Commissioning of Hospital Projects

Michael K. Mantai, PE, CCP, LEED AP
President, System WorCx, LLC

Kevin L. Stanley
Director of Engineering Services, Lexington Medical Center

Synopsis

Hospital projects are complex and demanding projects to design, construct, commission and occupy. Commissioning of a hospital project entails many challenges for both the Cx provider and the oner that are not present in commissioning of commercial buildings, schools, etc. This paper will discuss the inherent challenges in commissioning a hospital project from the commissioning provider's perspective and the driving factors for commissioning from the owner's perspective, discussing example problems typically encountered in the construction and operation of hospitals.

The overriding mission of any hospital is patient care. From the owner’s perspective, project deficiencies found after occupancy have particularly adverse consequences, and can negatively affect patient care. Commissioning methods must consider this when establishing performance criteria and test procedures. Above and beyond all considerations for energy efficiency, comfort, and other critieria typically focused on in the commissioning process, the systems' ability to provide adequate patient care is the primary design intent.

About the Authors

Michael K. Mantai, PE, CCP, LEED AP, is President of System WorCx, a building commissioning firm located in North and South Carolina. He graduated from Duke University with a degree in Mechanical Engineering and Materials Science. He spent seven years with Westinghouse performing various commissioning activities for mission critical nuclear facilities at the Savannah River Site. Michael pioneered commissioning procedures for fire alarm and fire protection systems at the site. He functioned as an ANSI certified test conductor, system engineer, operations technical advisor, and facility operations and maintenance engineer.

Michael spent 5 years in construction of large hospital projects, applying the principles of mission-critical facility commissioning to hospitals. He also spent three years as the lead mechanical design engineer for a $100 million-plus expansion/renovation project at Lexington Medical Center, one of the largest hospital projects in the history of South Carolina. He is now dedicated to the practice of commissioning all building types.

Kevin L. Stanley is Director of Engineering at Lexington Medical Center, a three hundred and nineteen bed hospital located in West Columbia, SC. In this capacity, Kevin is responsible for maintenance, landscaping, property management, construction, physical plant operations and biomedical services. He has served in this capacity for twelve years and has recently assumed the project manager responsibilities for a 400,000 square foot, $100 million-plus expansion on the main campus. Kevin has a bachelor's degree from Purdue University and a master's degree from University of South Carolina, both in electrical engineering, and is presently serving as the president of the South Carolina State Engineering Society, the state affiliate of the ASHE and the AHA.

Introduction

Hospital projects are set apart from most commercial projects by many factors:

- Mission
- Dynamic design and construction processes
- Complex systems
- Unique systems
- Central energy plants
- Phasing requirements
- Utility interruption limitations
- Inherent operational challenges during the construction phase.

Typically, a hospital project involves the addition of space to an existing hospital, renovation of an existing space within the hopital, or quite often both. The activities within the project can have a profound impact on the existing hospital. Because hospitals operate 24 hours a day, 7 days a week, there is no opportunity to commission systems during "unoccupied" periods to avoid disrupting occupants. Careful planning is required in the execution of commissioning procedures.

The overriding mission of any hospital is patient care, and the commissioning plan must be carefully crafted around this mission. The plan must focus on the systems' performance that is critical to patient care. The plan must also conceive strategies to manipulate systems during testing in a way that does not adversely affect existing hospital operations.

As one might expect, hospital projects have much more stringent design requirements than the typical commercial project. In addition to general building code requirements, most state building codes have special sections outlining requirements specific to hospital buildings. In addition to the building codes, states have licensing boards for hospital facilities. These boards have their own set of requirements for hospital design, construction, and operations.

The design intent for most commercial projects involves a balance between program needs, occupant comfort, energy efficiency, cost, and other factors depending upon the Owner's wants and needs. For a hospital project, the overriding factor that drives the design intent is patient care. All other considerations are prioritized after meeting the patient care needs of the project.

The following factors are normally the most critical and unique to hospitals in forming the design intent for a hospital project, as related to HVAC and electrical systems:

- Maintain minimum ventilation rates for patient care areas.
- Provide means for infection control through the ventilation systems.
- Provide redundancy in the energy providing systems to ensure cooling and heating are always available.
- Provide emergency power capacity for critical HVAC equipment, critical medical equipment, and critical lighting needs.
- Provide for phasing of renovation work and interfaces to existing systems to accommodate continuing operations.
- Include future capacity for planned projects.

The Commissioning Provider should pay special attention to these needs in helping to create the Design Intent or Owner's Project Requirement Documents.

While patient care is the overriding factor in design intent, hospitals are large energy users and, as such, often present opportunities for large-scale energy savings measures that are not available to smaller commercial projects. These can include thermal storage, heat recovery, and power generation, to name a few.

Design Intent and Basis of Design Documents for a hospital project can be useful in ways beyond guiding the design, construction and commissioning process. There is a good chance that the project either includes capacities or means for future expansion, or that the project being constructed will be renovated in the not-so-distant future. Having good commissioning documents gives the owner an excellent resource in developing these future projects.

Requirements for hospital commissioning are emerging in national consensus standards. The AIA Guidelines for Design and Construction of Hospital and Health Care Facilities includes recommendations for commissioning of not only HVAC systems, but Total Building Commissioning. Smoke control systems, often required in hospital facilities, require commissioning to meet International Building Code requirements.

ASHRAE's HVAC Design Manual for Hospitals and Clinics includes a chapter on commissioning, including both general commissioning considerations and specific commissioning considerations for hospitals.

While standards and manuals such as these provide good general guidance on the commissioning process as applied to hospital facilities, there are extensive specific technical and nontechnical considerations that must be incorporated into the commissioning plans for hospital projects.

Technical Challenges in Hospital Commissioning for the Commissioning Provider

Hospitals have many systems that require unique technical knowledge, experience, and commissioning approaches. These can include:

- Large central energy plants, or equipment that serves large portions of the hospital
- Steam at multiple pressures for sterilization, humidification, heating
- Smoke control systems
- Medical gas
- Three-branch emergency power
- Nurse call and other specialty communications systems

HVAC

HVAC systems typically perform more functions than just heating and cooling in a hospital. These include ventilation for infection control and hazardous exhaust, dehumidification and humidification, and smoke control. The commissioning provider may encounter HVAC systems in a hospital project that are seldom seen in commercial projects, including multi-pressure steam, humidification systems, hazardous exhaust, low temperature supply air, glycol cooling, etc.

Patient, staff, and visitor comfort functions of the HVAC system are similar to most commercial projects. But special areas of the hospital require attention by the commissioning provider. Regulations require specific filtration, air change rates, and pressurization criteria for many room types in the hospital, including operating rooms, patient isolation rooms, clean and soiled utility rooms, laboratories, morgues, etc. Test and Balance requires much more scrutiny by the commissioning provider for a hospital project. The typical "within 10%" acceptance criteria for Test and Balance airflow measurements can wreak havoc on pressurization requirements. Consider the following:

An operating room is required to be kept at positive pressure relative to adjacent spaces. The project drawings show an operating room with 2000 CFM of supply air and 1900 CFM of return air. The excess 100 CFM is used to create a net positive pressurization for the room. The Test and Balance contractor balances the supply and return grilles in the room using a standard flow hood.

Test and Balance - the "+ or – 10%" Trap

Design	Actual Balance	Difference
Supply = 2000 CFM	1950 CFM	-50 CFM (within acceptable 10%)
Return = 1900 CFM	2050 CFM	+150 CFM (within acceptable 10%)
100 CFM excess	100 CFM deficit	200 CFM:reversal of room pressure

The operating room meets the acceptance criteria for the test and balance contractor. Yet the room is negative!

Constant volume control is typical for spaces that require minimum air change rates or pressurization. However, constant supply air terminal units are often connected to variable air volume systems. Return air to individual spaces is not usually controlled. Commissioning should ensure that:

- At minimum volume by the system, minimum air change rates are maintained
- Space pressurization is not affected by varying the return fan speed.

For operating room systems and protective isolation patient rooms, duct cleanliness is an issue. Operating rooms require the cleanest supply air possible to prevent infections in exposed tissue. Protective isolation rooms also require very clean air for patients sensitive to infection (e.g. patients with compromised immune systems, bone marrow transplant patients, etc.). The commissioning provider needs to pay special attention to the protection and cleaning of ductwork and the sealing of filters in filter housings for these special spaces.

Operating Rooms often require low temperatures outside of normal design temperatures, while maintaining humidity within limits. It is not unusual to have operating room temperatures as low as 55°F, with the upper limit on room humidity being 60% RH. This requires special glycol or DX-type cooling equipment. Ductwork at low temperatures requires special attention to duct insulation effectiveness to prevent condensation.

Humidification systems are prevalent in hospital projects because of large outside air needs and needs to maintain minimum humidity levels in operating room, labs, and patient care areas. Steam systems involve pressure reducing stations, condensate traps, flash tanks, condensate pumps, expansion loops, and other elements that the commissioning provider needs to include in the commissioning plan.

One challenge to the commissioning provider is ensuring accessibility to above-ceiling items. Large air quantities and ducted return systems make for a lot of ductwork above ceilings. Add to this HVAC, plumbing, fire protection, and medical gas piping, cable trays, conduits, pneumatic tube systems, lighting, and various other services, and you won't find much space leftover in the typical hospital ceiling cavity. This can be aggravated by addition projects where the new floors must match the elevations of the existing floors of the hospital, restraining floor-to-floor clearances.

Typical problems found during commissioning of HVAC systems on hospital projects can include:

- Problems similar to commercial projects
- Constructability, accessibility, and maintainability of above-ceiling services
- Outside air control
- Space pressurization problems (incorrect or insufficient)
- Leaking AHU final filter housings
- Inadequate valving

Smoke Control

Hospitals operate under the "defend-in-place" premise for patient safety during a fire. This premise is that it is not possible to evacuate all of the patients from a hospital during a fire or other emergency. Fire and smoke barriers are designed to compartmentalize fires, so that only a small affected area will need to be evacuated. The HVAC systems are often used to accomplish smoke control, to allow patients in unaffected areas to remain in their rooms. Commissioning of smoke control systems should include the interface between fire alarm and HVAC systems, smoke dampers, doors that are required to close and latch for smoke control, and a check of the maximum forces on egress doors created by the smoke control systems. Commissioning tools to accomplish this include: smoke bombs, micromanometers, and door force testers. Smoke control systems have highly complex interactions and effects on other building systems and components, and often have many problems encountered during commissioning, including:

- Inadequate control of pressure differences between smoke areas by the building management system.
- Fire and smoke rated doors that close and latch normally, but not under pressure differences created during smoke control.
- Egress doors that require excessive force to open under pressure differences created during smoke control.
- Supply duct detectors shutting down AHUs before smoke control sequences can be enabled.
- Recirculation of smoke from AHU relief discharges to AHU outside air intakes.
- Undersized preheat coils (not sized for 100% outside air in winter).
- Accessibility of smoke damper actuators.
- Nonfunctional interlocks with security systems to unlock egress doors on fire alarm.

Electrical

Electrical systems in most hospitals are the most critical to maintaining building operations. Electrical power ensures patient care can be maintained in the form of power for medical equipment, power for critical HVAC systems, and lighting. Electrical systems provide for patient care, patient and occupant safety, and staff communication. Patient care systems include patient monitoring, nurse call, telemetry, and other systems, and are almost always interconnected by the facility's data communications system. Patient safety is provided by fire alarm, security, and emergency communications systems. Basic hospital operations rely heavily on the data and communications systems.

Normal and Emergency Power and Lighting

In a hospital, emergency power systems are separated into three different 'branches' in accordance with the National Electrical Code (critical, equipment, life safety). Commissioning should verify correct branch separation and equipment operation. From a technical standpoint, it

is relatively easy to test that circuits, panelboards, and switchgear are connected to the correct branch. The challenge in commissioning is to accomplish true performance testing without affecting facility operation. The best performance test is to shut off normal power at the main, and observe the operation of the emergency generators, transfer switches, and switchgear, and observe that the proper lighting, equipment, and receptacles remain energized. This is rarely achievable in a hospital where the generators and emergency power system serve other spaces in use. The commissioning plan needs to come as close to the true performance test as possible without jeopardizing the areas that are in use.

Typical commercial projects include lighting on emergency power only to egress the building safely. Hospitals need to maintain minimum lighting in most rooms, because the hospital's operations cannot afford to stop due to a loss of normal power. Commissioning must include procedures to verify correct circuiting of lighting fixtures and adequate lighting levels. Some fixtures have their own battery-packs that require commissioning to ensure proper activation under power loss, proper charging, and proper indication of low batteries.
Grounding is another area requiring special attention, as hospitals require redundant grounding by grounding the raceway for all patient care areas. Problems in grounding often occur where the contractor uses flexible conduit or cabling on patient care receptacles. The raceway must be listed for use as a grounding means.

Low-voltage Systems

Medical equipment and patient monitoring systems are typically commissioned by the equipment suppliers or hospital staff, but most require infrastructure in the form of power and data that needs to be part of the commissioning plan.

Telephone and data, nurse call, paging, and intercom systems are needed for patient monitoring, staff communications, and many other operating functions, and are always critical to overall building operations and patient care. The vendor is often relied upon to ensure functionality of these systems, and they can benefit from being included in the commissioning plan.

Because of the defend-in-place principal discussed above under HVAC systems, fire alarm systems in a hospital do much more than alert occupants and the fire department to a fire. The need for smoke control systems and special requirements for high rise buildings make hospital fire alarm systems more complex. The NFPA 72 fire alarm certification often falls short of true performance testing, and interactions with other systems such as HVAC, fire protection, and security necessitate thorough performance testing by the commissioning provider. Smoke bombs should be used wherever possible to simulate actual fire conditions.

Access control, CCTV, and infant abduction security systems are prevalent in hospital projects. Most critical to the commissioning provider is to test interlocks with the fire alarm system for release of doors held closed by security systems, as this is often a problem. An egress door that remains locked after a fire alarm is activated can have dire consequences.

Plumbing and Fire Protection

These systems often are overlooked in the typical commissioning process, but in a hospital they need to be part of the commissioning plan. Plumbing systems are much more critical in a hospital since they directly affect patient care. Plumbing systems in a hospital usually involve medical gas systems, in addition to domestic water, sanitary waste, and rainwater drainage. Fire Protection systems are critical to maintaining the defend-in-place principal to contain fires to small areas without affecting patient care in the remainder of the facility.

Domestic water is used for critical uses including infection control for hand washing, flushing fixtures for patient rooms, and makeup water for critical equipment such as cooling towers and boilers. Provision of cleanouts in sanitary waste systems is more critical, since problems with drainage must be corrected very quickly. The medical gas certification process required for these systems can have shortcomings that can be addressed in commissioning.

Fire Protection systems often have specific requirements, including: redundant water supplies for fire pumps, and quick response-type heads in patient areas.

The benefit of commissioning on these systems isn't always as obvious as other systems. A problem with an HVAC or electrical system will often manifest itself with observable symptoms after occupancy. Problems with plumbing and fire protection might not be discovered until an event, such as a backed-up drainage system or a fire occurs.

Other Challenges in Hospital Projects for the Commissioning Provider

Hospital projects present as many non-technical challenges to commissioning providers as technical challenges. Renovation projects and the interface of new construction to existing facilities can have complicated phasing plans.

For most hospital projects, building systems are not stand-alone, but are extensions or upgrades to systems that serve the entire hospital. Properly commissioning a system by functional performance testing can have a profound impact on spaces in the hospital that are in use.

In addition, hospital projects can have a long timeframe to get through the design-bid-build process, resulting in project dynamics not seen in the typical project. Changes in medical equipment technology, programming, staff, and hospital needs occur with regularity through the course of a large project. Commissioning must be able to react to these changes effectively.

Effects of Commissioning on existing facility systems

HVAC

Hospital project construction areas must be maintained under negative pressure with respect to occupied areas for infection control, following a formal infection control plan required of any project. This presents challenges to the commissioning process, where HVAC systems are manipulated to different modes that can impact the pressurization of the space. HVAC systems often serve occupied spaces of a hospital in addition to new or renovated spaces involved in the project. Or equipment must be upgraded, modified, or replaced as part of a project while maintainin services to the occupied spaces served by the equipment. For example, testing the shutdown interlock of an air handling unit from the fire alarm system would not be a good plan if the unit was serving operating rooms in use.

Emergency Power

As discussed earlier under the technical aspects of commissioning, performance testing of emergency power systems can be particularly challenging. The key to successful commissioning of emergency power is to set up procedures to come as close as possible to a true test as possible without adversely affecting the hospital operations. This involves working with the hospital staff to plan and set up for this situation. The commissioning provider has to know what will happen if normal power is lost in the hospital, and plan for what the effect of system testing will be. For example, if the staff knows that the normal power service will be interrupted for testing, they can ensure that patient medical equipment in use is plugged into emergency power receptacles prior to testing to avoid unplanned interruption of equipment. Commissioning may be forced to rely on load bank testing and simulate power outages by manipulating individual transfer switches or de-energizing individual power panels in lieu of a full system performance test.

Fire Alarm and other systems

Fire alarm, paging and other systems are typically connected to the building's master systems, and commissioning can activate disruptive audible and visual devices in the existing hospital, as well as activate interlocks with existing systems. Again, the commissioning provider will need to spend time analyzing existing systems to accomplish the goals of commissioning. Knowing only the project's systems is usually not sufficient.

Phasing

A system serving one phase of a project to be occupied should be commissioned, even if it is an incomplete system, due to work to be done in later phases. When the system is complete the effects on the earlier phases, which are now occupied, must be considered. The commissioning plan must carefully consider how phasing will be accommodated. Large projects may involve temporary utilities and/or equipment to allow phasing of the project. Commissioning of temporary equipment can be as important as permanent equipment. The commissioning provider should implement "partial" or "interim" functional testing wherever necessary.

Project Changes

Hospital design and construction is a very dynamic process. The rate and amount of change orders on a hospital project can be overwhelming to a team member not used to hospital projects. What causes so many changes? For one thing, the projects are often very complex, not only in system design but in architectural details. Quite simply, there are many more opportunities for design omissions, coordination issues, and constructability issues.

Medical equipment has caused a collective headache for many a project team; and this pain often extends to the commissioning provider as well. Many pieces of equipment require support from the building systems. This includes electrical power, data, ventilation, steam or water, drains, etc. Medical equipment is only tentatively selected during design. Changes in programming needs, medical equipment technology, or differences in the manufacturer or model of equipment actually purchased, in contrast to what was called for in the design, results in different needs in terms of space and utility connections. The commissioning provider can help this effort by reviewing design documents for coordination with medical equipment, design flexibility in allowing for changes to medical equipment, and early verification of equipment utility provisions.

As mentioned earlier in this paper, large hospital projects can have long design and construction schedules. During this time, hospital staff will inevitably have some turnover. Turnover in key positions can result in dramatic project changes due to different requirements by the new staff.

The commissioning provider needs to be able to adapt and respond to these changes. The most important thing is for the commissioning provider to be included in all change orders. The first task for the commissioning provider is to evaluate the impact of changes on the Design Intent and Basis of Design documents. The Design Intent for the project can easily be changed by a new key hospital staff member with a different idea of how the project should be designed. The commissioning provider should immediately identify effects on the Design Intent. If a change is not consistent with the project Design Intent, the Owner may wish to reconsider the change. If not, the commissioning provider should ensure the Design Intent is revised to reflect any changes. The impacts of these changes on the commissioning plan and procedures must be evaluated and implemented.

The Hospital's Perspective on Commissioning

Hospital engineering priorities are patient care, patient satisfaction, customer satisfaction and then engineering issues. Commissioning helps maintain these priorities in the following manner:

> The hospital has a large maintenance staff, which is a fixed cost. Time spent on troubleshooting systems that don't work properly is not so much an issue of cost as much as manpower allocation. The less time that is spent by hospital staff on troubleshooting systems the more time that can be spent on improvements, resulting in better facilities.

As a hospital with strong ties to our community, patient satisfaction is a high priority. Patient satisfaction also helps revenue and growth by keeping the Medical Center the first choice for our patients. Quality of patient care is dependent on attracting and maintaining quality staff. Systems which operate as designed allow us to better control environment to keep patients and staff satisfied.

Commissioning helps avoid problems that can translate into hard costs to the Medical Center. Down time on systems cause lost revenues, as revenue generating spaces can be rendered unusable by nonworking systems. Inefficient systems use monies in energy costs which otherwise could fund other items important to the hospital.

As a proactive owner, Lexington Medical Center puts an emphasis on design, proper installation, and thorough checkout to achieve the above goals.

The Medical Center's reasons for commissioning are similar in most aspects to any building owner's reasons. But being a medical center also gives us more reasons to use commissioning, including:

- Projects with High Tech Systems…..Central Energy Plant controls, Building Automation, Fire Alarm, Power Monitoring, Peak Shaving/Power Control, Thermal Storage, Glycol Cooling, etc.
- Having a Big Operation means greater possibility for problems
- Projects involve startup of multiple new, complex systems at once

The problems most found in the hospital's projects include the following:

- Phased Work
- All facets of HVAC
- Missing equipment
- Controls

The elements of commissioning we have found most useful as a Medical Center are Design Reviews, Prefunctional Checks, Functional Performance Tests, better training, written Design Intent and the all-inclusive final report.

Our reasons for having a commissioning firm work directly for the hospital are as follows:

- Architects are contracted with the hospital, with engineers normally working for them as consultants. Architectural design is as important as system operation in the Architects' eyes, and there is potential for higher priority on building form versus function. Having a dedicated commissioning firm ensures focus on system priority.
- Contractor/Subcontractors will do only as much as they feel they get paid to do.
- Most hospitals do not have a qualified construction engineer/manager on staff to oversee projects.

- Having a commissioning firm working for the hospital looking over new installations allows medical center staff to perform normal work tasks.

In summary, we look to commissioning as a means to achieve the following:

- Smooth turnover from construction to occupancy. Occupying a project is a monumental task for a hospital, in terms of installing or relocating medical equipment and supplies, familiarizing staff with the new space, obtaining licensing approval, and moving patients. Avoiding system problems with this transition allows focus on these necessary tasks.
- Systems which function as designed.
- Establishing "ground zero" baseline data for future comparison.
- Allowing the hospital to perform core business…patient care…patient satisfaction…customer satisfaction.

Summary

Hospital projects present many opportunities for improvement by implementing the commissioning process. But the inherent technical and logistical challenges associated with hospital projects present significant challenges to the project team and the commissioning provider. It is not nearly enough to simply apply the basic process of commissioning to these projects. The commissioning provider needs expertise in hospital operation and construction and needs unique tools and processes to accomplish the commissioning plan. The hospital owner has different expectations for the commissioning provider. The commissioning provider must also understand these expectations to be successful.

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