



CHICAGO TRANSIT AUTHORITY

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August 6, 2013

RE: Requisition No. C13FR101436408
IFB – 103rd St. Bus Garage Heating Upgrades & BAS Installation Project
CTA Project #2010-0017

SUBJECT: Addendum No. 1

Dear Plan Holder:

The following information is being distributed to all plan holders for the referenced requisition. Addendum No. 1 provides for the addition of Appendix A to Specification Section 23 08 00, Commissioning of HVAC. There are no other changes. The unaltered portions of the Contract Documents shall remain in effect. Please acknowledge this Addendum No. 1 in the box titled "BIDDERS MUST INSERT ADDENDA NUMBERS HERE" on Attachment I - Bidders Signature Page.

The bid opening date remains August 14, 2013 at 11:00 AM.

If you have any questions, please contact Terrence Faust at 312-681-2446.

Sincerely,

Robert Miller
General Manager, Purchasing

cc: J. Charleston
File

Chicago Transit Authority

103rd Bus Garage
Heating Upgrades and BAS Installation
CTA Project #2010-0017

Commissioning Plan

August 6, 2013



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Commissioning Authority



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Commissioning Plan

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INTRODUCTION

This document is the Commissioning Plan for the Chicago Transit Authority 103rd Bus Garage Heating Upgrades & BAS Installation Project #2010-0017. Its objective is to guide the project team through the specified commissioning processes by defining the extent of responsibility, commitment and coordination required by the various project team members involved in the commissioning process. This commissioning plan is a “living” document and as such, it will change and be updated as the project evolves through planning, design, construction, testing, verification, handover and occupation of the building. The general responsibilities and requirements as outlined within this document are not expected to change appreciably during the project and are intended as a further amplification of the requirements of Specification Section 019113 General Commissioning Requirements. Reference to the drawings, related specification sections and general provisions of the contract, including general and supplementary conditions should be made to ensure all commissioning requirements are satisfactorily discharged.

The plan shall be used by the project team as a working document to assist in achieving the common goal of successfully completing and commissioning the building's systems satisfying the goals defined by the Project Scope of Work document. The Commissioning Authority (CxA) shall monitor the projects shared commissioning goals as planned through the duration of the project, reporting observations directly to the Owner.

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COMMISSIONING GOALS & OBJECTIVES

Commissioning is a systematic process the purpose of which is to verify the functionality and operation of the building systems in accordance with the Project Scope of Work document and the requirements of the contract. Verification and review will encompass design, installation, start-up procedures, functional proving of operational systems, and verification that installation is correct, equipment & systems operate efficiently, are maintainable and comply with equipment manufacturer's recommendations. It is also intended that the quality of operational personnel training and maintenance practices, per manufacturers' recommended procedures, are verified. The CxA and this Cx commissioning plan/process will verify the completeness and correctness of the projects record documentation.

The commissioning procedures provide and establish process to:

- A. Evaluate the completed facility with respect to the drawings and specifications.
- B. Independently verify the operation of systems and components both individually and together as complete fully functional integrated systems.
- C. Evaluate and analyze the collective performance of various individual building systems, identifying conflicts between systems and propose solutions.
- D. Direct and define responsibilities for participating members of the project team responsible for the commissioning process during design, construction, testing, validation, and continuous occupation of the facility.
- E. Evaluate technical submittals with respect to the drawings and specifications.
- F. Evaluate the results of Functional Tests for each system per acceptance criteria as defined in the Contract Documents and advise compliance with the Project Scope of Work recommending resolution strategies.
- G. Evaluate the completeness and accuracy of the Cx record documentation with field conditions.
- H. Collect and compile all project commissioning documentation into a single manual organized by systems.
- I. Evaluate the suitability and standard of training of operational personnel.
- J. Evaluate initial running and opposite season performance and operation of systems.
- K. Review and assist the resolution of warranty issues post occupation.
- L. Review operation of the systems post facility occupation and assist in resolution of operational issues, recommend system fine tuning and assist in supplementing additional operational training where deficiencies are identified.

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ABBREVIATIONS

A/E	Architect/Engineer	GC	General Contractor
AHU	Air Handling Unit	GPM	Gallons Per Minute (Water Flow)
BOD	Basis of Design	HVAC	Heating, Ventilating & Air Conditioning
BAS	Building Automation System	MC	Mechanical Subcontractor
CMP	Commissioning Master Plan	MEP	Mechanical, Electrical, Plumbing
CxA	Owner's Commissioning Authority	OWN	Owner (Chicago Transit Authority)
CM	Construction Manager	O & M	Operation & Maintenance
C/O	Change Order	PC	Pre-Functional Checklist
CD	Contract Documents	PM	Owner's Project Manager
CFM	Cubic Feet per Minute (Air Volume)	RFI	Request for Information
Cx	Commissioning	SC	Substantial Completion
CxLog	Observation and Issues Log	SMC	Sheet Metal Subcontractor
DID	Design Intent Document	TAB	Test, Adjust and Balance Subcontractor
DD	Design Development Documents	TCC	Temperature Controls Contractor
DDC	Direct Digital Controls	UPS	Uninterruptible Power Source
EC	Electrical Subcontractor	VAV	Variable Air Volume
FC	Final Completion	VFD	Variable Frequency Drive
FD	Fire Department		
FPT	Functional Performance Test		
IFPT	Integrated Functional Performance Test		
FCxNB	Field Commissioning Notebook		

Cx DEFINITIONS

- A. **Acceptable Performance:** A component or system being able to meet specified design parameters and acceptance criteria, under actual load within acceptable tolerances including satisfactory documented completion of all Functional Test Procedures. Control system stability trending during performance period and resolution of outstanding Cx observation issues are an important part of the process.
- B. **Approval:** Acceptance by the Engineer of Record that a piece of equipment or system is the correct type for the given application, that installation considerations are compliant with the requirements of the Contract Documents.
- C. **Areas of Conflict within Commissioning Documentation:** Where section 230800 Commissioning of HVAC and/or Commissioning Plan requirements conflict with technical specifications in any individual specification section, or other Contract Document, the technical specification and/or Contract Document requirements shall take precedence. The responsibilities of the Commissioning Team members throughout the project are specified in the Contract Documents and referenced herein. This listing shall not detract in any way from the contractual responsibilities of the project team members and is not meant to be all-inclusive. Adherence to the scope of this plan shall in no way release the team member from the responsibility for complying with project requirements as defined within the Contract Documents.

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- D. **Commissioning Authority:** (CxA) The independent 3rd party agency hired by the Owner to validate the commissioning process and to document that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated and maintained satisfying the intent of the Project Scope of Work.
- E. **Commissioning Plan:** The Commissioning Plan (Cx Plan) is a living document that defines and manages the commissioning process. It outlines the organization, schedule, sequence, responsibility, allocation of resource and documentation requirements of the commissioning process.
- F. **Commissioning Meeting:** A meeting attended by members of the commissioning team held at the job site, chaired by the Commissioning Authority. Meetings will be scheduled on an agreed basis. Initially they will be held infrequently, towards start-up, testing and project completion they will be scheduled to take place regularly.
- G. **Dynamic Test:** A test performed by the installer or Test and Balance Agency on an operating item of equipment or system post initial start up. e.g. measuring the rotation speed of a pump is a dynamic test, as is measuring the current drawn by a motor. Dynamic tests shall be documented and results recorded by the Contractor. Pipework Flushing & Chemical cleaning is considered a Dynamic Test.
- H. **Electronic Format:** Electronic Cx files capable of being opened and read with MS Office or the latest revision of Microsoft Word (.doc files), Microsoft Excel (.xls files), Adobe Acrobat Reader (.pdf files), or approved equals as specified.
- I. **Field Commissioning Notebook (FCxNB):** The Field Commissioning Notebook will be used to identify and track all pertinent commissioning documentation required during the construction phase. This notebook will be maintained by the Construction Manager on-site and will be made available to all Subcontractors for their use. The notebook provides a central location for the commissioning team to identify, copy and organize all pertinent information and will include current copies of the Commissioning Plan, Commissioning Meeting minutes, Construction Schedule showing commissioning milestones, Issues/Observation Log, Installation Checklists, Functional Tests, other manufacture's installation or start-up checklists approved by the CxA. The Field Commissioning Notebook will also include key materials that will be provided by the Contractor to the CxA relating to the final Systems Manual. The Field Commissioning Notebook will contain those forms and tracking sheets as indicated in the appendix of this Commissioning Plan and other forms modeled from detailed samples issued by the Contractor and approved by the CxA and Owner.
- L. **Integrated Functional Performance Test (I-FTP):** A test to validate compliant functionality of a completed system or systems against the specified contract requirements and detailed system /equipment sequences of operation through all operating conditions. Operating conditions will include; summer, winter, occupied, unoccupied, emergency events, equipment failure. The tests are to be executed with assistance from the Construction Manager, relevant sub contractors and manufacturers representatives as required. Observations will be recorded and performance documented during the functional tests, any operational deficiencies will be logged. Methods of corrective action and responsibility will be identified and signed off upon resolution. The Owners operating and maintenance staff are encouraged to actively participate in the functional testing

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process as the testing is regarded as a valuable training tool which provides insight and orientation with respect to the building operation.

- M. **Functional Performance Test (FPT):** A test script authored by the Commissioning Authority detailing the specific process as to how functionality of a completed system or systems will be validated. The CxA will issue draft FPT's to all interested parties for comment. Approved comments from the team will be incorporated to the scripts. The updated test plans will be issued for execution/direction by the CxA with appropriate personnel support from the contractor and his specialists. During each test, test data will be recorded on each FPT, the FPT sheets populated with test data will serve as a test record to be signed off by the Engineer of Record and then included in the final commissioning manual.
- N. **Observation and Issues Log(CxLog):** An ongoing record of observations made during the commissioning process by the Commissioning Authority, owner or other members of the commissioning team. Each entry to the issues log includes a unique identification tracking number, date, originating party, and a description of the issue, recommended action, assignment of responsibility, item closed date and the name of the party verifying closure. The Commissioning Authority is responsible for maintaining the Issues log and distributing it to the necessary parties on a regular basis. The commissioning log will be reviewed at each commissioning meeting and may become part of the close-out punch list.
- O. **Project Scope of Work:** The construction documents detail the global requirements of the project and the expectations of how the facility will be used and operated. The final performance of the commissioned facility will be benchmarked by the CxA against the requirements of the construction documents.
- P. **Performance Period:** A specified period of time following the completion of functional performance testing when the systems operate continuously under natural building loads and normal automatic control. During this period the systems should not return any abnormal system failures, alarms, unplanned system shutdowns or control system malfunctions, confirming satisfactory systems operation. During this performance period the systems will be monitored via DDC trend logs which shall be set up by the ATC.
- Q. **Point to Point Tests:** Logical testing undertaken by the installing contractors. Point to Point testing is to be documented by the installing contractors and shall confirm that the wiring termination, addressing, monitoring, graphical display and control of intelligent equipment is programmed and terminated correctly. **Graphical Display testing** is part of the point to point check out stage. During this stage the TCC will set up a workstation with the graphics for this project load and operating. This bench top testing and demonstration of the graphical displays will take place two months prior to the field roll out. It will be conducted in the TCC office and a sample of the devices will be connected so the CxA can visually see the actions as the software is verified. Test records shall be issued to the CxA by the contractor for inclusion in the final commissioning manual. The CxA will observe and witness a sample of the contractors Point to Point Tests.
- R. **Pre Functional Checks:** System / Equipment inspections intended to confirm that the system / equipment is installed as specified and approved. That all manufactures recommendations and requirements have been met. Pre functional checkout shall be

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carried out by the installing contractors who shall document observations and complete pre functional check sheets which shall be issued to the CxA for inclusion in the commissioning report. Pre functional check out shall be undertaken prior to starting up any system or item of equipment. These sheets identify the minimum level of information to be collected and recorded by the installing contractors. The CxA will witness a selective number of pre functional checks.

- S. **Start Up:** The process of initial energizing of systems or items of equipment for the first time. Start up is carried out by the installing contractor with assistance from manufacturers representatives. The installing contractor shall develop and issue start up procedures for each item of plant, the procedures should list manufactures requirements and recommendations. Start up of each significant item of equipment shall be documented by the installing contractor and start up reports shall be issued by the installing contractor to the CxA for inclusion in the final commissioning manual. The installing contractor shall develop and issue start up procedures for each item of plant.
- T. **Static Test:** A test carried out prior to a system or item of equipment being energized. i.e. a duct leakage test is a static test, a pipe pressure test is a static test.
- U. **Test and Balance:** The process of systematically setting an air or hydronic system to operate to satisfy design criteria, generally by adding resistance using valves and dampers to force air and water through installed equipment at the design determined flow rates.
- V. **Trend Log:** Actual system 'live' operating data as collected and recorded from the DDC control system sensors identifying actual system performance. Trend logs are often plotted against time to provide a performance chart identifying how systems have been functioning. Trend logs can be analyzed and the findings utilized to identify the requirement to fine tune control strategies and equipment functionality to ensure best optimized performance of the building systems.

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PROJECT DESCRIPTION

The 103rd Bus Garage is located at 103rd Street and Doty Ave. in Chicago, IL. This garage houses bus operations and bus maintenance functions for numerous south side routes. The garage has a heating and ventilating system that is approximately 24 years old and is no longer reliable to heat the building. This project is to replace the existing boiler system, rooftop air handling units and add a new building automation system (BAS). Bid alternate 1 adds make-up air units and exhaust fans at bus maintenance areas and service areas. The garage is approximately 600 feet long on all four sides and has masonry and steel frame construction.

Air handling units (AHUs) are located on the roof and associated ductwork within the building is approximately 20 feet above finished floor (AFF). The existing boilers are located in a boiler room at the east side of the building, adjacent to the bus servicing area.

The two existing boilers and appurtenances will be demolished and replaced with two new boilers sized appropriately based on load calculations. All piping within the boiler room will be replaced but outside of the boiler room piping will only be replaced as required for an operational heating system. Allowances shall be made for an emergency connection to a portable back-up boiler. Three new hot water unit heaters will be installed to serve the boiler room.

The 13 existing AHUs located on the roof will be demolished and replaced one-for-one. The new AHUs with hot water coils will incorporate a heat pipe energy recovery system. Existing roof curbs will be evaluated for re-use or replacement.

New building maintenance area and storage area roof-mounted exhaust fans will be installed in bid alternate 1. In addition, new roof-mounted makeup air units with gas heat will provide the ventilation supply air.

A new Building Automation System (BAS) will be installed to communicate with new and selected existing equipment. Where existing equipment will remain, provisions shall be incorporated for the equipment in order for the BAS to monitor and control. The new web-based BAS will be able to communicate remotely to off-site locations. Other work includes duct and pipe insulation, cleaning of air systems, flushing/cleaning/filling of hydronic system, and testing, adjusting and balancing of systems.

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SYSTEMS TO BE COMMISSIONED

A. SYSTEMS TO BE COMMISSIONED:

The following systems will be commissioned.

1. Boiler system
2. Rooftop air handling units
3. Ventilation system (bid alternate 1 exhaust fans and makeup air units)
4. Building automation system (BAS)

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COMMISSIONING TEAM

Role Definitions			
A	Architect	PM	Owners Project Manager
CxA	Owner's Commissioning Authority	ME	Mechanical Design Engineer
TCC	Temperature Controls Subcontractor	OM	Owner's Facility O&M Staff
EC	Electrical Subcontractor	TAB	Testing, Adjusting & Balancing Subcontractor
EE	Electrical Design Engineer	SI	Systems Integrator
CM	Construction Manager	PC	Plumbing Subcontractor
MC	Mechanical Subcontractor	FPC	Fire Protection Subcontractor
SC	Security Subcontractor	GC	General Contractor
		EM	Energy Modeling professional

Team members will be further identified during construction.

Role	Member Firm & Address	Contact Person	Office Phone / Fax	Cell Phone	E-mail Address
PM					
CxA	Parsons Brinckerhoff	Ken Tella	314-206-4437	314-578-6909	tella@pbworld.com
A	KMI	Maria Caltsuni			
ME	HNTB	James Grant			
EE					
CM GC					
EM					
MC					
EC					
PC					

23 08 00A COMMISSIONING OF HVAC Appendix A - Commissioning Plan

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FPC					
SC					
TCC					
TAB					
OM	Chicago Transit Authority				

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COMMISSIONING APPROACH

Commissioning for the project shall be split into 5 distinct phases; Planning phase, Design Phase, Construction Phase, Testing & Acceptance Phase, Warranty Phase. Strategy and responsibilities in relation to these activities is defined in the next section, Team Member Responsibilities and the contract documents.

- A. Planning Phase commissioning shall include the following activities:
 - 1. Review the Project Scope of Work
- B. Design Phase commissioning shall include the following activities:
 - 1. DD stage design document review
 - 2. CD stage design document review
 - 3. Back Check of Cx review comments with project team prior to Final Bid Docs
 - 4. Development and coordination of project commissioning requirements
- C. Construction Phase commissioning shall include the following activities:
 - 1. Update of Cx Plan for Construction phase
 - 2. Equipment Submittal Review
 - 3. RFI & C/O review for Cx related items
 - 4. Commissioning Meetings
 - 5. Ongoing installation observation
 - 6. Development and maintenance of observation issues log (CxLog)
 - 7. Development of Pre Functional Check lists & procedures
 - 8. Development of Functional Acceptance Test Plans
 - 9. Collate Static Testing Records
 - 10. Execution of Pre functional Checks
 - 11. Collate Dynamic Testing Records
 - 12. Point to Point Testing
 - 13. Start up
 - 14. Test and Balance
 - 15. Develop Training Plan
 - 16. Development of the O&M Cx information
- D. Testing & Acceptance Phase commissioning shall include the following activities:
 - 1. Review & validation of Test and Balance report
 - 2. Execution of the Functional Acceptance Test Plans
 - 3. Maintenance of observation issues log
 - 4. Verify Trend Log set up
 - 5. Review of O&M Cx information
 - 6. Develop the interim commissioning systems manual
 - 7. Training verification
 - 8. Recommendation of Acceptance to the Engineer of Record
- E. Warranty Phase commissioning shall include the following activities:
 - 1. Interview facility staff to verify function and problems
 - 2. Operational facility Warranty review at 10 months post occupation
 - 3. Develop the final commissioning report & systems manual

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TEAM MEMBER RESPONSIBILITIES

Owner (PM):

Generally the Owner will facilitate and support the Cx process and will give final approval of all commissioning related work, issue resolution and direction.

- A. Will develop and maintain the Project Scope of Work.
- B. Will review, direct and approve commissioning related tasks in relation to the requirements of the contract documents.
- C. Will arrange and coordinate Owners facilities staff participation in the commissioning process as required.
- D. Will participate in commissioning related meetings as required.
- E. Will provide Direction to the Project Team for Cx issue resolution.

Architect/Engineers A/E (A, ME, EE):

Generally the A/E will support the Cx process. The A/E will develop the contractual requirements and review compliance of the works in relation to the requirements of the contract.

- A. Will incorporate commissioning requirements in the contract documents.
- B. Will review CxA comments, recommendations & observations and shall address CxA comments and recommendations as required at the direction of the Owner.
- C. Will review and approve the technical submittals, incorporating CxA review comments.
- D. Will review the commissioning documentation and provide comments as necessary.
- E. Will Assist in resolution of commissioning related issues.
- F. Will review and approve the Final TAB report and FPT records.
- G. Will review and approve the Operation and Maintenance Documents. Will participate in commissioning related meetings as required.
- H. Will participate in commissioning related meetings as required.

Commissioning Authority (CxA):

Generally the CxA will lead, review, and oversee the completion of all commissioning process activities. The CxA shall coordinate all commissioning related activities through the Owners Project Manager. The CxA will report directly to the Owner. The CxA observes reports and recommends, the CxA does not approve or accept.

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- A. Will review and comment on the submitted Project Scope of Work.
- B. Will review and comment on the submitted feasibility study.
- C. Will participate in design meetings & workshops as required by Owner.
- D. Will review and comment on the A/E design deliverables at DD stage.
- E. Will review and comment on the A/E design deliverables at CD stage prior to bid.
- F. Will develop and issue commissioning requirements for incorporation into the contract documents.
- G. Will develop issue and maintain a commissioning plan revising and updating, incorporating Owner approved comments from the commissioning team as required.
- H. Will develop, maintain and issue a commissioning Observation Issues Log.
- I. Will assist the CM or GC with scheduling commissioning activities.
- J. Will perform Cx technical submittal review for Cx systems equipment to verify suitability and compliance of proposed equipment with respect to the Project Scope of Work.
- K. Will provide outline installation and pre-functional check forms for completion, submission, and execution by Contractors.
- L. Will develop and issue Functional Performance Tests (FPTs) for the equipment and systems to be commissioned.
- M. Will coordinate and chair construction / testing phase commissioning meetings.
- N. Will perform site observations and reports.
- O. Will observe and witness a representative sample of the contractor performed pre functional testing and checks.
- P. Will observe and witness a representative sample of contractor performed equipment start up.
- Q. Will review and comment on the TAB agencies proposed procedures.
- R. Will review all installation, pre-functional, start-up and other commissioning related documentation provided by the Contractor. This includes Subcontractors Installation checklists, Controls Subcontractors point-to-point checklists and TAB Subcontractor's completed preliminary TAB report.
- S. Will assist in troubleshooting commissioning related issues.
- T. Will review and comment on the initial & final TAB report.

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- U. Will observe / direct witness / undertake independent TAB validation of a representative sample of equipment following Engineer submission of the TAB report.
- V. Witness contractor execution of the Functional Acceptance Tests per the CxA provided FPT procedures. Functional Performance Testing will not commence until the works are substantially complete, the systems are reported as functioning as per the design intent and the DDC Program has been loaded and de-bugged and the TAB report has been approved by the Engineer of Record.
- W. Will verify that the contractor training schedules and plans meet the requirements of the contract documents.
- X. Will observe and report regarding the adequacy of training.
- Y. Will perform Cx review and comment on the contractor supplied O&M documents.
- Z. Will assemble all commissioning related documentation and provide to the owner a commissioning final report and systems manual.
- AA. Will perform post occupancy system operation review at 10 months after occupation.
- BB. Will assist in the identification and monitoring and resolution of warranty issues.
- CC. Will ascertain if further additional operation staff training is required.

General Contractor (GC):

Generally the GC provides all means and methods necessary to discharge responsibilities as defined by the contract documents. With specific regard to commissioning the GC directs, organizes and coordinates the activities of the CM's own staff and the commissioning activities of the subcontractors. The GC schedules and coordinates, with assistance from the CxA, all commissioning activities to take place in a timely, logical and appropriate manner in order to meet the requirements of the construction schedule and the contract. The GC obtains and distributes all commissioning related documents and deliverables received from the subcontractors to the Owner and the CxA. The GC distributes all commissioning related documentation and deliverables issued by the Owner and the CxA to the construction team.

- A. Will obtain and coordinate all Subcontractor and/or supplier information and records required for development of a complete commissioning systems manual and shall provide this information to the Commissioning Authority in electronic format.
- B. Will review the Owner's commissioning plan and documentation and confirm in writing to the Owner, A/E and Commissioning Authority any identified areas of conflict with the contract documents or any items requiring clarification with the Owner's final commissioning plan.
- C. Will coordinate with assistance from the CxA all commissioning related activities including testing, witnessing, pre-functional checks, flushing, start-up, TAB activities, training, functional testing and the like, either self performed or performed by Subcontractors, suppliers, etc.

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- D. Will develop a Cx milestone schedule with assistance from the CxA incorporating Cx milestone dates as identified in this plan. The schedule is to be coordinated with the Master Construction Schedule. The Cx schedule will use logic-linked tasks that form a critical path to successful completion of all commissioning activities. The schedule will allow for specified functional testing to commence upon achieving substantial completion of system installations, but prior to owner occupation of the building.
- E. Will coordinate directly with each Subcontractor, and ensure their specific commissioning responsibilities and contractual obligations are discharged.
- F. Will participate in commissioning meetings as required.
- G. Will ensure availability and provision of qualified personnel, tools, calibrated test instruments and access equipment necessary to perform all commissioning related activities.
- H. Will provide the Owner, A/E and CxA written (e-mail) notification that individual on site commissioning activities are planned to take place. The Owner, A/E and CxA require seven days notice of all commissioning related activities.
- I. Will coordinate activities requiring attendance of the Owners Staff, the A/E and the CxA so that personnel can make best use of their time in visiting site in a concurrent visit.
- J. Will coordinate and issue documentation relating to, pre functional check out, start-up, initial testing, setting and TAB of equipment and systems and issue copies of records to the Owner and CxA for verification and inclusion in the commissioning systems manual.
- K. Will coordinate all associated integrated system testing such as HVAC, building automation, fire alarm, emergency power, life safety, security, etc. with the AHJ that falls outside of the scope of this commissioning plan.
- L. Will document inconsistencies or deficiencies identified by GC staff and third parties, in system operations and system compliance identified and provide a plan for resolution of deficiencies as required.
- M. Will action and monitor commissioning related directions issued by the Owner.
- N. Will review, collate and issue Operating and Maintenance Data provided by the various Subcontractors and suppliers for verification, organization, distribution to conform with the requirements of Contract Documents.
- O. Will retain copies of all commissioning related documentation on site, including that developed by the CxA and other members of the commissioning team, manufactures information and cut sheets, installation checklists, test sheets, pre-functional checklists, manufacturer's start-up forms, pressure tests, electrical tests, testing and balancing data (TAB), Functional Performance Tests (FPT), recorded performance data, record of equipment settings and any other reports (in electronic format) used to document the commissioning process in an accessible dedicated commissioning field notebook

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(FCxNB). Make this notebook available as required to all members of the commissioning team. At substantial completion turn this notebook over to the Commissioning Authority.

- P. Submit final commissioning documentation, in electronic format (pdf files), to the Owners O&M Manager, Mechanical and Electrical Engineers, and the Commissioning Authority for approval and inclusion in the Final Commissioning Systems Manual.
- Q. Will plan, coordinate and record all training of the Owners staff as specified. Will provide update and monitor the training schedule. Will provide video taping of training.

Mechanical Subcontractors (MC, PC, FPC):

- A. Will coordinate and direct participation of the Mechanical Subcontractors and suppliers in the commissioning process.
- B. Will review and comment on the Commissioning Plan, Cx milestone schedule and assist in preparing the Operational and Functional Acceptance Test Procedures if required. Provide input and documentation required to develop final plans and procedures.
- C. Will develop pre functional check sheets and start up procedures for each mechanical item of equipment and system to be commissioned. Collate these documents into a single check out and start up plan. The document will include procedures for all testing, cleaning, flushing and disinfection procedures to be employed. This plan will be issued prior to commencing check out or start up. Incorporate and execute any comments as directed by the GC, update and reissue as required.
- D. Will participate in commissioning meetings as required. Will coordinate participation of suppliers and subcontractors as required.
- E. Will Coordinate installation of mechanical systems and equipment with equipment suppliers, mechanical and electrical subcontractors. Verify that MEP coordination, installation, quality control, and Subcontractor testing have been completed and that installed systems and equipment comply with the requirements of the contract documents.
- F. Will issue formal notice to the GC of the intent to perform any commissioning related activity. Give adequate notice of each and every planned event (minimum 14 days).
- G. Will notify the GC in writing as soon as possible of any issues identified during construction that may affect the commissioning process or final system performance.
- H. Will action commissioning related directions issued by the GC.
- I. Will perform pre functional checks, start-up and testing of mechanical equipment and systems as specified and document as required issuing records to the GC.

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- J. Will perform manufactures recommended equipment maintenance as a minimum during the period between delivery, start up and when the owner takes beneficial occupancy.
- K. Will operate equipment and systems as required for Operational and Functional Acceptance Testing.
- L. Will participate in the fine-tuning or troubleshooting of system performance if either of these measures becomes necessary.
- M. Will coordinate and provide attendance, provision of qualified personnel, tools, calibrated test instruments and access equipment necessary to perform all mechanical commissioning related activities.
- N. Will execute under the direction of the CxA functional tests relating to all mechanical systems and equipment.
- O. Will provide complete operation and maintenance information in electronic format and as-built drawings to the GC as specified.
- P. Will Develop and issue training plans as specified to the Architect / Engineer and Commissioning Authority for comment and approval prior to training being scheduled to take place. Provide training for the mechanical systems as specified in accordance with the approved training plans.
- Q. Will execute under the direction of the CxA opposite season functional testing as required relating to all mechanical systems and equipment.

Electrical Subcontractors (EC):

- A. Will coordinate and direct participation of the Electrical Subcontractors and suppliers in the commissioning process.
- B. Will review and comment on the Commissioning Plan, Cx milestone schedule and assist in preparing the Operational and Functional Acceptance Test Procedures if required. Provide input and documentation required to develop final plans and procedures.
- C. Will develop pre functional check sheets and start up procedures for each electrical item of equipment and systems to be commissioned. Collate these documents into a single check out and start up plan. The document will include procedures for all electrical testing procedures to be employed. This plan will be issued prior to commencing testing. Incorporate and execute any comments as directed by the GC, update and reissue as required.
- D. Will participate in commissioning meetings as required. Will coordinate participation of suppliers and subcontractors as required.
- E. Will Coordinate installation of electrical systems and equipment with equipment suppliers, mechanical and electrical subcontractors. Verify that coordination,

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installation, quality control, and Subcontractor testing have been completed and that installed systems and equipment comply with the requirements of the contract documents.

- F. Will coordinate and schedule electrical installations and testing to be complete prior to the scheduled start up of mechanical equipment.
- G. Will issue formal notice to the GC of the intent to perform any commissioning related activity. Give adequate notice of each and every planned event (minimum seven days).
- H. Will notify the GC in writing as soon as possible of any issues identified during construction that may affect the commissioning process or final system performance.
- I. Will action commissioning related directions issued by the GC.
- J. Will perform pre functional checks, start-up and testing of electrical equipment and systems as specified and document as required issuing records to the GC.
- K. Will operate equipment and systems as required for Operational and Functional Acceptance Testing.
- L. Will participate in the fine-tuning or troubleshooting of system performance if either of these measures becomes necessary.
- M. Will coordinate and provide attendance, provision of qualified personnel, tools, calibrated test instruments and access equipment necessary to perform all electrical commissioning related activities.
- N. Will execute under the direction of the CxA functional tests relating to all electrical systems and equipment.
- O. Will provide complete operation and maintenance information in electronic format and as-built drawings to the GC as specified.
- P. Will Develop and issue training plans as specified to the Architect / Engineer and Commissioning Authority for comment and approval prior to training being scheduled to take place. Provide training for the electrical systems as specified in accordance with the approved training plans.
- Q. Will execute under the direction of the CxA opposite season functional testing as required relating to all Electrical systems and equipment.

Temperature Controls Subcontractor (TCC)

- A. Will provide controls system and wiring diagrams, points list, narrative sequences of operation, set points and printout of actual programmed sequences prior to loading programs to field controllers and in time for use in point to point testing. Provide Single-Line diagrams of system configurations on 11 X 17 inch sheets to the GC / Owner. Provide images of all head end graphical interfaces pages for Owner, A/E and CxA comment.

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- B. Will review and comment on the Commissioning Plan, Cx milestone schedule and assist in preparing the Operational and Functional Acceptance Test Procedures if required. Provide input and documentation required to develop final plans and procedures.
- C. Will participate in commissioning meetings as required.
- D. Will participate in any required efforts to finalize sequences of operations and interfaces of systems with Owner, Designers and Commissioning Authority.
- E. Will coordinate installation of controls systems with the GC, equipment suppliers, mechanical and electrical Subcontractors. Verify that coordination, installation, quality control, and final Subcontractor testing have been completed such that installed systems and equipment comply with the requirements of the contract documents.
- F. Will issue formal notice to the GC / Owner of the intent to perform any commissioning related activity. Give adequate notice of each and every planned event (minimum 14 days).
- G. Will notify the GC / Owner, A/E, Commissioning Authority as soon as possible of any system installation or interface issues identified during construction that may compromise system control capability.
- H. Will complete Installation and Pre-Commissioning Test Checklists and other supporting documentation as required and demonstrate completion of control system installation, point-to-point verification (including sensor and device calibration and operation), start-up and testing, BAS graphical interfaces, functionality, alarms and monitoring, remote communications, trending, networking and submit to the GC / Owner.
- I. Will execute and schedule installation, pre commissioning, testing and commissioning of the control systems and graphic software such that systems are operable and checked out and complete prior to commencement of the test and balance activities. Demonstrate operation of the controls systems to the A/E and CxA.
- J. Will provide attendance to the TAB agency as required.
- K. Will action commissioning related directions issued by the GC / Owner.
- L. Will participate in start-up and Operational and Functional Acceptance Testing as required. This will require dedicated, full time support of the Operational and Functional Acceptance Testing efforts during commissioning. This will require setting up maintaining, recording and downloading system trend logs as required at the direction of the CxA.
- M. Will participate in fine-tuning or troubleshooting of system performance with the CxA and Owner as necessary during Operational and Functional Acceptance Testing and fault-free running periods.

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- N. Will provide the Owner and Commissioning Authority with final documentation for all installed conditions, including as-built drawings and detailed narrative sequences of operation as determined during commissioning process, final copies of software, licenses, equipment details, O&M information and all other deliverables as specified.
- O. Will develop and issue training plans as specified to the GC / Owner for comment and approval. Provide training for the systems specified in accordance with the approved training plans.
- P. Will provide attendance and input during Mechanical Contractors Owner Staff training sessions as required.
- Q. Will provide attendance during opposite season functional testing as required.

Testing, Adjusting, and Balancing Subcontractor (TAB):

- A. Will review the Commissioning Plan, schedule, and Functional Acceptance Test Procedures. Provide the input required to develop final plans and procedures.
- B. Will develop and issue written TAB procedures for comment and approval.
- C. Will coordinate balancing activities with those of the Mechanical and Controls Subcontractors. Verify that coordination, installation, quality control, and final Subcontractor testing have been completed sufficiently to allow proper balancing work to be started and correctly performed. Schedule TAB activities such that they are complete and the final TAB report is approved by the A/E prior to scheduled commencement of system and equipment functional testing.
- D. Will notify the GC, A/E and Cx as soon as possible of any system installation or performance issues that may compromise the ability to balance the systems per the design requirements.
- E. Will participate in start-up and testing and documenting the same as required.
- F. Will provide attendance to the TCC as required, identifying and disseminating actual required control set points needed to program system operation as per the design intent.
- G. Will execute the test and balance and assist the CxA in system verification. Provide preliminary TAB report, indicating all actual field values recorded, to the A/E and Commissioning Authority within 48 hours of TAB of a system. Final TAB report must be issued and reviewed prior to initiation of Functional Acceptance Testing period.
- H. Will assist during the Functional Acceptance Testing as required.
- I. Will participate in fine-tuning P&I control loops or troubleshooting of system performance if either of these measures becomes necessary.

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- J. Will attend and assist during the opposite season Functional Acceptance Testing as required.

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COMMISSIONING COMMUNICATION AND PROTOCOL

The Owners PM will facilitate and support the Cx process and will direct and give final approval of all commissioning related work.

The A/E will act under the direction of the Owners PM. The A/E will report directly to the Owners PM. The A/E will interface and communicate with the CxA and GC as directed by the Owner. The A/E will approve all commissioning related work is in compliance with the requirements of the contract.

The CxA will act under the direction of the Owners PM. The CxA will report directly to the Owners PM. The CxA will interface and communicate with the A/E and GC as directed by the Owner. The CxA will observe, verify, report and verify commissioning activities are completed in accordance with the requirements of the Project Scope of Work. The CxA will assist the GC in coordinating commissioning activities.

The GC will act under the direction of the Owners PM. The GC will report directly to the Owners PM. The GC will interface and communicate with the A/E and CxA as directed by the Owner. The GC will ensure all means and methods are discharged necessary to comply with the requirements of the contract documents. The GC will coordinate and direct the commissioning activities of the sub contractors and equipment suppliers.

The Subcontractors will act under the direction of the GC. They will report directly to the GC. The Subcontractors will discharge commissioning activities as defined by the contract documents.

Commissioning Meetings will be arranged by the CxA as required and coordinated through the PM and GC. The CxA will chair commissioning meetings and record and distribute a summary of each meeting. Members of the commissioning team shall attend commissioning meetings as required.

COMMISSIONING SCHEDULE

As the Work progresses and until Functional Performance Testing of the Systems begin, the CxA will intermittently visit the Project Site on an agreed schedule during the Construction Phase. The Commissioning Authority will coordinate the Project site visits to coincide with Static & Dynamic Testing and/ or regular construction team coordination meetings. The Commissioning Authority shall participate and lead the commissioning coordination portion of those meetings. Additionally, Commissioning Authority shall directly observe Work in progress for general observation of conditions and shall be available to the Contractor for questions and clarification regarding the Contractor's commissioning responsibilities.

The Commissioning Schedule shall be organized as an important and integral part of the Master Construction Schedule. All Construction Phase Commissioning activities shall be scheduled in advance on the master schedule, with a minimum of 14 days notice to the Owner, A/E Commissioning Authority for any required witnessing or verification. The Construction Schedule will detail all commissioning activities including milestones for the following:

- a) Milestones for Infrastructure available at site;
 - 1. Contractor start on site date.
 - 2. Factory review of prototype units
 - 3. Factory review of remaining units.

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4. Equipment in place on roof.
 5. Power available for use.
 6. Communications infrastructure available.
- b) Commissioning milestones to be agreed. Test sheets referred to below are pre functional checklist sheets and functional test sheets included in draft form in appendix A.
1. Mechanical, Electrical and Control Subcontractors start on site dates.
 2. Building Envelope weather tight.
 3. Systems rough-ins complete.
 4. Systems Installation check out.
 5. Building power available to HVAC plant and equipment.
 - i. pre-functional testing complete.
 - ii. systems energization and start up.
 - iii. Pipework systems flushing & chemical cleaning complete i.e. ductwork flushing and cleaning complete.
 6. Controls point-to-point field tests, system safeties proven.
 7. BAS individual controllers P+I+D loops set to work.
 8. Controls point-to-point interface Head-end tests.
 9. TAB
 10. Sequence of operation auto running checks.
 11. BAS Systems integration preliminary control tests complete.
 12. O & M manuals submitted for review and approval.
 13. Systems Installation Punch Out
 14. Operational and Functional Performance Test period.
 15. Training period.
 16. Fault free running period.
 17. M&E systems commissioning complete.
 18. Post occupancy fine tuning period and 6 & 10 month Warranty phase checks.

The Commissioning Schedule will use logic-linked tasks that form a critical path linked to the master construction schedule to plan successful completion of all commissioning activities. The use of proprietary computer software to generate the logic linked commissioning tasks in GANTT bar or PERT format is required. The GC is responsible for monitoring and updating this schedule and reporting slippage and recovery actions to maintain program commissioning milestones. Commissioning progress reports are to be issued by the GC monthly and then weekly after the first energization of equipment.

Scheduling updates shall be done in advance of reported system completion. All reasonable accommodations shall be made to avoid completed systems or equipment standing idle as this is detrimental to system components.

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SYSTEM ACCEPTANCE CRITERIA

System acceptance criteria and tolerances shall be as defined by the A/E in the contract documents.

Prior to Functional Acceptance Testing of systems, the Commissioning Authority shall observe and verify that the physical installation, static testing, and pre-functional commissioning of components and systems are complete in accordance with the Contract Documents and manufacturer's recommendations and report his observations to the Owner. Ultimately system acceptance is the responsibility of the Architect and Engineer of Record. The Commissioning Authority will validate, verify, observe and report on the commissioning process, noting completeness and compliance with respect to the contract requirements the Project Scope of Work.

GC's verification required prior to executing Functional Acceptance Testing:

- A. System shall be checked and signed off by the GC and or Subcontractor for proper installation, shall be adjusted accordingly, and shall be calibrated. Written notice shall be provided by the GC that systems are ready for functional testing as specified.
- B. All system elements and checklists shall be reviewed through site observation and signed off by the contractor to verify that they have been installed properly and that all connections have been made correctly.
- C. All discrete elements and sub-systems shall be adjusted and shall be checked for proper stand alone operation.
- D. All inter system interfaces shall have been checked and shall be functional.
- E. Start-up and operational tests and interfacing of systems shall be complete, with all required Installation checklists and Pre-functional tests and checks documented. The Field Commissioning Notebook shall submitted for review by Commissioning Authority, prior to starting Operational and Functional Acceptance Tests.
- F. The TAB activities shall be complete and the final TAB report approved by the A/E prior to commencing Functional Performance Testing.

Commissioning Authority Witness of Operational and Functional Acceptance Tests:

- A. Objective of these tests is to demonstrate and validate that systems are operating and complying with specified performance requirements.
- B. Commissioning Authority witnessed Functional Acceptance Tests shall only be performed on complete systems. Each function shall be demonstrated to the Owner's Commissioning Authority on item by item basis by the relevant contractor or supplier at the direction of the CxA. Execution of the tests shall follow the approved written test procedures developed by the CxA.
- C. Functional Acceptance Tests shall be directed and witnessed by the Commissioning Authority, executed by the installer and signed off by Owner and A/E upon satisfactory completion.

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- D. Actual testing program shall be conducted in accordance with previously approved procedures and schedules.
- E. Contractor shall notify Project Team, Commissioning Authority and Owner at least fourteen (14) days prior to the intended date of execution of Functional Performance Tests.
- F. If it becomes apparent that a system being tested is not ready for testing by observing repeated failure of test procedures, the Commissioning Authority shall halt that test procedure. The team will identify and action remedial activities to resolve deficiencies and the GC shall schedule future retesting giving further formal notification of the intent to retest.
- G. Testing of each type of equipment/sensor/actuator/control point (one for each sequence of control) will be conducted.
- H. All subsequent retesting consequential to failures or portions of tests which have failed as a direct result of systems not being ready for functional testing at the notified and scheduled time, may be considered by the Owner as additional services to be provided by the Commissioning Team and associated additional time and expense may be back-charged by the Owner to the party at most fault.

ISSUE RESOLUTION

Misalignment, maladjustments, misapplied equipment, design deficiency and deficient performance under varying operating conditions may result in additional work being required to commission the systems to satisfy the Owners Requirements. Resolution of any identified deficiencies will be completed under the direction of the Owner and the supervision of the GC with input from the A/E, Equipment Supplier, TAB agency, Contractors, and Commissioning Authority. All associated parties will have input and the opportunity to discuss the work required to resolve the issue. The Owner will have final jurisdiction on the necessary work to be undertaken to achieve adequate performance.

The Commissioning Authority will provide observations and recommendations and as such will not be responsible for the means or methods of the A/E the GC or his subcontractors.

Corrective work shall be performed in a timely fashion to keep completion of the commissioning process as close to schedule as possible.

When a observation issue is reported, the GC shall notify the appropriate parties to initiate corrective action in an expeditious manner. The Commissioning Authority will keep an ongoing Observation Issues Log listing and tracking identified resolution of issues. An up to date copy of this Observation Issues Log will be kept on site in the Field Commissioning Notebook. The GC, Owner, and CxA will monitor the resolution of identified deficiencies.

PRE FUNCTIONAL CHECKS

Each installing contractor will develop pre functional check sheets and start up procedures for each item of equipment / system to be commissioned. The GC will collate these documents into a single check out and start up plan. The document will include checks and procedures for all testing (including flushing, cleaning and disinfection

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/ treatment of systems) to be employed including manufactures recommend start up procedures. This plan will be issued by the GC to the Owner and the CxA prior to commencing pre functional checks. Incorporate and execute any comments as directed by the Owner and GC, update and reissue as required.

Upon completing installations and prior to start-up or energization of any system or item of equipment , the relevant installing contractor shall inspect, check and confirm the correct and complete installation of all equipment and systems for which pre-functional checklists are included in Appendix A. The installing contractor shall document the results of all inspections and checks on the checklists and issue completed copies to the GC. If deficient or incomplete work is discovered, ensure corrective action is taken and re-check until the results are satisfactory and the system is ready for safe start-up. The CxA will observe and validate a representative sample of all pre functional checks and test.

EQUIPMENT / SYSTEM START UP

Following the completion of equipment / system pre functional checks and validation of the same by the CxA, equipment and systems shall be started up / energized by the installing contractor. Assistance may be required from equipment manufacturers and factory representatives. Start up of equipment shall adhere to the equipment manufactures recommendations and best industry practice. Formal written notice (14 days minimum) of the intent start up or energize equipment / systems shall be provided to the Owners PM & CxA by the GC. The CxA will observe and validate a representative sample of the energization and start up of systems/ equipment. Start up procedures shall be documented by the installing contractor. Completed start up reports for each item of equipment / system shall be issued to the GC by the installing contractor. A copy of completed start up reports will be maintained in the Field Commissioning Book on site and the GC shall issue a copy (electronic format) of all start up records to the Owner and CxA.

TEST AND BALANCE

The test and balance agency will provide a TAB execution plan prior to executing TAB activities. This plan shall be issued to the Owner for approval, the execution plan shall include TAB test sheets to be used during the TAB process, a description of all TAB activities and copies of the calibration certificates to be utilized in undertaking the TAB exercise. The approved TAB execution plan will be maintained in the Field Commissioning Book on site. The TAB process for each system to be balanced will not commence until completion of all related pre functional checks and equipment start up has been validated by the CxA. The TAB agency shall give minimum 7 days written notification of the intent to commence the TAB process. The TAB agency shall complete TAB procedures in accordance with the approved TAB execution plan. The TAB agency will notify the GC, A/E and Cx as soon as possible in writing of any system installation or performance issues that may compromise the ability to balance the systems per the design requirements. On completion of TAB activities the TAB agency shall issue a preliminary TAB report to the CxA for review and A/E for approval. The TAB agency shall undertake any corrective actions required by the A/E and directed by the Owner and shall record any resulting revised TAB data in the final TAB report, which shall be issued to the Owner, A/E and CxA . The CxA will witness and observe a random sample of TAB activities during the execution of the TAB process. The CxA will independently validate a random representative sample of TAB results as recorded in the approved preliminary TAB report. Copies of the TAB reports will be maintained in the Field Commissioning Book on site and issued in electronic format.

TRAINING OF OWNERS STAFF

With the assistance of the installing contractors, equipment suppliers and manufacturers the GC shall coordinate and develop an Instructional Program document for demonstration and training of the Owners operations and maintenance staff as per the requirements of specification section 019113 and other relevant sections of the contract

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documents. This instructional program document shall be submitted to the Owner for comment and approval. The GC shall coordinate and facilitate a Pre Instruction Conference prior to implementing training activities. A copy of the instructional training program shall be maintained in the Field Commissioning Book on site.

Training shall be scheduled and executed in accordance with the approved instruction program and the agreed procedures resultant from the pre instruction conference, all training activities will be coordinated with the owners staff by the GC with assistance from the CxA. The CxA will observe training sessions and shall report on the quality and adequacy of the training activities. The GC shall arrange that all training sessions be video taped/digitally recorded. At completion of the training process the GC shall compile and submit a completed training manual to the Owner. The manual shall be developed in accordance with the requirements of specification section 019113 and other relevant sections of the contract documents. During the warranty phase the CxA shall interview operating staff and identify if there is a need for further staff training.

FUNCTIONAL PERFORMANCE TESTING

Functional Performance Test Procedures shall be developed by the CxA for the systems to be commissioned and used to document and validate the Functional Performance of systems and equipment operating in accordance with the Engineers sequence of operation and the contract documents. Members of the commissioning team will have opportunity to comment on all test procedures. The CxA shall incorporate comments from the team into the FPT's at the direction of the Owner. The agreed FPT's will be maintained in the Field Commissioning Book on site.

Functional Performance Testing shall not commence until associated pre functional checks, documented start up and TAB activities have been validated as complete by the CxA. The owners operating and maintenance staff are strongly encouraged to participate in the functional testing process as it is viewed as a powerful orientation and training tool. With assistance from the CxA the GC shall coordinate, schedule and facilitate all functional testing.

The installing contractors shall operate each system / item of equipment through all modes of system operation and failure (for example, seasonal, occupied, unoccupied, warm-up, power failure, emergency power supply, alternate power supply, etc, as applicable) including interlocks, safeties and conditional controlled logical events, all control sequences, both full-load and part-load conditions, and simulation of abnormal conditions for which there is a specified parameter requiring controlled response, alarming and trending functions will be checked and validated, all as per the agreed FPT's and under the direction of the CxA.

When the Functional Performance Tests of individual systems has been validated, the interface or coordinated responses between systems may be checked. The systems involved may be within one discipline, such as the HVAC system, but, they may involve other systems, such as electrical and fire alarm systems, the GC shall assure all required attendances are provided to facilitate integrated testing as needed and scheduled in accordance with the requirements of the Functional Test Plans.

Corrective Measures: If acceptable performance cannot be achieved, then necessary corrective measures shall be executed at the direction of the Owner. Every check or test for which acceptable performance was not achieved shall be repeated once the necessary corrective measures have been complete. This retesting process shall be repeated until acceptable performance is achieved to the satisfaction of the Owner and the requirements defined in the contract documents are discharged. The CxA will record and submit completed FPT's for all executed tests. The completed FPT's will be incorporated into the final systems commissioning manual prepared by the CxA.

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OPPOSITE SEASON TESTS

Commissioning tests for Substantial Completion shall be performed at seasonal conditions experienced at the time of executing the FPT's under as near full load condition as possible. Methods of forcing environmental conditions may be employed to minimize the requirement to perform opposite season tests.

Opposite seasonal checks shall be executed if required and specified as soon after substantial completion as seasonal weather conditions will allow. The GC shall schedule and coordinate opposite season testing with the assistance of the CxA. The GC shall ensure availability and provision of qualified personnel, tools, calibrated test instruments and access equipment necessary to perform all opposite season commissioning related activities.

All heating equipment and systems shall be tested at peak season conditions to observe full load performance during winter design extremes. The Contractor and each relevant Subcontractor and supplier shall participate in the alternate peak season test of the systems to demonstrate performance, as scheduled by the GC, with fourteen day (minimum) advance notification.

WARRANTY FOLLOW-UP

The Commissioning Authority will return to the facility 10-12 months into the warranty period of the earliest accepted Systems and review with facility operating staff the current building operation and the condition of outstanding issues in relation to the original and seasonal Commissioning Work.

The Owner's staff is to be interviewed to identify any problems or concerns they have operating the systems as originally intended. Suggestions may be made for improvements and for recording these changes in the Systems manuals and in the final commissioning report for use in future projects. Problem issues identified with systems may be covered by warranty or that have resulted from other causes will be identified. The Commissioning Authority will assist facility staff in developing reports, documents, and requests for services to remedy outstanding problems at the facility.

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APPENDIX

The following pages contain some of the various checklists and forms (not all inclusive) used in executing the Commissioning Plan:

Observation Issues Log (Cx-Log)	Used to record, recheck and sign off deficiencies
Notification to Observe Test Form	Used to request testing dates
Equipment Commissioning Log	Used as a Completion Checklist
Training Evaluation	Used to evaluate the training process
Pre Functional check forms	Used to verify readiness for functional testing
Functional Test forms	Used to validate all control functions

Chicago Transit Authority 103 rd Bus Garage Observation/Issues - Commissioning Log (Cx-log)						
I.D. #	Date Entered	Location	System or Equipment	Observation / Deficiency	Comments	Date rechecked
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
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25						
26						
27						
28						
29						
30						

Issue cleared (Y/N)

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Chicago Transit Authority 103 rd Bus Garage – Training Evaluation		
System / Equipment		Party Providing Training
Training Hours specified:		Specification Reference:
Date training Agenda and / or outline was submitted to the Owner and Commissioning Authority :		
Does the Agenda or outline meet the intent of the specifications?		Yes / No
Does the content of the training plan provide sufficient information to operate and/or perform maintenance on the equipment and/or systems?		Yes / No
Equipment Covered in Training:		
Date of training:		
Name Trainer(s):		
Trainer title and company:		
Location of training:		
Present at training: Name		Organization:
Did training follow the agenda and / or outline submitted and approved?		Yes / No
Was the class size appropriate for the type of training?		Yes / No
(i.e. If the training was hands on type did everyone in the class have the opportunity to do the function demonstrated?)		
If there were handouts during the class did everyone get a copy?		Yes / No
Were they appropriate and helpful?		Yes / No
Were attendees given the opportunity to ask questions?		Yes / No
Were any questions asked adequately answered?		Yes / No
Was training material and video of the session issued as specified?		Yes / No
Was the training held in an organized manner? Did the trainer maintain control of the class during the session?		
How did the trainees evaluate the training?		
Comments:		
Submitted by:		Date:

HVAC COMMISSIONING
Pre-Functional Checklist /START-UP CHECKLIST
AIR HANDLING UNIT

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

System/Area Served: _____ Related Equipment: _____

Install Date _____ Warranty Expiration _____ Barcode Number _____

1. Model verification

	Fill-in information	OK	Deficient note #
Manuf.			
Model #.			
Serial #			
Heating Coil Capacity			
Supply Fan Volts/Ph/A			
Return Fan Volts/Ph/A			
Filter MERV #, Thickness, PD			
Unit Supply CFM			
Unit Outside Air CFM			

Supply fan VFD			
Return fan VFD			

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

2. PRE START UP INSPECTION

ITEM	OK	Deficient note #
ID Label permanently affixed		
Commissioning lock-out procedures reviewed		
Operation and maintenance information received		
Mounting/support system and internal vibration isolation		
2" Double wall insulated unit		
VFDs mounted with local disconnects visible from fans		
Condensate trap height large enough for static pressure difference		
Stainless Steel IAQ drain pans for Cooling Coil.		
Equipment guards		
Alignment & V-belt tension		
Fan freedom of rotation		
Lubrication fan/motor		
Plenums clean and free of loose material		
Temporary start-up filters installed		
Fire & balance dampers positioned		
Duct system tested and cleaned		
Access doors, Insulation and interior marine lights		
Local valving/piping complete (HWS, DCW, compressed air, condensate, drains)		
Drain pans, pitched, trapped		
Heating coils properly piped		
Outside air and exhaust air dampers		
Building & fan space cleanliness		
Filter bank, DP switch gauge		
Electrical wiring complete		
Motors rated for VFD service		

Overload protection (sized correctly)		
Disconnect switch (tested)		
Instrumentation (temperature, volume, pressure & humidity)		
Control system - point to point checks complete		

Check if Okay. Enter note number if deficient.

3. START-UP

AHU Start-up by manufacturer's representative	OK	Deficient note #
VFD Start-up by manufacturer's representative		
Direction of fan rotation correct		
Control valves stroke fully and spanning is calibrated		
Failed position of heating coil valve-open to coil		
No unusual noise or vibration		
Local air leakage acceptable, 1% at 8"		
Electrical interlocks - stop/start		
Measure line to line voltage phase imbalance for each AHU::		
AB/AC/BC:		
AHU Amps - Rated :		
Actual :		

. Check if Okay. Enter note number if deficient.

4. SIGN-OFFS

Pre-start checks by	
Date:	
Start-up checks by:	
Date:	
print name	signature

Comments:

HVAC COMMISSIONING Pre-Functional Checklist /START-UP CHECKLIST CIRCULATING PUMPS

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

System/Area Served: _____ Related Equipment: _____

Install Date _____ Warranty Expiration _____

Barcode Number _____

1. Model verification

Equip Tag	Manuf./Model	Flow/Total Head (GPM/FT H ₂ O)	Motor/Impeller (HP/inches)	Code (circle)	Deficient note #
				1 2 3	
Pump Serial No.	VFD Model No	VFD Serial No	Volts/phase/amps	VFD Serial No.	OK

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

2. PRE START UP INSPECTION

ITEM	OK	Deficient note #
PRE-START-UP INSPECTION		
Commissioning lock-out procedures reviewed		
Operation and maintenance information received		
ID Label permanently affixed		
Pumps in place and properly grouted		
Mounting/support system and vibration isolation		
Temperature, pressure and flow gages and sensors installed		
Equipment guards Installed		
Coupling alignment appears correct		
Pump rotates freely		
Pump/Motor Lubricated		
Insulation Complete		
Pipe fittings complete and pipes properly supported		
Pipes properly labeled		
Strainers in place and clean		
Piping system properly flushed		
Control system interlocks hooked up and functional		

Sensors Calibrated		
Power disconnects in place and Labeled		
All electric connections tight		
Proper grounding installed for motor and VFD		
Overload protection (sized correctly)		
Disconnect switch (tested)		
Control system - point to point checks complete		

Check if Okay. Enter note number if deficient.

3. START-UP

	OK	Deficient note #
VFD Start-up by manufacturer's representative		
HWS or CHWS available		
Direction of rotation verified		
No unusual noise or vibration		
No leaking apparent around fittings		
Electrical interlocks - stop/start		
Measure line to line voltage phase imbalance for each pump: AB/AC/BC		
Motor Amps - Rated : Actual :		
Motor Volts - Rated : Actual :		

4. SIGN-OFFS

Pre-start checks by	Date:
Start-up checks by:	Date:
print name	signature

Comments:

HVAC COMMISSIONING Pre-Functional Checklist /START-UP CHECKLIST ELECTRIC UNIT HEATERS

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

System/Area Served: _____ Related Equipment: _____

Install Date _____ Warranty Expiration _____

Barcode Number _____

1. Model verification

Equip Tag	Manuf./Model	Flow/Total Head (GPM/FT H ₂ O)	Motor/Impeller (HP/inches)	Code (circle)	Deficient note #
				1 2 3	
Pump Serial No.	VFD Model No	VFD Serial No	Volts/phase/amps	VFD Serial No.	OK

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

2. PRE START UP INSPECTION

ITEM	OK	Deficient note #
PRE-START-UP INSPECTION		
Commissioning lock-out procedures reviewed		
Operation and maintenance information received		
ID Label permanently affixed		
Installed level and plumb in AHU casing		
Mounting/support system and vibration isolation		
Temperature sensor installed		
Equipment guards Installed		
Fan blade rotates freely		
Motor Lubricated		
Control system interlocks hooked up and functional		
Sensors Calibrated		
Power disconnects in place and Labeled		
All electric connections tight		

Proper grounding installed for motor		
Overload protection (sized correctly)		
Disconnect switch (tested)		
Control system - point to point checks complete		

Check if Okay. Enter note number if deficient.

3. START-UP

	OK	Deficient note #
Direction of rotation verified		
No unusual noise or vibration		
Electrical interlocks - stop/start		
Motor Amps - Rated : Actual :		
Motor Volts - Rated : Actual :		

4. SIGN-OFFS

Pre-start checks by	Date:
Start-up checks by:	Date:
print name	signature

Comments:

HVAC COMMISSIONING

Pre-Functional Checklist /START-UP CHECKLIST

Bid Alternate EXHAUST FANS

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

System/Area Served: _____ Related Equipment: _____

Install Date _____ Warranty Expiration _____

Barcode Number _____

1. Model verification

Equip Tag	Manuf./Model	Flow/Total Head (GPM/FT H ₂ O)	Motor/Impeller (HP/inches)	Code (circle)	Deficient note #
				1 2 3	
Pump Serial No.	VFD Model No	VFD Serial No	Volts/phase/amps	VFD Serial No.	OK

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

2. PRE START UP INSPECTION

ITEM	OK	Deficient note #
PRE-START-UP INSPECTION		
Commissioning lock-out procedures reviewed		
Operation and maintenance information received		
ID Label permanently affixed		
Fan has correct rotation		
Fan/motor lubricated.		
Mounting/support system and vibration isolation		
Fan rotates freely		
Equipment guards Installed		
Drive belt tension correct		
Belt tension checked after 24 hours of operation		
Belt tension checked after 100 hours of operation		
Any motor over-heating?		
Control dampers function properly		

Control system interlocks hooked up and functional		
Control system - point to point checks complete		
Power disconnects in place and Labeled		
All electric connections tight		
Proper grounding installed for motor		
Overload protection (sized correctly)		
Disconnect switch (tested)		
Maximum Allowable fan RPM:		
Design Fan RPM:		
Measured fan RPM:		
Controls - Switches work:		
Controls - Alarms activate locally:		
Controls - Alarms activate in BAS:		
Controls - Fan will start/stop via BAS:		

Check if Okay. Enter note number if deficient.

3. START-UP

	OK	Deficient note #
Direction of rotation verified		
No unusual noise or vibration		
No leaking apparent around fittings		
Electrical interlocks - stop/start		
Design Amp Draw (L1/L2/L3): / / /		
Measured Amp Draw (L1/L2/L3): / / /		
Design Voltage (L1/L2/L3): / / /		
Measured Voltage (L1/L2/L3): / / /		
Maximum Allowable fan RPM:		
Design Fan RPM:		
Measured fan RPM:		

4. SIGN-OFFS

Pre-start checks by	Date:
Start-up checks by:	Date:
print name signature company	

Comments:

HVAC COMMISSIONING Pre-Functional Checklist /START-UP CHECKLIST HOT WATER UNIT HEATER

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

System/Area Served: _____ Related Equipment: _____

Install Date _____ Warranty Expiration _____

Barcode Number _____

1. Model verification

Equip Tag	Manuf./Model	Flow/Total Head (GPM/FT H ₂ O)	Motor/Impeller (HP/inches)	Code (circle)	Deficient note #
				1 2 3	
Pump Serial No.	VFD Model No	VFD Serial No	Volts/phase/amps	VFD Serial No.	OK

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

2. PRE START UP INSPECTION

ITEM	OK	Deficient note #
PRE-START-UP INSPECTION		
Commissioning lock-out procedures reviewed		
Operation and maintenance information received		
ID Label permanently affixed		
Installed level and plumb		
Mounting/support system and vibration isolation		
Temperature and flow gages and sensors installed		
Equipment guards installed		
Fan blades rotate freely		
Fan Motor Lubricated		
Pipe Insulation Complete		
Pipe fittings complete and pipes properly supported		
Pipes properly labeled		
Strainers in place and clean		
Piping system properly flushed		
Control system interlocks hooked up and functional		

Sensors Calibrated		
Power disconnects in place and Labeled		
All electric connections tight		
Proper grounding installed for motor		
Overload protection (sized correctly)		
Disconnect switch (tested)		
Zone thermostat installed		
Control system - point to point checks complete		

Check if Okay. Enter note number if deficient.

3. START-UP

	OK	Deficient note #
HWS available		
Direction of rotation verified		
No unusual noise or vibration		
No leaking apparent around fittings		
Electrical interlocks - stop/start		
Motor Amps - Rated :	Actual :	
Motor Volts - Rated :	Actual :	

4. SIGN-OFFS

Pre-start checks by	Date:
Start-up checks by:	Date:
print name	signature

Comments:

HVAC COMMISSIONING

Pre-functional Checklist /START-UP CHECKLIST

HOT WATER BOILER

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

System/Area Served: _____ Related Equipment: _____

Install Date _____ Warranty Expiration _____

Barcode Number _____

1. Model verification

Equip Tag	Manuf./Model	Capacity Steam Pressure input (lbs)	Recovery Capacity (GPM)	Serial No.	OK	Deficient note #
Equip Tag	Manuf./Model	Pump capacity (GPM/ TDH)	HP & voltage phase/amps	Serial No.	OK	Deficient note #

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

2. PRE START UP INSPECTION

ITEM	OK	Deficient note #
ID Label permanently affixed		
Commissioning lock-out procedures reviewed		
Operation and maintenance information		
Mounting/support system and vibration isolation, supply bolts released		
Flexible connections		
Equipment guards		
Freedom of rotation		
Lubrication, pumps, circulators and booster pump		

Volute clean and free of loose material		
Mixing Valve "Brain" by Armstrong & connected to BAS		
Piping (hot water) complete		
Cold water piping and booster pump complete		
Room cleanliness, free of loose material		
Electrical wiring complete		
Disconnect switch (tested)		
Control system - point to point checks complete		

Check if Okay. Enter note number if deficient.

3. START-UP

	OK	Deficient note #
Hot water boilers start-up by manufacturer's representative		
Water Booster Pump Start-up by manufacturer's representative		
Direction of rotation checked		
No unusual noise or vibration		
TAB report acceptable		
Safety/protective devices including high temperature shut-off, low water cut-off been tested		
Verify Pressure safety valve setting		
Hot water Pumps interlock installed and tested		
Hot water proof-of-flow switch installed and tested		
Control interlocks verified		
Electrical interlocks - stop/start		
Power disconnect located within sight of unit		
Measure line to line voltage phase imbalance for booster pump: AB/AC/BC:		
Motor Amps - Rated : Actual :		

Check if Okay. Enter note number if deficient.

4. SIGN-OFFS

Pre-start checks by	Date:
Start-up checks by:	Date:
print name	signature
Comments:	

HVAC COMMISSIONING Pre-Functional Checklist /START-UP CHECKLIST HYDRONIC PUMPS

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

System/Area Served: _____ Related Equipment: _____

Install Date _____ Warranty Expiration _____

Barcode Number _____

1. Model verification

Equip Tag	Manuf./Model	Flow/Total Head (GPM/FT H ₂ O)	Motor/Impeller (HP/inches)	Code (circle)	Deficient note #
				1 2 3	
Pump Serial No.	VFD Model No	VFD Serial No	Volts/phase/amps	VFD Serial No.	OK

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

2. PRE START UP INSPECTION

ITEM	OK	Deficient note #
PRE-START-UP INSPECTION		
Commissioning lock-out procedures reviewed		
Operation and maintenance information received		
ID Label permanently affixed		
Pumps in place and properly grouted		
Mounting/support system and vibration isolation		
Temperature, pressure and flow gages and sensors installed		
Equipment guards Installed		
Coupling alignment appears correct		
Pump rotates freely		
Pump/Motor Lubricated		
Insulation Complete		
Pipe fittings complete and pipes properly supported		
Pipes properly labeled		

Check if Okay. Enter note number if deficient.

3. START-UP

	OK	Deficient note #
VFD Start-up by manufacturer's representative		
HWS available		
Direction of rotation verified		
No unusual noise or vibration		
No leaking apparent around fittings		
Electrical interlocks - stop/start		
Measure line to line voltage phase imbalance for each pump: AB/AC/BC		
Motor Amps - Rated : Actual :		
Motor Volts - Rated : Actual :		

4. SIGN-OFFS

Pre-start checks by	Date:
Start-up checks by:	Date:
print name	signature

Comments:

HVAC COMMISSIONING

Pre-functional Checklist /START-UP CHECKLIST

VFD SUPPLY FAN/EXHAUST FAN

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

System/Area Served: _____ Related Equipment: _____

Install Date _____ Warranty Expiration _____

Barcode Number _____

1. Model verification

Equip Tag	Manuf./Model	AirFlow/TSP (CFM)/ (IN.WC.)	Wheel dia/Motor Inches/HP	Fan Serial Number	Deficient note # (circle)
					1 2 3
Fan Horsepower	Fan Volts\phase\amps	VFD Model No.	VFD Volts/phase/amps	VFD Serial Number	OK

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

2. PRE START UP INSPECTION

ITEM	OK	Deficient note #
ID Label permanently affixed		
Commissioning lock-out procedures reviewed		
Operation and maintenance information		
Mounting/support system and vibration isolation, supply bolts released		
Flexible connections		
Equipment guards		
Pulley Alignment & V-belt tension correct		
Freedom of rotation		
Lubrication, Fan, Motor, Linkage		
Plenum/volute clean and free of loose material		
Duct system tested and cleaned		
Fire & balance dampers positioned		

Exhaust Dampers, gravity motorized backdraft tested		
Building & fan room cleanliness, free of loose material		
Electrical wiring complete		
Motor rated for VFD service		
Overload protection (sized correctly)		
Disconnect switch (tested)		
Control system - point to point checks complete		

Check if Okay. Enter note number if deficient.

3. START-UP

	OK	Deficient note #
FAN Start-up by manufacturer's representative		
VFD Start-up by manufacturer's representative		
Direction of rotation checked		
No unusual noise or vibration		
Local air leakage acceptable		
Electrical interlocks - stop/start Control interlocks verified		
Measure line to line voltage phase imbalance for each pump: AB/AC/BC:		
Motor Amps - Rated : Actual :		

Check if Okay. Enter note number if deficient.

4. SIGN-OFFS

Pre-start checks by	Date:
Start-up checks by:	Date:
print name	signature

Comments:

HVAC COMMISSIONING Functional Test Heating Water System

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

Area Served: _____

1. Participants

<u>Party</u>	<u>Participation</u>
_____	_____
_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____

Date of test _____

2. System Narrative

3. Prerequisite Checklist

- a. ☐ These functional test procedures have been reviewed and approved by CTA and the design A/E
- b. ☐ These functional test procedures have been reviewed and approved by the installing contractor.
- c. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:
 - ☐ Benchmark Hydronic Testing on Existing _____
 - ☐ Boiler Heating Water System prior to _____
 - ☐ Demolition _____
 - ☐ Booster Pump DWP-1 _____
 - ☐ VFD Hot Water Pumps HWP-1,2,3 _____
 - ☐ Flushing and Cleaning Piping _____
- d. ☐ 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

- e. ☐ Vibration control report approved (if required).
- f. ☐ Test and balance (TAB) completed and approved for the hydronic systems and new terminal units connected.
- g. ☐ All CTA and A/E punchlist items for this equipment corrected, or have been noted on the attached list.

- h. ___ Safeties and operating ranges reviewed.
- i. ___ Test requirements and sequences of operation attached.
- j. ___ Schedules and setpoints attached.
- k. ___ False loading equipment, system and procedures ready (boilers, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)
- l. ___ 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.
- m. ___ See Sheet M-001 Sequence of Work, Notes #1-11, prior to completing functional tests.
- n. ___ **BAS Program Review.** Review the BAS 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, Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓

4. **Sensor Calibration Checks.** Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"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, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional 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 BAS Values	Instru. Meas'd Value	Final Gage BAS Values	Pas s Y/N ?

Sensor & Location	Loc- ation OK ¹	1st Gage BAS Values	Instru. Meas'd Value	Final Gage BAS Values	Pas s Y/N ?
Boiler Inlet Water Temperature Sensor					
Boiler Outlet water Temperature Sensor					
Boiler Exhaust Temperature Sensor					
Water Meter Sensor					
Mixed Water Temperature Sensor					
Differential Pressure Sensor					

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

5. 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 prefunctional 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 Pkg'd Value	Site Observation	Final Pkg'd Reading	Pas s Y/N
Boiler Gas Control Valve					
Boiler Firing Rate					
Gas Flow Control Sensor					

Device or Actuator & Location	Procedure / State	1st Pkg'd Value	Site Observation	Final Pkg'd Reading	Pas s Y/N

6. Verification of Misc. Prefunctional Checks.

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

General Conditions of Test

7. Functional Testing Record

Proce d. 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		Control drawing sequences of operation Provide for 32 sequence procedures TBD in accordance with the submitted boiler sequences.	Per spec and detail adequate	
2				
3				
4				

Proce d. 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 #
	--	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in Section 2 above when completed	

MONITORING AND TREND LOGGING. Five monitoring via BAS trend logs are required per test Procedures. Trend logs all shall be provided in electronic continuous columnar spreadsheet compatible format. Trends all shall be provided in hard tabular format (continuous columnar with time in left column and at least four columns of point values in adjacent columns). All points for a given trend will begin at exactly the same time. Provide a key to all abbreviations. Attach representative graphs or columnar data and explanatory analysis to this test report.

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.

-- END OF TEST --

Heating Water Energy Metering

Provide flow meter and temperature sensors to calculate the total energy usage by the heating water system.

Monitored Points

Pump On-Off Status (TYP. 2)
Pump VFD Frequency (TYP. 2)
Remote Static Pressure Sensor
HHWS Temperature Sensor
HHWR Temperature Sensor
Leaving HX Temp. Sensor (TYP.)
Boiler Control Valve Positions (TYP.)
Heating Water Flow Rate

Graphic Display Visual Points

Pump On-Off Status (TYP. 2)
Pump VFD Frequency (TYP. 2)
Pump Run-Time Hours (TYP. 2)
Remote Differential Pressure Sensor
Leaving BoilerTemp. Sensor (TYP.)
Entering BoilerTemp. Sensor (TYP.)
Boiler Control Valve Positions (TYP.)
Heating Water Energy Usage

Alarmed Points

HHWS temperature more than 3 degrees from set point (adjustable)
Primary pump failure (includes VFD failure)
Failure to start the stand-by pump with a pump failure
Failure to maintain differential pressure set point for 15 minutes (adjustable)
Failure of any control valve to move to its commanded position
Failure of leaving Boiler temperature sensor to maintain set point

Addendum #1
August 6, 2013

23 08 00A COMMISSIONING OF HVAC Appendix A - Commissioning Plan

HVAC COMMISSIONING Functional Test Bid Alt Exhaust Fan

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

Area Served: _____

1. Participants

<u>Party</u>	<u>Participation</u>
_____	_____
_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____
Date of test _____

2. System Narrative

3. Prerequisite Checklist

- a. ☐ These functional test procedures have been reviewed and approved by CTA and the design A/E.
- b. ☐ These functional test procedures have been reviewed and approved by the installing contractor.
- c. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:
 - ☐ Interlocked with MUA unit & Time Delay Start
- d. ☐ 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

- e. ☐ Vibration control report approved (if required).
- f. ☐ Test and balance (TAB) completed and approved for the makeup air supply and interlocked exhaust fans.
- g. ☐ All CTA and A/E punchlist items for this equipment corrected, or have been noted on the attached list.

- h. ___ Safeties and operating ranges reviewed.
- i. ___ Test requirements and sequences of operation attached.
- j. ___ Schedules and setpoints attached.
- k. ___ False loading equipment, system and procedures ready (boilers, heating coils, control loops, over-ride on OSA dampers, etc.)
- l. ___ 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.
- m. ___ See Sheet M-001 Sequence of Work, Notes #1-11, prior to completing functional tests.
- n. ___ **BAS Program Review.** Review the BAS 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, Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values <input checked="" type="checkbox"/>
Time Delay after MUA startup	5 sec	
Maintenance Area Daily Schedule (EF-27,28,29,30)	1:15-4:00 pm	
Storage Area Daily Schedule (EF-23 & 24, EF-25 & 26)	4:15-7:00 am	

4. **Sensor Calibration Checks.** Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"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, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional 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 BMS Values	Instru. Meas'd Value	Final Gage BAS Values	Pass Y/N?
None					

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

5. 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 prefunctional 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 Pkg'd Value	Site Observation	Final Pkg'd Reading	Pass Y/N
Exhaust Air Damper (EAD)					
End Switch (ES) – EAD					

***EA Damper. Procedure 1.** Change EA damper position setting to 0%. Change BAS parameter as necessary to cause damper close. Verify that the damper is shut. Change the minimum EA damper position setting to 100%. Verify that the damper is fully open. Return all to normal.

6. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully.

Pass? Y / N _____

General Conditions of Test

7. 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		Control drawing sequences of operation	Per spec and detail adequate	
2		With the EF operating in normal mode record the positions of the listed items.	1) EA Fan Status _____ 2) EAD _____ 3) ES – EAD _____	
3		Command the EF OFF through the BAS, record the positions of the listed items.	1) EA Fan Status _____ 2) EAD _____ 3) ES – EAD _____	
4		Command the EF ON through the BAS, record the positions of the listed items	1) EA Fan Status _____ 2) EAD _____ 3) ES – EAD _____	
5		<p><u>Alarmed Points</u></p> <p><u>1) Service Switch Shutdown (SSS)</u></p> <p>a) With the EF in normal operation use SSS to shutdown unit.</p> <p>b) Using SSS restore EF to normal status.</p>	<p>a) Verify that the EF shuts down and an alarm is sent to the BAS.</p> <p>b) Verify that the alarm clears on the BAS and the EF restarts.</p>	

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 #
5 (cont.)		2) Exhaust Fan Failure a) With the EF operating in normal mode fail the exhaust fan. **Fan Failure – <i>Procedure 1.</i> Disconnect power at unit. b) Restore the exhaust fan to normal operation.	a) Verify that the BAS sends out an exhaust fan failure alarm. b) Verify that the exhaust fan failure alarm clears.	
6		<u>Time Delay</u> a) With EF de-energized enable fan to be ON and measure delay in actual startup. b) Return EF to normal setting.	a) Verify supply fan runs continuously. Time Delay = _____ seconds. b) Verify EF is OFF .	
7		<u>Automatic Restart of EF</u> a) With the EF in the normal operating mode simulate a loss of power and verify that the unit damper closes. b) Restore power and verify the MUA returns to normal operation.	a) EA Damper _____ ES-EAD _____ b) EA Damper _____ ES-EAD _____ _____ _____	
8	--	Return all changed control parameters and conditions to their pre-test values⁵	Check off in Section 2 above when completed	

MONITORING AND TREND LOGGING. Five monitoring via BAS trend logs are required per test Procedure 6. Trend logs all shall be provided in electronic continuous columnar spreadsheet compatible format. Trends all shall be provided in hard tabular format (continuous columnar with time in left column and at least four columns of point values in adjacent columns). All points for a given trend will begin at exactly the same time. Provide a key to all abbreviations. Attach representative graphs or columnar data and explanatory analysis to this test report.

Record Foot Notes

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

-- END OF TEST --

HVAC COMMISSIONING Functional Test Bid Alt Makeup Air Unit

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

Area Served: _____

1. Participants

<u>Party</u>	<u>Participation</u>
_____	_____
_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____
Date of test _____

2. System Narrative

3. Prerequisite Checklist

- a. ☐ These functional test procedures have been reviewed and approved by CTA and the design A/E.
- b. ☐ These functional test procedures have been reviewed and approved by the installing contractor.
- c. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:
 - ☐ Exhaust Fans interlocked with MUA units ☐ CO Gas Detection System
- d. ☐ 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

- e. ☐ Vibration control report approved (if required).
- f. ☐ Test and balance (TAB) completed and approved for the makeup air supply and interlocked exhaust fans.
- g. ☐ All CTA and A/E punchlist items for this equipment corrected, or have been noted on the attached list.

- h. ___ Safeties and operating ranges reviewed.
- i. ___ Test requirements and sequences of operation attached.
- j. ___ Schedules and setpoints attached.
- k. ___ False loading equipment, system and procedures ready (boilers, heating coils, control loops, over-ride on OSA dampers, etc.)
- l. ___ 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.
- m. ___ See Sheet M-001 Sequence of Work, Notes #1-11, prior to completing functional tests.
- n. ___ **BAS Program Review.** Review the BAS 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, Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values <input checked="" type="checkbox"/>
Outdoor Air Temperature Low Limit Setpoint	52°F	
Outdoor Air Temperature High Limit Setpoint	58°F	
Active SA Heating Setpoint	65°F	
Heating Lockout Temperature Setpoint	55°F	
High CO Level Detection	25 PPM	
Maintenance Area Daily Schedule (MUA-1,2,3,4)	1:15-4:00 pm	
Storage Area Daily Schedule (MUA-5,6)	4:15-7:00 am	

4. **Sensor Calibration Checks.** Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"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, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is

within the tolerances specified in the prefunctional 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 BMS Values	Instru. Meas'd Value	Final Gage BAS Values	Pass Y/N?
Temperature Sensor (TS) - Outside Air (OSA)					
Differential Pressure Sensor (DP) - OSA Filter					
TS – SA Temperature					
TS – Space Temperature					
Carbon Monoxide (CO) Sensor					

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

5. 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 prefunctional 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 Pkg'd Value	Site Observation	Final Pkg'd Reading	Pass Y/N
Outside Air Damper (OAD)					
End Switch (ES) – OAD					

*OSA Damper. *Procedure 1.* Change OSA damper position setting to 0%. Change BAS parameter as necessary to cause damper close. Verify that the damper is shut. Change the minimum OSA damper position setting to 100%. Verify that the damper is fully open. Return all to normal.

6. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully.

Pass? Y / N _____

General Conditions of Test

7. 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		Control drawing sequences of operation	Per spec and detail adequate	
2		With the AHU operating in normal mode record the positions of the listed items.	1) Supply Fan Status _____ 2) Outside Air Damper _____ 3) ES – OAD _____	
3		Command the fans OFF through the BAS, record the positions of the listed items.	1) Supply Fan Status _____ 2) Outside Air Damper _____ 3) ES – OAD _____	
4		Command the fans ON through the BAS, record the positions of the listed items	1) Supply Fan Status _____ 2) Outside Air Damper _____ 3) ES – OAD _____	

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 #
5		<p><u>Alarmed Points</u></p> <p><u>1) Verify SA Heating Discharge Temperature Alarm</u></p> <p>a) Decrease the Active SA Heating setpoint 5-degF below SA Heating Discharge setpoint.</p> <p>b) Restore Active SA Heating Discharge setpoint to original temperature.</p>	<p>a) Verify that the BAS sends out an alarm 1 minute after Supply Air TS senses the low temperature.</p> <p>b) Verify that BAS Alarm clears.</p>	
5 (cont.)		<p><u>2) Activation of SA Smoke Detector</u></p> <p>a) Simulate the activation of the SA smoke detector installed in the MUA.</p> <p>****Smoke –</p> <p><i>Procedure 1.</i> Over-ride BAS.</p> <p><i>Procedure 2.</i> Spray smoke aerosol upstream of smoke detector.</p> <p>b) Restore smoke detector status to normal.</p>	<p>a) Verify that the unit shuts down and an alarm is sent to the BAS and FACP.</p> <p>b) Verify that the alarm clears on the BAS and FACP and the MUA restarts.</p>	

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 #
5 (cont.)		3) <u>Service Switch Shutdown (SSS)</u> a) With the MUA in normal operation use SSS to shutdown unit. b) Using SSS restore MUA to normal status.	a) Verify that the MUA shuts down and an alarm is sent to the BAS. b) Verify that the alarm clears on the BAS and the MUA restarts.	
5 (cont.)		4) <u>Supply Fan Failure</u> a) With the MUA operating in normal mode fail the supply fan. ***** <u>Fan Failure</u> – <i>Procedure 1.</i> Disconnect power at unit. b) Restore the MUA supply fan to normal operation.	a) Verify that the BAS sends out a supply fan failure alarm. b) Verify that the supply fan failure alarm clears.	

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 #
5 (cont.)		<u>5) OSA Filter Differential Pressure High Limit</u> a) With the MUA operating in normal mode increase the OSA Filter differential pressure. ***** <u>Filter High Pressure</u> – <i>Procedure 1.</i> Change alarm setpoint to be below the DP reading. b) Restore the OSA Filter alarm setting to normal setpoint.	a) Verify that the BAS sends out a high pressure alarm for OSA Filter with indicator to replace filters. b) Verify that the high pressure alarm clears.	
5 (cont.)		<u>6) Space Temperature Low Limit Alarm</u> a) Decrease the Active SA Heating setpoint 5-degF below SA Heating Discharge setpoint. b) Restore Active SA Heating Discharge setpoint to original temperature.	a) Verify that the BAS sends out an alarm 1 minute after Space Temperature Sensor senses the low temperature. b) Verify that BAS Alarm clears.	
5 (cont.)		<u>7) Carbon Monoxide (CO) High Limit Alarm</u> a) Decrease the CO High Limit alarm setpoint in the BAS to less than current reading of CO PPM. b) Restore the CO High Limit alarm setpoint to original setting.	a) Verify that the BAS sends out an alarm after CO Sensor detects the relative higher CO PPM. b) Verify that BAS Alarm clears.	

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 #
6		<p><u>MUA Operating Status – Heating Mode / Non-Heating Mode</u></p> <p>a) Heating Mode - With the MUA in its normal operating condition observe the BMS graphic.</p> <p>b) Heating Mode - Command the MUA OFF.</p> <p>c) Non-Heating Mode - Command the MUA ON.</p> <p>d) Non-Heating Mode – Command the MUA OFF.</p>	<p>a) Verify that the MUA is shown as running.</p> <p>b) Verify that the MUA is shown as OFF.</p> <p>c) Verify that the MUA is shown as running.</p> <p>d) Verify that the MUA is shown as OFF.</p>	
7		<p><u>Occupied Mode, Heating</u></p> <p>a) Raise the Zone Temperature setpoint to 3F above the space temperature.</p> <p>b) Return setpoint to normal.</p>	<p>a) Verify supply fan runs continuously, Space is heated to new setpoint. Supply air temperature = _____.</p> <p>b) Verify heating shuts off.</p>	

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 #
8		<u>Automatic Restart of MUA</u> a) With the MUA in the normal operating mode simulate a loss of power and verify that the unit dampers and valves go to that failed position. b) Restore power and verify the MUA returns to normal operation.	a) OSA Damper _____ Gas Solenoid Valve _____ b) OSA Damper _____ Gas Solenoid Valve _____	
9		<u>Supply Air Temperature – Heating</u> a) With the AHU in the normal operating mode increase supply air temperature setpoint to 3 degrees above setpoint. b) Restore supply air temperature to original setpoint.	a) Verify that the gas solenoid valve opens and heating section operates to maintain increased setting. b) Verify that the gas solenoid valve closes.	
11	--	Return all changed control parameters and conditions to their pre-test values⁵	Check off in Section 2 above when completed	

MONITORING AND TREND LOGGING. Five monitoring via BAS trend logs are required per test Procedures 6 and 9. Trend logs all shall be provided in electronic continuous columnar spreadsheet compatible format. Trends all shall be provided in hard tabular format (continuous columnar with time in left column and at least four columns of point values in adjacent columns). All points for a given trend will begin at exactly the same time. Provide a key to all abbreviations. Attach representative graphs or columnar data and explanatory analysis to this test report.

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.

-- END OF TEST --

HVAC COMMISSIONING Functional Test Rooftop Air Handling Unit

CTA 103rd Bus Garage Heating Upgrades and BAS Installation Project Number: 2010-0017

Equipment Name/Tag: _____ Location: _____

Area Served: _____

1. Participants

<u>Party</u>	<u>Participation</u>
_____	_____
_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____
Date of test _____

2. System Narrative

3. Prerequisite Checklist

- a. ☐ These functional test procedures have been reviewed and approved by CTA and the design A/E.
- b. ☐ These functional test procedures have been reviewed and approved by the installing contractor.
- c. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:
 - ☐ Existing Ductwork Cleaning ☐ Hot Water System ☐ Electric Unit Heater
 - ☐ HRP / Heat Pipe ☐ Supply Fan and VFD ☐ Exhaust Fan and VFD
 - ☐ Inline Pumps (2) for Heating Coils ☐ Field Tightness Test on AHU Casing
- d. ☐ 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

- e. ☐ Vibration control report approved (if required).
- f. ☐ Test and balance (TAB) completed and approved for the supply and exhaust fans, inline pumps, hot water system, and electric unit heater.

- g. ___ All CTA and A/E punchlist items for this equipment corrected, or have been noted on the attached list.
- h. ___ Safeties and operating ranges reviewed.
- i. ___ Test requirements and sequences of operation attached.
- j. ___ Schedules and setpoints attached.
- k. ___ False loading equipment, system and procedures ready (boilers, heating coils, control loops, over-ride on OSA dampers, etc.)
- l. ___ 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.
- m. ___ See Sheet M-001 Sequence of Work, Notes #1-11, prior to completing functional tests.
- n. ___ **BAS Program Review.** Review the BAS 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, Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values <input checked="" type="checkbox"/>
Outdoor Air Temperature Low Limit Setpoint	52°F	
Outdoor Air Temperature High Limit Setpoint	58°F	
Active SA Heating Setpoint	65°F	
Freezestat Setpoint / Heating Coil	40°F	
AHU Interior Space Low Limit Setpoint	39°F	
AHU Interior Space High Limit Setpoint	50°F	
SA Heating Discharge Temperature Setpoint	65°F	
EA Heating Intake Temperature Setpoint	55°F	

- 4. **Sensor Calibration Checks.** Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"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, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefuctional 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 BMS Values	Instru. Meas'd Value	Final Gage BAS Values	Pass Y/N?
Temperature Sensor (TS) - Outside Air (OSA)					
TS - OSA Intake					
Differential Pressure Sensor (DP) - OSA Filter					
TS – Heat Pipe (HP) OSA Entering Air Temperature (EAT)					
DP – HP OSA					
TS – HP Leaving Air Temperature (LAT) / Heating Coil (HC) Entering Air Temperature (EAT)					
Freezestat (FZ)					
DP - FZ					
TS - AHU Interior Space					
TS – SA Heating Discharge					
PS – SA Discharge					
TS – Zone					

Sensor & Location	Location OK ¹	1st Gage BMS Values	Instru. Meas'd Value	Final Gage BAS Values	Pass Y/N?
PS – Exhaust Air (EA)					
TS – EA Intake					
DP – EA Filter					
TS – HP EA EAT					
DP – HP EA					
TS – HP EA LAT					

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

5. 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 prefunctional 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 Pkg'd Value	Site Observation	Final Pkg'd Reading	Pass Y/N
Outside Air Damper (OAD) #1					
End Switch (ES) – OAD #1					
OAD #2					
ES – OAD #2					
Exhaust Air Damper (EAD) #1					
ES – EAD #1					
EAD #2					

Device or Actuator & Location	Procedure / State	1st Pkg'd Value	Site Observation	Final Pkg'd Reading	Pass Y/N
ES – EAD #2					
3-Way Temperature Control Valve (TCV) - HWS					
Supply Fan - VFD					
Exhaust Fan - VFD					

***VFD:** *Procedure 1.* Lower the controlling static pressure setpoint (duct or discharge) to be 1/4 of its current value. Verify that the fan speed is at minimum for VFD *and* packaged controller reads the same. Return the static pressure setpoint to normal.

****OSA Damper.** *Procedure 1.* Change OSA damper position setting to 0%. Change BAS parameter as necessary to cause damper close. Verify that the damper is shut. Change the minimum OSA damper position setting to 100%. Verify that the damper is fully open. Return all to normal.

6. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully.

Pass? Y / N _____

General Conditions of Test

7. 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 #
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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		Control drawing sequences of operation	Per spec and detail adequate	
2		With the AHU operating in normal mode record the positions of the listed items.	1) VFD Status Supply Fan _____ 2) Supply Fan Status _____ 3) VFD Status Exhaust Fan _____ 4) Exhaust Fan Status _____ 5) Supply Duct Static _____ 6) Exhaust Duct Static _____ 7) Outside Air Damper #1 _____ 8) ES – OAD #1 _____ 9) Outside Air Damper #2 _____ 10) ES – OAD #2 _____ 11) Exhaust Air Damper #1 _____ 12) ES – EAD #1 _____ 13) Exhaust Air Damper #2 _____ 14) ES – EAD#2 _____ 15) Hot Water TCV _____	
3		Command the fans OFF through the BAS, record the positions of the listed items.	1) VFD Status Supply Fan _____ 2) Supply Fan Status _____ 3) VFD Status Exhaust Fan _____ 4) Exhaust Fan Status _____ 5) Supply Duct Static _____ 6) Exhaust Duct Static _____ 7) Outside Air Damper #1 _____ 8) ES – OAD #1 _____ 9) Outside Air Damper #2 _____ 10) ES – OAD #2 _____ 11) Exhaust Air Damper #1 _____ 12) ES – EAD #1 _____ 13) Exhaust Air Damper #2 _____ 14) ES – EAD#2 _____ 15) Hot Water TCV _____	

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 #
4		Command the fans ON through the BAS, record the positions of the listed items	1) VFD Status Supply Fan _____ 2) Supply Fan Status _____ 3) VFD Status Exhaust Fan _____ 4) Exhaust Fan Status _____ 5) Supply Duct Static _____ 6) Exhaust Duct Static _____ 7) Outside Air Damper #1 _____ 8) ES – OAD #1 _____ 9) Outside Air Damper #2 _____ 10) ES – OAD #2 _____ 11) Exhaust Air Damper #1 _____ 12) ES – EAD #1 _____ 13) Exhaust Air Damper #2 _____ 14) ES – EAD#2 _____ 15) Hot Water TCV _____	
5		<u>Alarmed Points</u> <u>1) Verify SA Heating Discharge Temperature Alarm</u> a) Decrease the Active SA Heating setpoint 5-degF below SA Heating Discharge setpoint. b) Restore Active SA Heating Discharge setpoint to original temperature.	a) Verify that the BAS sends out an alarm 1 minute after Supply Air TS senses the low temperature. b) Verify that BAS Alarm clears.	

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 #
5 (cont.)		<p><u>2) Verify Exhaust Air Heating Temperature Alarm</u></p> <p>a) Decrease the EA Heating Intake Temperature 5-degF below EA Heating Intake setpoint.</p> <p>***<u>Decrease temperature</u> – <i>Procedure 1.</i> Override BAS reading of upstream temperature sensor below setpoint temperature. <i>Procedure 2.</i> Place dry ice at intake to reduce temperature sensed.</p> <p>b) Restore EA Heating Intake setpoint to original temperature.</p>	<p>a) Verify that the BAS sends out an alarm 1 minute after Exhaust Air Heating Intake TS senses the low temperature.</p> <p>b) Verify that BAS Alarm clears.</p>	
5 (cont.)		<p><u>3) Freezestat Shutdown</u></p> <p>a) With AHU in normal operating mode, activate freezestat. (See *** Procedures above.)</p> <p>b) Manually reset the freezestat.</p>	<p>a) Verify that the AHU shuts down in the freezestat mode and the BAS sends out an alarm.</p> <p>b) Verify that the freezestat alarm clears and the unit retarts in normal operating mode.</p>	

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 #
5 (cont.)		<p><u>4) Activation of SA Smoke Detector</u></p> <p>a) Simulate the activation of the SA smoke detector installed in the AHU.</p> <p>****Smoke –</p> <p><i>Procedure 1. Over-ride BAS.</i></p> <p><i>Procedure 2. Spray smoke aerosol upstream of smoke detector.</i></p> <p>b) Restore smoke detector status to normal.</p>	<p>a) Verify that the unit shuts down and an alarm is sent to the BAS and FACP.</p> <p>b) Verify that the alarm clears on the BAS and FACP and the AHU restarts.</p>	
5 (cont.)		<p><u>5) Activation of EA Smoke Detector</u></p> <p>a) Simulate the activation of the SA smoke detector installed in the AHU. (See ****Smoke: Procedures above.)</p> <p>b) Restore smoke detector status to normal.</p>	<p>a) Verify that the unit shuts down and an alarm is sent to the BAS and FACP.</p> <p>b) Verify that the alarm clears on the BAS and FACP and the AHU restarts.</p>	

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 #
5 (cont.)		6) <u>Service Switch Shutdown (SSS)</u> a) With the AHU in normal operation use BAS to shutdown unit. b) Using BAS restore AHU to normal status.	a) Verify that the AHU shuts down and an alarm is sent to the BAS. b) Verify that the alarm clears on the BAS and the AHU restarts.	
5 (cont.)		7) <u>Supply and Exhaust Fan Failure</u> a) With the AHU operating in normal mode fail the supply fan. ***** <u>Fan Failure</u> – <i>Procedure 1.</i> Disconnect power at VFD switch. b) Restore the AHU supply fans to normal operation. c) With the AHU operating in normal mode fail the exhaust fan. (See <i>Procedure 1</i> above.) d) Restore the AHU exhaust fan to normal operation.	a) Verify that the BAS sends out a supply fan failure alarm. b) Verify that the supply fan failure alarm clears. c) Verify that the BAS sends out an exhaust fan failure alarm. d) Verify that the exhaust fan failure alarm clears.	

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 #
5 (cont.)		<p><u>8) AHU Operating Pressure Alarm</u></p> <p>a) Lower the supply static set point 15% below initial setting and shorten the period from 15 minutes to 3 minutes.</p> <p>*****<u>Operating Pressure</u> – <i>Procedure 1.</i> With the AHU operating in the normal mode, override the VDF's for the supply and exhaust fans to their present RPM.</p> <p>b) Lower the exhaust static set point 15% below initial setting and shorten the period from 15 minutes to 3 minutes. (See <i>Procedure 1</i> above.)</p> <p>c) Restore the VFD's to automatic and the static pressure set points along with restoring the time delays to 15 minutes.</p>	<p>a) Verify that the BAS sends out a supply static more than 10% out of set point.</p> <p>b) Verify that the BAS sends out an exhaust static more than 10% out of set point.</p> <p>c) Verify that the BAS alarms clear.</p>	

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 #
5 (cont.)		<p>9) Circulating Pump Failure</p> <p>a) With the lead CP operating in normal mode fail the pump. *****CP Failure – <i>Procedure 1.</i> Disconnect power at pump.</p> <p>b) Restore the CP's to normal operation.</p> <p>c) Switch the lag pump to be the lead pump. With the new lead CP operating in normal mode fail the pump. (See <i>Procedure 1</i> above.)</p> <p>d) Restore the CP's to normal operation.</p>	<p>a1) Verify that the BAS sends out a circulating pump failure alarm for lead pump.</p> <p>a2) Verify lag circulating pump is energized as new lead pump.</p> <p>b) Verify that the circulating pump alarm clears.</p> <p>c1) Verify that the BAS sends out a supply fan failure alarm.</p> <p>c2) Verify lag circulating pump is energized as new lead pump.</p> <p>d) Verify that the circulating pump failure alarm clears.</p>	

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 #
5 (cont.)		<p>9) Electric Unit Heater Failure</p> <p>a) With the EUH operating in normal mode fail the unit.</p> <p>*****<u>EUH Failure</u> –</p> <p><i>Procedure 1.</i> Disconnect power at unit.</p> <p>b) Restore the EUH to normal operation.</p>	<p>a) Verify that the BAS sends out a failure alarm for EUH.</p> <p>b) Verify that the EUH alarm clears.</p>	

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 #
5 (cont.)		<p><u>10) OSA / EA Filter Differential Pressure High Limit</u></p> <p>a) With the AHU operating in normal mode increase the OSA Filter differential pressure. *****<u>Filter High Pressure</u> – <i>Procedure 1.</i> Change alarm setpoint to be below the DP reading.</p> <p>b) Restore the OSA Filter alarm setting to normal setpoint.</p> <p>c) With the AHU operating in normal mode increase the EA Filter differential pressure. (See <i>Procedure 1</i> above.)</p> <p>b) Restore the EA Filter alarm setting to normal setpoint.</p>	<p>a1) Verify that the BAS sends out a high pressure alarm for OSA Filter with indicator to replace filters.</p> <p>a2) Verify that the Supply Fan VFD increases speed to provide constant airflow.</p> <p>b) Verify that the high pressure alarm clears and Supply Fan VFD returns to previous speed.</p> <p>c1) Verify that the BAS sends out a high pressure alarm for EA Filter with indicator to replace filters.</p> <p>c2) Verify that the Exhaust Fan VFD increases speed to provide constant airflow.</p> <p>d) Verify that the high pressure alarm clears.</p>	

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 #
5 (cont.)		<p>11) Heat Pipe OSA / EA Differential Pressure High Limit</p> <p>a) With the AHU operating in normal mode increase the OSA Heat Pipe differential pressure.</p> <p>*****Heat Pipe High Pressure – <i>Procedure 1.</i> Change alarm setpoint to be below the DP reading.</p> <p>b) Restore the OSA HP alarm setting to normal setpoint.</p> <p>c) With the AHU operating in normal mode increase the EA HP differential pressure. (See <i>Procedure 1</i> above.)</p> <p>b) Restore the EA HP alarm setting to normal setpoint.</p>	<p>a1) Verify that the BAS sends out a high pressure alarm for OSA Heat Pipe with indicator to clean HP.</p> <p>b) Verify that the high pressure alarm clears.</p> <p>c) Verify that the BAS sends out a high pressure alarm for EA HP with indicator to clean HP.</p> <p>d) Verify that the high pressure alarm clears.</p>	

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 #
5 (cont.)		<p>11) <u>Heating Coil Differential Pressure High Limit</u></p> <p>a) With the AHU operating in normal mode increase the Heating Coil differential pressure.</p> <p>*****<u>HC High Pressure</u> – <i>Procedure 1.</i> Change alarm setpoint to be below the DP reading.</p> <p>b) Restore the HC alarm setting to normal setpoint.</p>	<p>a) Verify that the BAS sends out a high pressure alarm for HC with indicator to clean coil.</p> <p>b) Verify that the high pressure alarm clears.</p>	

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 #
6		<p><u>AHU Operating Status – Heating Mode / Non-Heating Mode</u></p> <p>a) Heating Mode - With the AHU in its normal operating condition observe the BMS graphic.</p> <p>b) Heating Mode - Command the AHU OFF.</p> <p>c) Heating Mode - Command the AHU ON.</p> <p>d) Non-Heating Mode – Command the AHU OFF.</p> <p>e) Non-Heating Mode – Command the AHU ON.</p>	<p>a) Verify that the AHU is shown as running.</p> <p>b) Verify that the AHU is shown as OFF and the heating valves are ON and the circulating pumps are ON.</p> <p>c) Verify that the AHU is shown as running and the valves ON.</p> <p>d) Verify that the AHU is shown as OFF and the heating valves are OFF and the circulating pumps are OFF.</p> <p>e) Verify that the AHU is shown as running and the valves OFF.</p>	
7		<p><u>Occupied Mode, Heating</u></p> <p>a) Raise the Zone Temperature setpoint to 3F above the space temperature.</p> <p>b) Return setpoint to normal.</p>	<p>a) Verify supply fan runs continuously, Hot Water Valve opens, and Space is heated to new setpoint. Supply air temperature = _____.</p> <p>b) Verify Hot Water Valve switches to bypass.</p>	

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 #
8		<p><u>Automatic Restart of AHU</u></p> <p>a) With the AHU in the normal operating mode simulate a loss of power and verify that the unit dampers and valves go to that failed position.</p> <p>b) Restore power and verify the AHU returns to normal operation.</p>	<p>a) OSA Damper #1 _____</p> <p>OSA Damper #2 _____</p> <p>EA Damper #1 _____</p> <p>EA Damper #2 _____</p> <p>Hot Water Control Valve _____</p> <p>b) OSA Damper #1 _____</p> <p>OSA Damper #2 _____</p> <p>EA Damper #1 _____</p> <p>EA Damper #2 _____</p> <p>Hot Water Control Valve _____</p>	
9		<p><u>Supply Duct Static Pressure Control</u></p> <p>a) With AHU in normal operation increase the supply air static set point by 0.25 inches.</p> <p>b) Return the supply duct static pressure set point to its initial setting.</p>	<p>a) Verify that the supply fan speed increases to maintain the required set point.</p> <p>b) Verify that the supply fan speed decreases to the required set point</p>	

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 #
10		<u>Exhaust Duct Static Pressure Control</u> a) With AHU in normal operation increase the exhaust air static set point by 0.25 inches. b) Return the exhaust duct static pressure set point to its initial setting.	a) Verify that the exhaust fan speed increases to maintain the required set point. b) Verify that the exhaust fan speed decreases to the required set point	
11		<u>Supply Air Temperature – Heating</u> a) With the AHU in the normal operating mode increase supply air temperature setpoint to 3 degrees above setpoint. b) Restore supply air temperature to original setpoint.	a) Verify that the hot water valve modulates to maintain increased setting. b) Verify that the hot water control valve switches to bypass.	
12	--	Return all changed control parameters and conditions to their pre-test values⁵	Check off in Section 2 above when completed	

MONITORING AND TREND LOGGING. Five monitoring via BAS trend logs are required per test Procedures 6 and 10. Trend logs all shall be provided in electronic continuous columnar spreadsheet compatible format. Trends all shall be provided in hard tabular format (continuous columnar with time in left column and at least four columns of point values in adjacent columns). All points for a given trend will begin at exactly the same time. Provide a key to all abbreviations. Attach representative graphs or columnar data and explanatory analysis to this test report.

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.
-- END OF TEST --