

Commissioning Scope of Work for Critical Healthcare Facilities

Anand K. Seth, Abbe E. Bjorklund, and Daryl Fournier
Sebesta Blomberg & Associates, Inc.

Synopsis

The traditional commissioning scope of work considered by many owners' project managers for most buildings are for HVAC systems alone. In some cases other electrical, plumbing and occasionally fire protection systems are commissioned in a limited manner. A broadened commissioning scope covering envelope and electrical would benefit healthcare facilities with complex diagnostic, operating, recovery, isolation, and patient care services. The paper will describe the difference between "quality control" services provided by the construction delivery team and "quality assurance" services which can only be provided by an independent third party commissioning agent. It will also describe a proposed scope for commissioning the building shell to ensure proper construction, and avoid moisture problems and excessive infiltration and leaks. Further, it will describe the need for commissioning of the interface between MEPFP systems to ensure a safe "environment of care" for the patient. It will also describe the need for a rigorous electrical system commissioning approach to ensure reliable emergency power is available in the critical areas where designed and required. How commissioning can successfully meet JCAHO requirements for the facility will also be discussed.

About the Authors

Anand Seth, PE, CEM is director of the Healthcare Service Sector at Sebesta Blomberg. In this role he is responsible for supporting all healthcare projects for the company throughout the country. Prior to joining Sebesta Blomberg, Mr. Seth was formerly the Director of Utilities and Engineering, first at Massachusetts General Hospital, and later on at Partners HealthCare System Inc. Partners was formed when two world class institutions and teaching hospitals of Harvard University, Massachusetts General Hospital and Brigham & Women's Hospital joined.

Abbe Bjorklund, PE is an Associate Principal and Group Leader at Sebesta Blomberg. Ms. Bjorklund is a specialist in analysis, design, construction, and commissioning of energy efficient building systems for new and existing buildings. Ms. Bjorklund is responsible for Sebesta Blomberg's Northeast Region commissioning, MEP and utility design engineering, and energy efficiency engineering services.

Daryl Fournier is a Mechanical Engineer at Sebesta Blomberg, and has several years of experience in the HVAC industry. He has been responsible for the mechanical design and construction administration of new and renovation construction projects as well as assessing facilities for code compliance and equipment/system adequacy with the objective of improving the energy efficiency and safety of the facility.

1. Introduction

Healthcare facilities are unique. Unlike many other facilities which shut down in the case of problems or natural disasters, these facilities need to be up and operational. Depending upon the mission, some of these facilities operate 24/7, 365 days a year. Recently, in the hurricane season of 2005, many of the hospitals in the Louisiana and Mississippi area battled heroically against overwhelming odds to remain open and provide patient care.

It is therefore necessary for mechanical, electric, and plumbing (MEP) systems serving healthcare facilities to be carefully designed with consideration given to reliability and continuity of operation. It is also essential that these facilities be well constructed and commissioned to ensure proper operation when opened and throughout continued operation.

The scope of this paper is to recommend a commissioning scope of work for a hypothetical clinical facility. The facility is programmed to house patient rooms, infectious isolation and protective isolation rooms, operating rooms, recovery rooms, possibly even labor and delivery rooms, clinical rooms, and more. In short, the building provides a microcosm of high-end, complicated healthcare.

It is assumed that the construction process is being managed by competent professionals, and it has a program of routine quality checks, testing and verification of all trades. We have used the word construction manager (CM) to describe the entity responsible for project delivery. It is acknowledged that there are other project delivery methods. The owner wishes to conduct independent commissioning of systems to ensure a high quality, operational facility. This paper will attempt to recommend a commissioning scope of work for consideration.

2. Structural/Building Skin

Traditionally these systems are not commissioned, however it is our recommendation that these are just as important as MEP systems, as inappropriate skin of the facility may result in air and/or water leakage in the facility. This leakage may result in possible mold growth, air pressure problems, and other environmental harm inside the facility. The intent of this service is to improve the performance of the building envelope, thereby providing the best enclosure for occupant comfort and for building system performance. The building envelope is defined by the roof and exterior walls, including foundations and basement slab-on-grade.

The following commissioning scope of service is recommended:

- Review construction documents to identify constructability issues and to verify envelope design integrity. Commissioning agent will provide suggested changes to the design documents as appropriate to improve building envelope performance.
- Review envelope-specific shop drawings and test reports for compliance with specifications, conformance with design documents and with industry standards.
- Perform site inspections at key junctures of construction to verify compliance with design details and industry standards. Suggested key junctures are as follows:

- Installation of foundation waterproofing systems.
- Installation of stone cladding.
- Installation of metal wall panels.
- Installation of glass curtain wall and storefront systems.
- Installation of roof.
- Participate in construction coordination meetings bringing together building envelope construction trade personnel to discuss coordination of trades and materials, as well as constructability issues. Suggested pre-construction conferences would be as follows:
 - Prior to installation of waterproofing systems.
 - Prior to installation of stone cladding.
 - Prior to installation of metal wall panels.
 - Prior to installation of curtain wall and storefront systems.
 - Prior to installation of roofing systems.
- Arrange for any additional independent tests of key envelope systems, in-situ and/or in laboratory settings, depending upon the test requested. Tests that may be recommended include:
 - Air infiltration (done in-situ).
 - Static water (done in-situ).
 - Thermal test (done at lab; provides “U” and “R” values of components).
 - Thermal imaging (done in-situ).
 - Dynamic water (done in-situ).
 - Structural design pressures (modeling).
 - Seismic drift (modeling).
 - Thermal cycling (done at lab)
- Pressure testing of selected spaces (in situ).
- Review O&M manuals for building envelope systems for completeness, including shop drawings, warranties, test reports, care and maintenance instructions, installing contractors’ and manufacturers’ contact information.

3. MEP Systems

MEP system commissioning is most prevalent in the commissioning industry. In this paper we will not attempt to define each and every commissioning step. We have instead described unique issues which can bring a facility to a higher level of completeness and preparedness. A typical commissioning scope of work and list of MEP systems commissioned is attached in Appendix A and B.

3.1 Design Review

3.1.1 Commissionability Design Review

Traditionally a commissionability design review is conducted which consists of the following scope:

Perform focused design reviews of the drawings and specifications at the Schematic Design, Design Development, 50%, 95% and 100% stages. The reviews will include the following:

1. Commissioning facilitation - providing input regarding how to make the building easier to commission.
2. Energy efficiency - reviewing the general efficiency of the HVAC system types, lighting system types, etc.
3. Operation and Maintenance (O&M) - providing input as to how O&M can be made easier, e.g., accessibility and system control.
4. Indoor environment quality (IEQ) - reviewing how air quality and/or thermal and acoustical comfort can be improved.
5. Clear and rigorous design documentation.
6. Access for reading gauges, entering doors and panels, observing and replacing filters, coils, etc.
7. Required isolation valves, dampers, interlocks, piping, etc., to allow for manual overrides, simulating failures, seasons and other testing conditions.
8. Pressure and temperature plugs close to controlling sensors for verifying their calibration.
9. Pressure gauges, thermometers and flow meters in strategic areas to facilitate verifying system performance and ongoing O&M.
10. Pressure and temperature plugs in less critical areas or on smaller equipment where gauges and thermometers would be overkill.
11. Specification of the locations and criteria for duct static pressure sensors and hydronic differential pressure sensors.
12. Adequate balancing valves and dampers, flow metering, and control stations and control system functions to facilitate and verify reliable test and balance.
13. Detailed and complete sequences of operation.
14. Sufficient monitoring points in the building automation (BAS), even beyond those necessary to control the systems, to facilitate performance verification and O&M.
15. Adequate trending and reporting features in the BAS.
16. Specification of required startup and testing functions to be performed by the contractors and/or manufacturer's field service personnel.
17. Complete O&M documentation requirements in the specifications.
18. Complete training requirements in the specifications.

3.1.2 Peer Design Review

In some cases a detailed peer review is provided which reviews system and equipment selection, checks system capacities, sizing of pipes, ducts, conductors, etc.

3.1.3 Reliability Review

We recommend that a “reliability review” be added to the design review scope of work. This will include review of system failure potential and the steps which can be taken to prevent it. This can mean critical systems like emergency generators not be installed in basements where they are susceptible to flooding, etc. Some of the typical issues are listed below:

1. Primary Electrical Systems: Most utility services enter in the building basement. A common design is also to install the incoming switchgear and other protective devices at the entrance. A higher location may be safer from flooding.
2. Multiple city water lines should feed the facility, so breakage of line in one street does not prevent water availability to the whole facility.
3. In a multiple building complex, interconnection of piping and valves should be provided so different buildings can be fed from different directions.
4. Cooling systems connected to emergency power: This has been an area of hot debate in the past, as this feature is expensive in first cost as well as operating cost. However recent experience has shown that lack of cooling and dehumidification for the patients in hot and humid weather has been problematic. This ability can be provided by installation of an outside connection where a temporary generator can be trucked in and connected, to the other end of the spectrum where at least one or more chillers, cooling towers, pumps, etc. are connected to internal stand-by generators. If this option is chosen, care should be taken to ensure that the “whole” system is capable of operation. Omission of a key component being connected to the emergency power can negate the whole effort.

Emergency Power capacity for the building takes a new meaning in this context. The original intent of “emergency power” was a short term duration where a minimum number of systems, primarily Life Safety systems, were enabled. All other systems were inoperable. From this original context to operational continuity in the healthcare facility is a large stretch, and careful planning and risk evaluation must be done to determine the appropriate level of preparedness.

For example, the facility may decide that some of the critical diagnostic and treatment equipment or systems must be on emergency power. Examples are X-ray equipment and CT scanners. An electrical sterilizer connected to emergency power can provide needed sterilized surgical implements for emergency surgery.

It is also very easy to over react and install very large stand-by systems which are expensive as well as difficult to maintain. For example very large emergency fuel storage for emergency generators can create its own problem due to fuel contamination, etc.

3.2 Electrical Systems

Testing of the building on emergency power should consist of disconnecting the building from its normal power source, observing the start-up of the emergency generator, transfer of critical building services over to emergency power, and restart and operation of critical equipment and systems. While performing the test, all time delays associated with generator start-up and Automatic Transfer Switch (ATS) transfers from primary power to emergency power should be verified.

Emergency power test activities should include operation of the heating system boilers. All boilers should be connected to the emergency power source, because in the event of a failure of the lead boiler, any of the two back-up boilers could provide heat to the building.

Loss of normal power test should be performed prior to occupancy, once all of the medical equipment is installed, to verify that the medical equipment functions properly during the transition to and from normal power, and is compatible with the emergency power system.

3.2.1 Factory and Field Testing of Emergency Generator System and Components

1. It is suggested, unless it can be arranged under special conditions, that the generator stage testing at the factory be eliminated. The factory site conditions usually are not favorable. Generator testing should be conducted at the project site.
2. Commissioning generator-ATS systems provides better validation with a 110% load bank. The completed facility would be better able to meet its monthly obligation with a permanent load bank for each ATS.
3. The commissioning agent (CA) should create a detailed checklist for observation of factory switchgear tests.
4. Testing of the elevators and fire pumps and all other life safety related ventilation loads to be included during emergency power system test.
5. VFD's to be specified to be able to ride through a momentary power blip. This applies to all VFDs.
6. Generator enclosure should be protected by a dry pipe sprinkler system or FM 2000 system.
7. All generators shall be tested to 100% of their capacity when installed in their enclosure at the factory. Most probably generators will be shipped to the enclosure manufacturer for such testing.

3.2.2 Normal Power Testing

Network protector settings will be verified during testing.

3.3 HVAC Systems

Functional testing should be performed on the chilled water plant, boiler plant, air handling units and terminal units. The tests should be executed by the installing contractors, including the controls contractor, and witnessed by the commissioning agent and the owner.

3.3.1 Issues Relating to Factory and Field-Testing of the Chiller and AHU Performance

- a) Chiller Factory and Field Testing
 - i) The chillers should be factory tested based upon ARI test method down to 25% capacity. Testing should also include:
 - (1) Low condenser water temperature at low capacity conditions.
 - (2) Operate the chillers at a load as low as possible before they trip off. Commissioning agent to prepare a test procedure, but there is no need for commissioning agent to witness this test (owner and designer can witness). Designer to provide minimum load chillers will operate at.
 - (3) Test Criteria to include 100% load to verify that the chillers' capacity meets or exceeds design tonnage. No tolerance for NPLV values should be acceptable. Chiller must meet or exceed values listed in the equipment submittal.
 - (4) Minimum Flow Rates: A time delay to be part of shutdown sequence for loss of flow to avoid nuisance trips due to pumping issues.
 - ii) Chiller manufacturer to be required to participate in the functional testing of the chillers on site.
 - iii) Eddy Current testing of the tubes to provide a baseline for future testing. Testing should be performed by an independent testing agency once the chillers are installed. Contractor should be responsible to take off heads and repair any defects. Water will not be allowed in the barrels until test results are approved by the owner.
 - iv) Vibration testing should be performed at the Factory and by owner in the field.
 - v) In response to the usual question: "Who controls the chillers? BMS or Chiller vendor through their control panel?" It is suggested that the BAS will send S/S signal to chillers, control pumps and chiller head pressure control. Chiller manufacturer will provide all safeties, ATC only to provide components needed to attain the sequence of operation.
 - vi) The whole chilled water system should be tested in full and partial load conditions and under all operating sequences. Note that the speed in which specific control valves open and close and the rate in which the chilled water pumps speeds up and slows down may produce nuisance chiller trips and fluctuations in the chilled water pressure throughout the building.

Use of a “clamp-on” ultrasonic water flow meter, will allow measurement of the chilled water flow throughout the system at these different operating scenarios.

b) Air Handler Unit (AHU) Testing

- i) The AHUs should be factory tested for pressure and flow. Design pressure should be maximum pressure generated by the fan at no flow plus 50% safety margin.
- ii) All units that are to be field assembled are to be factory assembled and tested.
- iii) The AHU needs to be retested in field as installed to confirm air flow capacity with risers connected.
- iv) The AHU specification should call for condensate drain pan, floor pan, and drain testing in the field.
- v) The AHU coil piping in the packaged units need to be reviewed for access.
- vi) The AHU should be tested with its common unit so performance at parallel operation can be verified. This can occur in the field. Units should be factory tested for uniform face velocities, field tested for uniform face velocities at the cooling coils and match a uniform temperature profile after the mixing plenum. TAB spec to include the requirement to provide grid profile of cooling coil velocities. 0.25 in wc is the maximum allowed static pressure in the mixing plenum.
- vii) Testing of patient room floors in the 100% outside air mode should be conducted. Floors to be negative pressure for Infection Control purposes say at -0.01 in wg.

3.3.2 Isolation Room Testing

Assessments of the pressurization relationship between airborne infection isolation rooms/protective environmental rooms and their adjoining corridors should be performed. An electronic manometer to measure actual differential pressures across the patient rooms, ante rooms and corridors is an excellent tool.

The differential pressures should be monitored while climate control testing takes place. Climate control testing consists of changing space temperature set points and verifying that the reheat valve and perimeter heat valve operate in an appropriate manner. Note that while the pressure relationships may be correct for the room’s use, the pressure differentials may fall short of the minimum AIA (2001) requirement of 0.01 in. w.g. This shortfall can make the infection control process susceptible to such factors as seasonal variations and air filter cleanliness.

3.3.3 Boiler or Hot Water System Testing

For facilities with local heating boilers, functional testing should include an examination of the boiler staging sequence for excessive boiler cycling. This condition may result in large swings in reheat water temperatures and difficulty maintaining critical spaces at setpoint.

A performance review of the burners should be conducted to check if sufficient turndown for the changing heating requirements of the building is provided. Insufficient turndown will increase equipment wear and tear and provide a notable loss in heating plant efficiency.

The primary hot water pumps, preheat heat exchangers, preheat circulation pumps, reheat heat exchangers, and reheat circulation pumps, should be commissioned to verify proper operation as well as to ensure their operation with emergency power.

3.3.4 HVAC Testing and Air Balancing (TAB)

For multiple storied buildings, air supply systems should be tested as a whole for the final balancing, not one floor at a time. The TAB contractor employed by the CM or HVAC contractor should pre-balance all life safety systems as required to obtain the certificate of occupancy, and shall be responsible for demonstrating that all air and water flow design criteria have been met. The owner should employ an independent TAB contractor to check the CM or HVAC contractor's TAB.

3.3.5 Other HVAC System Desired Features

- a. Use of the main HVAC system for the temporary heat or dehumidification is not recommended unless protocols are established and maintained by an independent service organization to prevent any dust from entering the duct systems.
- b. All variable frequency drives used on fans, pumps and elevators, escalators would be specified with UPS and programming required to "ride-through" any loss of power and the restoration thereof without the need for operator intervention.
- c. MEP installation subcontractors (and all other providers of rotating equipment such as pneumatic tube, vertical transportation, etc.) would have the cost of pre-functional work and all other pre-commissioning and commissioning activities established as a line item in their respective trade payment breakdowns. This is to ensure that they are covering these costs in their bids, and to provide a value to be approved by the commissioning agent to be paid when pre-commissioning and commissioning activities are successfully executed.
- d. All equipment that is to operate under a loss of normal power such as chillers, should have their controller also powered through UPS supplied by the equipment vendor to eliminate the need for a restart after the 8-second loss of power.
- e. Chiller technicians must be required to fully integrate the chiller and BAS operations.
- f. The chiller vendor is to provide all safety flow sensing with a high enough resolution to allow the machine to operate consistently at the minimum flow rate of the machine.

3.3.6 ACS Review

The automatic control system (ACS) is one of the more critical components of the mechanical system. It is recommended that this be reviewed carefully. Most control specifications these days are "performance" specifications. They do not provide detailed design of ACS implementation. This allows a tremendous flexibility and ingenuity to the ACS contractor but also may create some problems. We are all unique and there is a tendency for many ACS designers and programmers to "reinvent" the wheel and try different strategies, some of which may be untried before. Now, there is nothing wrong with originality and creativity. If the human race had not

shown this aptitude we probably would still be in the Stone Age. However, there needs to be a balance between well-tried solutions and new approaches.

We recommend that an approximately one day long meeting of all stake holders in ACS be scheduled during the early construction phase of the project to review in great detail how the control strategies will be implemented. We have found interaction between owner, designers, ACS contractor/vendor, mechanical contractor; construction manager, and above all, the commissioning agent can be extremely useful.

ACS specifications should require that the ACS vendor provide a UPS at every network or unitary controller to eliminate the need for a system reboot after the loss and restoration of power. It is recommended that all UPS shall have a minimum of 30-minute capacity.

4. Fire Protection Systems

It is highly recommended that healthcare facilities be fully equipped with sprinklers. The sprinkler not only provides a high level of life safety, but fully sprinkler-equipped buildings enjoy favorable treatment from the Life Safety Code (NFPA 200x). A source of reliable water is essential for the sprinkler systems to operate. This has been achieved by more than one water supply line to the local utility. In some cases water storage tanks provide alternate water storage on the site, connection to local rivers or lakes has also been attempted. In the case of high rise healthcare facilities, multiple risers on every floor may be required. Flow switches and tamper proof devices must be located appropriately. Flow testing stations need to be provided so the system can be tested on an as-needed basis without flooding the space.

In order for the sprinklers to operate, a fire pump may be needed. If this fire pump is electric, it should be connected to the emergency power system. Some jurisdictions allow a separate dedicated electrical connection. In our opinion, this does not provide a reliable alternative. If a diesel driven fire pump is used, it must be installed in an appropriate, well-ventilated space with sufficient fuel storage. To increase reliability, it may be appropriate to connect the fuel supply for the fire pump to the other emergency generator fuel supply.

5. Fire Alarm Systems and Smoke Management Systems

Fire and smoke detectors in the patient rooms and corridors provide early warning.

Stairwell pressurization, elevator hoist way, and other pertinent life safety systems should be commissioned. The contractor should ensure system works before commissioning agent and other AHJ (authorities having jurisdiction) are invited to witness tests.

The commissioning agent should begin testing the smoke control system by performing a visual inspection of the smoke dampers and check for dampers which do not close tight and dampers which could not be accessed due to missing service openings per NFPA (1999). Underwriters Laboratory (UL555S) provides leakage ratings for each classification of smoke dampers.

Following the visual inspection, a functional test of the smoke control system should be conducted. Following NFPA guidelines the automatic controls associated with the smoke dampers should be tested at least annually.

6. JCAHO

The installing HVAC contractors shall test each fire damper for access and operation and shall provide a testing report for all fire/smoke dampers. Drawings with all dampers numbered should be provided. This needs to be repeated every four years by the owner under JCAHO. The initial report will form the foundation for future reports. Many of the other issues discussed here allow for a safer “environment of care” for the patient.

7. Owner’s Operating Personnel Training and Participation

Building operators who understand how to start/stop system equipment, how to respond to abnormal conditions and how to monitor and assess ongoing equipment and system performance are a valuable asset to the building owner. Knowledgeable operators provide quick response to situations, accurate assessment of the nature of the problems and a quick resolve to the issues at hand. It is for these reasons that operator involvement in the commissioning process is important.

One way to involve the operators in the commissioning process is by their participation during the functional performance testing. This testing provides a step-by-step process by which each mode of operation, each control sequence and all safeties and interlocks associated with a system are tested. During the testing, the building operators have the opportunity to familiarize themselves with equipment location and areas served, to monitor all phases of systems operations, to observe how the equipment responds to seasonal conditions and occupancy and to identify when the systems are operating inefficiently. This “hands-on” learning afforded the building operators is invaluable to the overall success of the construction project. The result of this educational experience is a competent workforce ensuring long-term performance of the building’s systems.

The construction team, including the commissioning agent, leaves after the construction is complete and the owners take possession of the facility. It is vital that maintenance and operating personnel from the owner are well trained and fully knowledgeable of the facility systems, location of the equipment, maintenance tasks and frequencies. Some of the suggested commissioning scope to achieve this end are as follows:

- a. Concise Basis of Design (BOD) or Design Intent Document
- b. Systems description
- c. Participation of O&MP personnel in functional performance testing
- d. Witnessing pre-functional testing
- e. Populating CMMS database
- f. Systems training and documentation
- g. Contractor invoice approval process with respect to completion of commissioning requirements.

8. Valuable Commissioning Documentation

1. The Design Intent Documentation is one of the most critical pieces of documentation to have on record for any building. This narrative, typically provided by the MEP design engineers and supplemented by the commissioning consultant, provides an overview of what design criteria were used in the design process, assumptions that were made, and a description of the types of systems serving the facility.
2. The Verification Test Procedures are usually included in the commissioning report. Blank copies provide the in-house O&M staff a means to retest the systems in the future. Actual field copies are also included which, like a start-up sheet, provide documentation of how the system was performing at the time that it was commissioned.
3. The Corrective Action Log documents any issues that were discovered during the verification testing process by providing a quick description of the problem and how it was resolved. This log has a diagnostic value as well. The O&M staff can look through the log to find out if a similar problem was discovered that they are currently having, its resolution, and the contractor who resolved it. This provides them with a starting point in the troubleshooting process.
4. System Training Documentation, provided by the commissioning agent, is designed to provide the O&M staff with an understanding of how the systems are designed and operated as a system, and are useful for ongoing training of O&M staff. The Systems Training is designed to supplement the contractor/equipment manufacturer training, which is more on the component level for individual pieces of equipment. Systems training deals with the interaction of these components into one entire system. Schematics are provided which show examples of the system flow diagrams and control sequences. Typically, a systems training session is provided to review this documentation with the building's O&M staff.
5. The Commissioning Specification in the contract documents had extensive requirements for contractors to submit detailed Preventive Maintenance data for owner's Computerized Maintenance Management System (CMMS). The MEPFP contractors who provides the equipment, and who are responsible for the equipment during the warranty phase, could be tasked with providing the preventative maintenance procedures, schedules, and data retrieval information needed for the CMMS in a downloadable electronic format, or this task could be part of the commissioning agent's scope of work.
6. The Commissioning Manual includes the final Testing and Balancing Report and As-Built Controls Submittal. These documents are critical for facility O&M staff in ongoing facility operations.

Overall, the commissioning documentation is a great reference to assist new personnel on how the building should be operating and its original history. It can be a single source guide to quickly get acclimated to the major systems of the building.

9. Project Quality Control (QC) and Quality Assurance (QA) Processes

In broad terms, the construction team provides the QC and the independent commissioning process provides the QA on the project. In our opinion, both are essential to successful project execution. The following points must be considered:

- a. Owner must provide and demonstrate a strong commitment for the QC/QA process, including commissioning.
- b. The CM must provide capable personnel dedicated to QC and submit a written QC process and provide documentation of its performance.
- c. Commissioning agent (CA) should review the QC personnel qualifications and written QC process and documentation provided by CM. Perhaps interview and participate in the selection process.
- d. The CM should ensure that sufficient manpower from contractors is available for functional testing of systems.
- e. Owner should back charge CM for retesting by the commissioning agent after an agreed upon allowance is consumed.
- f. CA should attend the project construction meetings on a regular basis. CA should be kept in the loop by the owner and will attend meetings as directed. CA will conduct commissioning focused meetings.
- g. Owner should have a Clerk of Works onsite.
- h. Contractor's QC personnel to inspect the equipment in the field to confirm appropriate condition and ensure that correct equipment is onsite.
- i. It is critical that CA be kept in the loop by the CM and/or Architect on design changes during construction for systems being commissioned.
- j. CA attendance in the coordination meetings will not add value.

10. Field Support

The traditional commissioning scope for most projects is limited interaction by the commissioning agent in the field during construction and to rely on the construction manager's QC leadership and documentation. The process works well if the CM is strong, communicates well with all subcontractors, consultants, and owner's agents, including commissioning agent, and keeps good schedules.

However, if that leadership is not strong, the commissioning process does not work well. The recommendation here would be to provide additional field capability by the commissioning agent, which can be very effective.

It is suggested that the commissioning agent provide more field presence to witness equipment pre-functional testing, and inspection of installation quality. The traditional practice of preparing and witnessing Functional Testing Procedures (FTP's) will continue.

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References

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NFPA 101, *Safety to Life from Fire in Buildings and Structures*, National Fire Protection Association, Quincy, MA, 2000
UL1999, UL555S, *Standard for Smoke Dampers*, Underwriters Laboratory, Inc., Northbrook, IL

Appendix A: Suggested Commissioning Scope of Work

Category & Scope of Work	Phase	
	Hours	Fee
Design Intent Document (DID) Development & Update		
Project Drawing & Specification Reviews (Schematic, DD, 50% CD, ATC(2), Pre-Purchase, and CD Sets)		
Submittal / Shop Drawing Reviews		
Commissioning Specification		
Prefunctional / Startup Checklist Development		
Functional Performance Test Development		
O &M Manual Review & Comments		
Prefunctional Checklist Review and Approval, Selective Witnessing of Start-ups, Field Inspections		
Functional Performance Tests, Reports, & Logs		
TAB Review and Confirmation		
LEED® Recommissioning Manual (Required for Additional Commissioning Credit - EAC3)		
Building Envelope Commissioning		
Project Management		
ATC Mock-up		
Coordination Document Review		
Monitor Contractor Training		
Project Meetings		
Electrical Coordination Study Review		
10 Month Warranty Review		
Subtotal		
Expenses (Allowance)		
Retest & Documentation Fee (20% Retest allowance)		

Appendix B

Systems to be Commissioned

Fire Protection

- Hydraulic cleaning and flushing
- Performance verification

Plumbing

- Hydraulic cleaning and flushing
- Thermometers and gauges
- Sump pumps and ejectors
- Traps and applications
- Backflow preventers
- Water heaters
- Domestic water booster pumps
- Vibration isolation
- Reverse osmosis and/or de-ionized water systems
- Medical gas systems
- Oxygen systems
- Vacuum Systems
- Medical air systems
- Medical gas alarms

It is assumed that the functional testing portion of the commissioning of the plumbing and fire protection systems will encompass monitoring the contractor testing for adherence to the required NFPA standards.

Heating, Ventilating and Air Conditioning (HVAC)

- Thermometers and gauges
- Sensors and actuators
- Vibration isolation
- Steam and condensate systems
- Hot water heating systems
- Glycol heating systems
- Chemical water treatment systems
- Chillers
- Cooling towers
- Condenser water system
- Chilled water system
- Air terminal system and VAV components
- Humidifiers
- Duct silencers, other sound attenuation devices

- Fire, Smoke and Combination Smoke/Fire Dampers
- Variable speed drives
- Air distribution systems
- Air handling (supply and return) systems
- Smoke control systems
- Exhaust air systems
- Exhaust fans
- Utility metering

Terminal box functional testing is assumed to be performed on a sampling basis of 50% of the boxes serving critical spaces and 10% of those serving non-critical areas.

Automatic Temperature Control System (ATC)

- Component calibration
- Control air supply
- Sensors and actuators
- Sequence of control
 - Chillers
 - Cooling towers
 - Stairwell Pressurization H&V
 - Smoke Control Systems incl. Fire Command Center
 - Exhaust air fans
 - Heat exchangers
 - Air terminal units
 - Pumping systems
 - Condenser water system
 - Steam humidifiers
 - Water heaters
 - Duct heating coils and radiant panels
 - Economizer systems
 - Critical Alarms and Sensors
- Graphics displays and display recommendations

Electrical Systems

- Electrical primary voltage
- Emergency power system
 - Life safety
 - Critical
 - Equipment
- Emergency generators and paralleling gear
 - Load Shedding Sequence
- Complete Power Outage
- Automatic transfer switches
- Lighting controls

- Electrical sub-metering
- Network Protectors
- Isolated Power System
- Nurse Call System

Fire Alarm/Life Safety Systems/ Security

- Fire alarm systems
- Emergency lighting system
- Access control and alarm monitoring

Intersystem Functional Performance Tests

- Building Automation Systems Controls
- Heating, Ventilating and Air Conditioning
- Automatic Temperature Control
- Emergency Power
- Fire Alarm (Engineered Smoke Control Systems)