

Mission Critical Commissioning for Healthcare Facilities

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Synopsis

Healthcare Facilities serve a critical and unique mission. Few facilities delivered by the construction industry serve occupants and staff with such critical, life supporting needs. These facilities care for patients who in many cases are neither ambulatory nor healthy. In case of emergency, many patients are not physically able to egress from the facility. Systems must contain and isolate any life threatening event that may occur. Many of the patients require protection from contamination as they recover from surgery or illness. Patients may be so ill that they must be isolated so they do not contaminate staff or other patients. The systems in healthcare facilities must address these needs in all possible scenarios of operation.

This paper will discuss the various critical systems that create the required environment for healthcare facilities and the criticality of the commissioning tasks that must be performed for such facilities. The critical nature of integrating systems will also be discussed.

About the Author

Steven R. “Rusty” Ross, PE, LEED® AP, CxA, Director of Commissioning Services for SSRCx, is a 1974 graduate of Vanderbilt University in Nashville, TN with a Bachelor of Science in Mechanical Engineering. He is a member of BCA, ASHRAE, USGBC, ACG, and is a registered mechanical engineer in 8 states.

Mr. Ross has championed commissioning at SSR, starting the commissioning group in the late 1990’s. Prior to SSRCx, he served as Director of Construction Administration at SSR for 20 years, primarily involved in healthcare projects in over 30 states. As Director of Commissioning Services he is responsible for all commissioning related operations. He is also responsible for developing commissioning standards, plans and specifications, and other commissioning tools used by his firm’s commissioning team. He has been involved in hundreds of commissioning projects since starting SSRCx.

Mission Critical Equipments and Systems

There are several mission critical systems that must be addressed when commissioning healthcare facilities. These systems are certainly not all the systems that should be commissioned in this type facility, but these are the most critical. These systems can be categorized by system type. Additionally, interdependency between system types is critical as well.

Mechanical Systems

The mechanical systems that are most critical to healthcare facilities are:

- Chilled Water Systems
- Steam and Heating Systems Including Humidification
- Airside Systems
- HVAC Controls

These systems create an environment that meets the operational needs of the facility. The criticality of these systems is discussed below.

Chilled Water Systems

The chilled water system is critical to providing the cooling for dehumidification and temperature control required in healthcare facilities. This system must efficiently provide the required CHW flow and temperature as the loads vary from the facility. Usually there are multiple chillers and multiple pumps involved in the design of these systems. These most often are variable flow primary or primary/secondary systems. The central system must efficiently satisfy the dynamic nature of loads served. It is critical to insure that the chillers cycle as the loads vary and, in case of failure of a chiller, stand-by capacity starts without losing control on the load side of the system.

This system has one of greatest impacts on the facility's energy bill. It is critical this system operates correctly and efficiently. The challenge of operating this system efficiently is usually greatest in the spring and fall when the system is not required to operate near its peak capacity. Most systems operate more chiller capacity than needed. This is created by the need to satisfy flow in lieu of actual tonnage needs. This often results in operating more chillers than necessary, which is a waste of energy. Chillers operate most efficiently when they are fully loaded, thus it is critical to operate the central system so that the tonnage production from each operating chiller is maximized. The chilled water system may be the cause of this excess flow, or there may be load side conditions that create this problem. It is critical that functional testing addresses central plant functions and the load side conditions to insure the chilled water systems are operating correctly and efficiently.

System Integration

Numerous systems are involved in providing chilled water to the facility. Chillers, cooling towers, pumping systems, plate and frame heat exchangers, make-up water systems, chemical treatment systems, etc. must be integrated to properly provide chiller water to a facility. All individual components and systems must be tested prior to testing the integrated chilled water system. In some facilities, the owner's project requirements (OPR) or the climate will require this system to operate on emergency power. The automatic restart of a chilled water system after the loss of power must be seamless and it must be timely. The criticality of temperature and humidity control demands this system restart with as little impact as possible to the load side control.

The integration between the chilled water system and the air handling units is critical as well. This integration is discussed further in the air handling unit section below. There are often other loads that may be served by the house chilled water system such as radiology equipment, but these loads are more often than not served by independent systems, not the "house" system.

Steam and Heating Systems

These systems meet the critical needs for humidification, heating and sterilization in healthcare facilities. The plant systems can be steam boilers or a combination of steam boilers and heating hot water boilers. These systems must operate correctly and they must be on emergency power and operational at all times. They must have redundant capabilities able to be operated automatically in the case of equipment failure. The steam system must meet the varying load demands of varying critical loads for heating, humidification, sterilization and sometimes domestic hot water systems.

The heating system must satisfy dynamic load conditions also. The heating system may be a series of hot water boilers served by a primary/secondary pumping system. Frequently the heating system involves multiple steam to water heat exchangers with variable flow pumping system. The total capacities of these systems must be confirmed and stand-by capabilities must be tested under all scenarios. There may be energy efficiency controls that must be confirmed such as reset controls for heating hot water temperatures based on outside air temperatures.

System Integration

Numerous systems are involved in providing steam and heat to the facility. Boilers, make-up systems, fuel oil systems, pressure reducing stations, heat exchangers, pumping systems, steam condensate return systems, etc. must be tested individually and as integrated systems. They must be tested on normal and emergency power. Depending on the fuel oil system design, the integration of how that system serves the boilers and emergency generators must also be confirmed. The heating hot water system serves multiple critical loads including zone controls and air handling unit heat and pre-heat needs.

Air Side Systems

These systems meet the critical needs for temperature control, outside air requirements, humidification, and local room pressurization and overall building pressurization. Confirming

these needs are satisfied by the proper operation of these systems is very important. These systems include air handling units, return/relief fans, make-up air systems, exhaust fans, filtration, local zone controls, humidifiers, smoke evacuation systems, stair pressurization systems, etc. The criticality of the individual systems is determined by the loads they serve. Systems that serve the operating suite, isolation room, laboratory, nursery, or ICU are examples of critical systems.

All operational scenarios must be confirmed, including normal power operation, transfer to and from emergency power, operating on emergency power, peak load conditions, varying load conditions, in alarm mode, stand-by modes, night setback modes and over-ride conditions for these setback modes, various filter load conditions, all extreme seasonal conditions, redundancy or stand-by capabilities, etc. All these scenarios and capabilities must result in the load being maintained within the required tolerance (i.e., under all conditions the operating room temperature, humidity, air change, outside air change and pressure relationship must be maintained). This must be true for all areas served, and it is essential for life safety.

System Integration

Sophisticated system integration is required to create the environment needed in each individual space. Air handling systems, terminal boxes, air valves, humidifiers, exhaust systems, return air systems interface to satisfy space conditions. As systems interact dynamically, such as fan tracking between AHUs and return fans, the individual space conditions must be maintained as well as the overall building pressurization and minimum outside air requirements.

Systems often are able to operate inefficiently maintain space conditions. Hospitals require a great deal of energy. It is important to minimize the use of energy by documenting systems operate efficiently. For example, chilled water coils must be balanced and controlled to maximize heat transfer and CHW delta T across the coil. Failure to do so will require chilled water system to control to meet water flow requirements, not tonnage requirements. Make-up air systems must modulate the discharge air temperature to match the supply air temperature off the AHUs. Proper system integration is critical to an energy efficient facility.

HVAC Control System

The control system obviously controls all the components of the systems listed above and is an integral part of their proper operation both for function and energy efficiency. It is critical to the facility operator as well. In today's economic environment the HVAC control system is relied upon to maximize the capabilities of the building operator. It must be accurate and reliable. It must be calibrated, points must be mapped properly, alarms must be programmed properly, communications must function properly, etc. These elements must be tested and confirmed during functional testing.

Electrical Systems

The most important electrical systems in healthcare facilities are:

- Unit Subs/Main Electrical Switchgear/Distribution Level Switchgear

- The Essential Electrical System
- Fire Alarm System
- Nurse Call System

These systems provide power to all critical systems in a hospital and provide protection to the staff and occupants.

Main Switchgear/Unit Subs/ Distribution Switchgear

The main switchgear, unit subs and distribution level switchgear are core elements of the normal power electrical distribution system. This gear must be installed correctly and the breakers in the system must be coordinated so that a fault in the system only disrupts power at that level in the distribution system. The adjustable settings throughout the distribution switchgear must be confirmed to be set per the coordination study. Any manual or automatic “throw-over” schemes, kirk-key arrangements, etc. must also be tested. If monitoring systems such as SCADA systems are used or if various levels of the distribution system are monitored by the building management system, these functions must be functionally tested.

Essential System

The essential system consists of two systems: the emergency system, which consists of the life safety branch, and critical branch and the equipment system. The essential system is the most important electrical distribution system in a hospital. All three branches (life safety, critical and emergency) are required to serve the hospital through distribution systems that are physically separated from each other and independent from the normal system (non-essential system). Both the essential system and equipment system are served from the generator or in the case when multiple generators are required, the generators via the paralleling switchgear. Automatic transfer switches are dedicated to the various branches.

All the generators and distribution level equipment (paralleling switchgear, transfer switches, distribution level switchgear within the three branches) must be commissioned. All switchgear operation must be confirmed and all alarms must be observed. All transfer times and delay times must be confirmed. Cool down modes must be confirmed. In systems with multiple generators, priority loads and load shed schemes must be confirmed to be correct. The interface between this system and the fuel oil system, all remote alarms, etc. must be confirmed.

Functionally testing the electrical distribution system is different from functionally testing the loads connected to this distribution system. Because the purpose of this system is to provide power for the connected loads, the essential system must be tested with all connected loads operating and under control. It is essential to confirm these loads are properly configured to operate seamlessly connected to either utility power or emergency and during the transition between the two power sources.

The electrical distribution system and the essential systems are closely reviewed by government agencies and consequently some might consider commissioning these systems redundant to the

code authority's reviews. Commissioning facilitates the process for preparing for the code authority's review and often uncovers issues that must be addressed for code authority approval. Commissioning can also discover issues that may not be identified in reviews by others.

Fire Alarm System

The fire alarm system is a crucial aspect of the life safety of the staff and patients. This system interfaces with multiple systems including the HVAC control system, elevators, the security system, fire protection system, doors, paging system, specialty systems such as smoke evacuation systems, stair pressurization systems, kitchen equipment, etc. There are unique sequences for various fire alarm conditions associated with these other systems that must be confirmed. It is critical to the life safety of all occupants of the facility that all these integrated functions operate correctly. Similar to the electrical distribution systems and emergency power systems, the fire alarm system is closely reviewed by code officials. Again, commissioning helps to insure the systems are prepared for review by the code officials.

Nurse Call System

The nurse call system is the critical communication system between the patients and the staff and in the case of the code blue system, it is a means of communication among the staff. It is critical to document this system function correctly.

Plumbing and Fire Protection Systems

The systems that are most critical in hospitals are the domestic hot and cold water systems and the fire protection system. Medical gas systems are critical as well, but these systems are required to have independent certification, thus they are not discussed here.

Domestic Hot and Cold Water System

The water supply to a hospital is critical. The functionality of the booster pumps, water softeners, and the domestic heating system must be confirmed. Often the hot water is distributed from the heating system at a higher temperature, then mixed to code required levels when distributed to the load. Mixing valves utilized in these instances must be tested under varying flow conditions. The distribution systems can be extensive and the balancing of the distribution system must be verified. If an interface between these systems and the HVAC control system is desired, this interface must be confirmed. .

Fire Protection System

The fire protection system includes the fire and jockey pump, the automatic sprinkler system, pre-action systems, dry systems, etc. These systems must be tested and the interface between these systems and systems such as the emergency power system, fire alarm system must be confirmed.

Similar to the fire alarm system, the fire protection system is closely reviewed by code officials. Again, commissioning helps to insure the systems are prepared for review by the code officials.

Mission Critical Commissioning Tasks

There has been a tremendous amount of effort in the commissioning industry to develop standards for commissioning services. The BCA/PECI, ASHRAE, the USGBC, and others define methods for commissioning. Many of the tasks described in these standards are similar. Not all tasks suggested are as critical to the commissioning process as others. The tasks that are critical to the success of healthcare commissioning will be discussed here. Commissioning is delivered over the course of the project. The phases most often defined are Pre-Design and Design Phase, Construction Phase, Acceptance Phase, and Post-Occupancy Phase. This discussion of tasks will be developed by each of these phases.

Pre-Design and Design Phase Tasks

There are numerous pre-design and design phase tasks that can be performed. These tasks are critical to the success of the commissioning process.

- Development and Review of the Owner's Project Requirements (OPR)
- Commissioning Specifications
- Plan Reviews, SD, DD, CD level reviews

These tasks are critical because the owner's expectations for the project must be well defined, the scope of the commissioning process and the roles and responsibilities of all stakeholders in the commissioning process must be well defined in the contract documents and plan reviews are critical to providing input to the scope of work prior to establishing the final budget price for a project. At the end of the design process, the construction documents must reflect the owner's project requirements and they must define the scope of commissioning.

Owner's Project Requirements

The most important document for defining the expectations for a facility is the Owner's Project Requirement (OPR) document. It describes in measurable terms the owner's expectations for functional requirements and how the facility will be operated. It defines efficiency goals, equipment expectations, owner and user requirements, system expectations, O&M requirements, etc. It is a document that should be developed prior to beginning design. It is a programming document for mechanical, plumbing and electrical systems (and others) similar to programming documents developed for each department in a hospital.

The design and construction industry often confuses the design narrative with the OPR. These two documents serve different purposes. The OPR defines performance criteria and life cycle issues, etc. and design narratives usually describe what building systems will be reflected in the final design. The narrative is often used to quantify the systems so construction budgets can be

established. There is a tremendous difference between defining expectations on how systems are to perform from a description of what systems are to be provided. Without an OPR there is no tool for measuring the adequacy of the systems being designed and constructed against the owner and user expectations. It is critical that these criteria not be assumed. Without an OPR, the commissioning agent is left to assume the design incorporates the owner's expectations. It is critical to be able to measure the design documents' ability to comply with the owner's expectations, and not assume that they do.

Various standards define ways for this document to be developed. The USGBC LEED programs and ASHRAE define the OPR and how it is to be developed. The commissioning agent is involved in the development and/or review of the OPR in these programs. There can be many discussions concerning how an OPR should be developed and what criteria it should address, but at the end of all these discussions, it is critical that this document be developed.

Plan Reviews

The most cost effective design phase commissioning process is the plan review. It is critical because it often serves as a proactive feedback and input to the project team prior to finalizing the project bids. This feedback identifies conflicts, coordination items, maintainability items, incomplete items such as control sequences, system interface issues. All items discovered in the design reviews reduce conflicts and confusion in the construction phase and in the operation of a facility. Items addressed in the design phase will reduce construction costs and operational costs. It is crucial that at least one review be performed on design documents that reflect adequate detail of the systems and required functionality. This detail is often not available until late in the construction document phase. The development of the design and the design review must be coordinated to allow the review comments to be addressed in the design prior to final bid stage.

Should the commissioning agent not be engaged on a project until after the bid stage, reviews conducted post bid stage will provide valuable feedback on items that need to be addressed. Even though the opportunity to address these items prior to the bid phase will be lost, they can still address potential problems before they are discovered in the field.

Commissioning Specifications

It is critical that the contract documents incorporate the commissioning scope through the commissioning specification. This spec informs the construction manager and the sub-contractors of their obligations related to the commissioning process and allows them to incorporate commissioning in their pricing. It is important that the scope as defined in the specifications reflect the commissioning scope as defined in the commissioning agent's scope of work.

Construction Phase Tasks

There are numerous construction phase tasks that can be performed. Below are listed the tasks critical to healthcare facilities.

- A construction phase commissioning plan must be prepared.
- Project specific installation checklists and functional performance test procedures must be prepared.
- The commissioning process must be managed and coordinated with the construction team and commissioning activities must be integrated into the overall project construction master schedule.
- The commissioning plan, installation checklists and test procedures must be updated with any revisions in scope that occur during this phase due to design changes, shop drawing modifications, owner changes, etc.
- The installation of the work must be confirmed as the work is installed.
- Start-up – monitor the planning for and execution of this process

The construction phase should document systems are installed per the contract documents. Installation of all systems should be complete and the preparation of the operating staff should be well underway. Any systems that have been started should have been done so in accordance with all requirements of the contract documents and they should be operating with the appropriate care, chemical treatment, and maintenance to protect the systems from damage.

Commissioning Plan, Installation Checklists and Functional Performance Test Procedures

The commissioning plan should define the commissioning process, identify critical milestones, and define the project deliverables required during the commissioning process. The installation checklists should be project specific, developed such all items are tied to contract document requirements, and when executed should document that the systems are installed per all contract document requirements. The functional test procedures should also be project specific, developed such that all system functions are tied to contract document requirements, and they should reflect all integrated system functional requirements. In some cases separate integrated system functional test should be developed (for example a chilled water system functional test in addition to test procedures for the chillers, or cooling towers, or plate and frame heat exchangers). It is critical the plan, checklists and test procedures be developed. Often the plan is developed during the design phase, but at that stage the plan offers similar definition of the commissioning scope to that offered by the commissioning specification. Depending on when adequate definition of systems is provided in the design phase, the project specific installation checklists and test procedures may also be created in the late stages of the design phase.

Construction Phase Field Activities

The commissioning plan should be a “roadmap” for planning and executing the commissioning activities throughout the project. It is critical that the construction phase commissioning activities document completed system installation, system start-up and preparation of operating personnel. The process should be proactive and integrated into the master project construction schedule. Site visits should occur to document installation as the work is completed such that if any problems are identified they are addressed with no or little impact on the project schedule.

Commissioning meetings may be incorporated into existing project meetings, such as MEP coordination meetings, to eliminate the need for additional meetings for commissioning.

The start-up of systems must be planned. The equipment must be operated correctly, with the proper maintenance and chemical treatment. If the permanent systems are used for temporary heat or cooling, IAQ plans must be developed to define how these systems are to be operated such that they are protected from the construction activities.

O&Ms must be completed and reviewed by the design and commissioning team such that they are available to the operating staff as early as possible, and at least by the completion of this stage. The process of preparing operating personnel must be underway. Plans must be made to coordinate the delivery of training to the operating staff.

Acceptance Phase Tasks

There are numerous construction phase tasks that can be performed. Below are listed the tasks critical to healthcare facilities.

- Functional testing – testing individual pieces of equipment, individual systems, system integration with other systems, testing at part load and full capacity, testing on normal power and the transition to and from emergency power, testing alarms and safeties, etc.
- Owner training and other required documentation
- Final commissioning report

The acceptance phase should document systems are functioning per the contract documents. The operating staff should be trained and equipped to operate the completed facility and the final commissioning report should be delivered to the owner. It is critical that the completion of the acceptance phase delivers to the owner a completed, functional facility. Equally as critical is that all training of the operating staff is completed and all resources required to operate the facility are available to them.

Functional Performance Testing

It is critical that the functional performance testing (FPTs) be complete prior to occupancy. To demonstrate complete system functionality, these tests must be conducted after test and balance of the HVAC system is completed. FPTs must be complete prior to the final functional reviews by the code authorities.

Most often healthcare facilities are completed in stages. Construction schedules are designed to “walk the construction process out of the facility”. It may be top down, bottom up, patient tower first, ancillary second, etc. It is critical to integrate FPTs with the scheduled completion of the construction process. To accomplish this, it must be determined how the systems serve the facility. Then the testing sequence must be defined so that testing of systems can occur as the areas of facility that these systems serve are completed. An integrated functional testing plan is critical to the efficient completion of the construction and commissioning process.

Final Documentation

It is critical that the operators of the facility have in hand all documentation required to operate the facility. The O&Ms should have been delivered at the end of the construction phase and thus available to the operating staff during the owner training program. All other documentation such as record documents and the commissioning final report should be available to the operators before the building is accepted for beneficial use.

Post Occupancy Phase Tasks

There are numerous post occupancy phase tasks that can be performed. The most critical task is the opposed season systems testing. It is critical to functionally test systems in appropriate season, and at peak load conditions. Some systems cannot be adequately tested (humidifiers, air and water side economizers, chilled water systems, etc.) except in the appropriate peak season.