SECTION 230800

COMMISSIONING OF HVAC SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. This project will have selected building systems commissioned. The complete list of equipment and systems to be commissioned are specified in Section 019100 GENERAL COMMISSIONING REQUIREMENTS. The commissioning process, which the Contractor is responsible to execute, is defined in Section 019100 GENERAL COMMISSIONING REQUIREMENTS. A Commissioning Agent (CxA) appointed by the Owner Affairs will manage the commissioning process.

B. Systems to be commissioned:
   1. Packaged Rooftop Units & Make-up Air Unit
      a. Supply, return, and exhaust air fans, motors, and drives.
      b. Automatic and gravity dampers.
      c. Heating and cooling devices.
      d. Air filters.
      e. Hangers and supports.
      f. Interlock between air-handling system and fire/smoke alarm system.
   2. Exhaust Fans
   3. Air-Cooled Condenser
   4. HVAC Terminal Units, including the following:
      a. VAV/CAV Boxes.
   5. Air duct systems, including the following:
      a. Duct systems.
      b. Air-duct accessories, including volume dampers, fire and smoke dampers, turning vanes, sound attenuators, and flexible connectors.
      c. Duct-mounted access doors and panels.
      d. Hangers and supports.
      e. Meters and gauges.
      f. General-duty and specialty valves.
      g. Heat tracing.
   6. Controls and instrumentation, including the following:.
      a. Sensors, Actuators, and Field Wiring
      b. Field Level Controllers including Application Specified and Programmable Type
      c. Building Level Controller(s)
      d. Operators Workstation including system Graphics
      e. Programmed Sequence of Operations, including regular operations, alarms and notifications, and scheduling
      f. Demand-control systems.
   7. TAB Verification:
      a. Airflow.
      b. Water flow.
   8. Documentation:
      a. Mechanical systems manuals.
      b. Documentation of required commissioning.
   9. Mechanical insulation, including the following:
      a. Duct and plenum insulation.
      b. HVAC piping insulation.

1.2 RELATED DOCUMENTS

A. Section 019100 Commissioning General Requirements

1.3 DEFINITIONS

A. For complete list of definitions, Refer to Section 019100 “General Commissioning Requirements.”

B. CxA: Commissioning Authority, as defined in Section 019100 “General Commissioning Requirements.”

C. CxC: Commissioning Coordinator, as defined in Section 019100 “General Commissioning Requirements.” A qualified individual appointed by the Contractor to manage the commissioning process on behalf of the Contractor.

D. CxR: Commissioning Representative, as defined in Section 019100 “General Commissioning Requirements.” An individual appointed by a sub-contractor to manage the commissioning process on behalf of the sub-contractor.

1.4 SUBMITTALS

A. The commissioning process requires Submittal review simultaneously with engineering review. Specific submittal requirements related to the commissioning process are specified in Section 019100 GENERAL.

B. Commissioning Representative (CxR) Assignment and Qualifications. The contractor shall submit the qualifications and resume for proposed persons to be assigned as the project CxRs, with responsibilities and minimum experience outlined below:
   1. The HVAC CxR Responsibilities are to perform HVAC systems System Verification Checklists, Functional Performance Testing, and Functional Performance Test Demonstration, and other work required for commissioning
   2. The HVAC CxR shall have the following minimum qualifications:
      a. Journey level or equivalent skill level; vocational school four-year-program graduate or an Associate's degree in mechanical systems, air conditioning, or similar field.
      b. Degree may be offset by three years' experience in installing, servicing and operating mechanical systems in the HVAC industry. Generally, required knowledge includes HVAC systems, electrical concepts, building operations, and application and use of tools and instrumentation to measure performance of HVAC equipment, assemblies, and systems.

C. Training Plan:
   1. The contractor shall submit a comprehensive Training Plan. Specific Training Plan requirements are specified in 019100.

D. Training Verification: After training has been completed the Contractor shall submit the following information to the Owner and the Commissioning Agent:
   1. Training Agenda: For each training module submit the agenda that was used during the training session.
   2. Attendance Record: For each training module, submit list of participants and length of instruction time.
   3. Training Recording: For Training Modules which require videography (see Technical Specifications) provide the final edited video to the CxA for review.

E. O&M Manuals:
   1. Prepare O&M manuals according to the contract documents,
   2. Include the Final As-Built Control Drawings
   3. Submit O&M manuals to CxA for review prior to O&M personnel training.

4. Provide O&M Manuals to the CxA for inclusion in the Systems Manual

F. System Verification Checklists
   1. The Commissioning Agent will prepare and submit System Verification Checklists based on the Systems to be Commissioned.
   2. The contractor shall complete the SVCs and submit completed forms to the CxA.

G. Startup
   1. The Contractor shall submit the Startup Plan as specified in this section.
   2. The Contractor shall submit Startup Reports as specified in this section.
   3. The Contractor shall submit Controls Startup reports (aka Point-to-Point checkout) as specified in this section.

H. Functional Performance Test Procedure:
   1. The Commissioning Agent will prepare and submit Functional Performance Test Procedures.
   2. The Contractor shall review proposed FPT scripts and may submit comments to CxA.
   3. The Contractor shall execute FPT and submit completed forms to the CxA.
   4. The contractor shall complete the FPTs and submit completed forms to the CxA.

I. Test and Balance (TAB)
   1. TAB Report: Contractor to provide CxA with final TAB report which must have mechanical engineer of record (MEOR) stamp.

J. Trend Review:
   1. For Trend Review the Contractor shall prepare and submit graphical plots as specified in 019100 to the CxA for review and analysis.

K. As Built Drawing Review:
   1. The CxA shall provide a list of as built drawings relevant to the Cx Process to the contractor.
   2. The contractor shall provide the indicated as built drawings to the CxA for review concurrently with the Design Professionals
   3. The CxA shall review selected As built drawings and provide review comments.

L. Systems Manual: The contractor shall provide the following information to the CxA for use in the Systems Manual. The final System Manual shall be complied and submitted by the CxA:
   1. As-built control drawings (by CxC)
   2. As-Built Sequences of Operation (by CxC)
   3. Table of Original Setpoints (by CxC)
   4. Table of Original Programmed Time Schedules (by CxC)
   5. Recommended schedule of maintenance requirements and frequency per manufacturer's recommendations (by CxC)
   6. Recommended schedule for calibrating sensors and actuators (byCxC)
   7. Equipment O&M (by CxC)
   8. Equipment Preventative Maintenance Schedules (by CxC)
   9. Confirmation of Training (by CxC)

PART 2 - PRODUCTS

2.1 TOOLS

A. Division 23 shall provide all test equipment necessary to fulfill the testing requirements of this Division. Refer to 019100.

B. Testing Equipment and Instrumentation Quality and Calibration:
   1. Capable of testing and measuring performance within the specified acceptance criteria.

2. Be calibrated at manufacturer's recommended intervals with current calibration tags permanently affixed to the instrument being used.
3. Be maintained in good repair and operating condition throughout duration of use on Project.
4. Be recalibrated/repaired if dropped or damaged in any way since last calibrated.

C. Equipment Manufacturer's Proprietary Instrumentation and Tools:
1. Contractor shall provide all Manufacturer's Proprietary Instrumentation and Tools required for execution of FPTs.
2. Test instrumentation and tools prescribed by equipment manufacturer to service, calibrate, adjust, repair, or otherwise work on its equipment or required as a condition of equipment warranty, shall comply with the following:
   a. Be calibrated by manufacturer with current calibration tags permanently affixed.
   b. Include a separate list of proprietary test instrumentation and tools in operation and maintenance manuals.

PART 3 - EXECUTION

3.1 COMMISSIONING PROCESS

A. Perform all commissioning activities as defined and specified in section 019100.

3.2 Cx ACTIVITY COMMON TO HVAC SYSTEMS

A. The following activities are a summary of the required Commissioning Process. Additional requirements for each activity and responsible parties are found in Section 019100. All requirements for Section 019100 apply.

COMMISSIONING PROCESS		
ACTIVITY	Responsible Party	Description
COMMISSIONING PLAN	CxA	The document that specifies the project specific commissioning process, commissioning scope commissioning team responsibilities, schedules, and documentation requirements of the Commissioning Process.
SUBMITTAL REVIEW	CxA	Contractor Provides Submittals to the CxA concurrently with the Design Professionals. CxA reviews and provides comments.
SYSTEM VERIFICATION CHECKLISTS (SVC)	Authored by CxA Completed by Contractor	SVC forms are generated by the CxA and executed by the contractor to verify that Commissioned Systems are installed, started up, functional and ready for FPT.
START-UP VERIFICATION	Installing Contractor	CxA to verify that the startup activities specified in the contract documents have been executed and deficiencies corrected. Contractor to provide startup forms & reports to CxA for review & comment.
TEST AND BALANCE VERIFICATION	Directed by CxA Executed by Contractor	TAB contractor to re-measure a sample of Air & Water flows in the presence of CxA to demonstrate the correctness of the TAB measurements reported in the final TAB report.

T-24 ACCEPTANCE TESTING VERIFICATION	Contractor	Contractor to provide completed CA Energy Code Certificates of Installation (NRCC-CI) and Certificates of Acceptance (NRCC-CA) form to CxA for review and comment. Design Professional to document which forms are required. Contractor to conduct testing and complete forms.
FUNCTIONAL PERFORMANCE TEST (FPT)	Authored by CxA Executed by Contractor	CxA to author FPT forms. Contractor to conduct physical testing of 100% of commissioned systems following the written protocol and provide the results to the CxA. Contractor to correct any issues or deficiencies.
FUNCTIONAL PERFORMANCE TEST (FPT) DEMONSTRATION	Directed by CxA Executed by Contractor	Contractor to demonstrate operation of a sample of commissioned systems in the presence of the CxA. CxA to direct the demonstration in accordance with the FPT forms. CxA to document demonstration results on the FPT forms.
TREND REVIEW	Trend Collection and Plotting by Contractor Review by CxA	CxA to review commissioned system operation over time by reviewing data logged by the building automation system. Contractor to provide data for CxA review.
SYSTEMS MANUAL	Supporting Docs by Contractor Manual by CxA	Compilation and writing of the Systems manual by CxA. Contractor to provided specified supporting documents
AS BUILT DRAWING VERIFICATION	As Built Drawings by Contractor Verification by CxA	Contractor Provides As Built drawings to the CxA concurrently with the Design Professionals. CxA reviews and provides comments.
TRAINING VERIFICATION	Training by Contractor Verification by CxA	Contractor to provide records of training conducted to CxA for their verification.
COMMISSIONING REPORTING	CxA	Reports on Cx activity and results prepared by the CxA
SEASONAL/DEFERRED TESTING	Directed by CxA Executed by Contractor	Tests that cannot be completed at the end of the acceptance phase due to ambient conditions, schedule issues or other conditions preventing testing will be rescheduled to occur at a more appropriate time during the warranty period. Scheduling/Coordination by the CxA. Contractor to support testing requirements per FPT requirements.

3.3 Cx TESTS COMMON TO HVAC

A. In accordance with the approved SVC and FPT document, test systems, assemblies, subsystems, equipment, and components for operating modes, interlocks, control responses, responses to abnormal or emergency conditions, and response in accordance with acceptance criteria.

B. Provide technicians, instrumentation, tools, and equipment to perform and document the required testing.

C. Coordinate schedule with, and perform Cx activities at the direction of, CxA

D. CX TEST PREPARATION - Prior to Cx Testing:
   1. Contractor shall Certify that HVAC systems, subsystems, and equipment to be tested have been installed, calibrated, and started and that they are operating in accordance with the Contract Documents and approved submittals.
   2. Contractor shall Certify that HVAC instrumentation and control systems to be tested have been completed and calibrated, point-to-point checkout has been successfully completed, and systems are operating in accordance with their design sequence of operation, Contract Documents, and approved submittals. Certify that all sensors are operating within specified accuracy and all systems are set to and maintaining set points as required by the design documents.
   3. Contractor shall Certify that TAB procedures have been completed and that TAB reports have been submitted, discrepancies corrected, and final report accepted by MEOR.
   4. Contractor shall Set systems, subsystems, and equipment into operating mode to be tested in accordance with approved test procedures (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).

E. If tests cannot be completed because of a deficiency outside the scope of the HVAC system, document the deficiency and report it to General Contractor. After deficiencies are resolved, reschedule tests.

F. If seasonal testing is specified, complete appropriate initial performance tests and documentation, and schedule seasonal tests.

PART 4 - SYSTEM VERIFICATION CHECKLIST EXAMPLE - These examples are not the final system verification checklists used for this project and are intended to represent the typical rigor of checklists of this type.

Project Name Equipment Tag

Makeup Air Unit Date: _____

System Verification Checklist

1. Revision

Revision No.	Name	Company	Date	Reason for Revision

2. General Notes, Directions, & Abbreviations

NOTES:

1. This checklist does replace the manufacturer's recommended checkout and start-up procedures or report(s).
2. This checklist does not comprehensively address fire and life safety or basic equipment safety controls.
3. Items that do not apply shall be noted with the reasons on this form (N/A = not applicable)
4. Each contractor is to find their designated sections of this checklist and complete it accordingly with respect to their discipline.

DIRECTIONS:

1. System verification checklist to be completed by the sub-contractor(s) prior to the factory startup process. Each discipline is to initial or N/A each item on each list.
2. Contractors are to 100% complete the checklist before requesting CxA to inspect.

ABBREVIATIONS:

Commissioning Agent (CxA), Commissioning Coordinator (CxC), General Contractor (GC), Plumbing Contractor (PC), Mechanical Contractor (MC), Electrical Contractor (EC), Control Contractor (CC), Landscape Contractor (LC), Not Applicable (N/A)

3. Commissioning Agent Final Sign-Off

The commissioning agent has reviewed and verified the completeness of this checklist. Missing items are noted on the issues log.

Name	Signature	Date

4. Responsible Party Sign-Off

The equipment listed here is complete and ready for startup. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor.

Discipline	Company	Initials	Signature	Date

Project Name Equipment Tag

5. Issues Log		
Record any non-conformance items. CxA to date and initial when completed		
No.	Item	Date Resolved
1		Init:_____
2		Init:_____
3		Init:_____
4		Init:_____
5		Init:_____
6		Init:_____
7		Init:_____
8		Init:_____
9		Init:_____
10		Init:_____

Project Name Equipment Tag

6. NOTES	
CxA to record deviations from this form or noted items due to RFI/ ASI or other clarifications	
No.	Item
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	

Makeup Air Unit SVC Revision 0 Page 3 of 7

Project Name Equipment Tag

7. Prerequisite Verification		
Verify that the following prerequisites have been provided prior to beginning equipment installation.		
Deliverable/Submittal	Provided (Y/N)	Issue No
Approved Submittals		
Shop Drawings		

8. Equipment				
Equipment Tag	Location	Serves	Per Plan (Y/N)	Issues No.

9. Equipment Data				
	As Designed	As Submitted	As Found	Issue No.
Equip ID				
Manufacturer				
Model#				
Serial #				
SF Capacity (CFM)				
SF Motor BHP				
SF Motor Volts / PH				
Cooling Capacity (MBH)				
Heating Capacity (MBH)				
VFD (Y/N)				

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capital engineering

Project Name Equipment Tag

10. Mechanical		
Verify that each of the following items are completed by checking the columns below. Note any discrepancies. The CxA will spot check some of the line items for verification		
No	**Item**	**Mechanical Contractor**
		Equip ID
	General Installation	
1	MAU properly installed	
2	Label permanently attached and visible	
3	Maintenance access is adequate for unit and components	
4	Unit supports and seismic restraints installed	
5	Vibration isolation devices installed and functional	
6	Casing in good condition	
7	Access doors door gaskets in good condition	
8	Thermal insulation installed per specs	
9	Sound attenuation installed per specs (if required)	
10	Instrumentation installed per specs and drawings	
11	Fire Alarm Devices installed per specs and drawings	
12	Construction filters installed	
13	Filter differential pressure measuring device installed	
14	Equipment cleaned per specs	
15	Unit equipped with supply fan VFD	
16	Outside Air Intake Weatherhood installed	
17	Modulating power exhaust installed	
18	Duct smoke detector mounted in supply air duct downstream of unit	
	Coil, Valves and Piping	
19	Coils are clean, fins are in good condition	
20	Condensate drain pans are clean and sloped per spec	
	Ducts (Immediately Around The Unit)	
21	Duct installation complete and connected to unit	
22	Duct joint sealant properly installed	
23	Duct insulation and duct liner thickness per specs	
24	No apparent duct restrictions	

Makeup Air Unit SVC Revision 0 Page 5 of

Project Name Equipment Tag

10. Mechanical		
Verify that each of the following items are completed by checking the columns below. Note any discrepancies. The CxA will spot check some of the line items for verification		
No	**Item**	**Mechanical Contractor**
		Equip ID
25	Turning vanes in square elbows as per Drawings	
26	OSA intake located away from pollutant sources & exhaust outlets	
27	Duct pressure tests completed	
28	Ducts cleaned per specs	
CxA has verified the equipment noted by initials		
End of Mechanical Pre-Functional Checklist		

Project Name Equipment Tag

11. Electrical		
Verify that each of the following items are completed by checking the columns below. Note any discrepancies. The CxA will spot check some of the line items for verification		
No	**Item**	**Electrical Contractor**
		MAU 1-1
	Electrical	
29	Power disconnects in place and labeled	
30	All electric connections tight	
31	Proper grounding installed for components and unit	
32	Motor shaft-grounding device installed on each fan	
33	Motor safeties in place and operable	
34	Starter overload breakers installed and correct size	
CxA has verified the equipment noted by initials		
End of Electrical Pre-Functional Checklist		

12. Controls		
Verify that each of the following items are completed by checking the columns below. Note any discrepancies. The CxA will spot check some of the line items for verification		
No	**Item**	**Controls Contractor**
		MAU 1-1
	Controls	
35	All control devices installed	
36	Control system interlocks complete and functional	
37	Smoke detectors installed and functional	
38	System is ready for point to point checks	
CxA has verified the equipment noted by initials		
End of Controls Pre-Functional Checklist		

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PART 5 - FUNCTIONAL PERFORMANCE TESTING EXAMPLE - These examples are not the final system verification checklists used for this project and are intended to represent the typical rigor of checklists of this type.

capital engineering

Project Name Equipment Tag

Makeup Air Unit

Date: _____

FUNCTIONAL PERFORMANCE TEST

1. Revision

By signing the below, you acknowledge that you have reviewed this test script and reported any comments.

Revision No.	Name	Company	Signature	Date

2. Pre-Requisite Verification

By signing the below, you acknowledge that the pre-requisite document has been submitted to the Commissioning Agent

Item	Mechanical/ Controls Contractor	General Contractor	Commissioning Agent	Date
Installation Verification				
Start-up Report				
TAB Report				
Controls Point-to-Point				

3. Test Attendees

The following parties have witnessed the execution of the test procedures

Discipline	Company	Name
OWNER		
CxA		
GC		
MC		
CC		
Other		

4. Execution of Functional Tests

Prior to the execution of functional tests, the CxA has provided a copy of the primary equipment tests to the installing subcontractor (via the GC) who has reviewed the tests for feasibility, safety, warranty, and equipment protection. The CxA oversees, witnesses, and documents the functional testing of all equipment and systems. The subcontractors execute the tests.

capital engineering Project Name Equipment Tag

6. NOTES	
CxA to record deviations from this form noted items due to RFI/ ASI or other clarifications	
No.	Item
A	
B	
C	
D	
E	
F	
G	
H	
I	

capital engineering Project Name Equipment Tag

5. Issues		
Record any non-conformance items.		
No.	Item	Date Resolved / By
1		Init:_____
2		Init:_____
3		Init:_____
4		Init:_____
5		Init:_____
6		Init:_____
7		Init:_____
8		Init:_____
9		Init:_____
10		Init:_____

7. Basis of Test
The following document(s) were used to develop this test:

8. System Equipment		
The following equipment is included in this test		
Equipment	Location	Note

9. Schedule			
Record each system setpoint. Record the value reported by the system and the independently verified value. Note any unexpected or failed results.			
Days of Week	Time	Verified	Note
Occupied – MON TUE WED THUR FRI SAT SUN			
Unoccupied – MON TUE WED THUR FRI SAT SUN			

10. Setpoints				
Record each system setpoint. Record the value reported by the system and the independently verified value. Note any unexpected or failed results.				
Setpoint	Design (Adj.)	BMS	Verified	Note
Supply Air Temperature				
Cooling Setpoint				
Heating Setpoint				

capital engineering Project Name Equipment Tag

11. Control Points				
Verify that the following points are reporting to the BMS. For measurement devices, verify reported values against independently measured values. Note any unexpected or failed results.				
Description	Verification	Graphics	Trend	Note
Setpoints				
Unit Discharge Air Temperature Setpoint				
Dead Band – Minimum Heating and Cooling Temperature Setpoint Difference				
Heating – Discharge Air Temperature Setpoint				
Programmed Control Features				
HVAC System Occupied / Unoccupied Mode				
Equipment Components, Accessories and Control Features				
Cooling Coil (Dx-Staged Capacity) – Status				
Dehumidification – Modulating Hot Water Reheat – Status				
Heating – Heat Pump – Staged Heating – Status				
Heating – Natural Gas – Modulating – Status				
Outside Air Damper – Motor Operated – Status				
Optimum Start Sequence – Status				
Pre-Occupancy Purge – Status				
Supply Fan Control Methods				
Constant Speed Supply Fan Operation – Status				
Safeties, Interlocks, and Alarms				
Gas Valve Safety				
Kitchen Exhaust Interlock				

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Project Name Equipment Tag

12. KEF 1-1 and KEF 1-2 Interlock				
Perform each of the steps below and record the results. Note any unexpected or failed results.				
#	Test Procedures	Expected Results	Equip ID	Note
1	Turn on KEF 1-1 and KEF 1-2	MAU 1-1 is on and OSA damper is open		
2	Turn on KEF 1-1 and KEF 1-2 individually	MAU 1-1 is on and OSA damper is open of one or both KEF is turned on.		
3	Turn off KEF 1-1 and KEF 1-2	MAU 1-1 turns off and OSA damper is closed		
END OF KEF INTERLOCK TEST				

13. Cooling Mode				
Perform each of the steps below and record the results. Note any unexpected or failed results.				
#	Test Procedures	Expected Results	Equip ID	Note
1	Lower thermostat setpoint below room temperature	MAU 1-1 enters cooling mode		
2	Record lowest temperature achieved during cooling mode			
3	Cooling setpoint reached	Cooling mode disabled and supply fan running		
END OF COOLING MODE TEST				

Project Name Equipment Tag

14. Cooling Mode				
Perform each of the steps below and record the results. Note any unexpected or failed results.				
#	Test Procedures	Expected Results	Equip ID	Note
1	Raise thermostat setpoint above room temperature	MAU 1-1 enters heating mode		
2	Record highest temperature achieved during heating mode			
3	Heating setpoint reached	Heating mode disabled and supply fan running		
END OF COOLING MODE TEST				

15. Unoccupied Mode				
Perform each of the steps below and record the results. Note any unexpected or failed results.				
#	Test Procedures	Expected Results	Equip ID	Note
1	Unoccupied Mode	Outside Air Damper is closed and return air damper is open to all recirculation of indoor air		
END OF UNOCCUPIED MODE TEST				

END OF SECTION