarify as needed, reconcile and document differences with controls contractor. If too many corrections exist with this sample, controls contractor shall recheck all programming.

3. Sampling and Additional Testing.

The terminal unit testing requirements in the specifications call for a random sample of ____% of all Terminal Units of each type to be tested. Total number to be tested of this type = __________. The specifications also require that if __% of the sampled TU's fail in the testing (any No Pass items), then another __% of the total population must be tested. This applies to the subsections of the test, i.e., if sub-sections fail, only subsections of additional TU's need to be tested. Record results in the table below.

Sub-Section	% Failed of 1st Sample	% Failed of 2nd Sample
I. Sensor calibration		
II. Actuator calibration		
III. Static inspections		
IV. Programming		
V. Functional tests		

4. Testing of TU 3-Way Valves

All TU 3-way heating valves shall be verified to have been programmed and setup properly. When programmed or wired backwards, the valve will open when being commanded to close, causing the space to overheat. To verify proper wiring and programming, during a period of general cooling, verify that the actual space temperature is within 2F of the (setpoint plus any user adjustment), unless in a fluctuating area (entry, etc.). Space temperatures more than 2F above the net setpoint indicate possible 3-way valve problems. Investigate.

TU Space Temperature Control for TU's With Three-Way Valves

TU ID	Actual Space Temp.	Setpoint	User Adjustment	OK?
None				

5. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the construction checklist requirements (__________________________). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK[1]	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
Space temp.					

[1] Sensor location is appropriate and away from causes of erratic operation.

6. Device Calibration Checks. Check the actuators or devices listed below for calibration.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

HCV: Set pumps to normal mode. *Procedure 1.* Command valve to a few intermediate positions. Verify that reading in BAS reasonably correspond to the actual positions. For heating coil valves (NO): *Procedure 2a.* Set heating setpoint 20°F above room temperature. Verify BAS reading says 100% open. Visually verify valve is fully open. *2b.* Remove control air or electricity from the valve and verify that the valve stem and actuator position do not change. *Procedure 3.* Restore to normal. Set heating setpoint to 20°F below room temperature. Observe the valve close. *4.* For pneumatic actuators, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator rating). Verify valve stem & actuator position does not change. Restore to normal.

Damper or Flow: --Checked during Functional Testing Section.

Device or Actuator & Location	**Procedure / State**	BAS Value	Site Observation	Corrections	Pass Y/N
Heating coil valve (HCV) position or command and stroke	1. Intermediate positions				
	2a. Full open				
	2b. Remove power or air (full open)				
	3. Closed				
	4. Increase pressure (close)				

Proced. No.	**Req ID No.[2]**	**Test Procedure[3]** (including special conditions)	**Expected and Actual Response[4]** [Write ACTUAL response or finding in brackets or circle]	**Pass Y/N& Note #**
III. STATIC INSPECTIONS				
1.		Verify sufficient clearance around equipment for servicing.		
2.		Verify installation of specified sound wrapping and joint sealant.		
3.		Unit secured per spec.		
4.		Model and tag checked against plans & equipment list. TU & valve tags affixed.		
5.		Verify that inlet conditions are OK: Smooth, round, straight duct for at least 3 duct diameters when possible and 2 diameters minimum for velocity pressure sensor and 3 to 5 diameters for single point electronic sensors, else airflow straighteners.		

Proced. No.	Req ID No.[2]	Test Procedure[3] (including special conditions)	Expected and Actual Response[4] [Write ACTUAL response or finding in brackets or circle]	Pass Y/N& Note #
IV. CONTROL PROGRAMMING. **In the procedures of this section, compare specified written sequences and parameters with that found programmed in the TU or BAS. Variances that, in the CA's opinion, reduce performance must be corrected. Variances that make no difference or enhance performance pass. Document all variances.**				
6.		Control drawing sequences of operation	Per spec and detail adequate.	
7.		Verify that the TU address matches the TU location and ID on the plan drawings and control drawings.	Address matches.	
8.		Verify that the TU max and min setpoints in the BAS match (within 10%) the latest plan drawings and balance report (TAB).	Cooling: Drawing max =_____ min =_____ BAS max = [______] min = [______] TAB max = _______ min = _______ Heating: Drawing max =_____ min =_____ BAS max = [______] min = [______] TAB max = _______ min = _______	
9.		Verify that BAS TU K factor is within 20% of K on the submitted control drawings, unless explained by TAB.	Drawing K = _____ BAS K = [_____] TAB K = ________	
9.		Temperature adjustment range by tenants (indicate if a setting was spec'd)	Spec'd or reasonable value _______ Found [_______]	
10.		Cooling-- occupied zone temp. setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _______ Found [_______]	
11.		Heating-- occupied zone temp. setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _______ Found [_______]	
12.		Unoccupied zone temperature setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _______ Found [_______]	
13.		Occupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _______ Found [_______]	
14.		Unoccupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _______ Found [_______]	
15.		Heating coil valve stroke time (for incremental valves)	Actual timed ________ Input found in BAS _______	
16.		Cooling space setpoint proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _______ Found [_______]	
17.		Heating space setpoint proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _______ Found [_______]	
18.		Cooling cfm proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _______ Found [_______]	
19.		Duct area (sf)	From prints ______ Found [______]	
20.		Damper stroke time (Spec'd value comes from controller spec, unless oval duct, which should then be timed)	Spec'd ________ Found [_______]	
21.		Auto-zero function schedule set and enabled.	Set and enabled.	
22.		Differential CFM alarm	Set and enabled	
V. FUNCTIONAL TESTING.				
23.		CFM Capacity Test, Cooling. With the duct SP setpoint being met, lower the space temp. set point 20F. Verify in the BAS that the specified max. cfm is achieved (within deadband). For TU's controlled by damper position only, observe that the damper goes to max.	Specified max. cooling cfm = ______ Achieved cfm or position= [______] Within deadband? _______	

Proced. No.	Req ID No.[2]	Test Procedure[3] (including special conditions)	Expected and Actual Response[4] [Write ACTUAL response or finding in brackets or circle]	Pass Y/N& Note #
24.		CFM Capacity Test, Heating. With the duct SP setpoint being met, raise the space temp. setpoint 20F. Verify in the BAS that the specified min. or heating cfm is achieved (within deadband). For TU's controlled by damper position only, observe that the damper goes to min. as expected.	Specified min. or heating cfm = __________ Achieved cfm or position = [______] Within deadband? _______	
25.		Auto VAV Diagnostics. In the control system diagnostics, check the controller and actuator accumulated run times, the moving avg. flow error and moving avg. space temp. deviation from setpoint.	The ratio of actuator to controller runtime should be ideally < 3% & < 5% is acceptable. [______%]. Moving avg. flow error should be < 10% of max. cooling cfm [______%]. The moving avg. space temp. deviation should be < 3F [______F].	
26.		HCV leakage. *Method 1.* Use any of three methods. With the TU in cooling, with the damper in a stable position, using matched sensors, measure the duct air temperature within 4 ft. upstream and downstream of the coil.	Upstream: _____F Down: _____F The temperature down stream should not be warmer than the air up stream. If more than 1.0F greater, unit fails. Investigate.	
27.		HCV leakage. *Method 2.* Use any of three methods. Turn off the air handler during test. Command HCV open. After 5 min., slide temp. sensor 3/4" underneath insulation near actuated valve. Shut isolation valves to stop flow. Record ambient & initial pipe temp. and temp. after 10 min. Open isolation valves, allow temp. to reach within 3F of initial temp. and record pipe and ambient temp. Command HCV closed. Record temp. after 10 min.	Isolation valves closed (no flow): Ambient=____F. Initial pipe=____F @ 10 min=____F. T. drop = ____F Isolation valves open, HCV closed: Ambient=____F. Initial pipe=____F @ 10 min=____F. T. drop = ____F Isolation valves closed T. drop *minus* isolation valves open T. drop must be *less than* +2F [_____], else valve is leaking.	
28.		HCV leakage. *Method 3.* Use any of three methods. With the heating water system in normal and the TU in full cooling, close coil supply isolation valve, open air bleed cap, open drain-down cock and drain water from coil. Return all to normal. This method is not applicable for 3-way valves.	Water should stop draining, else there may be a leak through the control valve.	
29.		Trending: HCV and Damper Control. Over an 26 hour occupied and unoccupied period, trend at 2 min. intervals, the HCV position, the HCV command, the damper position or cfm, the damper or cfm command, the space temperature, OSAT and the duct static pressure at the controlling sensor. The trend period shall have both heating and cooling conditions. Simulate if necessary.	Compare actuals to cfm and space temp. setpoints. Compare to the schedule. Observe that there is little or no overshoot of space temp or hunting of the damper or valve, that cfm is within its deadband and that the cfm and valve change from heating to cooling as the space temp goes outside deadbands.	

Proced. No.	Req ID No.[2]	Test Procedure[3] (including special conditions)	Expected and Actual Response[4] [Write ACTUAL response or finding in brackets or circle]	Pass Y/N& Note #
30.	BSL3	*(Trend for only 1/2 of the tested TU's)* Trending. Over a 3 day period, during near design conditions for heating and cooling, trend space temp. at 10 minute intervals. Omit this test if auto diagnostics has a moving avg. space temp. deviation log and it was completed.	Observe that the space temp. does not drift more than 1°F outside the deadband range around the setpoint.	
31.	**--**	**Return all changed control parameters and conditions to their pre-test values[5]**	**Check off in program printout when completed**	

MONITORING AND TREND LOGGING

Monitoring via BAS trend logs are required for test procedures 29; 30. Attach representative graphs or columnar data and explanatory analysis to this test report. The data should have time down the left column and four to six columns of parameters to the right. Provide a key to all abbreviations and attach setpoints and schedules for all trended parameters.

**Abbreviations: BAS = building automation system, CA = commissioning agent, HCV = heating coil valve, TU = terminal unit, SA = supply air, plan drawing = building drawings and schedules from design engineer.

[1]Sequences of operation attached to this test.
[2]Mode or function ID being tested from testing requirements section of the project Specifications.
[3]Step-by-step procedures for manual testing, trend logging or data-logger monitoring.
[4]Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.
[5]Record any permanently changed parameter values and submit changes to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

CHILLED WATER SYSTEM
Construction Checklist – AIR COOLED CHILLER
Tag No.: ________

Associated checklists: Chilled Water Piping, and CHW Pumps.

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________________.

Approvals This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested Documentation Submitted

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
Performance data (pump curves, coil data, etc.)			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ___ YES ___ NO***

3. Chiller Model Verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manuf.	1			
	2			
	3			
Model	1			
	2			
	3			
Capacity, tons	1			
	2			
	3			
Compressor, kW	1			
	2			
	3			
Serial Number	3			
Amb Cond Temp	1			
	2			
	3			
EWT/LWT	1			
	2			
	3			
Fan/Total Power	1			
	2			
	3			
Unit EER	1			
	2			
	3			

- ***The equipment installed matches the specifications for given trade ___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Pre installation Checks			
Physical Checks			
The chiller is free of physical damage			
The water openings are sealed with plastic plugs			
The refrigerant openings are sealed with copper caps			
Installation & startup manual in verification envelope			
Power disconnect switch			
Unit tags are affixed			
Component Verification			
Manufacturers rating readable			
Manufacturers rating accurate			
Number of condenser fans, design / actual			
Evaporator has sight glass, filter dryer, elec. exp. valve			
Starter pre-wired			
Each refrigeration circuit includes compressor suction and discharge valve, liquid line shutoff valve, removable core filter, drier line sight glass with moisture indicator, charging port, and electric expansion valve			
Factory leak test (report attached)			
Digital control interface			
Fans for low ambient temperature operation			
Vibration isolators and seismic restraints			
__-inch chilled water connections			
Control Verification			
__ step chilled water temperature controller			
__ min. solid state compr. anti-cycle timer provided			
Load limit t-stat provided			
High ambient unloader pressure stat provided			
Compressor current sensing unloader provided			
Auto compressor lead-lag provided			
Low ambient lockout provided			
Condenser fan sequencing provided			
RS232 communication port provided			
Installation Checks			
Physical Checks			
Concrete pad allows for minimum code distance in front of starter.			
Pad provides sleeves to accommodate piping and other service connections.			
Chiller properly labeled			
Proper vibration isolators installed and adjusted			
Seismic restraints in place and adjusted			
Access clearance is sufficient for service			
Refrigerant Circuit – each circuit has the following:			
Liquid line shutoff valve			
Filter dryer			
Liquid line sight glass and moisture indicator			
Electronic expansion valve			
Charging valve			
Discharge and oil line check valves			
High side pressure relief valve			
Full operating charge of oil and refrigerant			

Check	Name	Contr.	Date
Electrical Installation			
Weatherproof control panel mounted on chiller			
Star-delta starter provided for each compressor			
Starters, power and control wiring contained			
Size of overcurrent heater in motor starter correct			
Lugs for single point electrical service by Div 16 provided			
Lug size matches wire size requirement			
Coordinated disconnection devices with that provided by the manufacturer			
Safety disconnect switch by Div 16 provided			
Disconnect switch installed			
Disconnect switch properly operates			
Reviewed Motors field wiring diagrams and validated conformance			
Primary and secondary fused control power transformer provided			
Power wiring installed properly			
All electrical components grounded properly			
Electrical connections complete			
Terminations tight			
Controls Installation			
Control wiring and control system hooked up			
Control system interlocks hooked up and functional			
Flow switches field installed			
All control devices, pneumatic tubing and wiring complete			
Sensors calibrated (see calibration section below)			
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent			
Communication with remote BAS: Remote start stop signal Chilled water temperature reset signal (0-5vDC)			
Piping Installation			
Isolation valves and balancing valves installed			
Pipe fittings and accessories complete			
Pipes not supported from chiller			
Hydronic system flushing complete and strainers cleaned			
Piping sufficiently purged of air to run chiller			
Thermometers installed			
Pressure gages installed			
Test plugs installed near all control sensors & as per spec			
Flow meters installed			
Refrigerant leak test complete			
Purge unit installed, if specified			
Piping type and flow direction labeled on piping			
Chilled water piping and pumps construction checklists completed			

- ***The checklist items of Part 3 are all successfully completed for given trade. ___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
General			
Owner / CxA given notice __ days prior to startup			
Construction checklist completed __ days prior to startup			
Specified sequences of operation and operating schedules have been implemented with all variations documented			
Specified point-to-point checks have been completed and documentation record submitted for this system			
Startup report completed with this checklist attached. (Includes full listing of all internal settings with notes as to which settings are BAS controlled or monitored and which are integral.			
Startup report includes written certification from chiller manufacturer that all specified features, controls and safeties have been installed and are functioning properly and that the installation and application comply with the manufacturer's recommendations.			
Mechanical Start-up			
Manufacturer provided individual as a factory trained service technician			
System leak checked, evacuated and charged by manufacturers technician			
Manufacturers check, test, and start forms completed by manufacturer's technican (attach forms)			
No unusual noise and vibration when running			
Compressor interlocking with oil pressure			
Adequate oil pressure when compressor is operating			
Piping gages, BAS and chiller panel temperature and pressure readouts match (see calibration section below)			
Electrical Start-up			
Measure line to line voltage phase imbalance for compressor: (%Imbalance = 100 x (avg. - lowest) / avg.) Record imbalance of compressor. Imbalance less than 2%?			
Record full load running amps for compressor. _____rated FL amps x ______srvc factor = ________ (Max amps). Running less than max?			
Controls Start-up			
Capacity modulation:			
Provided by slide valve modulation			
Operable down to 10%			
The following safety controls with indicating lights or diagnostic readouts operational and verified:			
Low chilled water temperature			
High refrigerant pressure			

Check	Name	Contr.	Date
Low oil flow protection			
Loss of chilled water flow			
Contact for remote emergency shutdown			
Loss of refrigerant protection			
Motor current overload			
Phase reversal/unbalance/single phasing			
Over/under voltage			
Failure of water temp sensor used by controller			
Compressor status (on or off)			

The checklist items of Part 4 are all successfully completed for given trade. ___ YES ___ NO

6. Sensor and Actuator Calibration

All field-installed temperature, relative humidity, CO, CO_2 and pressure sensors and gages, and all actuators (dampers and valves) on this piece of equipment shall be calibrated using the methods and tolerances given in the Calibration and Leak-by Test Procedures document. All test instruments shall have had a certified calibration within the last 12 months: Y/N______. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated.

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?

Gage reading = reading of the permanent gage on the equipment. BAS = building automation system. Instr. = testing instrument. Visual = actual observation. The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the referenced procedures are followed.

- ***All sensors are calibrated within required tolerances___ YES ___ NO***

-- END OF CHECKLIST --

CHILLED WATER SYSTEM
Construction Checklist – CHILLED WATER PUMP
Tag No.: ________

Associated checklists: Chiller and Chilled Water Piping

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested documentation submitted

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
Performance data (pump curves, coil data, etc.)			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manuf.	1			
	2			
	3			
Model	1			
	2			
	3			
Serial #	3			
Flow (GPM)	1			
	2			
	3			
Head (FT)	1			
	2			
	3			
Volts/Ph/A	1			
	2			
	3			
Starter Model	1			
	2			
	3			

- ***The equipment installed matches the specifications for given trade ___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
General			
Installation is per manufacturers instructions			
Manufacturers recommended spare parts are provided			
Equipment label permanently affixed			
Pump lubricated			
Pump drive properly aligned			
Pump turns freely			
Drive guard or shield is properly installed			
Pump foundation is level within manufacturer’s tolerances			
Pumps in place and properly anchored			
Pipes are supported independently of the pump			
Vibration isolation devices installed and functional (non-short circuiting)			
Seismic anchoring installed and functional where applicable (non-short circuiting)			
Isolation valves and piping specialties installed			
Shaft seal is leak free			
Pump detail checked against the drawings and all devices gages and appurtenances are in place			
Insulation installed per requirements. Pumps for cold water insulated to avoid condensation yet allow for service.			
Venting in place as required			
Inlet strainers and suction diffusers cleaned			
Piping type and flow direction labeled on piping			
Size of overcurrent heater in motor starter correct			
Configured the system to obtain maximum output from pump and measure the capacity			
Net positive suction head checked and the pump operates in range			
Electrical and Controls			
HOA Switch			
Operation of HOA switch checked in all positions			
Proper safeties in control when HOA switch in hand position			
Installation per manufacturer’s instructions			
Rotates in the correct direction			

- ***The checklist items of Part 4 are all successfully completed for given trade. ___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point checks have been completed and documentation record submitted for this system			
Startup report completed with this checklist attached. (Includes full listing of all internal settings with notes as to which settings are BAS controlled or monitored and which are integral.			
Startup report includes written certification from pump manufacturer that all specified features, controls and safeties have been installed and are functioning properly and that the installation and application comply with the manufacturer's recommendations.			
Start up Complete			

-- END OF CHECKLIST --

CHILLED WATER SYSTEM
Functional Performance Test – CHILLED WATER PUMP
(Fixed Speed)

Related Tests: Heating Water System

1. Commissioning Participants:

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	City Inspector	Date
Other	Date	Other	Date

Pump ID: _______

Design max.: Hp: ______ GPM: _____ Head ______ Ft

The following functional performance test is for a fixed speed pump in a hydronic system with three-way valves to provide a constant flow. ***A check-mark denotes acceptance or compliance.***

2. Prerequisite Checklist

a. The following have been started up and startup reports and construction checklists submitted and approved ready for functional testing:

- __ Chiller
- NA Boiler
- __ Air Handling Unit
- NA Cooling towers
- __ Chilled Water Piping and Valves
- __ Heating Water Piping and Valves
- NA Terminal Unit
- NA Variable speed drives for pumps

b. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

Controls Contractor Signature or Verbal　　　　Date

c. __ Piping system flushing complete and required reports approved.
d. __ Water treatment system complete and operational.
e. __ Vibration control report approved (if required).
f. __ Test and balance (TAB) completed and approved for the hydronic systems and terminal units connected.
g. __ All A/E punchlist items for this equipment corrected.
h. __ These functional test procedures reviewed and approved by installing contractor.
i. __ Safeties and operating ranges reviewed.
j. __ Test requirements and sequences of operation attached.
k. __ Schedules and setpoints attached.
l. __ False loading equipment, system and procedures ready (boilers, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)
m. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
n. __ **Control Program Review.** Review the software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
o. __ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	**Pre-Test Values**	**Returned to Pre-Test Values √**
Pump start/stop		
Pump run status		

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during construction checklisting.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the construction checklist requirements (___________________________). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
System differential pressure sensor					

4. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during construction checklisting and startup.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	**Procedure / State**	**1st** BAS Value	Site Observation	**Final** BAS Reading	Pass Y/N
None					

5. Verification of Misc. Construction Checks.

Misc. site checks of the construction checklist and startup reports completed successfully.
Pass? Y / N _______

6. General Conditions of Test

____

____

7. Functional Testing Record

Seq. ID From Specs[1]	**Mode ID[2]**	**Test Procedure[3]** (including special conditions)	**Expected Response[4]**	**Pass Y/N**	**Note**
1	PUMP START	Command all control valves full open with pump in auto command pump on	Pump turns on		
2	PUMP RUNNING	Pump Speed Check the amperage of the pump.	Amperage should be less than the rated amps. Rated=________ Tag No. [__________]		
3	PUMP STOP	With all control valves full open with pump in auto command pump off	Pump turns off		
4		**Return all changed control parameters and conditions to their pre-test values[5]**	**Check off in section 2 above when completed.**		

Record Foot Notes

[1]Sequences of operation specified in Contract Documents (attached).
[2]Mode or function ID being tested from testing requirements section of the project Specifications.
[3]Step-by-step procedures for manual testing, trend logging or data-logger monitoring.
[4]Include tolerances for a passing condition.
[5]Record any permanently changed parameter values and submit to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

CHILLED WATER SYSTEM
Construction Checklist – CHILLED WATER PIPING

Components Included: All valves, excluding coil valves

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested documentation submitted

	Name	Contr.	Date
Manufacturer's cut sheets			
Performance data (fan curves, coil data, etc.)			
Flushing and cleaning plan			
O&M manuals			

- ***Documentation complete as per contract documents*** ___ ***YES*** ___ ***NO***

3. Installation Checks

Check	Name	Contr.	Date
General			
Piping installed per the drawings and details			
Verified that valves for equipment/zone isolation have been provided per the drawings and specs.			
Record drawings updated to reflect the actual installation			
Piping, fittings, valves and equipment properly supported and seismically anchored per the details			
Support certification inspection provided (where applicable)			
Provisions in place for expansion compensation			
Welder certification submitted (where applicable)			
Weld inspections submitted with all passing (where applicable)			
Non-destructive testing completed per spec with all test passing and results submitted (where applicable)			
Piping, fittings and valves insulated per specification			
In-line equipment insulated per specification			
Piping painted per specification			
Piping labeled per specification with flows indicated in the correct direction			
In-line equipment labeled per specification with flows indicated in the correct direction			
Pressure tested piping per specifications (equipment isolated not in the pressure test)			
Piping system properly flushed and cleaned (Minimum flushing velocity in all pipe sections is the greater of 4 ft. per second or 1.5 times the velocity at design flow) temporary piping removed (report attached)			
100% of strainers and Owner-selected low-point drains opened and witnessed by Owner to be clean			
Construction strainers removed			
Chemical treatment program initiated, chemical injected and treatment supplier report submitted			
Air vents and bleeds at high points of systems functional			

Check	Name	Contr.	Date
Expansion tanks verified to not be air bound and system completely full of water. System completed purged of air.			
ASME pressure vessel data sheet or certification tag posted and inspection complete for each expansion tank			
Isolation valves and balancing valves installed			
Test ports (P/T) installed near all control sensors and as per spec			
Valves (except coil valve checklists are with the unit checklist)			
Valves tagged and valve schedule submitted and displayed as required			
Isolation valves provided at all branches and main takeoffs to facilitate isolation			
Valve labels permanently affixed			
Valves installed in proper direction			
Manual isolation valves checked for proper seal and no leakage and found to travel freely and be accessible			
Valves stroke fully and easily and spanning is calibrated (see calibration section below)			
Valves that require a positive shut-off are verified to not be leaking when closed at normal operating pressure per “Calibration and Leak-by Test Procedures” document.			
Bypass Control Valve			
Installation per manufacturer’s instructions			
Adequate maintenance clearance in provided and valve is accessible			
Valve travels freely through full range			
Valve closes off and seals tightly			
Unions installed to allow easy removal			
Sensors and Gages			
Temperature, pressure and flow gages and sensors installed			
Piping gages, BAS and chiller panel temperature and pressure readouts match (see calibration section below)			
TAB			
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents			

- ***The checklist items of Part 3 are all successfully completed for given trade. ___YES ___NO***

4. Sensor and Actuator Calibration [ ]

All field-installed temperature, pressure, and flow sensors and gages, and all actuators (dampers and valves) on this system shall be calibrated using the methods and tolerances given in the Calibration and Leak-by Test Procedures document. All test instruments shall have had a certified calibration within the last 12 months: Y/N______.

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?

Gage reading = reading of the permanent gage on the equipment. BAS = building automation system. Instr. = testing instrument. Visual = actual observation. The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the referenced procedures are followed.

- ***All sensors are calibrated within required tolerances___YES ___NO***

-- END OF CHECKLIST --

CHILLED WATER SYSTEM
Functional Performance Test – CHILLED WATER SYSTEM

Including:
Air Cooled Chillers: ____
Chilled Water Pumps: ____
Air Handlers Units: ____

1. Commissioning Participants:

______________________ Facilities	_________ Date	______________________ Commissioning Authority	___________ Date
______________________ Construction Manager	_________ Date	______________________ Controls Contractor	___________ Date
______________________ TAB Contractor	_________ Date	______________________ Mechanical Contractor	___________ Date
______________________ Electrical Contractor	_________ Date	______________________ City Inspector	___________ Date
______________________ Other	_________ Date	______________________ Other	___________ Date

Party filling out this form and witnessing testing ____________________________

Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________

2. Test Prerequisites

a. __ The following have been started up and startup reports* and construction checklists submitted and approved ready for functional testing:

__ Chiller
__ Chilled Water Pumps
__ Chilled Water Piping and Valves
__ AHU`s

*The written chiller startup report must contain a full listing of all adjustable internal program settings.

b. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.

________________________________ ____________________________
Controls Contractor Signature or Verbal Date

c. __ Piping system flushing complete and required report approved.
d. __ Water treatment system complete and operational.
e. __ Vibration control report approved (if required).
f. __ Test and balance (TAB) complete and approved for the hydronic system.
g. __ All A/E punchlist items for this equipment corrected.
h. __ These functional test procedures reviewed and approved by installing contractor.
i. __ Safeties and operating ranges reviewed.
j. __ Test requirements and sequences of operation attached.
k. __ Schedules and setpoints attached.
l. __ False loading equipment, system and procedures ready (cross-over piping, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)
m. __ Sufficient clearance around equipment for servicing.
n. __ Sump or crankcase heaters have been on long enough to allow immediate starting of chillers.
o. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this chiller and control system are capable of? If not, list recommendations below.
p. __ Schedules and setpoints attached.
q. __ **Control Program Review.** Review the software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences
r. __ Schedules and setpoints attached.
s. __ Record made of All Values for Current Setpoints (SPt), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values
Chiller____ Mounted Control Values		
Outside air temperature		
Temperature and pressure of operating setpoints		
Entering and leaving temperatures of chilled water		
Refrigerant pressure in evaporators and condenser		
Saturation temperature in evaporator and condenser		
No cooling load condition		
Water pump status		
Anti-recycling timer status		
Percent of maximum motor amperage		
Current limit setpoint		
Number of compressor starts		

Parameter	Pre-Test Values	Returned to Pre-Test Values
Chiller____ Control Functions		
Entering and Leaving chilled water temperature		
Current limit and demand limit		
External chiller emergency stop		
Low ambient head pressure		
Chiller flow switch		
Chiller____ Manual Reset Safety Controls		
Low evaporator pressure		
Low chilled water temperature		
Refrigerant high pressure		
High or low oil pressure		
High oil temperature		
Loss of chilled water flow		
Control device failure		
Compressor motor current-overload		
Starter fault		
Air Handlers		
AHU Discharge Air Temperature Setpoints (DAT)		
AHU Cooling coil valve (auto, manual)		
Chilled Water Pumps		
Lead Chilled Water Pump CWP______ (hand, off, auto)		

3. **Sensor Calibration Checks.** The sensors listed below checked for calibration and adequate location. This is a spot check on a sample of the calibrations done during construction checklisting.*

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the construction checklist requirements. If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Test instrument, air pressure: ____________________________ ___ Certified calibration within last 12 mo's.

Test instrument, water pressure: __________________________ ___ Certified calibration within last 12 mo's.

Test instrument, temperature: ____________________________ ___ Certified calibration within last 12 mo's.

Sensor & Location	Location OK[1]	Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
Outside Air Temperature Sensor					
CHW Supply Temperature Sensor					
CHW Return Temperature Sensor					
AHU Discharge Air Temperature sensor					

Sensor & Location	Location OK[1]	Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
AHU CC temperature sensor					
CHW Differential Pressure Sensor					
CHW System Flow Sensor					

[1]Sensor location is appropriate and away from causes of erratic operation.
*For every sensor originally found out of calibration, check one additional sensor not listed.

4. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during construction checklisting and startup.**

"In calibration" means observing readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	BAS Reading	Site Observation	**Final** BAS Reading	Pass Y/N
Outside Air Temperature Sensor				
CHW Supply Temperature Sensor				
CHW Return Temperature Sensor				
AHU chilled water control valve actuator				
CHW Differential Pressure Sensor				
CHW System Flow Sensor				

**For every actuator or device originally found out of calibration, check one additional one not listed.

5. Verification of Misc. Construction Checks.

Misc. site checks of the construction checklist and startup reports completed successfully.
Pass? Y / N _______

6. Notes on Methods Used to False Load Chiller (for reference, see Note 6 at end of test)

____
____
____
____
____
____
____

7. Seasonal Testing and General Conditions of Test

Due to the building completion being during winter, this test will be completed in two stages. The first testing will occur prior to substantial completion, during cold weather. The objective of this first stage test is to provide reasonable assurance that the chiller will function properly during lower load conditions. This will prepare the chiller for operation during the beginning of the cooling season. As many of the test procedures as possible will be executed during this first test, through the use of the methods of false loading noted above and in Note 6 at the end of the test. Tests chiller close to full load and full cooling tower fan staging will not be able to be executed until summer. Chiller safeties will be tested prior to occupancy.

At the beginning of the cooling season, the chiller will be started and operated, without further testing, unless problems arise. Then, when conditions are warmer (approximately 80F-85F), the second test will be performed. This will likely require some false loading to create close to full load conditions and subsequently may need to be executed on a weekend to minimize discomfort to occupants. During this second test, some of the sequences performed during the first test will be retested and recorded, as necessary, to get to the staging and full load tests not performed during the first test. Also, the benchmarking and trending will be completed during the second test period.

8. Test Procedure Table of Contents

9. Testing Procedures and Record

Proced. No. & Spec. Seq. ID[1]	Test Procedure[3] (including special conditions)	Expected and Actual Response[4] [Write ACTUAL response in brackets or circle]	PassY /N	Note #
1	**Startup Sequence**. CH-1 (This is not the initial startup by factory reps). With chiller system off, with schedule allowing chillers ON and OSAT >50F, turn chiller and pumps to auto. Turn on AHU's to cause a call for cooling sufficient to call for chiller (manually open preheat coil valve, lower space temperature SPt)	Observe CHW pump, CWP-1, energizes. Observe the Chiller, CH-1 starting sequence energizes and chiller starts.		
2	**Chiller Staging:** Continue to load chiller. Specified Sequences: Poll CHW every 4 min. (Confirm Chiller compressor staging sequence and setpoints with Chiller Manufacturer).	CHW Discharge = [_______F]. Observe that the chiller compressors successively stage up as the setpoint remains unsatisfied. Record results for each compressor. Time Setpoint/Actual Compressor Observe that there is no abnormal vibration or operation.		

Proced. No. & Spec. Seq. ID[1]	**Test Procedure[3]** (including special conditions)	**Expected and Actual Response[4]** [Write ACTUAL response in brackets or circle]	PassY /N	Note #
3	**<u>Chiller Condenser Fans:</u>** Continue to load chiller. Specified Sequences: Poll CHW every 4 min. (Confirm Condenser Fan sequence and setpoints with Chiller Manufacturer).	OSAT = [_______F]. OSAWB = [_______F]. Observe that the chiller condenser fans successively stage up as the setpoint remains unsatisfied. Record results for each fan. <u>Time</u> <u>Setpoint/Actual</u> <u>Cond. Fan</u> Observe that there is no abnormal vibration or operation.		
4	**<u>Chiller Staging - OFF.</u>** Raise space setpoints so CCV's at AHU's close. Wait as Chiller unloads all stages. Record time. (Confirm Chiller compressor unloading sequence and setpoints with Chiller Manufacturer).	<u>Chiller Staging OFF*</u> Observe that the chiller compressors successively unload as the setpoint remains unsatisfied. Record results for each compressor. When all CCV's are closed for 10 min. and after an additional 20 min. delay, chiller and pump should shut down. <u>Time</u> <u>Setpoint/Actual</u> <u>Compressor</u> *No no-flow alarms should be generated during normal staging down.		
5	**<u>General Staging By Monitoring:</u>** Trend the status of CH, CWP, OSAT, CHWST).	Observe that there are no anomalies in operation, comparing to the specified sequences and staging. This is not a detailed "to the minute" staging verification, which was done manually above. Attach representative graphs or columnar data and explanatory analysis to this test report.		
6	**<u>OSAT Lockout.</u>** With chiller(s) running in auto, overwrite OSAT sensor to be 55F.	Observe a shutdown of the chillers, including CHW pumps.		
7	**<u>OSAT Lockout By Monitoring.</u>** During chilled water pressure control monitoring:	Observe a shutdown of the chiller, including CHW pump, whenever the OSAT is less than 55F. Attach representative graphs or columnar data and explanatory analysis to this test report.		
8	**<u>Lead CHW Pump Failure, CH-1</u>** With the chiller running (in auto), manually shut off the lead primary CHW pump.	Operating chiller should stop and go into failure alarm. The lag pump then becomes the lead pump and should start. Observe chiller restart once chilled water flow has been re-established.		

Proced. No. & Spec. Seq. ID[1]	Test Procedure[3] (including special conditions)	Expected and Actual Response[4] [Write ACTUAL response in brackets or circle]	PassY /N	Note #
9	**System Stabilization** Analyze CHW reset and pressure control monitoring data.	Verify that the CHWS temperature is stable and maintains the CHWS SPt within 0.5F over a range of conditions and days.		
10	**Pumps for Freeze Protection** With chillers in auto, overwrite OSAT to be 38F.	Observe that CWP pumps operate normally.		
11	**CHW Flow Switch CH-1.** If CHW pumps are wired in series with proof of flow switches, jumper pumps out of this loop. With chiller manually off, but under conditions that will call for chiller, manually turn off CHW pumps. Turn Chiller 1 to auto.	Observe that chiller won't start because of no CHW flow condition and that an alarm is generated.		
12 MANUF O&M	**Low evaporator pressure** TBD	Indicator lights for alarms, cutouts and normal running function properly. Chiller does not restart after cutout.		
13 MANUF O&M	**Low Chilled Water Temperature** TBD	Indicator lights for alarms, cutouts and normal running function properly. Chiller does not restart after cutout.		
14 MANUF O&M	**High refrigerant pressure** TBD	Indicator lights for alarms, cutouts and normal running function properly. Chiller does not restart after cutout.		
15 MANUF O&M	**High or low oil pressure** TBD	Indicator lights for alarms, cutouts and normal running function properly. Chiller does not restart after cutout.		
16 MANUF O&M	**High oil temperature** TBD	Indicator lights for alarms, cutouts and normal running function properly. Chiller does not restart after cutout.		
16 MANUF O&M	**Control Device Failure** TBD	Indicator lights for alarms, cutouts and normal running function properly. Chiller does not restart after cutout.		
17 MANUF O&M	**Compressor motor current overload** TBD	Indicator lights for alarms, cutouts and normal running function properly. Chiller does not restart after cutout.		

Proced. No. & Spec. Seq. ID[1]	Test Procedure[3] (including special conditions)	Expected and Actual Response[4] [Write ACTUAL response in brackets or circle]	PassY /N	Note #
18 MANUF O&M	**Starter fault protection** TBD	Indicator lights for alarms, cutouts and normal running function properly. Chiller does not restart after cutout.		
CHILLER SYSTEM STARTUP				
19	**Chiller Testing and Benchmarking.** A. Obtain calculated kw/ton values from the manufacturer of the chiller for all possible combinations of 4 LCHW temps and 100, 75, 50 and 25% loads. Plot kw/ton vs % Load. Perform a regression based on DOE-2 chiller curve equation forms through the data, using the PG&E Chiller Performance Evaluation Tool. Use the same equation form for each chiller model. B. During a near design day and a moderate cooling day, trend the LCHWT, kw, RCHWT, CHW gpm at 15 min. intervals over the occupied period. Calculate % load and tons at each point. Trend chiller as needed to establish a good variety of load, and reset CHWT. Plot kw/ton vs % Load. Perform a regression based on the same curve forms as for the manufacturer's data. C. Compare the chiller plots in B. to mfr's plots in A. Significant difference between manufacturer's data in A and actual data plots in B may indicate problems. If the ARI APLV (Application Part Load Value) kw/ton efficiency calculated in the PG&E tool, for the actual chiller is more than 15% greater than the calculated APLV from the manufacturers data, then full site verification and testing of full and part load efficiencies at ARI conditions, as per the original specs, will be necessary, unless the reason for inefficiency can be traced to site installation problems and remedied. D. The plots in B provide the efficiency benchmark for this chiller.			
20	**Return all changed control parameters and conditions to their pre-test values[5]**	**Check off in table of Section 2 above when completed**		
SEQUENCES AND COMPONENTS NOT TESTED				
21		<u>Vibration Isolators.</u> Not tested.		
22		<u>Capacity Testing</u> Not tested.		
MONITORING AND TREND LOGGING Monitoring via BAS trend logs are required per test procedures 5, 7, 9 and 19. Attach representative graphs or columnar data and explanatory analysis to this test report.				

**<u>Abbreviations:</u> CHW = chilled water, dP = diff. pressure, SPt = setpoint
CHWS = chilled water supply, BAS = building automation system.

[1]Sequences of operation attached to this test.
[2]Mode or function ID being tested from testing requirements section of the project Specifications.
[3]Step-by-step procedures for manual testing, trend logging or data-logger monitoring.
[4]Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.
[5]Record any permanently changed parameter values and submit changes to Owner.
[6] <u>Methods to False Load Chillers</u>

1) If OSAT is less than 75F, prevent economizer cool OSA from entering the building.
   a) Manually close the economizer OSA dampers, OR
   b) Overwrite the OSAT value to be 80F or more so dampers won't open.
2) Use heating coils to heat incoming OSA.

Enable the boiler by removing any lockouts, etc. Manually open the min. OSA preheat coil valve to preheat the OSA. Increase the min. OSA discharge temperature setpoint and the heating water supply temperature, as necessary.

3) Lower the space temperature setpoint.
4) Prior to the chiller test, manually preheat the building space temperature to 78F - 80F.
5) Lower the chilled water supply temperature setpoint.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

HEATING WATER SYSTEM
Construction Checklist – HEATING WATER BOILER
Tag No.: ________

Associated checklists: Pump and Heating Water Piping

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested documentation submitted

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
Performance data (pump curves, coil data, etc.)			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manuf.	1			
	2			
	3			
Model	1			
	2			
	3			
Serial #	3			
Output (MBH)	1			
	2			
	3			
Ent. Water Temp (Deg F)	1			
	2			
	3			
Lvg Water Temp (Deg F)	1			
	2			
	3			
Flow (GPM)	1			
	2			
	3			
Pressure Drop (Ft. Head)	1			
	2			
	3			
Volts/Ph/A	1			
	2			
	3			

- ***The equipment installed matches the specifications for given trade..........___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
General Installation			
General appearance good, no apparent damage			
Installation is per manufacturer's instructions			
Site sufficiently clean for testing			
Equipment labels affixed			
Tube pulling, and access door space adequate and to code			
Required seismic restraints in place			
Combustion air supply complete			
System filled			
Pressure gages installed			
Thermometers installed			
Burner (w/Motor)			
Installed per manufacturer's instructions			
Rotates in correct direction			
Starter installed and size coordinated with motor			
Motor correctly aligned			
Voltage applied is matched with motor rating			
Fuel supply complete and purged of air.			
Fuel pressure within range			
Atomizing sources are piped and adjusted			
Flame adjusted and optimized			
Controls and Interlocks are operational			
Fire safety controls and interlocks are operational			
Draft Fan (w/Motor)			
Fan is installed per manufacturer's instructions			
Casing in good condition; no dents			
Mountings checked and shipping bolts removed			
Vibration isolators installed			
Plenums free of debris			
Fan rotates freely and in correct direction			
Bearings lubricated			
Maintenance access per manufacturers instructions			
Equipment guards and safety devices installed			
Dynamically balanced			
Starter installed and size coordinated with motor			
Motor correctly aligned			
Voltage applied is matched with motor rating			

Check	Name	Contr.	Date
Low Water Cutoff			
Installed per manufacturer's instructions			
Wire terminations checked and correct			
Gas Train			
Gas train Installed in accordance with NFPA, FM and IRI			
Low gas pressure switch is accessible			
Gas control bfly valve installed per manufacturer's instructions			
Gas control bfly valve installed vertical with direction of flow confirmed			
Gas control bfly valve accessible and travels freely			
Gas control bfly valve leak checked in closed position with the other gas train valves open			
Gas control bfly valve had no visible damage			
Gas control bfly valve nameplate readings checked against application and is applied correctly			
Drum relief valve setting adequate for application			
Drum relief valve discharge properly piped			
Stop-Check valve pressure rating applicable for duty			
Stop-Check valve installed per manufacturers instructions			
Heating hot water piping and pump(s) construction checklists completed			
Electrical			
Power to unit and disconnect installed			
All electrical components grounded			
Flue			
Installed per manufacturers instructions			
Properly sloped			
Adequate clearance to combustibles			
Proper personnel protection to prevent burning hazard			
Discharge is protected from rain and blockage			
Proper anchors and expansion compensation devices have been installed			
Discharge is located to preclude re-entrainment back into the building			
Draft checked and meets minimum requirements of boiler manufacturer			
Connected to boiler per manufacturer's instruction			
Barometric damper installed per manufacturer's instructions			
Piping (Immediately around unit. Full piping in HW Piping Checklist.)			
Gas piping installed and tested (supply is at proper pressure)			
Hydronic piping complete, including blowdown system, makeup water piping and safety reliefs			

Check	Name	Contr.	Date
Hydronic system flushing complete and strainers cleaned			
Isolation valves and balancing valves installed			
Pipe fittings and accessories complete			
Test ports installed near all control sensors and per spec			
Flow switch installed as required			
Flow meters installed as required			
Piping type and flow direction labeled on piping			
Chemical treatment system or plan installed			
ASME pressure vessel data sheet or certification tag posted and inspection complete for each expansion tank			
Expansion tanks verified to not be air bound and system completely full of water			
Air vents and bleeds at high points of systems functional			
Final			
Startup report completed with this checklist attached			
Startup report includes written certification from boiler manufacturer that all specified features, controls and safeties have been installed and are functioning properly and that the installation and application comply with the manufacturer's recommendations.			
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent			
Heating water piping and pumps construction checklists completed			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point checks have been completed and documentation record submitted for this system			
Startup report includes optimal and actual percent CO_2, CO, O_2, stack temperature; combustion efficiency			
Startup report completed with this checklist attached. (Includes full listing of all internal settings with notes as to which settings are BAS controlled or monitored and which are integral.			
Boiler safeties energized and tested			

-- END OF CHECKLIST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

HEATING WATER SYSTEM
Construction Checklist – HOT WATER PUMP
Tag No.: ________

Associated checklists: Boiler and Heating Hot Water Piping

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

____________________ Mechanical Contractor	________ Date	____________________ Controls Contractor	__________ Date
____________________ Electrical Contractor	________ Date	____________________ Construction Manager	__________ Date
____________________ TAB Contractor	________ Date	____________________ Other	__________ Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ____________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

________________________ Owner's Representative	____________ Date	________________________ Commissioning Authority	__________ Date

2. Requested documentation submitted

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
Performance data (pump curves, coil data, etc.)			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents*** ***___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manuf.	1			
	2			
	3			
Model	1			
	2			
	3			
Serial #	3			
Flow (GPM)	1			
	2			
	3			
Head (FT)	1			
	2			
	3			
Volts/Ph/A	1			
	2			
	3			
Starter Model	1			
	2			
	3			

- ***The equipment installed matches the specifications for given trade*** ***___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
General			
Installation is per manufacturers instructions			
Manufacturers recommended spare parts are provided			
Equipment label permanently affixed			
Pump lubricated			
Pump drive properly aligned			
Pump turns freely			
Drive guard or shield is properly installed			
Pump foundation is level within manufacturer's tolerances			
Pumps in place and properly anchored			
Pipes are supported independently of the pump			
Vibration isolation devices installed and functional (non-short circuiting)			
Seismic anchoring installed and functional where applicable (non-short circuiting)			
Isolation valves and piping specialties installed			
Shaft seal is leak free			
Pump detail checked against the drawings and all devices gages and appurtenances are in place			
Insulation installed per requirements. Pumps for cold water insulated to avoid condensation yet allow for service.			
Venting in place as required			
Inlet strainers and suction diffusers cleaned			
Piping type and flow direction labeled on piping			
Size of overcurrent heater in motor starter correct			
Configured the system to obtain maximum output from pump and measure the capacity			
Net positive suction head checked and the pump operates in range			
Electrical and Controls			
HOA Switch			
Operation of HOA switch checked in all positions			
Proper safeties in control when HOA switch in hand position			
Installation per manufacturer's instructions			
Rotates in the correct direction			

- ***The checklist items of Part 4 are all successfully completed for given trade. ___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point checks have been completed and documentation record submitted for this system			
Startup report completed with this checklist attached. (Includes full listing of all internal settings with notes as to which settings are BAS controlled or monitored and which are integral.			
Startup report includes written certification from pump manufacturer that all specified features, controls and safeties have been installed and are functioning properly and that the installation and application comply with the manufacturer's recommendations.			
Start up Complete			

-- END OF CHECKLIST --

HEATING WATER SYSTEM
Functional Performance Test – HOT WATER PUMP
(Fixed Speed)

Related Tests: Heating Water System

1. Commissioning Participants:

____________________ Facilities	________ Date	____________________ Commissioning Authority	________ Date
____________________ Construction Manager	________ Date	____________________ Controls Contractor	________ Date
____________________ TAB Contractor	________ Date	____________________ Mechanical Contractor	________ Date
____________________ Electrical Contractor	________ Date	____________________ City Inspector	________ Date
____________________ Other	________ Date	____________________ Other	________ Date

Pump ID: ______

Design max.: Hp: ______ GPM: _____ Head ______ Ft

The following functional performance test is for a fixed speed pump in a hydronic system with three-way valves to provide a constant flow. ***A check-mark denotes acceptance or compliance.***

2. Prerequisite Checklist

a. The following have been started up and startup reports and construction checklists submitted and approved ready for functional testing:

__ Chiller
NA Boiler
__ Air Handling Unit
NA Cooling towers
__ Chilled Water Piping and Valves
__ Heating Water Piping and Valves
NA Terminal Unit
NA Variable speed drives for pumps

b. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

____
Controls Contractor Signature or Verbal

____
Date

c. __ Piping system flushing complete and required reports approved.
d. __ Water treatment system complete and operational.
e. __ Vibration control report approved (if required).
f. __ Test and balance (TAB) completed and approved for the hydronic systems and terminal units connected.
g. __ All A/E punchlist items for this equipment corrected.
h. __ These functional test procedures reviewed and approved by installing contractor.
i. __ Safeties and operating ranges reviewed.
j. __ Test requirements and sequences of operation attached.
k. __ Schedules and setpoints attached.
l. __ False loading equipment, system and procedures ready (boilers, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)
m. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
n. __ **Control Program Review.** Review the software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
o. __ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	**Pre-Test Values**	**Returned to Pre-Test Values √**
Pump start/stop		
Pump run status		

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during construction checklisting.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the construction checklist requirements (__________________________). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
System differential pressure sensor					

4. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during construction checklisting and startup.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	**Procedure / State**	**1st** BAS Value	Site Obser vation	**Final** BAS Reading	Pass Y/N
None					

5. Verification of Misc. Construction Checks.

Misc. site checks of the construction checklist and startup reports completed successfully.
Pass? Y / N _______

6. General Conditions of Test

____

____

7. Functional Testing Record

Seq. ID From Specs[1]	**Mode ID**[2]	**Test Procedure**[3] (including special conditions)	**Expected Response**[4]	**Pass Y/N**	**Note**
1	PUMP START	Command all control valves full open with pump in auto command pump on	Pump turns on		
2	PUMP RUNNING	Pump Speed Check the amperage of the pump.	Amperage should be less than the rated amps. Rated=________ Tag No. [__________]		
3	PUMP STOP	With all control valves full open with pump in auto command pump off	Pump turns off		
4		**Return all changed control parameters and conditions to their pre-test values**[5]	**Check off in section 2 above when completed.**		

Record Foot Notes
[1]Sequences of operation specified in Contract Documents (attached).
[2]Mode or function ID being tested from testing requirements section of the project Specifications.
[3]Step-by-step procedures for manual testing, trend logging or data-logger monitoring.
[4]Include tolerances for a passing condition.
[5]Record any permanently changed parameter values and submit to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

HEATING WATER SYSTEM
Construction Checklist – HOT WATER PIPING
Components Included: All valves, excluding coil valves

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested documentation submitted

	Name	Contr.	Date
Manufacturer's cut sheets			
Performance data (fan curves, coil data, etc.)			
Flushing and cleaning plan			
O&M manuals			

- ***Documentation complete as per contract documents……………… ___ YES ___ NO***

3. Physical Installation Checks

Check	Name	Contr.	Date
General			
Piping installed per the drawings and details			
Verified that valves for equipment/zone isolation have been provided per the drawings and specs.			
Record drawings updated to reflect the actual installation			
Piping, fittings, valves and equipment properly supported and seismically anchored per the details			
Support certification inspection provided (where applicable)			
Provisions in place for expansion compensation			
Welder certification submitted (where applicable)			
Weld inspections submitted with all passing (where applicable)			
Non-destructive testing completed per spec with all test passing and results submitted (where applicable)			
Piping, fittings and valves insulated per specification			
In-line equipment insulated per specification			
Piping painted per specification			
Piping labeled per specification with flows indicated in the correct direction			
In-line equipment labeled per specification with flows indicated in the correct direction			
Pressure tested piping per specifications (equipment isolated not in the pressure test)			
Piping system properly flushed and cleaned (Minimum flushing velocity in all pipe sections is the greater of 4 ft. per second or 1.5 times the velocity at design flow) temporary piping removed (report attached)			
100% of strainers and Owner-selected low-point drains opened and witnessed by Owner to be clean			
Construction strainers removed			
Chemical treatment program initiated, chemical injected and treatment supplier report submitted			
Air vents and bleeds at high points of systems functional			

Check	Name	Contr.	Date
Expansion tanks verified to not be air bound and system completely full of water. System completed purged of air.			
ASME pressure vessel data sheet or certification tag posted and inspection complete for each expansion tank			
Isolation valves and balancing valves installed			
Test ports (P/T) installed near all control sensors and as per spec			
Valves (except coil valve checklists are with the unit checklist)			
Valves tagged and valve schedule submitted and displayed as required			
Isolation valves provided at all branches and main takeoffs to facilitate isolation			
Valve labels permanently affixed			
Valves installed in proper direction			
Manual isolation valves checked for proper seal and no leakage and found to travel freely and be accessible			
Valves stroke fully and easily and spanning is calibrated (see calibration section below)			
Valves that require a positive shut-off are verified to not be leaking when closed at normal operating pressure per "Calibration and Leak-by Test Procedures" document.			
Bypass Control Valve			
Installation per manufacturer's instructions			
Adequate maintenance clearance in provided and valve is accessible			
Valve travels freely through full range			
Valve closes off and seals tightly			
Unions installed to allow easy removal			
Sensors and Gages			
Temperature, pressure and flow gages and sensors installed			
Piping gages, BAS and chiller panel temperature and pressure readouts match (see calibration section below)			
TAB			
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents			

- ***The checklist items of Part 3 are all successfully completed for given trade. ___YES ___NO***

4. Sensor and Actuator Calibration [ ]

All field-installed temperature, pressure, and flow sensors and gages, and all actuators (dampers and valves) on this system shall be calibrated using the methods and tolerances given in the Calibration and Leak-by Test Procedures document. All test instruments shall have had a certified calibration within the last 12 months: Y/N______

Sensor or Actuator & Location	Location OK	**1st** Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?

Gage reading = reading of the permanent gage on the equipment. BAS = building automation system. Instr. = testing instrument. Visual = actual observation. The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the referenced procedures are followed.

- ***All sensors are calibrated within required tolerances ___ YES ___ NO***

-- END OF CHECKLIST --

HEATING WATER SYSTEM
Functional Performance Test
Including:

Boiler____
Hot Water Distribution Pumps______________________________
Air Handler Units______________________________________

1. Commissioning Participants:

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	City Inspector	Date
Other	Date	Other	Date

Party filling out this form and witnessing testing ____________________________

Dates of tests _____________________
Dates of tests _____________________
Dates of tests _____________________
Dates of tests _____________________

2. Test Prerequisites

a. __ The following have been started up and startup reports* and construction checklists submitted and approved ready for functional testing:

__ Boilers
__ Heating Water Pumps
__ Heating Water Piping and Valves
__ AHU`s

*The written boiler startup report must contain a full listing of all adjustable internal program settings.

b. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.

____________________________________ ____________________
Controls Contractor Signature or Verbal Date

c. __ Piping system flushing complete and required report approved.
d. __ Water treatment system complete and operational.
e. __ Vibration control report approved (if required).
f. __ Test and balance (TAB) complete and approved for the hydronic system.
g. __ All A/E punchlist items for this equipment corrected.
h. __ These functional test procedures reviewed and approved by installing contractor.
i. __ Safeties and operating ranges reviewed.
j. __ Test requirements and sequences of operation attached.
k. __ Schedules and setpoints attached.
l. __ False loading equipment, system and procedures ready (cross-over piping, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)
m. __ Sufficient clearance around equipment for servicing.
n. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this boiler and control system are capable of? If not, list recommendations below.
o. __ Schedules and setpoints attached.
p. __ **Control Program Review.** Review the software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences
q. __ Schedules and setpoints attached.
r. __ Record made of All Values for Current Setpoints (SPt), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values
Heating System Parameters		
Outside air temperature		
Boiler circulating pump start/stop		
Temperature and pressure of operating setpoints		
Entering and Leaving heating water temperature		
Water pump status		
External boiler emergency stop		
Heating Water flow switch		
Boiler - Manual Reset Safety Controls		
High heating water temperature		
Loss of heating water flow		
Control device failure		
Low water cutoff		
Blocked Vent Safety Switch		
Rollout Safety Switch		

Parameter	Pre-Test Values	Returned to Pre-Test Values
Air Handler Unit		
AHU Discharge Air Temperature Setpoints (DAT)		
AHU Heating coil valve (auto, manual)		
Hot Water Pump		
Lead Heating Water Distribution Pump HWP (hand, off, auto)		

3. **Sensor Calibration Checks.** The sensors listed below checked for calibration and adequate location. This is a spot check on a sample of the calibrations done during construction check listing.*

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the construction checklist requirements. If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Test instrument, air pressure: ______________________________ ___ Certified calibration within last 12 mo's.
Test instrument, water pressure: ____________________________ ___ Certified calibration within last 12 mo's.
Test instrument, temperature: ______________________________ ___ Certified calibration within last 12 mo's.

Sensor & Location	Location OK[1]	Gage or BAS Value	Instrument Measured Value	**Final** Gage or BAS Value	Pass Y/N?
Outside Air Temperature Sensor					
HW Supply Temperature Sensor					
HW Return Temperature Sensor					
AHU Discharge Air Temperature sensor					
AHU HC temperature sensor					
HW Differential Pressure Sensor					
HW System Flow Sensor					

[1]Sensor location is appropriate and away from causes of erratic operation.
*For every sensor originally found out of calibration, check one additional sensor not listed.

4. **Device Calibration Checks.** The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during construction checklisting and startup.**

"In calibration" means observing readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	BAS Reading	Site Observation	**Final** BAS Reading	Pass Y/N
Outside Air Temperature Sensor				
HW Supply Temperature Sensor				
HW Return Temperature Sensor				
AHU heating water control valve actuator				
HW Differential Pressure Sensor				
HW System Flow Sensor				

**For every actuator or device originally found out of calibration, check one additional one not listed.

5. Verification of Misc. Construction Checks.

Misc. site checks of the construction checklist and startup reports completed successfully.
Pass? Y / N _______

6. Notes on Methods Used to False Load Boiler (for reference, see Note 6 at end of test)

____
____
____
____
____
____
____

7. Seasonal Testing and General Conditions of Test

Should the building completion occur during summer, this test will be completed in two stages. The first testing will occur prior to substantial completion, during warm weather. The objective of this first stage test is to provide reasonable assurance that the boiler will function properly during lower load conditions. This will prepare the boiler for operation during the beginning of the heating season. As many of the test procedures as possible will be executed during this first test, through the use of the methods of false loading noted above and in Note 6 at the end of the test. Tests of all boilers close to full load will not be able to be executed until winter. Boiler safeties will be tested prior to occupancy.

At the beginning of the heating season, the boiler will be started and operated, without further testing, unless problems arise. Then, when conditions are colder (approximately 40F-45F), the second test will be performed. This will likely require some false loading to create close to full load conditions and subsequently may need to be executed on a weekend to minimize discomfort to occupants. During this second test, some of the sequences performed during the first test will be retested and recorded, as necessary, to get to the staging and full load tests not performed during the first test. Also, the benchmarking and trending will be completed during the second test period.

8. Test Procedure Table of Contents

9. Testing Procedures and Record

Proced. No. & Spec. Seq. ID[1]	Req ID No.[2]	**Test Procedure[3]** (including special conditions)	**Expected and Actual Response[4]** [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
HEATING WATER SYSTEM STARTUP AND STAGING					
1		**Startup Sequence**. B-1 (This is not the initial startup by factory reps). With heating system off, with schedule allowing Boiler ON and OSAT <50F, turn Boiler and Pumps to auto. Turn on AHU's to cause a call for heating sufficient to call for boiler (manually open cooling coil valve if required to, lower space temperature SPt)	Observe Heating Water Pump HWP-1 energizes. Observe Boiler B-1 starting sequence energizes and Boiler starts.		
2		**Boiler Modulation:** Continue to load Boiler. Specified Sequences: Poll HW every 4 min. (Confirm Boiler burner modulation and setpoints with Boiler Manufacturer).	HW Discharge = [_______F]. Observe that the burner output increases as the setpoint remains unsatisfied. Record result. Time Setpoint Actual		
3		**Boiler Staging - OFF.** Lower space setpoints so HCV's at AHU's close. Wait as Boiler burner modulates down. Record time. (Confirm burner turndown and setpoints with Boiler Manufacturer).	Observe that the burner output decreases as the setpoint remains unsatisfied. Record results. When all HCV's are closed for 10 min. and after an additional 20 min. delay, boiler and pump should shut down. Time Setpoint Actual *No no-flow alarms should be generated during normal unloading.		
4		**General Staging By Monitoring:** Trend the status of B-1, HWP-1 and 2, OSAT, HWST).	Observe that there are no anomalies in operation, comparing to the specified sequences and modulation. This is not a detailed "to the minute" modulation verification, which was done manually above. Attach representative graphs or columnar data and explanatory analysis to this test report.		

Proced. No. & Spec. Seq. ID[1]	Req ID No.[2]	Test Procedure[3] (including special conditions)	Expected and Actual Response[4] [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
MISC. BOILER SYSTEM FUNCTIONS					
5		**OSAT Lockout.** With Boiler running in auto, overwrite OSAT sensor to be 75F.	Observe a shutdown of the Boiler, including HW pump.		
6		**OSAT Lockout By Monitoring.** During Boiler water pressure control monitoring:	Observe a shutdown of the Boiler, including HW pump, whenever the OSAT is above 75F (verify setpoint). Attach representative graphs or columnar data and explanatory analysis to this test report.		
7		**Lead HW Pump Failure, B-1** With the Boiler running (in auto), manually shut off the lead HW pump.	Operating Boiler should stop and go into failure alarm. The lag pump then becomes the lead pump and should start. Observe Boiler restart once Heating Water flow has been re-established.		
8		**System Stabilization** Analyze HW reset and pressure control monitoring data.	Verify that the HWS temperature is stable and maintains the HWS SPt within 0.5F over a range of conditions and days.		
9		**Pumps for Freeze Protection** With boiler in auto, overwrite OSAT to be 38F.	Observe that HWP operates normally.		
BOILER SAFETY CONTROLS					
10		**HW Flow Switch B-1.** If HW pumps are wired in series with proof of flow switches, jumper pumps out of this loop. With Boiler manually off, but under conditions that will call for Boiler, manually turn off HW pumps. Turn Boiler to auto.	Observe that Boiler won't start because of no HW flow condition and that an alarm is generated.		
11 MANUF O&M		**High Cutoff** TBD	Indicator lights for alarms, cutouts and normal running function properly. Boiler does not restart after cutout.		
12 MANUF O&M		**Low Water Cutoff** TBD	Indicator lights for alarms, cutouts and normal running function properly. Boiler does not restart after cutout.		
13 MANUF O&M		**Blocked Vent Safety Switch** TBD	Indicator lights for alarms, cutouts and normal running function properly. Boiler does not restart after cutout.		
14 MANUF O&M		**Rollout Safety Switch** TBD	Indicator lights for alarms, cutouts and normal running function properly. Boiler does not restart after cutout.		
15 MANUF O&M		**Motorized Vent Damper** TBD	Indicator lights for alarms, cutouts and normal running function properly. Boiler does not restart after cutout.		
16 MANUF O&M		**Operator Pressure Control** TBD	Indicator lights for alarms, cutouts and normal running function properly. Boiler does not restart after cutout.		

Proced. No. & Spec. Seq. ID[1]	Req ID No.[2]	Test Procedure[3] (including special conditions)	Expected and Actual Response[4] [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
HEATING WATER SYSTEM STARTUP					
17		**Return all changed control parameters and conditions to their pre-test values[5]**	**Check off in table of Section 2 above when completed**		
SEQUENCES AND COMPONENTS NOT TESTED					
18		Vibration Isolators. Not tested.			
19		Capacity Testing Not tested.			
MONITORING AND TREND LOGGING Monitoring via BAS trend logs are required per test procedures 4 and 6. Attach representative graphs or columnar data and explanatory analysis to this test report.					

**Abbreviations: HW = Heating Water, dP = diff. pressure, SPt = setpoint
HWS = Heating Water Supply, BAS = building automation system.

[1]Sequences of operation attached to this test.
[2]Mode or function ID being tested from testing requirements section of the project Specifications.
[3]Step-by-step procedures for manual testing, trend logging or data-logger monitoring.
[4]Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.
[5]Record any permanently changed parameter values and submit changes to Owner.
[6] Methods to False Load Boiler

1) If OSAT is less than 75F, prevent economizer cool OSA from entering the building.
   a) Manually close the economizer OSA dampers, OR
   b) Overwrite the OSAT value to be 80F or more so dampers won't open.
2) Use heating coils to heat incoming OSA.
   Enable the boiler by removing any lockouts, etc. Manually open the min. OSA preheat coil valve to preheat the OSA. Increase the min. OSA discharge temperature setpoint and the heating water supply temperature, as necessary.
3) Lower the space temperature setpoint.
4) Prior to the boiler test, manually precool the building space temperature to 60F - 65F.
5) Lower the heating water supply temperature setpoint.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

POWER DISTRIBUTION SYSTEM
Construction Checklist – MOTOR CONTROL CENTER
LOW VOLTAGE (480 VOLT) MCC
Tag No.: ________

Associated checklists: Wire/Cable testing, Unit Substation

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Commissioning Authority	Date

2. Requested Documentation

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		NAME	CONTR.	DATE
	1			
Manuf.	2			
	3			
	1			
Model	2			
	3			
Serial #	3			
Manuf. Shop Order #	3			
Short Circuit Capacity #	3			
Voltage Rating #	3			
Main Bus Amperage #	3			
Other	2			
	3			

- ***The equipment installed matches the specifications for given trade ....___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
MCC – Enclosure/cabinetry			
Inspected for physical, electrical and mechanical condition of equipment and cabinet. No damage evident			
Verify mounting, location and clearances are per plans and specifications			
Equipment installed agrees with shop drawings and specifications			

Check	Name	Contr.	Date
Equipment installed per manufacturer's instructions and specifications			
Inspect panels and doors for proper fit and alignment			
Verify that bottom feed conduits align with appropriate openings in MCC and can accommodate seismic motion.			
Verify or confirm the application of manufacturer recommended torque values applied to bolted connections – especially shipping split bus connections			
Verify three or four wire configuration			
Verify or confirm that all manufacturer control wiring between shipping splits is properly connected per manufacturer's drawings and specifications.			
Verify correct fuse and circuit breaker sizes and types per the specifications and manufacturer's drawings			
Metering (if provided) matches specified.			
Cabinets are clean and clear of dust or dirt on inside			
Cabinet exterior is clean			
Inspected insulators, barriers and shields for damage or contamination			
Verify that MCC is properly grounded and resistance to ground meets grounding specifications.			
Megger test of bus – phase to phase and phase to ground. Test voltage per manufacturer's recommendations.			
Verify the vents and air inlets are free and unobstructed. Clean air filters installed (if required)			
Equipment labels permanently affixed			
Seismic anchoring installed and functional where applicable (non-short circuiting)			
Main Circuit Breaker (if provided)			
Installed per manufacturer's instructions, plans and specifications			
No physical damage			
Verify voltage and current rating of circuit breaker are per plans and specifications			
Verify all maintenance and service clearances are maintained			
Feeder Circuit Breakers			
Installed per manufacturer's instructions, plans and specifications			
No physical damage			
Verify voltage and current rating of circuit breakers are per plans and specifications			
Verify all maintenance and service clearances are maintained			

Check	Name	Contr.	Date
Motor Starters			
Installed per manufacturer's instructions, plans and specifications			
Verify voltage and current rating of Motor Circuit Protectors (MCP's) are per plans and specifications			
Verify motor starter sizes (NEMA) are per plans and specifications			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Additional Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Verify proper phasing (A, B, C)			
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point external control wiring interconnect checks have been completed and documentation record submitted for this system			

-- END OF CONSTRUCTION CHECKLIST --

POWER DISTRIBUTION SYSTEM
Functional Performance Test – MOTOR CONTROL CENTER
LOW VOLTAGE (480 VOLT) MCC
Tag No.: ________

Memo sent to all relevant parties_____________

1. Participants

Commissioning Participants:

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	City Inspector	Date
Other	Date	Other	Date

Party filling out this form and witnessing testing ______________________________

Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________

2. Test Prerequisites

a. The following equipment has been started up and that startup reports and Construction checklists have been submitted and approved ready for functional testing:
   __ Low Voltage Switchgear
   __ Incoming Feeder Cables (if MCC has a main circuit breaker).

b. All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning, sensor and device calibrations completed.

Controls Contractor Signature or Verbal ______________________ Date ______________

c. All A/E punch list items for this equipment corrected.
d. These functional test procedures reviewed and approved by installing contractor.
e. Safeties and operating ranges reviewed.
f. Test requirements and sequences of operation attached.
g. Schedules and setpoints attached.
h. False loading equipment, system and procedures ready (if any)
i. Sufficient clearance around equipment for servicing.

3. Protective Device Calibration Checks. The Devices listed below are set and checked for calibration[1].

[1]"Set and checked for calibration" means following the manufacturer's recommendations for those devices that can be set and checked without removal from the motor control center. In general, this would exclude thermo-magnetic, motor circuit protectors and other basic solid state trip systems that have only adjustable instantaneous trip capability. Included in the "set and checked" category are solid state trip units which offer expanded functionality such as long time, short time, I2t and ground fault protection. Secondary current injection may be used to set and check for calibration of these units. Settings per the Coordination Study.

PROTECTIVE DEVICES	NOMINAL RATING (FRAME)	SETTINGS							
		Long Time (Amps)	Long Time Delay (Sec.)	Short Time (Amps)	Short Time Delay (Sec)	Inst.	I^2t	Gnd. Fault (Amps)	Gnd. Fault Delay (Sec)
Main Circuit Breaker[1]									
Feeder Circuit Breakers[2, 6] (CKT #)									
Motor Circuit Protector[3, 4, 6] (CKT #)		N/A	N/A	N/A	N/A	[5]	N/A	NA/	N/A

[1]If provided
[2]Settings for feeder breakers will be dependent on the type of breakers provided. Larger size breakers may have more sophisticated trip systems that provide the full array of protection. Basic thermo-magnetic breakers will have only frame and long time trip ratings.
[3]MCP's provide instantaneous protection only. Frame and long time are generally the same value. Overcurrent protection is provided by the motor overloads.
[4]Instantaneous settings for MCP's must meet the requirements of NEC Article 430-52, c(3).
[5]MCP instantaneous settings are usually graduated by letter code (A, B, C… etc.). Consult manufacturer's information regarding actual values and adjustable ranges.
[6]Add feeder circuit breakers and MCP as required to list all devices supplied in the MCC.

4. Verification of Misc. Pre-functional Checks.
Misc. site checks of the pre-functional checklist and startup reports completed successfully.
Pass? Y / N _______

5. Testing Procedures and Record

Proced. No. & Spec. Seq. ID[1]	Req ID No.[2]	Test Procedure[3] (including special conditions)	Expected and Actual Response[4] [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
Motor Control Center Startup					
1		At minimum, the main circuit breaker (if provided) or the up stream circuit breaker protective device calibration should be complete.	Y/N		
2		Megger MCC – phase to phase, phase-to-ground and neutral-to-ground. Testing voltage per manufacturer's recommendations. Incoming Main Circuit Breaker (if provided) should be in the off position. If no main circuit breaker, then the up-stream source breaker must be in the off position. All MCC feeders and motor circuits must be turned off. NOTE: If there is no main circuit breaker in the MCC, the megger test will include the incoming feeder cables.	The minimum insulation resistance should be equal to one megohm for every 1000 volts of operating voltage plus one megohm.		
3		Energize MCC			
4		Verify proper phase to phase and phase to ground voltage for each vertical section of MCC.			
5		Verify proper phase sequence for vertical bus.			
SEQUENCES AND COMPONENTS NOT TESTED					
6		Feeder breakers and motor starters not tested at this time. These units to be tested during commissioning of respective loads.			

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

POWER DISTRIBUTION SYSTEM
Construction Checklist - NORMAL POWER 600 VOLT FEEDERS
Megger Test Report

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ____________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Commissioning Authority	Date

2. Cable Electrical Megger Test Report List

MCC/ Dist. Panel	Circuit/Feeder Number	A Ph	B Ph	C Ph	N (if insl[1])	Test Voltage	Tester Signature	Date

-- END OF CHECKLIST --

POWER DISTRIBUTION SYSTEM
Construction Checklist - POWER DISTRIBUTION PANELS
208/120 VOLT NORMAL POWER DISTRIBUTION PANEL
Tag No.: ________

Associated checklists: Wire/Cable testing; Dry Type Transformer Testing

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ____________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Commissioning Authority	Date

2. Requested Documentation

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manuf.	1			
	2			
	3			
Model	1			
	2			
	3			
Serial #	3			
Manuf. Shop Order #	3			
Short Circuit Capacity #	3			
Voltage Rating #	3			
Main Bus Amperage #	3			
Other	2			
	3			

- ***The equipment installed matches the specifications for given trade ....___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Distribution panel – Enclosure/cabinetry			
Inspected for physical, electrical and mechanical condition of equipment and cabinet. No damage evident			
Verify mounting, location and clearances are per plans and specifications			
Equipment installed agrees with shop drawings and specifications			
Equipment installed per manufacturer's instructions and specifications			

Check	Name	Contr.	Date
Inspect panels and doors for proper fit and alignment			
Verify or confirm the application of manufacturer recommended torque values applied to bolted connections			
Neutral bus isolated from cabinet.			
Verify correct circuit breaker sizes and types per the specifications and manufacturer's drawings			
Panel is clean and clear of dust or dirt on inside			
Cabinet exterior is clean			
Inspected insulators, barriers and shields for damage or contamination			
Verify that ground bus is properly bonded to enclosure, enclosure is grounded and resistance to ground meets grounding specifications.			
Megger test of bus – phase to phase and phase to ground. Test voltage per manufacturer's recommendations.			
Equipment labels permanently affixed			
Seismic anchoring installed and functional where applicable (non-short circuiting)			
Circuit Breakers – 208/120 Volt Distribution Panels			
Installed per manufacturer's instructions, plans and specifications			
No physical damage			
Verify voltage and current rating of circuit breaker are per plans and specifications			
Verify breakers are mounted securely and operates smoothly			
Verify wire is properly installed and suitable size for breaker			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Additional Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point external control wiring interconnect checks have been completed and documentation record submitted for this system			

-- END OF CONSTRUCTION CHECKLIST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

POWER DISTRIBUTION SYSTEM
Functional Performance Test – POWER DISTRIBUTION PANEL
480/277 or 208/120 Volt Power Distribution Panel
Tag No.: ________

Memo sent to all relevant parties_____________

1. Participants

Commissioning Participants:

____________________	__________	________________________	_____________
Facilities	Date	Commissioning Authority	Date
____________________	__________	________________________	_____________
Construction Manager	Date	Controls Contractor	Date
____________________	__________	________________________	_____________
TAB Contractor	Date	Mechanical Contractor	Date
____________________	__________	________________________	_____________
Electrical Contractor	Date	City Inspector	Date
____________________	__________	________________________	_____________
Other	Date	Other	Date

Party filling out this form and witnessing testing ______________________________

Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________

2. Test Prerequisites

a. The following equipment has been started up and that startup reports and Construction checklists have been submitted and approved ready for functional testing:
   __ In coming Feeder Cables
   __ Up-stream Switchgear/Transformer (owner and/or Utility owned equipment).

b. All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning, sensor and device calibrations completed.

______________________________ ______________________

Controls Contractor Signature or Verbal Date

c. All A/E punchlist items for this equipment corrected.
d. These functional test procedures reviewed and approved by installing contractor.
e. Safeties and operating ranges reviewed.
f. Test requirements and sequences of operation attached.
g. Schedules and Fault/Coordination Study attached.
h. False loading equipment, system and procedures ready (if any)
i. Sufficient clearance around equipment for servicing.

3. Protective Device Calibration Checks.

The Devices listed below are set and checked for calibration[1].

[1]"Set and checked for calibration" means following the manufacturer's recommendations for those devices that can be set and checked without removal from the switchgear other than for "plug-in" style protective devices. Secondary current injection may be used to set and check for calibration of these units. Settings per the Coordination Study.

PROTECTIVE DEVICES	NOMINAL RATING (FRAME)	SETTINGS								
		Long Time (Amps)[3]	Long Time Delay[2] (Sec.)	Short Time (Amps)[3]	Short Time Delay (Sec)[3]	Inst.[3]	I^2t	Gnd. Fault (Amps)[3]	Gnd. Fault Delay (Sec)[3]
Main Circuit Breaker[1, 2]									
Feeder Circuit Breakers[2, 4] (CKT #)									

[1]If provided
[2]Settings for main circuit breaker and feeder breakers will be dependent on the type of breakers provided. Larger size breakers may have more sophisticated trip systems that provide the full array of protection. Some types of breakers with electronic trips may have only an adjustable instantaneous setting. Basic thermo-magnetic breakers will have only frame and long time trip ratings. List values as required and N/A if not available.
[3]Per phase
[4]Add feeder circuit breakers as required to list all feeder breakers supplied in the panelboard.

4. Verification of Misc. Pre-functional Checks.

Misc. site checks of the pre-functional checklist and startup reports completed successfully.
Pass? Y / N _______

5. Testing Procedures and Record

Proced. No.	Req ID No.	Test Procedure (including special conditions)	Expected and Actual Response [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
Medium Voltage Switchgear Startup					
1		At minimum, the main circuit breaker (if provided) or the up stream circuit breaker protective device calibration should be complete.	Y/N		
2		Megger panelboard phase to phase, phase-to-ground. Testing voltage per manufacturer's recommendations. Incoming Main Circuit Breaker (if provided) in the off position. If no main circuit breaker, then the up-stream source breaker must be in the off position and racked out of the enclosure (if draw out type). All feeder breakers must be in the off position. Fuses or primary disconnects for any Potential Transformers and Control Power Transformers must be removed or in the off position, respectively. NOTE: If there is no main circuit breaker in the switchgear, the megger test will include the incoming feeder cables.	The minimum insulation resistance should be equal to one megohm for every 1000 volts of operating voltage plus one megohm. Typical applied DC test voltages: Operating Voltage Test Voltage 1000 to 2500 volts ------ 500 to 1000 volts 2501 to 5000 volts ------ 1000 to 2500 volts 5001 to 12,000 volts ---- 2500 to 5000 volts over 12,000 volts -------- 5000 to 10,000 volts Test Voltage should be applied for 60 seconds.		
3		Ensure all feeder breakers are in the off position. Energize switchgear.			
4		Verify phase relationship is true A, B, C, left to right facing distribution panel.			
5		Verify phase to phase and phase to neutral voltages are correct.			

[1]Manufacturer's Factory Acceptance Tests may be accepted in lieu of completing all of these tests in the field.

SEQUENCES AND COMPONENTS NOT TESTED					
1		Energization of feeder breakers to be completed as downstream loads are commissioned.			

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

POWER DISTRIBUTION SYSTEM
Construction Checklist - LOW VOLTAGE DRY TYPE TRANSFORMER <500 KVA
Tag No.: ________

Associated checklists: Wire/Cable testing

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

________________________	____________	______________________	___________
Mechanical Contractor	Date	Controls Contractor	Date
________________________	____________	______________________	___________
Electrical Contractor	Date	Construction Manager	Date
________________________	____________	______________________	___________
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ___________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

________________________	____________	______________________	___________
Commissioning Agent	Date	Commissioning Authority	Date

2. Requested Documentation

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

			Name	Contr.	Date
	1				
Manuf.	2				
	3				
	1				
Model	2				
	3				
Serial #	3				
Manuf. Shop Order #	3				
Short Circuit Capacity	3				
Voltage Rating #	3				
Main Bus Amperage #	3				
Other	2	225 KVA			
	3				

- ***The equipment installed matches the specifications for given trade ....___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Distribution panel – Enclosure/cabinetry			
Inspected for physical, electrical and mechanical condition of equipment and cabinet. No damage evident			
Verify mounting, location and clearances are per plans and specifications			
Equipment installed agrees with shop drawings and specifications			
Equipment installed per manufacturer's instructions and specifications			

Check	Name	Contr.	Date
Inspect panels and doors for proper fit and alignment			
Verify or confirm the application of manufacturer recommended torque values applied to bolted connections			
Enclosure is clean and clear of dust or dirt on inside			
Cabinet exterior is clean			
Inspected insulators, barriers and shields for damage or contamination			
Verify that ground bus is properly bonded to enclosure, enclosure is grounded and resistance to ground meets grounding specifications.			
Megger test of transformer – Primary and secondary – phase to ground. Test voltage per manufacturer's recommendations.			
Equipment labels permanently affixed			
Seismic anchoring installed and functional where applicable (non-short circuiting)			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Additional Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point external control wiring interconnect checks have been completed and documentation record submitted for this system			

-- END OF CONSTRUCTION CHECKLIST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

POWER DISTRIBUTION SYSTEM
Functional Performance Test - LOW VOLTAGE DRY TYPE TRANSFORMER < 500 KVA
Tag No.: ________

Memo sent to all relevant parties_____________

1. Participants

Commissioning Participants:

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	City Inspector	Date
Other	Date	Other	Date

Party filling out this form and witnessing testing ______________________________

Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________

2. Test Prerequisites

a. The following equipment has been started up and that startup reports and Construction checklists have been submitted and approved ready for functional testing:
__ Low Voltage Switchgear/MCC
__ Incoming Feeder Cables (if MCC has a main circuit breaker).

b. All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning, sensor and device calibrations completed.

Controls Contractor Signature or Verbal	Date

c. All A/E punchlist items for this equipment corrected.
d. These functional test procedures reviewed and approved by installing contractor.
e. Safeties and operating ranges reviewed.
f. Test requirements and sequences of operation attached.
g. Schedules and setpoints attached.
h. False loading equipment, system and procedures ready (if any)
i. Sufficient clearance around equipment for servicing.

3. **Protective Device Calibration Checks.** The Devices listed below are set and checked for calibration[1].

[1]"Set and checked for calibration" means following the manufacturer's recommendations for those devices that can be set and checked without removal from the motor control center. In general, this would exclude thermo-magnetic, motor circuit protectors and other basic solid state trip systems that have only adjustable instantaneous trip capability. Included in the "set and checked" category are solid state trip units which offer expanded functionality such as long time, short time, I2t and ground fault protection. Secondary current injection may be used to set and check for calibration of these units. Settings per the Coordination Study.

4. Verification of Misc. Pre-functional Checks.

Misc. site checks of the pre-functional checklist and startup reports completed successfully.
Pass? Y / N _______

5. Testing Procedures and Record

Proced. No.		**Test Procedure** (including special conditions)	**Expected and Actual Response** [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
Low Voltage Dry Type Transformer - <500kVA					
1		Feeder circuit breaker protective device calibration complete.	Y/N		
2		Megger transformer high voltage windings and low voltage windings – phase-to-ground. Testing voltage per manufacturer's recommendations. The up-stream source breaker must be in the off position. Down stream circuit breaker (or distribution panel main breaker) must be turned off. NOTE: The megger test will include the incoming feeder cables and the load side cables.	The minimum insulation resistance should be equal to one megohm for every 1000 volts of operating voltage plus one megohm. Test voltage typically at 500 to 1000 volts DC.		

Proced. No.		**Test Procedure** (including special conditions)	**Expected and Actual Response** [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
3		Energize Transformer			
4		Verify proper phase to phase and phase to ground voltage for primary and secondary of transformer.			
SEQUENCES AND COMPONENTS NOT TESTED					

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

POWER DISTRIBUTION SYSTEM
Construction Checklist - ELECTRICAL GROUNDING

Associated checklists: Switchgear, Power Distribution Panels, Electrical panels and all Equipment requiring grounding

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Commissioning Authority	Date

2. Requested Documentation

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

			Name	Contr.	Date
Manuf.	1				
	2				
	3				
Model	1				
	2				
	3				
Serial #	3				
Capacity	1				
	2				
	3				
Volts/Ph/A	1				
	2				
	3				
Starter Mod	1				
	2				
	3				
Other	1				
	2				
	3				

- ***The equipment installed matches the specifications for given trade ....___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Grounding			
Size and type of grounding and bonding conductors are in accordance with the drawings and specifications			
Grounding electrodes have been installed in accordance with drawings and specifications			
Connections to grounding electrodes have been made in accordance with manufacturer's specifications			
Grounding conductors have been routed in accordance with the drawings and specifications			
Grounding conductors have been properly terminated at the service equipment or separately derived source. Bonding conductors have been installed as required			
Resistance of the grounding system has been measured and recorded. Provide method of measurement.			
Test wells are accessible and clearly marked.			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point checks have been completed and documentation record submitted for this system			

-- END OF CHECKLIST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

POWER DISTRIBUTION SYSTEM
Construction Checklist - DISCONNECT SWITCH
600 VOLT & 250 VOLT NORMAL FUSED/UN-FUSED DISCONNECT SWITCHES
Tag No.: ________

Associated checklists: Wire/Cable testing

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ____________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Commissioning Authority	Date

2. Requested Documentation

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Model Verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
	1			
Manuf.	2			
	3			
	1			
Model	2			
	3			
Serial #	3			
Manuf. Shop Order	3			
Short Circuit Capacity	3			
Voltage Rating	3			
Amperage Rating	3			
Other	2			
	3			

- ***The equipment installed matches the specifications for given trade ....___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Distribution panel – Enclosure/cabinetry			
Inspected for physical, electrical and mechanical condition of equipment and cabinet. No damage evident			
Verify mounting, location and clearances are per plans and specifications			
Equipment installed agrees with shop drawings and specifications			
Equipment installed per manufacturer's instructions and specifications			

Check	Name	Contr.	Date
Inspect panels and doors for proper fit and alignment			
Verify or confirm the application of manufacturer recommended torque values applied to bolted connections			
Neutral bus isolated from cabinet.			
Verify correct fuse size (if fused switch) and type per the specifications and drawings			
Panel is clean and clear of dust or dirt on inside			
Cabinet exterior is clean			
Inspected insulators, barriers and shields for damage or contamination			
Verify that enclosure is grounded and resistance to ground meets grounding specifications.			
Megger test of bus – phase to phase and phase to ground (prior to connection of wiring). Test voltage per manufacturer's recommendations.			
Equipment labels permanently affixed			
Seismic anchoring installed and functional where applicable (non-short circuiting)			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Additional Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point external control wiring interconnect checks have been completed and documentation record submitted for this system			

-- END OF CONSTRUCTION CHECKLIST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

POWER DISTRIBUTION SYSTEM
Functional Performance Test – DISCONNECT SWITCH
600 Volt and 250 Volt Fused & Un-fused Disconnect Switch
Tag No.: ________
Voltage: ________

Memo sent to all relevant parties_____________

1. Participants

Commissioning Participants:

____________________ Facilities	________ Date	____________________ Commissioning Authority	________ Date
____________________ Construction Manager	________ Date	____________________ Controls Contractor	________ Date
____________________ TAB Contractor	________ Date	____________________ Mechanical Contractor	________ Date
____________________ Electrical Contractor	________ Date	____________________ City Inspector	________ Date
____________________ Other	________ Date	____________________ Other	________ Date

Party filling out this form and witnessing testing ______________________________

Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________

2. Test Prerequisites

a. The following equipment has been started up and that startup reports and Construction checklists have been submitted and approved ready for functional testing:
   __ In coming Feeder Cables
   __ Up-stream Switchgear/Transformer (owner and/or Utility owned equipment).

b. All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning, sensor and device calibrations completed.

______________________________ Controls Contractor Signature or Verbal

______________________________ Date

c. All A/E punch list items for this equipment corrected.
d. These functional test procedures reviewed and approved by installing contractor.
e. Safeties and operating ranges reviewed.
f. Test requirements and sequences of operation attached.
g. Schedules and Fault/Coordination Study attached.
h. False loading equipment, system and procedures ready (if any)
i. Sufficient clearance around equipment for servicing.

3. Protective Device Calibration Checks. The Devices listed below are set and checked for calibration[1].

[1]"Set and checked for calibration" means following the manufacturer's recommendations for those devices that can be set and checked without removal from the switchgear other than for "plug-in" style protective devices. Secondary current injection may be used to set and check for calibration of these units. Settings per the Coordination Study.

PROTECTIVE DEVICES	NOMINAL SWITCH RATING	FUSES	
		CURRENT RATING	TYPE
Switch Current Rating			
Fuse Rating and Type			

4. Verification of Misc. Pre-functional Checks.

Misc. site checks of the pre-functional checklist and startup reports completed successfully.
Pass? Y / N _______

-- THIS SPACE IS INTENTIONALLY LEFT BLANK --

5. Testing Procedures and Record

Proced. No.	Req ID No.	**Test Procedure** (including special conditions)	**Expected and Actual Response** [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
Medium Voltage Switchgear Startup					
1		At minimum, the main circuit breaker (if provided) or the up stream circuit breaker protective device calibration should be complete.	Y/N		
2		**For disconnect used as secondary transformer protection:** Megger Switch phase to-ground on incoming terminals for switches on transformer secondary's (With transformer secondary connected, phase to phase would read through the transformer windings). It is necessary to disconnect upstream transformer neutral from ground to perform this test. Primary circuit to the transformer must be in the off position. Testing voltage per manufacturer's recommendations. Megger load side of the switch phase to phase and phase to ground with switch open. Down stream panel main breaker (if provided) must be in the open position. If no main, then all feeder breakers must be in the open position. NOTE: If there is no main circuit breaker in the down stream panel, the megger test will include the feeder cables and the panel.	The minimum insulation resistance should be equal to one megohm for every 1000 volts of operating voltage plus one megohm. Typical applied DC test voltages: Operating Voltage Test Voltage <500 volts-----------------500 volts 1000 to 2500 volts ------ 500 to 1000 volts 2501 to 5000 volts ------ 1000 to 2500 volts 5001 to 12,000 volts ---- 2500 to 5000 volts over 12,000 volts -------- 5000 to 10,000 volts Test Voltage should be applied for 60 seconds.		
3		**For local device disconnect switches:** With primary circuit breaker open and disconnect closed (fuses not installed), megger phase to phase and phase to ground on primary switch terminals. Megger load terminals phase to ground. This will megger the load feeder cables and the motor or other connected load. Testing voltage per manufacturer's recommendations.	The minimum insulation resistance should be equal to one megohm for every 1000 volts of operating voltage plus one megohm. Typical applied DC test voltages: Operating Voltage Test Voltage <500 volts-----------------500 volts 1000 to 2500 volts ------ 500 to 1000 volts 2501 to 5000 volts ------ 1000 to 2500 volts 5001 to 12,000 volts ---- 2500 to 5000 volts over 12,000 volts -------- 5000 to 10,000 volts Test Voltage should be applied for 60 seconds.		
4		With primary power off, exercise switch to insure smooth operation and proper contact closure.			

Proced. No.	Req ID No.	Test Procedure (including special conditions)	Expected and Actual Response [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
5		Install proper fuses per drawings and specifications ensuring proper fuse contact to stabs for barrel and stab mount fuses and proper torque of bolts for bolt in fuses.			
6		When circuit is fully energized, verify phase to phase and phase to neutral voltages are correct.			

SEQUENCES AND COMPONENTS NOT TESTED					
1		Energization of circuit to be completed as downstream loads are commissioned.			

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

LIGHTING SYSTEM
Construction Checklist – INTERIOR LIGHTING CONTROL SYSTEM

Associated checklists: 480/277 Volt Power Distribution Panels, 208/120 Volt Distribution Panels

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Commissioning Authority	Date

2. Requested Documentation

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

	SYM.	Manufacturer & Model #	Name	Contr.	Date
1					
2					
3					
1					
2					
3					
1					
2					
3					
1					
2					
3					

1					
2					
3					
1					
2					
3					
1					
2					
3					
1					
2					
3					
1					
2					
3					
1					
2					
3					

- ***The equipment installed matches the specifications for given trade ....___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Lighting			
Lighting installed per plans, specifications and manufacturer's recommendations			
All zone circuits and inputs are wired			
Lighting control system is installed per plans, specifications and manufacturer's recommendations			
Communications interconnection/interface connected			
Lighting control panels installed per plans, specifications and manufacturer's recommendations			
Switches, dimmers and occupancy sensors are mounted at correct height and are the correct color plate			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point checks have been completed and documentation record submitted for this system			
Lighting control processor powered and battery backup operation checked.			
Lighting control processor diagnostics performed			
Lighting control communications interconnect checked.			

-- END OF CHECKLIST --

LIGHTING SYSTEM
Functional Performance Test – INTERIOR LIGHTING CONTROL SYSTEM

1. Commissioning Participants:

______________________ Facilities	__________ Date	______________________ Commissioning Authority	________ Date
______________________ Construction Manager	__________ Date	______________________ Controls Contractor	________ Date
______________________ TAB Contractor	__________ Date	______________________ Mechanical Contractor	________ Date
______________________ Electrical Contractor	__________ Date	______________________ City Inspector	________ Date
______________________ Other	__________ Date	______________________ Other	________ Date

Party filling out this form and witnessing testing ________________________________

Dates of tests ________________________
Dates of tests ________________________
Dates of tests ________________________
Dates of tests ________________________

2. Sweep Controller Type: ____ part of EMS, ____ separate PC system, ________ stand-alone controllers (give quantity), ____ stand-alone integrated into EMS.

Brand and model: ____
Type of system: ____ Sweeps off lights until morning. Override timers allow zones to be turned back on.
____ Sweeps off lights. Any light can than be turned back on by a:
___standard switch, ___phone call within building

3. Documentation: Verify that full documentation of the controller is *permanently* on site and includes the following:

___ specifications and features
___ list of loads and zones each relay controls attached*
___ contact number for additional assistance attached*
___ current written list of sweep schedules for all zones attached*
___ programming instructions attached*

___ controller warranty (in submittals)
___ written instructions for tenants in using the local overrides and a description of the areas they control

Attached = attached to the controller panel door **or** if PC computer controlled, in documentation manual

4. **Training:** If there is a full-time building operator in the building or building complex, they must be trained to fully understand the programming of the sweep controls, the operation of the total override and of the local overrides and have access to the system's full documentation. Full-time operator? ___Yes ___No

   If Yes, installing contractor performing training ________________________________.

   If Yes, individual trained as the "operator" _____________________________________.

   Review and approve the written instructions distributed to the tenants regarding the operation of the local overrides. Approved and distributed: ___Yes ___No

5. **Verification of capabilities and performance:** Verify that the controller has the following features and capabilities: (check-mark denotes acceptance)

   a. ____Programming capabilities via keypad or EMS interface. Verify by running through the current program and schedules.
   b. ____Back-up power supply (automatically recharged) that will retain program for ____ weeks without power. Verify by viewing specifications and battery pack.
   c. ____Lockable controller enclosure or room with key or code-only access for programming and total override **or** access is in a restricted PC program.
   d. ____The controlling time clock is reading the appropriate time.
   e. ____Override duration *set* to not more than **2** hours
   f. ____Each override as tested below, energizes no more than 5000 sf of floor area.
   g. ____Verify actual sweep and override operation of each controller as per table below.

Sweep Operation Verification

Day Type and Sweep No.	Schedule of Sweeps (hour of day)				
	Zone 1 ID:	Zone 2 ID:	Zone 3 ID:	Zone 4 ID:	Zone 5 ID:
	Relay ID:	Relay ID:	Relay ID:	Relay ID:	Relay ID:
Weekdays 1					
(enter schedules **2**					
in these rows) **3**					

Day Type and Sweep No.	Schedule of Sweeps (hour of day)				
	Zone 1 ID:	Zone 2 ID:	Zone 3 ID:	Zone 4 ID:	Zone 5 ID:
	Relay ID:	Relay ID:	Relay ID:	Relay ID:	Relay ID:
Saturday 1					
2					
Sunday 1					
2					
Fixtures/rooms excluded from sweep					
Sweep verification type[1]					
No. of local override switches (actual / spec'd)					
No. of override switches tested[2]					

Test Procedures

[1] **Sweeps.** 50% of the zones with a minimum of 2 zones per controller or relay must be verified by turning on at least 25% of the lights in the zone and witnessing an actual sweep. The remainder of the zones must have the programming of their schedules verified.

In the table above, enter all of the following codes that apply:
0 = not verified, **S** = verified **S**chedule in keypad or EMS display, **W** = verified operation by **W**itnessing a sweeping off of the lights at a special scheduled time, **F** = witnessed sweep, but sweep **F**ailed to function properly. Refer to comments.

[2] **Overrides.** 25% of the local override switches with a minimum of 4 overrides must be verified by turning the override switches on after a sweep and seeing the lights turn back on. 100% of the remainder of the switches should be sight verified to be in place. For each Zone, enter the number of override switches where functionality was actually witnessed. Verify that the local override only controls the specified zone.

Comments:

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

LIGHTING SYSTEM
Construction Checklist – EXTERIOR LIGHTING CONTROL SYSTEM

Associated checklists: 480/277 Volt, 208/120 Volt Distribution Panels

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Commissioning Authority	Date

2. Requested Documentation

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Light Fixture Model Verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

	SYM.	Manufacturer & Model #	Name	Contr.	Date
1					
2					
3					
1					
2					
3					
1					
2					
3					
1					
2					
3					

- ***The equipment installed matches the specifications for given trade ....___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Lighting			
Lighting installed per plans, specifications and manufacturer's recommendations			
All zone circuits and inputs are wired			
Lighting control system is installed per plans, specifications and manufacturer's recommendations			
Communications interconnection/interface connected			
Lighting control panels installed per plans, specifications and manufacturer's recommendations			
Switches, dimmers and occupancy sensors are mounted at correct height and are the correct color plate			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point checks have been completed and documentation record submitted for this system			
Lighting control processor powered and battery backup operation checked.			
Lighting control processor diagnostics performed			
Lighting control communications interconnect checked.			

-- END OF CHECKLIST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

LIGHTING SYSTEM
Functional Performance Test – EXTERIOR LIGHTING CONTROL SYSTEM

Project: ____

1. Participants

____________________ Facilities	_________ Date	____________________ Commissioning Authority	_______ Date
____________________ Construction Manager	_________ Date	____________________ Controls Contractor	________ Date
______________________ TAB Contractor	_________ Date	______________________ Mechanical Contractor	________ Date
______________________ Electrical Contractor	_________ Date	______________________ City Inspector	________ Date
______________________ Other	_________ Date	______________________ Other	________ Date

Party filling out this form and witnessing testing ____________________________

Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________

2. Prerequisite Checklist

a. All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final set points, schedules, debugging and fine tuning of photo-cell parameters.

______________________________ Controls Contractor Signature or Verbal

__________ Date

b. ___All A/E punch list items for this equipment corrected.
c. ____Safeties and operating ranges reviewed.
d. ____Test requirements and sequences of operation attached.
e. ____Schedules and set points attached.

f. ____Have all energy savings control strategies, set points and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.

g. ____**BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, set points and logic sequences appear to follow the specified written sequences.

h. ____Schedule of fixtures on each control type (Parking or Security) has been reviewed.

i. ____Record of All Values for Current Set points (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Parking lot lights schedule	ON by photo cell OFF by sched: ____________	
Photo-cell BAS parameters		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Exterior security lights schedule	ON by photo cell OFF by photo-cell	

1. Sensor Calibration Checks.

Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during pre-functional check listing. Test the packaged controls and BAS readings.

2. Device Calibration Checks.

---NONE---

3. Verification of Misc. Pre-functional Checks.

Misc. site checks of the pre-functional checklist and startup reports completed successfully.
Pass? Y / N _______

__ Photo-cell (PC) mounted securely.
__ PC mounted where it won't be tampered with.
__ PC mounted so it won't become dirty easily.
__ PC accessible for servicing.

4. Functional Testing Record

Proced. No. & Spec. Seq. ID[1]	Req ID No.[2]	**Test Procedure[3]** (including special conditions)	**Expected and Actual Response[4]** [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1		Near dusk, observe exterior lights until they come ON. (Witnessed by Owner's Rep: ___________________________	All exterior lights come on at dusk, before dark, but not when still very light.	
2		a) Change the Parking Lot light schedule OFF to be in 5 minutes. b) Return schedule to normal.	a) Observe that the parking lot lights, designated by the approved schedule, shut OFF. Designated signage remains ON. b) Schedule returned to normal.	
3		Before daylight in the morning, observe the security lights ON. Wait until dawn. (Witnessed by Owner's Rep: ___________________________	When sufficiently light, Security Lights and signage lights shut OFF.	
4	**--**	**Return all changed control parameters and conditions to their pre-test values[5]**	**Check off in Section 2 above when completed**	

Record Foot Notes
[1]Sequences of operation specified in Contract Documents (attached).
[2]Mode or function ID being tested, per testing requirements section of the project Specifications.
[3]Step-by-step procedures for manual testing, trend logging or data-logger monitoring.
[4]Include tolerances for a passing condition.
[5]Record any permanently changed parameter values and submit to Owner.

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

AUTOMATION SYSTEM
Construction Checklist - BUILDING AUTOMATION SYSTEM

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Construction Manager	Date	Controls Contractor	Date
TAB Contractor	Date	Mechanical Contractor	Date
Electrical Contractor	Date	Other	Date

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ____.

Approvals This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Requested documentation submitted

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
Performance data			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Operating manual			
Written copy of all control parameters, settings & setpoints			
Full written sequences and control strategies			
Design criteria			
Completed control drawings			
Full descriptive points list			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
Manufacturer	1			
	2			
	3			
Model	1			
	2			
	3			
Serial #	3			
CPU	1			
	2			
	3			
Monitor	1			
	2			
	3			
Other primary features:	1			
	2			
	3			

- ***The equipment installed matches the specifications for given trade...___ YES ___ NO***

4. Initial Setup and Checkout

4.1. User Terminal Interface and Sub-Panel Checks

Check if Okay. Enter comment or note number if deficient.

Check	Y / N	Contr.
General appearance good, no apparent damage		
Equipment labels affixed		
Layout and location of control panels matches drawings		
Areas or equipment panels serve clear in control drawings		
Wiring labeled inside panels (to controlled components)		
Controlled components labeled/tagged		
BAS connection made to labeled terminal(s) as shown on drawings		
Shielded wiring used on electronic sensors		
110 volt AC power available to panel		
Psig compressed air available to panel (if applicable)		
Battery backup in place and operable		
Panels properly grounded		
Environmental conditions according to manufacturer's requirements		
Date and time correct		

- ***The above setup and checkout was successfully completed for given trade__ YES __ NO***

4.2. Device and Point to Point Checkout (Static Commissioning)

The following procedures are required to be performed and documented for each and every point in the control system. The following procedures are minimum requirements. The control contractor is encouraged to identify better and more comprehensive checkout procedures in their submitted plan. These procedures are not a substitute for the manufacturer's recommended start-up and checkout procedures, but are to be combined with them, as applicable. The documentation may be provided on the vendor's stock form, as long as all the information in the sample table below can be clearly documented on the form.

Similar checkout and calibration requirements are found on the equipment construction checklists. Redundant documentation is not required. Cross reference, by name and form number, to other forms that contain documentation left blank on the current form (attached below).

<u>Procedures</u>

1. [Wire] Verify that the wiring is correct to each point.
2. [Actu] If the device is or has an actuator, verify full free movement through its full range.
3. [Addr] Verify that the software address is correct.
4. [Load] For devices with a controller, verify that current software program with proper setpoints has been .downloaded.
5. [DevCal] Device stroke/range calibration. This applies to all controlled valves, dampers, fans, pumps, .actuators, etc. Simulate maximum and minimum transmitter signal values and verify minimum and maximum controller output values and positively verify each and every control device minimum and maximum stroke and capacity range. Follow procedure 6.2 below.
6. [SensLoc] Verify that all sensor locations are appropriate and away from causes of erratic operation.
7. [SensCal] Sensor calibration. Calibrate or verify calibration of all sensors and thermostats, including temperature, pressure, flow, current, kW, rpm, Hertz, etc. Verify that the sensor readings in the control system are within the sensor accuracies specified in this section, using hand-held or other external measuring instruments. Follow procedure 6.1 below.

8. [OperCk] For controlled devices (dampers, valves, actuators, VAV boxes, etc.), after mechanical equipment control becomes operational, perform an operational test of each control loop. Follow procedure 6.2 below. Operational checks are preparatory to the later *functional testing*.
   Other Abbreviations:
   [BAS] Building automation system or gage-read value.
   [Instru] Instrument (calibrated) read value.
   [Ofset] Offset programmed into the point to correct the calibration.

5. Device and Point by Point Checkout (Dynamic Commissioning)

The following procedures are required to be performed and documented for each and every point in the control system. The following procedures are minimum requirements. The control contractor is encouraged to identify better and more comprehensive checkout procedures in their submitted plan. These procedures are not a substitute for the manufacturer's recommended start-up and checkout procedures, but are to be combined with them, as applicable. The documentation may be provided on the vendor's stock form, as long as all the information in the sample table below can be clearly documented on the form.

Similar checkout and calibration requirements are found on the equipment construction checklists. Redundant documentation is not required. Cross reference, by name and form number, to other forms that contain documentation left blank on the current form.

Procedures

Each control point will be verified to be commanding, reporting and controlling according to their intended purpose. Every analog and digital input and output in the central control system shall be verified to be functioning properly. Points within and controlled by packaged equipment controllers do not require a point-by-point checkout except for actuator positions or other points listed in the specifications or manufacturer's start-up and checkout procedures. For each output, commands will be initiated and verified to be functioning by visually observing and documenting the status of the controlled device (e.g., command cooling coil valve to full open, or command heating water pump off). For each input, the system or conditions will be perturbed to initiate the input response being tested and the response in the control system observed and recorded (e.g., high duct static pressure alarm). Sensors and actuators will also be calibrated according to the Sections below.

6. Sensor Calibration Methods

All Sensors. Verify that all sensor locations are appropriate and away from causes of erratic operation (in stratified air flow, touching coils, etc.). Verify that sensors with shielded cable are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, make sure they are reading within 0.2°F of each other for temperature and within a tolerance equal to 2% of the reading, of each other, for pressure. Tolerances for critical applications may be tighter. Hand-held instrument readings should be taken at five or more locations for mixed air temperatures and three or more locations for hot and cold deck temperatures to ensure a good average value to check against the BAS reading.

A. Sensors Without Transmitters--Standard Application. Make a one-point reading within the normal expected range of operation of the sensor with a calibrated test instrument, having an accuracy per table below, within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.

B. Sensors With Transmitters--Standard Application. Make a two point calibration. Check the calibration at a condition near the low end and near the high end of expected operating values (temperature, pressure, etc.) using the procedure in (A). If sensor is not within tolerances, calibrate: Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum expected temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature expected matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Take a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.

C. Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors, such as making multiple point readings throughout the expected range of sensor operation. Describe any such methods used on an attached sheet.

D. Terminal Unit Flow Sensors. Flow sensors in air terminal units shall be calibrated during testing; adjust and balance using NEBB or AABC approved procedures.

E. Required Instrument Accuracy and Calibration Tolerances--Standard Applications

Sensor	Required Calibrating Instrument Accuracy (+/-)	Required Calibration Tolerance (+/-)
Cooling coil, chilled and cond. water temps	1.3F	0.4F
AHU wet bulb or dew point	2.0F	2.0F
Hot water coil and boiler water temp	1.3F	2.0F
Outside air, space air, duct air temps	1.3F	0.4F
Combustion flue temps	2.0F	5.0F
Relative humidity	2% RH	5% RH
Watt hour, voltage & amperage	2% of reading	1% of design
Pressures, air, water and gas	2% of reading	3% of design
Building differential pressure	1% of full span	0.01 in. WC
Variable frequency drive	2 Hz	2 Hz
Flow rates, water	4% of reading	4% of design
CO_2 monitor	5% of reading	50 ppm
CO monitor	3% of span	0.6 ppm / deg C
Natural gas & oil flow rate	2% of reading	1% of design
Steam flow rate	2% of reading	3% of design
Flow rates, air	3% of reading	10% of design[1]
Air velocity rates	3% of reading	10% of design

[1] Flow rate accuracy for laboratory control will vary with the device and the space pressurization direction to ensure that the maximum allowed error in a worst case scenario will not result in the space requirements being violated.

F. Relative Sensor Calibration. This procedure makes sure that sensors are accurate relative to each other in a given piece of equipment. Sensors calibrated in this way, do not need separate calibration as given in Procedures A-D. For example, for a heating water system all the sensors in the fluid stream would be checked at one time, e.g., boiler entering and leaving temperatures, bypass, building supply and return temperatures. This would include building automation sensors, equipment panel readouts and gages. For an air handler it may include the return air temperature, coil temperatures and supply air temperatures. Calibrating sensors with this method is preferable to calibrating them each separately.

The procedure is as follows. 1) Record all current sensor calibration offsets. 2) Remove all sensor calibration offsets. 3) Put the system in a mode that will offer constant flow of water or air past the sensors, e.g., turn off boilers; turn on pumps, or turn on air handler and close outside air dampers and heating and cooling coil valves, etc. 4) Check with the reference instrument that the temperatures across coils and dampers are equal indicating that there is no leak-by. 5) With the reference instrument record the temperature rise across fans. 6) Use the entering fluid temperature to the system as a reference by inserting a reference measuring instrument there. 7) Compare the sensor readings with the reference reading. Take into account temperature rises across fans and pumps. 8) Install offsets or replace sensors and gages as required so sensor readings, compared to the reference, are within the tolerances given in Section E above. 9) Record all conditions, readings and offsets and submit. 10) Return systems to normal.

7. Valve and Damper Stroke Setup and Check

A. Actuator Arrangement. Verify that the actuator is using its full stroke to move the damper or valve through its full range of motion without sacrificing kinematics. Verify that linked or paired actuators are arranged the same. Verify that the linkages and ball joints are lubricated and that linkage rods are not binding or bent.

B. Spring Returns. For valves and dampers with spring returns, apply or remove power to the actuator and see that it moves to the correct position and that the spring has enough torque to fully close or open valve or damper.

C. EMS Readout and Stroke. For all valve and damper actuator positions checked, verify BAS address and the actual position against the BAS readout and verify that the valve or damper strokes fully and that “normal” position is correct. Set pumps or fans to normal operating mode. Command valve or damper closed, visually verify that valve or damper is closed and adjust output zero signal as required. Dampers shall be adjusted to provide a tight positive closure. Command valve or damper open, verify position is full open and adjust output signal as required. Command valve or damper to a few intermediate positions. If actual valve or damper position doesn’t reasonably correspond, replace actuator or add pilot positioner (for pneumatics). Remove the control signal to the valve or actuator from the BAS. Observe that the failure mode (current position, open, closed) is as per specifications.

D. Closure for heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Then, for pneumatic actuators only: Set heating setpoint to 20°F below room temperature. Observe the valve close. Override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

E. Closure for cooling coil valves (NC): Set cooling setpoint 20°F above room temperature. Observe the valve close. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. For pneumatic actuators only: Set cooling setpoint to 20°F below room temperature. Observe valve open. Override the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

8. Coil Valve Leak Check

A. Method 1--Water Temperature With 2- or 3-Way Valve. Calibrate water temperature sensors on each side of coil to be within 0.2°F of each other.

Method 1, Option 1 Test Across Coil--for valves that are tight against AHU cabinet or valves that are away from the cabinet. Turn off air handler fans, close OSA dampers; keep pump running and valve open. Fix the supply water temperature setpoint. Place one sensor in moving supply water stream P/T plug or use existing thermometer, else strap-on sensor and insulate. Place one sensor on the return side of the coil, but not in the main return stream from other coils, ideally in a P/T plug, or strap-on and insulate. Sensor on the valve side of the coil must be on the far side of the valve from the coil. Verify that temperatures on both sides of the coil read the same. If not the same, record differences and compensate in the next part of the test.

Close the valve by software command. After 10 minutes observe water delta-T across coil or valve. If delta-T is not greater than 2°F, leakage is probably occurring. If leaking, reset valve stroke to close tighter. Repeat test until in compliance.

Method 1, Option 2 Test Just Across Valve—for valves more than 4 feet from the coil. Command the valve closed and measure the temperature difference with one sensor in the moving water stream on one side of the valve and one in the dead water at least 3 ft. from both the valve or the coil if the fan is on, if the fan is not on it can be closer to the coil than 3 ft. After 10 minutes observe water delta T across valve. If it is not greater than 2°F, leakage is probably occurring.

B. Method 2--Air Temperature With 2 or 3-Way Valve. Calibrate air temperature sensors on each side of coil to be within 0.2°F of each other. Change mixed or discharge air setpoint, override values or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance. Water leak-by less than 10% will likely not be detected with this method.

C. Method 3 Coil Drain Down for Terminal Units (not for 3-way valves). Put systems in normal mode. If cooling coil valve, remove all call for cooling or if heating coil valve put system in full cooling. Close isolation valve on supply side of coil, open air bleed cap, open drain-down cock and drain water from coil. Water should stop draining; else there may be a leak through the control valve. Return all to normal when done.

9. Isolation Valve or System Valve Leak Check (for valves not by coils)

A. Method 1--Ultra-sonic flow meter. With full pressure in the system, command valve closed. Use an ultra-sonic flow meter to detect flow or leakage.

END OF CHECKLIST

(See documentation forms on following pages)

BAS Point to Point Verification Sample Form
(Static Commissioning)

Project #		Project Name:	
Address:		Location:	

Point	Type	Description	Point to Point	Sensor Calibration	Initials/Date

(Duplicate as Necessary)

Notes:

BAS Point to Point Verification Sample Form
(Static Commissioning)

Project #		Project Name:	
Address:		Location:	

Point	Type	Description	Point to Point	Sensor Calibration	Initials/Date

(Duplicate as Necessary)

Notes:

BAS Point by Point Verification Sample Form
(Dynamic Commissioning)

Project #		Project Name:	
Address:		Location:	

Point	Type	Description	Point by Point (Loop)	Sensor Calibration	Initials/Date

(Duplicate as Necessary)

Notes:

____

____

____

____

BAS Point by Point Verification Form
(Dynamic Commissioning)

Project #		Project Name:	
Address:		Location:	

Point	Type	Description	Point by Point (Loop)	Sensor Calibration	Initials/Date

(Duplicate as Necessary)

Notes:

Sensor Calibration Documentation (sample form)

Sensor & Location	Location OK?	**1st** Gage or BAS Value	Instr. Meas'd Value or Visual	**Final** Gage or BAS Value	Pass Y/N?
TEMPERATURES					

Sensor & Location	Location OK?	**1st** Gage or BAS Value	Instr. Meas'd Value or Visual	**Final** Gage or BAS Value	Pass Y/N?

Valve and Damper Actuator Check Documentation

VALVES, DAMPERS and STATES							
Procedure Number→	3A;B	3C					3D;E
Name and Location	Linkage OK	Initial BAS Value	Initial Visual Observation	Final Visual Observation	OK Y/N?	Normal OK?	Closure OK?
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					
		Open Closed					

Valve and Damper Actuator Check Documentation

VALVE LEAK-BY TESTS		
4A; B or C		
Name and Location	State Leak-By method used (4A, B or C) and results, (final dT, etc.)	OK Y/N ?

CCV = cooling coil valve, HCV = heating coil valve, DPR = damper, EA=exhaust or relief air, OA = outdoor air, RA= return air

TEST, ADJUST, AND BALANCE
Functional Test Plan

Project ______________________________________

FT-_________ TEST AND BALANCE (TAB) CHECKOUT

1. Participants (fill out once, to cover all TAB work)

Party	Participation	Party	Participation
____________	____________	____________	____________
____________	____________	____________	____________

Party filling out this form and witnessing testing ______________________________
Dates of tests ____

2. TAB Scope

The scope of the TAB for this project includes:

__ supply and return air handling systems, including __cooling coil capacity verification, __heating coil capacity verification, __heat exchanger efficiency verification, __OSA quantity verification

__ exhaust fan flows for all exhaust fans except
____

__ chilled water system TAB, including __ chilled water, condenser water and cooling tower flows.

__ heating water TAB

__ laboratory or specialty room balancing

__ fume hood balancing

__ sound level testing in the following areas:
____

__ other:
____

3. Test Prerequisites (fill out once, to cover all TAB recheck work)

a. The following have been started up and startup reports and pre-functional checklists submitted and approved and the TAB work completed for this equipment and draft TAB report submitted:

__ All air handlers, except
____

__ All terminal units, except
____

__ All exhaust fans

__ Hot water system

__ Chilled water system
__ Other
____

b. __ All control system functions for the above applicable systems and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed. Exceptions:

____

________________________________ ___________________________
Controls Contractor Signature or Verbal Date

c. __ All A/E punch list items for this equipment corrected that may affect TAB, except

____

d. __ All deficient items identified during TAB have been addressed and verified to have been corrected, except:

____

e. __ These functional test procedures reviewed and approved by TAB contractor.
f. __ Verify that final settings of all valves, splitters, dampers and other adjustment devices have been permanently marked by the TAB Contractor. List devices checked:
____
____

4. Verification Requirements

From interpreting the TAB testing requirements in the specifications, the verification of the following systems will be required:

1. The total supply air flow of ____% of the air handlers, which equals _____ units to test.
2. The total return air flow of ____% of the air handlers, which equals _____ units to test.
3. The fan static discharge pressure during full cooling of ____% of the air handlers, which equals _____ units to test.
4. The OSA flow at air handler flows of: ___near minimum, ___intermediate, ___near maximum, for ____% of the air handlers, which equals _____ units to test.
5. The total measured flow for the TU, at near minimum and maximum flows, matches the value shown on the BAS readout. of _____% of each TU type, which equals _____ units to test total.
6. ___ The measured flow of the diffusers and the total maximum and minimum flows of the TU match that of the TAB report for the TU's verified.
7. The discharge velocity of ____% of the diffusers of ____% of the TUs tested.
8. The coil capacity of ____% of the cooling coils and ____% of the heating coils, which equals _____ units to test.
9. The efficiency of ____% of the heat exchangers, which equals _____ units to test.
10. The chilled water flow through ____% of the chillers, which equals _____ units to test.
11. Chilled water pump discharge pressure during full cooling on ____% of the pumps, which equals _____ units to test.
12. Condenser water pump discharge pressure during full cooling on ____% of the pumps, which equals _____ units to test.
13. The condenser water flow through ____% of the chillers, which equals _____ units to test.
14. The condenser water flow through ___% of the cooling towers, which equals___ units to test.

15. The heating water flow through ____% of the boilers, which equals _____ units to test.
16. The flow requirements for ____% of the fume hoods under the following conditions: ____
____

17. Sound levels in the following areas:
____
____

18. ___Verification that the air system is being controlled to the lowest possible static pressure while still meeting design loads, less diversity. This shall include a review of TAB methods, control setpoints established by TAB and a physical verification of at least one leg from fan to diffuser having all balancing dampers wide open and that during full cooling of all TUs taking off downstream of the static pressure sensor, the TU on the critical leg has its damper 90% or more open.
19. ___Verification that the water system is being controlled to the lowest possible pressure while still meeting design loads, less diversity. This shall include a review of TAB methods, control setpoints established by TAB and a physical verification of at least one leg from the pump to the coil having all balancing valves wide open.
20. ___Other:____
____

5. Acceptance Criteria

According to the specifications, section ___________________:
A failure[1] of more than 10% of the selected items of a given system[2] shall result in the failure of acceptance of the final TAB report for that system and the TAB contractor shall be responsible to rebalance the system, provide a new system TAB report and repeat random verifications of the new TAB report.

[1]Failure of an item is defined as follows:

For air flow of supply and return: A deviation of more than 10% of instrument reading

For minimum outside air flow: 20% of instrument reading (30% for reading at intermediate supply flow for inlet vane or VFD OSA compensation system using linear proportional control)

For temperatures: A deviation of more than 1°F

For air and water pressures: A deviation of more than 10% of full scale of test instrument reading

For sound pressures: A deviation of more than 3 decibels. (Variations in background noise must be considered)

[2]Examples of a “system” are: the air distribution system served by one air handler or the hydronic chilled water supply system served by a chiller or the condenser water system. Systems can be defined smaller if inaccuracies in TAB work within the smaller defined system will have little or no impact on connected systems.

-- END OF TAB PLAN CHECKOUT--

THIS PAGE IS INTENTIONALLY LEFT BLANK

TEST, ADJUST, AND BALANCE
TAB Functional Test Record

FT-______ TAB CHECKOUT

Seasonal Testing and General Conditions of Test

Air handler or rooftop unit and boilers (if applicable) should be running in normal and occupied mode, unless noted. The tests may be performed in any season, if any temperature lockouts can be overridden.

___ TAB is using the same equipment for verification as for the original work. If not, explain.

1. TU and Diffuser Flow Procedures (for each terminal box)

Party filling out this form and witnessing testing ______________ Date of tests ______________

Objectives:

1) Verify that the total measured flow for the TU, at *near or at* minimum and maximum flows, matches the value shown on the BAS readout, that is verify calibration of the EMS readout.
2) Verify that the measured flow of the diffusers and the *total* maximum and minimum flows of the TU match that of the TAB report.

Procedures:

Measure the flow of each diffuser at minimum flow (by raising the space temperature setpoint 10F). Repeat for maximum flow (by lowering the space temperature set point 10F below the current space temperature). On a copy of the original TAB report along side the original report values, record the flow at each diffuser and the percent difference from the report. Sum for the total box flow and record with the percent difference from the report (clearly identify which values are the recheck values). At both the minimum and maximum flows, record the flow shown in the BAS and record the percent difference from the current actual measured flow. Attach the documentation to this form. Record summary data in the table below.

2. Summary Record. Record the results in the table below. Pass means within 10% of TAB report reading.

TU ID	**AHU, FCU, OR SF ID**	**All Diffusers Pass?** (List Failed Diffusers and Percent Variance From TAB Report)	**TU Actual Max. & Min's Match TAB Report?** (Give Percent Variance From TAB Report)	**TU Actual Max. & Min's Match BAS Readout?**	Setpoints Returned to Original?

2. Minimum Outside Air Volume Procedures

Party filling out this form and witnessing testing _____________ Date of tests _____________

This test applies for designs where there is a requirement for a constant volume of OSA into the building with VAV, but no requirement for constant OSA volume at the zone level inside the building.

1. Adjust air handler flow to minimum, intermediate, and maximum, by lowering, adjusting and raising the duct static pressure setpoint, after locking out economizer by raising its changeover setpoint or other method.
2. Measure the OSA flow at the intake using the same method as during original balance. Describe measurement method:

____
____

3. Record the results in the table below. Pass means within 20% of TAB report reading for maximum and minimum supply fan flows. Within 30% is acceptable for intermediate reading, if using a OSA compensating routine with a linearly proportional strategy between max. and min. supply fan flows. If compensating routine, list parameters for each AHU, FAN COIL UNIT, OR SUPPLY FAN in notes below.

AHU, FAN COIL UNIT, OR SUPPLY FAN	Design Min. OSA (cfm)	Min. Supply Fan Flow		Intermediate Supply Fan Flow		Maximum Supply Fan Flow		Return Parameters to Original?
		OSA (cfm) TAB Report	OSA (cfm) ReCheck	OSA (cfm) TAB Report	OSA (cfm) ReCheck	OSA (cfm) TAB Report	OSA (cfm) ReCheck	

Notes:

____
____

3. Minimum Duct Static Pressure Setpoint Verification Procedures
AHU, FAN COIL UNIT, OR SUPPLY FAN- ____________________

Party filling out this form and witnessing testing ______________ Date of tests ______________

This test applies to systems where the fan volume is controlled by a static pressure sensor with a fixed setpoint (not being reset).

<u>**Objectives:**</u> Verify that the air system is being controlled to the lowest possible static pressure while still meeting design loads, less diversity.

1. Review TAB *methods* for determining static pressure setpoint. OK? Y/N _________
2. Review control setpoints established by TAB. OK? Y/N ________
3. Physically verify that at least one leg (the critical leg or TU) from fan to diffuser has all balancing dampers wide open. Critical TU:

   ____

   All balancing dampers full open? ____

4. Verify by one of the following methods that the TU on the critical leg has its damper 90% or more open when all TUs (less some TUs for diversity, if applicable) taking off upstream of the static pressure sensor are in full cooling (TU's downstream may be or may not be in full cooling). With the units in full cooling and the critical TU meeting design flow:

<u>Do 4a or 4b:</u>

4a. Lower static pressure setpoint:

1) Lower static pressure setpoint 0.2". The critical TU should be starved (not getting to within its max. cfm setpoint deadband). Does critical TU starve? ______________. If so, original setpoint is OK. If not, permanently lower static pressure setpoint and repeat until lowest satisfying setpoint is found.

4b. Physically examine ducts:

1) Put all TUs, with branch takeoffs downstream of the static pressure sensor, in full cooling.
2) Examine the critical TU damper. Is it at least 90% open? _________. If so, original setpoint is OK. If not, permanently lower the static pressure setpoint and repeat until lowest satisfying setpoint is found.

5. ___Record any permanently changed parameter values and submit changes to University Representative.

4. Minimum Hydronic Differential Pressure Setpoint Verification Procedures

Party filling out this form and witnessing testing ______________ Date of tests ______________

This test applies to systems where the water volume is controlled by a differential pressure sensor with a fixed setpoint (not being reset).

Hydronic system type: ___Chilled water, ___Heating water

Objective: Verify that the water system is being controlled to the lowest possible differential pressure while still meeting design loads, less diversity.

1. Review TAB methods for determining differential pressure setpoint. OK? Y/N _________
2. Review control setpoints established by TAB. OK? Y/N ________
3. Physically verify that at least one leg (the critical leg or coil) from pump to coil has all balancing valves wide open. Critical coil:

   ____

   All balancing valves wide open? ___________

4. Verify that the coil on the critical leg has its valve 90% or more open during full load of all coils taking off upstream of the pressure sensor (less any diversity) by one of the following methods. With the coils in full cooling and the critical coil meeting design flow:

Do 4a or 4b:

a. Lower pressure setpoint:
   1) Lower pressure setpoint 10%. The critical coil should be starved (not getting to within its max. gUR setpoint deadband). Does coil starve? _________ If so, original setpoint is OK. If not, permanently lower pressure setpoint and repeat until lowest satisfying setpoint is found.

b. Physically examine the valves:
   1) Put all coils, with branch takeoffs downstream of the static pressure sensor, in full load or demand (less any diversity).
   2) Examine the critical coil. Is it at least 90% open? _________. If so, original setpoint is OK. If not, permanently lower the pressure setpoint and repeat until lowest satisfying setpoint is found.

5. ___Record any permanently changed parameter values and submit changes to University Representative.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TAB TEST RECORD --

FIRE SUPPRESSION SYSTEM
Construction Checklist

Note: Contractor is to use this guideline to develop an individual Construction Checklist for each unique piece of like equipment/system to be commissioned as scheduled in the Commissioning Plan, on the drawings and/or listed in the project specifications. The Contractor is to provide the CA on-going updates to these Construction Checklists reflecting changes based on the equipment actually purchased, final installed configuration, device addresses, etc. as applicable in order to provide a complete Construction Checklist document for the record.

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Facilities	Date	Commissioning Authority	Date
Construction Manager	Date	Plumbing Contractor	Date
____________________	________	____________________	________

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, EC = electrical contractor, CM = Construction Manager, FPC = Fire Protection Contractor, TAB = test and balance contractor, ____ = ____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Owner's Representative	Date	Commissioning Authority	Date

2. Fire Suppression System

1) Entire system completed and tested as required by NFPA 13. ____ FPC

2) Proper notification provided for Certification. ____ FPC

3) Ready for Certification by Authority Having Jurisdiction. ____ FPC

4) Certification obtained and on File. ____ FPC

5) Record Drawings submitted. ____ FPC

6) Copy of NFPA 25 submitted to Owner. ____ FPC

7) Personnel in charge of Fire Protection equipment have been instructed as to location and care and maintenance of his new equipment per NFPA 13. ____ FPC

8) System Component instructions are on file on site per NFPA 13. ____ FPC

9) Care and Maintenance instructions for all equipment are on file on site. ____ FPC

10) Certified that no additives, corrosive chemicals, sodium silicate or its derivatives, brine, or any other toxic or corrosive chemicals have been used for testing or stopping leaks. ____ FPC

11) Double check valve operation checked in both forward flow and static operation. ____ FPC

12) All service mains and test connections have been inspected for the possibility of freezing and measures are in place to prevent it. ____ FPC

13) All underground mains and lead in connectors to system risers were flushed prior to connection was made to sprinkler piping. ____ FPC

14) Where applicable, a sample of power driven fasteners has been tested successfully. ____ FPC

15) WELDING: Certify that welding procedures conform to AWA D 10.9 Level AR-3 ____ FPC

16) WELDING: Certify that welding was performed by welders qualified in compliance with AWA D 10.9, Level AR-3 ____ FPC

17) WELDING: Certify that welding was carried out in accordance with a documented quality control procedure that ensures all discs are retrieved, that all holes in piping are smooth, that slag and other welding residue are removed, and that the internal diameters of the pipe are not penetrated. ____ FPC

Remarks:

____

____

3. Sprinkler Flow

Start Date:____________ **Pass / Fail / Couldn't / Didn't**

Opened an inspector test valve to check the operation of the flow indicating device. Y / N

Flow indication enunciated in ____ min ____ sec (less than 5 min) Drain was adequate. Y / N

Remarks:

____

____

4. Hydrostatic (Fire)

Start Date:_____________ **Pass / Fail / Couldn't / Didn't**

All interior piping and attached appurtenances subjected to system working pressure was hydrostatically tested at 200 psi (13.8 bars) to ensure no pressure loss for 2 hours. Loss was determined by a drop in gauge pressure or visual leakage. Y / N

Static pressure was maintained for 2 hours without a drop in gage pressure Y / N

Verified the stamped and approved Sprinkler Plans have been submitted and are on file.

1. Authority Having Jurisdiction: ____
2. Names of individuals approving plans: ____
3. Certify that Installation conforms to accepted plans: Y / N
4. Shop Drawings and Submittals filed on site: Y / N
5. O&M (detailed description, repair, maintenance, etc) instructions filed on Site: Y / N
6. Parts lists for all components filed on site: Y / N
7. Electrical schematic for fire pump, controller, ATS, and alarm panels filed on site: Y / N

Remarks:

____

____

____

5. Fire Suppression System Sprinkler Piping (Sprinkler)

1) Hydrostatic pressure tests completed per NFPA 13 Chapter 16 ____ FPC
2) NFPA Material and Test Certificates completed and on file ____ FPC
3) Welder certification submitted ____ FPC
4) Drains provided at all low points and vent provisions provided to facilitate venting. ____ FPC
5) Properly identified per NFPA ____.FPC
6) Confirmed record drawings accurately reflect the installed condition ____ FPC
7) Properly supported and anchored. Seismic anchoring provided as required. Expansion provisions in place. Where applicable, support certification inspection provided. ____ FPC
8) Cleaned and Flushed per NFPA ____ FPC
9) Standpipe pressure as required at top of riser. ____ FPC

6. Fire Suppression System Sprinkler Zone

1) Zone Pressure Tested in accordance with NFPA 13 ____ FPC
2) All labeling affixed ____ FPC
3) Inspectors test orifice installed coordinated with sprinklers installed in zone ____ FPC
4) Tested zone to validate signal and adequate drain ____ FPC

7. Fire Suppression System Sprinkler Zone - Flow Switch

1) Installation per manufacturer's instructions ____ FPC
2) Has proper orientation ____ FPC
3) Installed in a non turbulent area ____ FPC
4) Switch is wired correctly ____ FPC
5) Switch accessible ____ FPC
6) Point Address: ___ FPC

8. Fire Suppression System Sprinkler Zone - Sprinkler Head

1)	All heads verified against record drawings	____ FPC
2)	Check all heads and verified that no obstructions unduly restrict discharge	____ FPC
3)	Ensured that all heads are properly remote from cooling air outlet discharge	____ FPC
4)	No leakage evident in any of the heads	____ FPC
5)	All special tools for removal and repair provided	____FPC
6)	Spare heads provided per spec.	____ FPC

9. Fire Suppression System Sprinkler Zone – Tamper Switch

1)	Switch is installed per manufacturer's installations	____ FPC
2)	Closed valve enunciates at the enunciator panel	____ FPC
3)	Wiring terminations tight	____ FPC
4)	Mounting is secure and not subject to damage	____ FPC

10. Fire Suppression System Sprinkler Dry Pipe Zone

1)	Dry Pipe Assembly installed per NFPA 13 and man's recommendations.	____ MC
2)	Time to trip through test connection of ______ seconds is acceptable be NFPA 13	____ MC
3)	Water pressure of ______ psi is adequate	____ MC
4)	Air Pressure of ______ psi is adequate	____ MC
5)	Adjusted trip point air pressure to ______ psi	____ MC
6)	Time water took to reach outlet of ______ seconds is acceptable	____ MC
7)	Alarm Operated Properly	____ MC

11. Fire Suppression System Sprinkler Preaction Zone –

1)	Preaction Valve and assembly installed per NFPA 13	____ MC
2)	Preaction charge sequence checked	____ MC

3) Piping Supervised ____ MC

4) Detecting Media Supervised ____ MC

5) Preaction Valve Tripping checked for [Manual] [and] [Remote] ____ MC

6) Accessible facility for testing provided ____ MC

7) Each circuit operate loss of supervision alarm ____ MC

8) Each circuit operates Valve release ____ MC

9) Maximum time to operate release of ______ seconds is acceptable ____ MC

Remarks:

____

____

____

____

____

____

-- END OF CHECKLIST --

FIRE SUPPRESSION SYSTEM
Functional Performance Test

Note: Contractor to use this guideline to develop an individual Functional Performance Test for each unique piece of like equipment/system to be commissioned as scheduled on drawings and/or listed in the project specifications. The Contractor is to provide the CA on-going updates to these Functional Performance Test reflecting changes based on the equipment actually purchased, final installed configuration, revised sequence of operation, etc. as applicable in order to provide a complete Functional Performance Test document for the record.

1. Commissioning Participants:

____________________	____________	____________________	____________
Facilities	Date	Commissioning Authority	Date
____________________	____________	____________________	____________
Construction Manager	Date	Plumbing Contractor	Date
____________________	____________	____________________	____________
TAB Contractor	Date	Mechanical Contractor	Date

Party filling out this form and witnessing testing ______________________________

Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________

2. Prerequisite Checklist

a. The following have been started up and startup reports and construction checklists submitted and approved ready for functional testing:
_____ Fire Protection System

b. __ Piping system flushing complete and required reports approved.

c. __ Vibration control report approved (if required).

d. __ All A/E punchlist items for this equipment corrected.

e. __ These functional test procedures reviewed and approved by installing contractor.

f. __ Safeties and operating ranges reviewed.

3. Fire Suppression System

Emergency Power Operation FPT Date: ___________ Pass / Fail / Couldn't / Didn't

In concert with the building black out tests, Observed system transfer to emergency power. Restored normal power.

System shut down and proof alarms were filtered. System resumed operation on emergency power and controlled normally. System transitioned back to normal power without incident. Backup not sequenced (lead failure filtered by power outage). (Elaborate on expected sequence)

Remarks:

____

____

____

Verified the stamped and approved Sprinkler Plans have been submitted and are on file.

1) Authority Having Jurisdiction: ______________________________
2) Names of individuals approving plans: ______________________________
3) Certify that Installation conforms to accepted plans: Y / N
4) Shop Drawings and Submittals filed on site: Y / N
5) O&M (detailed description, repair, maintenance, etc) instructions filed on site: Y / N
6) Parts lists for all components filed on site: Y / N
7) Electrical schematic for fire pump, controller, ATS, and alarm panels filed on site: Y / N

Remarks:

____

____

____

Check Start FPT Date: ___________ Pass / Fail / Couldn't / Didn't

Checked the Construction Checklist documentation to ensure the system has been adequately started and the start up has been documented. Reviewed the manufacturer's [factory test][start up] documentation.

Start up was adequate. [Certified copies of the start up were submitted]. Anomalies include:

Remarks:

____

____

____

Configuration Check FPT Date:__________ Pass / Fail / Couldn't / Didn't

Checked the configuration. Reviewed it against the contract documents and ensured its compliance Installation is per the contract documents. Specifically, (indicate any details, sheets, spec sections, that apply.)

Remarks:

____

____

____

Maintenance Functions FPT Date: _________ Pass/Fail/Couldnt/Didnt

With system running and under load, simulated various maintenance functions to validate that the system can be maintained without impacting the function of the system.

Access was available for service. System continued to deliver required capacity during all maintenance functions.

Remarks:

____

____

Alarm Switch FPT Date: ______________ Pass / Fail / Couldn't / Didn't

Configured the system to cause an alarm condition (describe how this is done) (elaborate on specific alarm sequences) ____ FPC

Switch made at _____________ Alarm was enunciated. [System shut down] ____ FPC

Remarks:

____

____

____

____

-- END OF TEST --

LOW VOLTAGE SYSTEM
Construction Checklist - FIRE ALARM SYSTEM

Associated checklists:

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Commissioning Authority	Date

2. Requested Documentation

Check	Name	Contr.	Date
Manufacturer’s cut sheets and submittal data available			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
	1			
Manuf.	2			
	3			
	1			
Model	2			
	3			
Serial #	3			
	1			
Capacity	2			
	3			
	1			
Volts/Ph/A	2			
	3			
	1			
Starter Mod	2			
	3			
	1			
Other	2			
	3			

- ***The equipment installed matches the specifications for given trade..........___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Fire Alarms			
Completely installed per plans, specifications and manufacturer's instructions			
Record drawings completed for all phases of the project and submitted to the local authority having jurisdiction.			
Batteries			
Installed per drawings and specifications			
No corrosion or leakage			
Verified tightness of all connections			
Electrolyte level is correct (where applicable)			
Terminations torqued per manufacturer's recommendations			
Power supply connected and ready to be energized			
Control Panel(s)			
Mounted in accordance with plans, specifications and manufacturer's instructions			
Adequate service access provided			
Power supply connected			
Communications interface/interconnect terminated per manufacturer's instructions			
Panel grounded in accordance with manufacturer's instructions and code			
Communications interconnect installed and terminated per manufactures instructions			
Power supply connected and ready to be energized.			
Power supply disconnect installed per drawings and specifications			
Printer			
Installed per plans and specifications			
Power supply connected			
Communications interconnect installed and terminated per manufacturers instructions			
Two Way Voice Communications System			
Installed per manufacturer's instructions			
Fire Alarm Zone Circuit xxxx (required for each zone)			
Conduit and wire installed per plans and specifications			
Wiring terminated and checked			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point checks have been completed and documentation record submitted for this system			
Battery			
Apply power and verify battery charging			
With charger disconnected, verify open circuit voltage of charged batteries			
Control Panel(s)			
Power energized			
Processor diagnostics performed			
Power Supply			
Energized and voltages correct			
Fire alarm Zone Circuit xxxx (required for each zone)			
Control power energized			
Voltage drop within acceptable ranges			
Verified that there are no stray voltages between installed conductors or between installed conductors and ground			

-- END OF CHECKLIST --

LOW VOLTAGE SYSTEM
Functional Performance Test - FIRE ALARM SYSTEM

1. Participants

Commissioning Participants:

______________ Facilities	______ Date	______________ Commissioning Authority	______ Date
______________ Construction Manager	______ Date	______________ Controls Contractor	______ Date
______________ TAB Contractor	______ Date	______________ Mechanical Contractor	______ Date
______________ Electrical Contractor	______ Date	______________ City Inspector	______ Date
______________ Other	______ Date	______________ Other	______ Date

Party filling out this form and witnessing testing ______________________________

Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________

2. Certification of System Installation: (Fill out after installation is complete and wiring checked for opens, shorts, ground faults, and improper branching, but prior to conducting operational acceptance tests.)

a. This system installation was inspected by ___________________________________ on ________________________ and found to comply with the installation requirement of:

b. ________NFPA 72
c. ________Article 760 of NFPA 70, National Electrical Code
d. ________Manufacturer's Instructions
e. ________Other (specify) ____

SIGNED: _________________________ DATE: _________________________

ORGANIZATION: ____

3. Certification of System Operation:

a. All operational features and functions of this system were tested by _________________ on ____________________________ and found to be operating properly in accordance with the requirements of:

b. ________Job Specifications
c. ________Manufacturer's Instructions
d. ________Other (specify) ____

SIGNED: __________________________ DATE: __________________________

ORGANIZATION: ____

Test Witness for the Authority having Jurisdiction ______________________________

4. Type(s) of Systems or Service:

a. ________NFPA 72 – Local

b. If alarm is transmitted to location(s) off premise, list where received:

____

c. ________NFPA 72 - Auxiliary. Indicate type of connection:
_______ Local Energy _______________ Shunt _______________ Parallel Telephone.

Location and telephone number for receipt of signals: _________________________________

d. ________NFPA 72 - Remote Station
Location and telephone number for receipt of signals.
Alarm: _____________________________________
Supervisory: _________________________________

e. ________NFPA 72 – Proprietary If alarms are retransmitted to Public Fire Service Communications Center or Central Station, indicate location and telephone number of the organization receiving alarm. ____

Indicate how alarm is retransmitted ____

f. ________NFPA 72 - Emergency Voice/Alarm Service

Quantity of voice/alarm channels: _____ Single _____ Multiple(specify) _______________

Quantity of speakers installed: ____

Quantity of speak zones: ____

Quantity of telephones or telephone jacks included in system: _______________________

5. Alarm Initiating Devices and Circuits:

a. Quantity and style (See NFPA 72, Table 20-12.1) of initiating circuits connected to system:

Quantity: ____

Style: ____

b. Types and quantities of alarm initiating devices installed

- i. Manual Stations
  1. Non-coded ____
  2. Coded ____
  3. Quantity ____
- ii. Smoke Detectors
  1. Ion____
  2. Photo ____
  3. Quantity ____
- iii. Duct Detectors
  1. Ion____
  2. Photo ____
  3. Quantity ____
- iv. Sprinkler Water Flow Switches_________________________________
  1. Quantity ____
- v. Other: ____
  1. Quantity ____

6. Alarm Indicating Appliances and Circuits

a. Quantity of indicating appliance circuits connected to system:_______________

b. Types and quantities of alarm indicating appliances installed:

- i. Bells ________________Size __________Quantity__________
- ii. Horns _______________Quantity_____________
- iii. Chimes ______________Quantity_____________
- iv. Other: _______________Quantity_____________

c. Visible Signals ______________Type __________Quantity_________

- i. Indicate whether: ______combined with audible, or__ mounted separately

7. Supervisory Signal Initiating Devices and Circuits:

a. Quantity and style (see NFPA 72, Table 2-12.1) of supervisory circuits:

- i. Quantity:_____________Style_________________________

b. Types and quantities of supervisory signal initiating devices installed:

- i. Sprinkler Control Valve__________ Quantity_____________
- ii. Building Temperature ___________ Quantity_____________
- iii. Site Water Temperature _________ Quantity_____________
- iv. Site Water Supply Level _________ Quantity_____________

c. Electric Fire Pump:

- i. Fire Pump Power ______________ Quantity_____________
- ii. Fire Pump Running_____________ Quantity_____________

d. Engine Driven Fire Pump:

- i. Selector in Auto Position ________ Quantity_____________

ii. Engine or Control Panel Trouble __ Quantity_____________
iii. Fire Pump Running_____________ Quantity_____________

e. Engine Driven Generator:
   i. Selector in Automatic Position ____ Quantity_____________
   ii. Control Panel Trouble___________ Quantity_____________
   iii. Transfer Switch________________ Quantity_____________
   iv. Engine Running _______________ Quantity_____________

f. Other Supervisory Function (specify):

____

   i. Quantity____

8. Signaling Line Circuits:

a. Quantity and style (see NFPA 72, Table 2-13.1) or signaling line circuits connected to system:
   i. Quantity: _____________________ Style:___________________

9. System Power Supplies

a. Primary (Main):
   i. Nominal Voltage: ______________ Amps:___________________
   ii. Overcurrent Protection:
      1. Type: _________________ Amps:___________________
   iii. Location: ____

b. Secondary (Standby):
   i. Storage Battery: Amp-Hr. Rating __ ________________________
   ii. Calculate capacity to operate system in hours: ______(24)________(60)
   iii. Engine-driven generator dedicated to fire alarm system:
      1. Location of fuel storage: __ __________________________
   iv. Emergency system described in NFPA 70, Article 700.
   v. Legally required standby system described in NFPA 70, Article 701__________
   vi. Option standby system described in NFPA 70, Article 702, which also meets the performance requirements of Article 700 or 701._____________________

-- THIS SPACE IS INTENTIONALLY LEFT BLANK --

10. Fire Alarm Device Checks

DEVICE	PROCEDURE	VALUES[1]	PASS/FAIL
FIRE ALARM DEVICE CHECK OUT			
MAIN CONTROL PANEL	Install and document program and parameters for the fire alarm system		
	Manufacturer's specific start up documentation provided. (should be in electronic format)		
	Verify that audio-visual alarms that were annunciated were silenced correctly.		
	Verify that with one or more annunciated alarms, subsequent incoming alarms are correctly annunciated.		
REMOTE ANNUNCIATION[1]	Verify that correct remote annunciation occurs at _________ for the various system alarms (trouble, zone, battery status, etc.).		
2-WAY FIRE COMMUNICATION	Test operation of the emergency communication telephone (test to be completed under emergency power conditions)		
	Test simultaneous operation of at least 5 telephone connections. Verify acceptable voice clarity.		
FIRE ALARM PAGING SYSTEM	Verify that while system is alarming, announcements made through the fire alarm paging system can be clearly heard and that the announcements interrupted the audible alarms and any recorded messages.		
MULTIPLEX COMMUNICATIONS	Verify communications between sending and receiving units under both normal and emergency power conditions.		
	Verify communications between sending and receiving units under open circuit condition.		
	Verify communications between sending and receiving units under short circuit/trouble conditions.		1
FIRE ALARM BATTERY	With battery charger disconnected, measure open circuit voltage	Measured value ____________	
	With battery charger disconnected, measure the load and voltage level on the batteries while discharging at maximum anticipated load for specific durations	After ____ min. at demand of approx. _____ VA Recorded voltage ________	
		After _____ min. at demand of Approx ______ VA Recorded voltage ________	
FIRE ALARM POWER SUPPLY	Operate system under peak load.	Record peak load ________VA	
FIRE ALARM PRINTER	Verify printer configuration and that all alarms print.		

DEVICE	PROCEDURE	VALUES[1]	PASS/FAIL
FIRE ALARM ZONE CIRCUITS			
STRAY VOLTAGE	Test conductors with a volt-ohm meter to verify that there are not stray voltages between conductors or between conductors and ground – each circuit	Measured stray voltage is less than 1 V	
LOOP RESISTANCE	Short circuit conductor pair at one end and measure and record circuit resistance	Measured resistance _________ Less than Mfr's recommendation?	
Note: All points will be provided by the CA when drawings are available. The Contractor is to provide to the CA on-going revisions including device addresses, final locations, etc. in order to provide a complete testing document for record.			

[1]If applicable
[2]SD – x Smoke detector
[3]Duct smoke detector
[4]Manual pull station

11. System Deviations from the referenced NFPA Standards:

a. None_____________
b. As follows (describe fully):

____
____
____
____
____

-- END OF TEST --

LOW VOLTAGE SYSTEM
Construction Checklist - TELECOM SYSTEM

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off **only by parties having direct knowledge of the event**, as marked below, respective to each responsible contractor. This Construction Checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.

___ List attached.

Mechanical Contractor	Date	Controls Contractor	Date
Electrical Contractor	Date	Construction Manager	Date
TAB Contractor	Date		

Construction checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractor's assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, CM = Construction Manager, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = ______________________________.

Approvals. This filled-out checklist has been reviewed; its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Commissioning Authority	Date

2. Requested Documentation

Check	Name	Contr.	Date
Manufacturer's cut sheets and submittal data available			
O&M Manuals submitted and approved			
Factory test results submitted and turned over to Owner			
Installation and startup manual and plan			
Sequences and control strategies			
Warranty Certificate provided to owner			
Warranty valid through the project warranty period			

- ***Documentation complete as per contract documents ....___ YES ___ NO***

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

		Name	Contr.	Date
	1			
Manuf.	2			
	3			
	1			
Model	2			
	3			
Serial #	3			
	1			
Capacity	2			
	3			
	1			
Other	2			
	3			

- ***The equipment installed matches the specifications for given trade ....___ YES ___ NO***

4. Installation Checks

Check	Name	Contr.	Date
Telecom main frame			
Completely installed per plans, specifications and manufacturer's instructions			
Record drawings completed for all phases of the project and submitted to the local authority having jurisdiction.			
Mounted in accordance with plans, specifications and manufacturer's instructions			
Adequate service access provided			

Check	Name	Contr.	Date
Power supply connected			
Communications interface/interconnect terminated per manufacturer's instructions			
Panel grounded in accordance with manufacturer's instructions and code			
Communications interconnect installed and terminated per manufactures instructions			
Power supply connected and ready to be energized.			
Power supply disconnect installed per drawings and specifications			
Batteries			
Installed per drawings and specifications			
No corrosion or leakage			
Verified tightness of all connections			
Electrolyte level is correct (where applicable)			
Terminations torqued per manufacturer's recommendations			
Power supply connected and ready to be energized			
Printer (if provided)			
Installed per plans and specifications			
Power supply connected			
Communications interconnect installed and terminated per manufacturers instructions			
Data and telephone Circuit xxxx (required for each telephone and data port)			
Conduit and wire installed per plans and specifications			
Proper plug types installed			
Wiring terminated and checked			

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check	Name	Contr.	Date
Specified sequences of operation and operating schedules have been provided with all variations documented			
Specified point-to-point checks have been completed and documentation record submitted for this system			
Battery			
Apply power and verify battery charging			
With charger disconnected, verify open circuit voltage of charged batteries			
Main Frame			
Power energized			

Check	Name	Contr.	Date
Processor diagnostics performed			
Power Supply			
Energized and voltages correct			
Data and telephone ports (required for each port)			
Verified that there are no stray voltages between installed conductors or between installed conductors and ground			

-- END OF CHECKLIST --

LOW VOLTAGE SYSTEM
Functional Performance Test - TELECOM SYSTEM

1. Participants

Commissioning Participants:

______________________	__________	______________________	__________
Facilities	Date	Commissioning Authority	Date
______________________	__________	______________________	__________
Construction Manager	Date	Controls Contractor	Date
______________________	__________	______________________	__________
TAB Contractor	Date	Mechanical Contractor	Date
______________________	__________	______________________	__________
Electrical Contractor	Date	City Inspector	Date
______________________	__________	______________________	__________
Other	Date	Other	Date

Party filling out this form and witnessing testing ______________________________

Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________
Dates of tests ______________________

2. Certification of System Installation: (Fill out after installation is complete and wiring checked for opens, shorts, ground faults, and improper branching, but prior to conducting operational acceptance tests.)

a. This system installation was inspected by ____________________________________ on ______________ and found to comply with the installation requirement of:

b. ________Manufacturer's Instructions

c. ________Other (specify) ____

SIGNED: ________________________ DATE: ________________________

ORGANIZATION: ____

3. Certification of System Operation:

a. All operational features and functions of this system were tested by ________________ on _________and found to be operating properly in accordance with the requirements of:

b. ________Job Specifications

c. ________Manufacturer's Instructions

d. ________Other (specify) ____

SIGNED: _________________________ DATE: _________________________

ORGANIZATION: ____

Test Witness for the Authority having Jurisdiction _____________________________

4. Type(s) of Systems or Service:

a. Type of system and/or service meets standards and specifications_________________

6. Communication Line Circuits:

a. Quantity and style(Cat 5/6):
Quantity: ______________________________ Style_____: __________________

7. System Power Supplies:

a. Primary (Main):
   i. Nominal Voltage: _____________ Amps:__________________

   ii. Over current Protection:
      1. Type: ________________ Amps:__________________

   iii. Location: ____

b. Secondary (Standby):
   i. Storage Battery: Amp-Hr. Rating __ _______________________

   ii. Calculate capacity to operate system in hours: ______(24)________(60)

   iii. Engine-driven generator dedicated to Telecom system:
      1. Location of fuel storage: __ _______________________

   iv. Emergency system described in __________________________

v. Legally required standby system described in ___________________

vi. Option standby system described in ______________, which also meets the performance requirements of_________________________________

8. Telecom Checks

DEVICE	PROCEDURE	VALUES[1]	PASS/FAIL
TELECOM CIRCUIT CHECK OUT			
MAIN FRAME	Install & document program & parameters for the fire alarm system		
	Manufacturer's specific start up doc. provided. (should be in electronic format)		
	Verify that audio-visual alarms that were annunciated were silenced correctly.		
	Verify that with one or more annunciated alarms, subsequent incoming alarms are correctly annunciated.		
	Test simultaneous operation of at least 5 telephone connections. Verify acceptable voice clarity.		
MULTIPLEX COMMUNICATIONS	Verify communications between sending and receiving units under both normal and emergency power conditions.		
	Verify communications between sending and receiving units under open circuit condition.		
	Verify communications between sending and receiving units under short circuit/trouble conditions.		1
SYSTEM BATTERY	With battery charger disconnected, measure open circuit voltage	Measured value ____________	
	With battery charger disconnected, measure the load and voltage level on the batteries while discharging at maximum anticipated load for specific durations	After ____ min. at demand of Approx. _____ VA Recorded voltage ________	
		After ____ min. at demand of Approx ______ VA Recorded voltage ________	
SYSTEM POWER SUPPLY(S)	Operate system under peak load.	Record peak load ________VA	
TELEPHONE AND DATA CIRCUITS			
STRAY VOLTAGE	Test conductors with a volt-ohm meter to verify that there are not stray voltages between conductors or between conductors and ground – each circuit	Measured stray voltage is less than 1 V	
LOOP RESISTANCE	Short circuit conductor pair at one end and measure and record circuit resistance	Measured resistance ____ Less than Mfr's recommend?	

DEVICE	PROCEDURE	VALUES[1]	PASS/FAIL
TELECOM CIRCUIT CHECK OUT			
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		
	Using an approved cable certification tester, test cable in accordance with TIA or ISO standards to determine if the link is compliant with the specified category or Class of cable.		

9. System Deviations from the referenced TIA and/or ISO Standards:

a. None_____________

b. As follows (describe fully):

____
____
____
____
____
____
____
____
____

-- END OF TEST --

THIS PAGE IS INTENTIONALLY LEFT BLANK

OVERALL STAFF TRAINING AND ORIENTATION PLAN

Project: ________________________________ Date: ____________ Prepared by:______________

Form is to be completed by the General Contractor for each system to be commissioned.

Equipment / System	Spec Section	Total Hours (if spec'd)	Scope Code [5]	Trainee Type [6] (list no. of ea.)	Primary Responsible Contractor	Trainers' Company	Agenda Recv'd?	Planned Training Date(s)
Mechanical / HVAC								
Electrical								
Re-Commissioning[1]								
Architect[2]								
Mechanical Designer[3]								
Electrical Designer[4]								

[1]**Re-commissioning.** The commissioning Authority will provide instruction on the use of blank functional test forms for periodic re-commissioning of equipment and systems, per the specification.

[2]**Architect.** The architect will provide a general overview of the facility, its use, special features, tenant and public considerations, etc.

[3] **Mechanical Design Engineer.** The mechanical designer will provide an overview of the major systems and equipment in the facility, including for each system: the design intent, why the system was chosen, an overview of its operation, and interactions with other systems, any special areas to be aware of, issues regarding future expansion and remodeling, etc.

[4] **Electrical Design Engineer.** The electrical designer will provide an overview of the major electrical systems and equipment in the facility, particularly the lighting control systems, fire alarm, security and emergency power, focusing on the design intent, why the system was chosen, an overview of its operation, and interactions with other systems, any special areas to be aware of, issues regarding future expansion and remodeling, etc.

[5] **General Scope Codes** (refer to the specifications and to the specific equipment Training Agenda for additional details)

A Provide an ***overview*** of the purpose and operation of this equipment, including required interactions of trainees with the equipment.

B At an ***intermediate level***, provide technical information regarding the purpose, operation and maintenance of this equipment, expecting that serious malfunctions will be addressed by factory reps.

C At a ***very technical level,*** provide information regarding the purpose, operation, troubleshooting and maintenance of this equipment, expecting that almost all operation, service and repair will be provided by the trainees.

[6] **Trainee Types**

FM = facility manager, FE = facility engineer and assistants, FT = facility technician / maintenance,

PM = project manager, T = tenants, O = other

*OSCI = Owner supplied, contractor installed

TRAINING AND ORIENTATION AGENDA

Project: _______________________________________ Date: __________________

Equipment / System:______________________________ Spec Section: ____________

Form is to be completed by the General Contractor for each system to be commissioned.

Section 1. Audience and General Scope *General Contractor to fill out this section and transmit entire form to responsible contractors. Attach training specification section.*

Intended audience type (enter number of staff): ___facility manager, ___facility engineer, ___facility technician, ___project manager, ___tenant, ___other:_______________________________________

General objectives and scope of training: (check all that apply)

___ A. Provide an overview of the purpose and operation of this equipment, including required interactions of trainees with the equipment.

___ B. Provide technical information regarding the purpose, operation and maintenance of this equipment at an intermediate level, expecting that serious malfunctions will be addressed by factory reps.

___ C. Provide technical information regarding the purpose, operation, troubleshooting and maintenance of this equipment at a very detailed level, expecting that almost all operation, service and repair will be provided by the trainees.

Section 2. Instructors *[Commissioning Authority fills in Company. Trainer fills out the balance, prior to training.]*

ID	Trainer	Company	Position / Qualifications
1)	______________________	________________	___________________________________
2)	______________________	________________	___________________________________
3)	______________________	________________	___________________________________

Section 3. Agenda *[The responsible contractors have their trainers fill out this section and submit to Owner and Commissioning Authority for review and approval prior to conducting training.]*

Location: ___site __________________________________ Date ________________
___classroom (location)__________________________________, Date_________________

Agenda of general subjects covered (√ all that will be covered) (√ when completed)	**Duration** (min.)	**Instructor** (ID)	**Completed** (√)
___General purpose of this system or equipment (design intent)	_______	_______	_____
___Review of control drawings and schematics (have copies for attendees)	_______	_______	_____
___Startup, loading, normal operation, unloading, shutdown, unoccupied operation, seasonal changeover, etc., as applicable	_______	_______	_____
___Integral controls (packaged): programming, troubleshooting, alarms, manual operation	_______	_______	_____
___Building automation controls (BAS): programming, troubleshooting, alarms, manual operation, interface with integral controls	_______	_______	_____
___Interactions with other systems, operation during power outage and fire	_______	_______	_____
___Relevant health and safety issues and concerns and special safety features	_______	_______	_____
___Energy conserving operation and strategies	_______	_______	_____
___Any special issues to maintain warranty	_______	_______	_____

___Common troubleshooting issues and methods, control system warnings and error messages, including using the control system for diagnostics	________	________	______
___Special requirements of tenants for this equipment's function	________	________	______
___Service, maintenance, and preventative maintenance (sources, spare parts inventory, special tools, etc.)	________	________	______
___Question and answer period	________	________	______
<u>Other subjects covered, specific to the equipment:</u>	**<u>Duration</u>**	**<u>Instructor</u>**	**<u>Completed</u>**
____	________	________	______
____	________	________	______
____	________	________	______
____	________	________	______
____	________	________	______
____	________	________	______
____	________	________	______
Total duration of training (hrs) --->			______

<u>Training methods that will be included (clarify as needed):</u> (Trainer checks all that apply)

__use of the O&M manuals, illustrating where the verbal training information is found in writing
__each attendee will be provided: 1) the control drawing schematic and sequence of operations; 2) a copy of this agenda.
__discussion/lecture at site____
__site demonstration of equipment operation______________________________
___written handouts____
___manufacturer training manuals__________________________________
___classroom lecture____
___classroom hands-on equipment__________________________________
___video presentation____
__question and answer period______________________________________

Section 4. Approvals and Use *[Once the Agenda has been filled out by the* Trainer*, the Owner and Commissioning Authority review, make edits, sign and return to Contractor who provides to the Trainer for use during training. Copies of Agenda shall be provided to trainees.]*

This *plan* has been approved by the following individuals, subject to the additions and clarifications noted in the left columns marked "add." *(This is not an approval of training completion.)*

______________________________ ____________________
Owner's Representative Date

______________________________ ____________________
Commissioning Authority Date

STAFF TRAINING AND ORIENTATION RECORD

Project: ______________________________ Date: _____________ Prepared by:________________

System or Equipment: ____

Trainee Signature[2] and Position	Total Req'd Hrs[1]	Hrs Done	Training Date	General Topics Covered	Trainer Signature and Company	CA Initials/ Note ID
1.						
2.						
3.						
4.						

[1]The hours of required training have been filled out from the *Specifications*. Refer to the *Specifications* for additional details regarding the training requirements.

[2]Trainee signs after the training session is completed.

Notes attached. (Y/N) ____

Final Approval of Training Completion
According to the Contract Documents:

______________________________ ______________
Owner's Representative Date

______________________________ ______________
Commissioning Authority Date

THIS PAGE IS INTENTIONALLY LEFT BLANK