
PART 1 – GENERAL**1.1 WORK OF THIS SECTION**

- A. This section of the specification details the requirements for the following:
1. Start-up, testing and commissioning of the Mechanical and Plumbing System for LEED compliance.
 2. Coordination and participation of the commissioning of the Electrical and BMCS systems.
 3. Coordinating of start-up and testing of the interface to any Electrical System or interface to the BMCS.
 4. Providing assistance to the Commissioning Authority to develop, edit, and document system operation descriptions.
 5. Providing qualified personnel to execute commissioning tests approved or written by Commissioning Authority (CA), including seasonal testing required after the initial commissioning as specified in this specification.
 6. The Division 23 subcontractor shall take the lead responsibility for inspecting, completing and documenting the Pre-Functional Testing for the Mechanical Systems to ensure the systems are fully operational and ready for Functional Testing.
 7. Assist in the completion and endorsing electrical checklist items of Pre-Functional Test forms for Division 23 and 26 equipment and systems to ensure the systems are fully operational and ready for functional testing.
 8. The Division 23 subcontractor shall take the lead responsibility for demonstrating the operations of the Mechanical Systems for the Functional Tests.
 9. Assist in the demonstration of the operations of the Electrical and BMCS Systems for the Functional Tests.
 10. Provide equipment, materials, and labor necessary to correct deficiencies found during the commissioning process, which fulfill contract and warranty requirements.
 11. Coordinating and scheduling with the Electrical and BMCS Subcontractors per specification requirements.
 12. Providing operation and maintenance information and record drawings to the Commissioning Authority for review, verification and organization, prior to the start of training.
 13. Providing training for the systems specified in this Division with coordination by the Commissioning Authority.
 14. Delivery of copies of all required engineering calculations and test documentation as noted in the specifications for review by Commissioning Authority. This includes, but is not limited to, manufacturer's factory and field tests, subcontractor installation and start-up reports and independent testing agency reports.
- B. Mechanical commissioning is primarily the responsibility of the Division 23 subcontractor, but is led under the guidance and approval of the CA. The commissioning process does not diminish the role and obligations of this subcontractor to complete all portions of work in a satisfactory and fully operational manner.

1.2 SCHEDULING

- A. Commissioning shall comply with the Construction Contract schedule. Cooperate with the Commissioning Authority in the following manner:
1. Allow sufficient time before final completion dates so that test and balance and commissioning testing can be accomplished.
 2. Provide labor and material to make corrections when required without undue delay.

PART 2 – PRODUCTS**2.1 TEST EQUIPMENT**

- A. Provide all necessary test equipment to confirm proper operation of the Mechanical Systems.
- B. All testing equipment shall be properly calibrated and documentation of such calibration shall be submitted prior to any verification testing.

PART 3 – EXECUTION**3.1 WORK PRIOR TO COMMISSIONING**

- A. The CA shall provide the Pre-Functional Checklists and Functional Testing forms.
- B. Upon request of the Commissioning Authority and General Contractor, the subcontractor shall provide assistance and consultation with finalization of the Commissioning Plan. All subject Subcontractors shall utilize the Commissioning Plan during project execution. The Subcontractor is obligated to assist the Commissioning Authority in executing the Plan by providing all necessary information pertaining to the actual equipment, installation and related schedules.
- C. Review Pre-Functional and Functional Test forms provided by the CA prior to finalization of the test forms.
- D. Coordinate with the Division 26 and BMCS subcontractors for performing and documenting Pre-Functional checks for each of the equipment items listed in Division 26.
- E. If system modifications / clarifications are incorporated to this and related sections of work, commissioning of this work will be made at no additional cost to the Owner.
- F. If Subcontractor initiated system changes have been made that alter the commissioning process, the Commissioning Authority will notify the Architect, and the Subcontractor may be obligated to compensate the Commissioner to test the revised product, or confirm the suitability / unsuitability of the substitution or revision.

3.2 PARTICIPATION IN COMMISSIONING

- A. The Division 23 subcontractor shall take the lead in commissioning of the following Mechanical Systems:
 - 1. HVAC Systems and Equipment.
 - 2. Domestic Hot Water Systems.
- B. Provide skilled technicians to start-up and debug all systems within this Division of work. These same technicians shall be made available to assist the Commissioning Authority in completing the commissioning program as it relates to each system and their technical specialty. Work schedules, time required for testing, etc., will be requested by the Commissioning Authority and coordinated by the Subcontractor. The Subcontractor shall ensure the qualified technician(s) are available and present during the agreed upon schedules and of sufficient duration to complete the necessary tests, adjustments, and/or problem resolutions.
- C. System problems and discrepancies may require additional technician time, Commissioning Authority time, redesign and/or reconstruction of systems, and system components. The additional technician time shall be made available for the subsequent commissioning periods until the required system performance is obtained.
- D. The Commissioning Authority reserves the right to judge the appropriateness and qualifications of the technicians relative to each item of equipment, system, and/or sub-system. Qualifications of technicians include expert knowledge relative to the specific equipment involved, adequate documentation and tools to service/commission the equipment, and an attitude/willingness to work with the Commissioning Authority to get the job done. A liaison or intermediary between the Commissioning Authority and qualified factory representatives does not constitute the availability of a qualified technician for purposes of this work.
- E. Complete start-up and Pre-Functional Test documentation of the Mechanical Systems. Submit completed Pre-Functional Test forms to the CA.

- F. Lead the team in the demonstration of the operations of the Mechanical Systems to complete the Functional Test documentation.
- G. Participate in Commissioning Mechanical, Electrical and BMCS meetings organized by the Commissioning Authority and General Contractor.
- H. Division 23 Subcontractor and the BMCS Subcontractor are responsible for completing Point-To-Point Testing, Pre-Functional Testing and Functional Testing of the HVAC and Plumbing Systems.
- I. Division 26 Subcontractor and the BMCS Subcontractor are responsible for completing Point-To-Point Testing, Pre-Functional Testing and Functional Testing of the BMCS interface to the specified Electrical Systems.
- J. Provide any manufacturer's testing reports for components of the Mechanical Systems and attached these reports to the appropriate completed Pre-Functional Test forms.
- K. Support Commissioning Authority efforts to satisfy commissioning documentation requirements of the LEED accreditation process for Fundamental and Additional Commissioning.
- L. Provide reporting, scheduling, and notification of testing and work in progress. If a review or testing session has been scheduled with the CA and it is found that the systems are not ready to test, then the subcontractor shall be liable for any additional testing sessions.

3.3 SEASONAL COMMISSIONING AND OCCUPANCY VARIATIONS

- A. Provide a demonstration of the operation of the Mechanical Systems at approximately 10 months into the initial warranty period. The CA shall witness the demonstration of the systems.
- B. The intent of the warranty review will be to identify any operational concerns, document and suggested solutions, and review the long-term operational and re-commissioning requirements of the systems.
- C. The Functional Test forms shall be the basis of the demonstration.

3.4 WORK TO RESOLVE DEFICIENCIES

- A. In some systems, maladjustments, misapplied equipment, and/or deficient performance under varying loads will result in additional work being required to commission the systems. This work will be completed under the direction of the Owner, with input from the General Contractor, equipment supplier, and Commissioning Authority. Whereas all members will have input and the opportunity to discuss, debate, and work out problems, the Engineer of Record will have final jurisdiction on the necessary work to be done to achieve performance.
- B. Corrective work shall be completed in a timely fashion to permit the timely completion of the commissioning process. Experimentation to render system performance will be permitted. If the Commissioning Authority deems the experimentation work to be ineffective or untimely as it relates to the commissioning process, the Commissioning Authority will notify the Owner indicating the nature of the problem, expected steps to be taken, and the deadline for completion of activities. If the deadline(s) passes without resolution of the problem, the Owner reserves the right to obtain supplementary services and/or equipment to resolve the problem. Costs incurred to solve the problems in an expeditious manner will be the Subcontractor's responsibility.
- C. Provide written response, within two weeks of receipt of any corrective action items noted by the CA.

3.5 PRE-FUNCTIONAL TEST FORMS

- A. After the initial equipment submittal phase, the CA shall prepare Pre-Functional Test forms for each item of equipment as part of the commissioning. Review respective Pre-Functional Test forms for

accuracy and completeness and provide comments to the General Contractor and CA.

B. The following is a sample Pre-Functional Test form:

SAMPLE						
BMCS - PRE-FUNCTIONAL TEST						
Prerequisite Tests: Sensor calibration and point to point checkout.						
Equipment Included: BMCS panels, networks, and operator interface.						
1. Approvals						
The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off <i>only by parties having direct knowledge of the event</i> , as marked below, respective to each responsible contractor. This pre-functional checklist is submitted for approval and is subject to an attached list of outstanding items yet to be completed. A Statement of Correction (SOC) will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. ___ SOC list attached.						
_____	_____	_____	_____			
Mechanical Contractor	Date	Controls Contractor	Date			
_____	_____	_____	_____			
Electrical Contractor	Date	Certified Start-up Technician	Date			
_____	_____	_____	_____			
TAB Contractor	Date	General Contractor	Date			
Pre-functional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.						
This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.						
Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).						
Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.						
"Resp." or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E - architect/engineer, All - all contractors, CxA - commissioning authority, CC - controls contractor, EC - electrical contractor, GC - general contractor, MC - mechanical contractor, ST - Star-up technician certified by the equipment manufacturer, TAB - test and balance contractor						
This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below or on attached Statement of Correction.						
_____	_____	_____	_____			
Commissioning Agent	Date	Owner's Representative	Date			
2. Documentation						
The following has been submitted to the CxA and Owner's representative						
Check if provided. Enter comment or note number on SOC						
	Operator Interface	CCP controllers	DCP Controllers	UC Controllers	Networks	Resp.

Manufacturer's cut sheets						
Performance data						
Operational checkout reports						
Installation and startup manual						
O&M manuals						

	Dampers and Actuators	Valves and Actuators	Sensors			Resp.
Manufacturer's cut sheets						
Performance data (ratings, accuracy data, etc.)						
Manufacturer's factory sensor calibration reports						
Installation and startup manual						
O&M manuals						

Documentation complete as per contract documents

___ YES ___ NO

3. Model Verification

List information. Enter note number if deficient on SOC.

	BMCS	Resp.
Operator interface PC Manufacturer PC Model #		
Operator interface Software Package and Version		
CCP #1 Controller panel manufacture Model #		
CCP #2 Controller panel manufacture Model #		
DCP #1 Controller panel manufacture Model #		
DCP #2 Controller panel manufacture Model #		
UC #1 Controller panel manufacture Model #		
UC #2 Controller panel mfg Model #		
Damper Manufacturer Model #		
Damper Actuator Manufacturer Model #		
Space temp sensor Manufacturer Model #		
Duct temperature sensor Mfg Model #		
Outside air temp sensor Mfg Model #		
Duct static pressure sensor Mfg Model #		
High static shutdown sensor Mfg Model #		
CO2 sensor Mfg		

Model #		
Space humidity sensor Mfg		
Model #		
Outside air humidity sensor Mfg		
Model #		
Control Relay Mfg		
Model #		

The equipment installed matches the specifications for given trade YES NO

4. Installation Checks

Check if Complete. Enter comment or note number on SOC if deficient

	BMCS	Resp.
General Installation		
General appearance good, no apparent damage		
Proper panel mountings		
All components enclosed within panels		
All cabling in conduit or plenum rated cable		
All cabling in equipment rooms in conduit		
All cabling in conduit not sharing with high voltage cabling		
All shielded cabling grounded at one end only		
All cabling labeled		
All conduit labeled		
Flexible conduit used at final connection to vibrating equipment		
Network cables terminated at all panels		
Operator interface PC and software installed		
Operator printers installed		
Electrical and Controls		
Power wiring installed properly		
All electrical components grounded properly		

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

5. Operational Checks

(This augments the manufacturers' list. This is not the functional performance testing.)

Check if Complete. Enter comment or note number on SOC if deficient.

	BMCS	Resp.
Communication to all panels confirmed		
Control to all outputs confirmed		
Monitoring of all inputs confirmed		
Alarm limits input for all monitored points		

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

6. Sensor and Actuator Calibration

All sensors are calibrated within required tolerances YES NO

SYSTEM - XXX										
Point Name / Description	Point Type	Point Function	Installation Inspected	Point To Point Continuity Checked	Full stroke and Modulation Check	BMCS Displayed Value	Test Instrument / Actual Value	Accepted	Technician Initials	Date

END OF CHECKLIST

3.6 FUNCTIONAL TEST FORMS

- A. After the finalization of the Pre-Functional Test forms, the CA shall prepare Functional Test forms for each system to be documented as part of the commissioning. Review respective Functional Test forms for accuracy and completeness and provide comments to the General Contractor and CA.
- B. The following is a sample Functional Test form:

SAMPLE

VAV AHU - FUNCTIONAL TEST

Equipment Included in Test:
 AHU
 Associated control valves, and sensors

1. Participants

Name	Company	Name	Company

 Party filling out this form and witnessing testing

 Date

2. Prerequisite Checklist

AHU startup reports submitted and approved as ready for functional testing:

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

Test and balance (TAB) complete and approved for the airside
 All A/E punch list items for this equipment corrected.
 These functional test procedures reviewed by installing contractor.
 Safeties and operating ranges reviewed.
 Test requirements and sequences of operation attached.
 False loading equipment, system and procedures ready
 (control loops, over-ride on OSA dampers, etc.)
 Sufficient clearance around equipment for servicing.
 Have all energy savings control strategies, set points and schedules been incorporated that this AHU and control system are capable of? If not, list recommendations below.
 Control Program Review. Review the software control program(s) for this equipment. Parameters, set points and

logic sequences appear to follow the specified written sequences.

3. Sensor Calibration Checks.

The sensors listed below need to be rechecked by the T&B for calibration as we found problems associated with their operation during testing.

Sensor Location	Location Correct?	Require recheck
Duct Static Pressure sensor		
Duct Static Pressure High Limit		
Return Duct Low Limit		
Outside air flow monitors.		

4. Test Procedure Table of Contents

- Supply Fan Static Pressure Control
- High Static Pressure Shutdown
- Low Static Pressure Shutdown
- Supply Air Temperature Control – Chilled Water Valve
- Occupied Mode
- Unoccupied Mode
- Night Heating
- VFD Communication Link Failure

5. Testing Procedures and Record
(Provide for each AHU)

Test 1	
Test Description	Supply Air Static Pressure Control
Expected Operation	Monitor fan speed, output signal, set point, and static pressure input for stable operation. Modify set point and trend control loop performance. Verify return to stable operation within reasonable time frame. Utilize dynamic graphical trending to track loop performance.
Actual Operation	

Test 2	
Test Description	High Static Pressure Shutdown
Expected Operation	Cause fan to shut down on high static. Verify alarm, and equipment shut down, including closed chilled water valve, closed OA damper, and closed return air damper. Verify return to stable operation within reasonable time frame after clearing alarm.
Actual Operation	

Test 3	
Test Description	Supply Air Temperature Control – DX control
Expected Operation	Modify set point and trend control loop performance. Verify return to stable operation within reasonable time frame. Utilize dynamic graphical trending to track loop performance. Perform testing during load testing and IR scanning.
Actual Operation	

Test 4	
Test Description	
Expected Operation	
Actual Operation	

Test Description	Occupied Mode
Expected Operation	All automatic modes are enabled. View system off positions of dampers, then enable unit operation. View stable operation of all control loops. Disable unit and then view all disabled positions.
Actual Operation	
Test 5	
Test Description	Unoccupied Mode
Expected Operation	Supply and return fans normally off. Outside air and exhaust air dampers closed, return air dampers closed.
Actual Operation	
Test 6	
Test Description	Unoccupied Mode
Expected Operation	With supply, return and exhaust fans normally off. Outside air and exhaust air dampers closed, return air dampers open. Initiate operation of systems by false input of an 85 degree temperature in a telecommunications room.
Actual Operation	.
Test 7	
Test Description	After Hours Mode
Expected Operation	All automatic modes are enabled. Limit operation to a single area of the building. Verify both AHU's, exhaust fan etc operate, and that boxes in unoccupied areas remain off. View system off positions of dampers, then enable unit operation. View stable operation of all control loops. Disable unit and then view all disabled positions.
Actual Operation	
Test 8 -	
Test Description	VFD Communication Link Failure
Expected Operation	Disconnect VFD Com Link to a single AHU. Observe the AHU's end state. AHU should continue to operate in last commanded state.
Actual Operation	.
Test 9 -	
Test Description	Fire Alarm Shutdown
Expected Operation	Upon initiation of a building fire alarm, supply and return fans off. Outside air and exhaust air dampers closed, return air dampers open. Verify alarm. Operation not to resume until alarm is reset.
Actual Operation	
Test 10 -	
Test Description	Freeze-stat Alarm
Expected Operation	Close contacts on Freeze-stat #1 (38 DEG) to verify receipt of alarm at BMS. Outside air damper to remain open.
Actual Operation	
Test 11 -	
Test Description	Freeze-stat Alarm
Expected Operation	Close contacts on Freeze-stat #2 (32 DEG) to verify unit shut down and receipt of alarm at BMS. Shut down of AHU as specified causes Chilled water valve to close.
Actual Operation	
Test 12 -	
Test Description	Low Static Alarm.
Expected Operation	Reset low static alarm above operating static and verify unit shut down and receipt

Actual Operation	of alarm at BMS.
Test 14 – BAS Monitoring (each AHU)	
VFD	
Duct Static Pressure	
Supply air damper end switch	
High static pressure sensor	
Low static pressure sensor	
Supply Fan Status by current sensing relay	
Supply and return smoke detectors	
AHU start/stop	
Outside Air Flow	
Supply air damper end switch	
Return air damper end switch	
--END OF TEST--	

End of Section