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Successful Commissioning of BSL Facilities Requires Teamwork

New Developments and Solutions Call for Coordination Among Stakeholders

The successful commissioning and subsequent start-up of complex biocontainment facilities can be achieved with teamwork and collaboration among all stakeholders at the beginning of a project. The full commitment of stakeholders who are part of the project team is the cornerstone upon which the proper commissioning and smooth start-up will be achieved.

"Having knowledgeable representation from all sides that are practical in their approach and can bring real-life experience to the process is important," says Michael Sholders, manager of preconstruction services at Hensel Phelps Construction Co. in Denver. "It can be a challenge to achieve the correct balance between cost and quality when trying to integrate the resources and efforts of designers, contractors, and the owner/user representatives. This requires having the people on board with the experience who understand where and what can be compromised without impact or with reasonable impact that can be dealt with."

The commissioning process provides a win-win environment for all parties with the owners benefiting from fully operational systems, move-in ready buildings, increased occupant satisfaction, and efficient energy use. The design professionals benefit via operational feedback during the design and reduced requests for information, change orders, and punch lists during construction. The contractors benefit from a focused start-up process, fewer warranty callbacks, and expedited project completion.

"It is critical to get the early involvement of a commissioning agent who knows and has commissioned biocontainment zones in the past," says Paul Stasiewicz, commissioning practice leader at Affiliated Engineers Inc. in Madison, Wis. "Making sure your commissioning agent has experience is priceless."

The primary goals of commissioning are to ensure the systems function per the design and performance requirements, and to make sure the individuals operating and maintaining the equipment have detailed building systems manuals and are properly trained. Incorporating the standard operating procedures of the user groups, researchers, and maintenance personnel will facilitate a more efficient project completion, commissioning, start-up, and eventual operation of a facility.

The Regional Biocontainment Lab (RBL), completed at the end of 2007 at Colorado State University, is a prime example of effective commissioning. The $30-million, 38,500-sf facility features BSL-2 and BSL-3 labs, animal space, offices, support space, and a small GMP manufacturing facility. Design was started in 2003 and construction began in late 2005. The facility is designed to advance the capabilities in research of infectious diseases already conducted at the University.

Commissioning Challenges

The inherent challenges of commissioning are exacerbated by the complexities and interdependencies of today's biotechnology facilities. The challenges can be overcome by obtaining significant involvement of all team members as early as possible in the process of starting a project.

Commissioning challenges include containment integrity, design changes, pressure cascade, redundant system response, system performance limitations, system performance vs. basis of design, user-friendly building documentation, and commissioning specifications, which include integration of commissioning activities, operational demonstration of systems, incremental verification, training, and the use of systems manuals.

"Mock-ups, development of early testing protocol, assignment of dedicated quality control personnel, and early testing are all essential to meeting the containment requirements," says Sholders. "Design changes also pose a significant issue to the commissioning process as changes implemented during the commissioning process may have ripple effects on the other systems and, in most cases, require extensive retesting of systems to ensure functionality."

Project team synergy is paramount to the successful design, construction, commissioning, start-up, and operation of a biocontainment facility. Synergy can be achieved by obtaining input during design from all stakeholders and users, including the construction manager/general contractor and facilities maintenance staff; having the commissioning provider on board during schematic design; holding partnering sessions to keep the lines of communication open; and engaging federal agencies early in the project process. Establishing this synergy and collaboration will help stakeholders resolve problems before they become major issues.

Design Phase Considerations

Proper planning during the design phase will greatly facilitate the commissioning effort. First, it is important to determine the owner's expectations and fully understand the intended uses of the facility by a myriad of user groups. It is equally important to determine the real cost of construction and expected operations during the programming phase. Work within the owner's standards, taking into consideration the equipment service needs, and let the biosafety criteria define how the standards are implemented.

Projects must start right in order to finish right. This also means operating within the rules established by the appropriate federal agencies.

"I had a client tell me 'Don't let your building get in my way. I don't want to put in extra effort to fix something you put in wrong,'" says Randall Larsen, president of The FWA Group in Charlotte, N.C., which served as the lead design team for the RBL project. "The easier a facility is to maintain, the better the facility is going to be and the easier it is to commission. You have to consider quality, expectations, and budget to get the best project result, working as one team with one goal."

Critical design phase considerations must include containment integrity and pressure cascade; true redundancy vs. "belt and suspenders;" testing strategies, criteria, and design development; control sequence strategies; and early procurement of long lead times.

"Redundancies relate directly to the commissioning piece. It goes back to your risk assessments and risk analysis," says Larsen. "If a piece of equipment fails and we lose $100, that's no big deal. However, if the equipment fails and we lose two researchers, that's a big deal. Thinking through everything in this manner will help you get the right redundancies and you won't end up with double suspenders."

Control sequences are the foundation of a commissioning program and redundancies must be included for a facility like the RBL at Colorado State.

"You have to build redundancies for a facility like the RBL," says Stasiewicz, who was the commissioning agent for the project. "You have two air handlers supporting one space--one is the lead and one is a standby--each has redundant sensors. If one sensor fails, make sure you have the redundant sensor from the other unit that can take over for the system. The control sequence is critical to meeting containment and pressure cascade requirements."

It is helpful to have the control sequence developed by an engineer who has experience with a similar facility. Upfront reviews by the National Institute of Allergy and Infectious Diseases and other entities were utilized for the Colorado State project.

"The best thing that was done on the Colorado State project was a joint review headed by the commissioning agent that included the mechanical subcontractor, the controls subcontractor, the facilities personnel, and the design team in which the controls sequence was evaluated in detail and many meaningful changes were made as a result," notes Sholders. "In order to optimize this process with minimal cost impact, these meetings should occur prior to the controls subcontractor preparing his submittal package or at least prior to finalizing the controls sequence."

Building Information Modeling (BIM), a three-dimensional modeling tool which is becoming popular for enhancing project delivery, was not used at the onset of the Colorado project in 2003. However, it was used to coordinate the layout of the mechanical and electrical systems, which provided a more accurate picture for the construction subcontractors. BIM means buildings can be virtually designed before construction starts, resulting in a higher return on investment with improved productivity and reduced downtime. The virtual modeling enables the project team to work together to resolve discrepancies during the design phase rather than in the field.

There are several other design phase aspects that must be considered relevant to biocontainment facilities. For instance, the RBL pioneered the use of a high-pressure water misting fire protection system in the containment zones, which minimizes water and necessary cleanup.

“You must also consider the number of penetrations in the spaces and in our RBL, all of our services come through overhead carriers,” says Stephen Keiss, project manager of facilities management at the University. “Most of them go through plates that are sealed as they are installed.”

Smoke testing was used to ensure the penetrations were properly sealed at the University’s new facility. A negative pressure scenario was created using the bubble-type isolation dampers for supply and return to create the appropriate pressure relationships to adjacent areas. A safety factor of four was used in the test to confirm the integrity of the barrier. Initial smoke tests exposed sealant application procedures that were subsequently modified. This included shutting down the HVAC system in the space to allow the sealant to properly cure prior to testing. The incidents of failed smoke tests were significantly reduced with the changes in application and by allowing adequate curing time.

During the design phase, it is also imperative to right size mechanical space, conduct thorough mock-up testing of the labs, identify emergency spare parts that must be kept in stock for operation and allocate space for them, and leave sufficient room for offices, equipment, and general operating needs.

Construction Phase Considerations

Collaboration of the project team must begin at the onset of a project with active and engaged interaction of all stakeholders. This partnering gives all team members an opportunity to actively participate in the process by working to resolve potential problems proactively, rather than reacting to an issue as the project progresses.

Considerations that should be addressed during the construction phase include the early rough-in of equipment, interstitial collision management planning using computer modeling, addressing air- and water-tight integrity challenges, and eliminating rework by mocking up one room in the containment zone.

“These facilities often contain large, complicated pieces of equipment that oftentimes require early installation and unique rough-in requirements. The pieces of equipment are sometimes purchased outside of the construction agreement and have lengthy lead times,” says Sholders. “Ultimately, equipment rough-in requirements must be determined early so that coordination efforts around the equipment can be completed prior to construction taking place to ensure that containment requirements are met and that work can take place in sequence. It is essential to order equipment early in light of the lead time and the rough-in requirements.”

Testing Phase Considerations

It is never too early to develop a final functional performance test (FPT) protocol because the more familiarity the contractors have with the expectations, the greater the chances are of having a smooth testing sequence. The contractors should use FPTs as a trial run before actual commissioning.

“Encourage and write in the specifications that the contractor will be responsible for executing this functional test protocol prior to the actual testing period,” says Stasiewicz. “They will discover and address issues prior to discovering them during testing, which will slow down the testing at the time you are turning over the facility.”

Establishing the testing and construction schedules is paramount and should be started well in advance of the functional testing. Start at least two months before start-up. Certain commissioning and construction milestones may conflict if all team members do not work together. Have weekly updates and remember that the commissioning schedule includes not only testing, but also training and the transition from construction to occupancy.

During the testing phase, it is important to refrain from doing any system upgrades. It is also important to have a building automation system (BAS) that can provide real time data. The BAS used at Colorado State was a Web-based system where the response time varied significantly and, at times, created delays in the testing and troubleshooting process.

If possible, conduct a bench test of the BAS program and let a controls contractor create a failed mode in a controlled mock-up setting. This will facilitate debugging the system prior to further testing. Do as much upfront testing as possible, simulating true-to-form scenarios and simultaneously testing for more than one failure.

“Your basic commissioning program tests each system to make sure each one functions properly,” says Keiss. “For a critical facility like the RBL, you need to demonstrate repeatable outcomes utilizing a 21-day test. The building systems are challenged with various operational and failure scenarios to confirm correct and repeatable outcomes for a continuous 21 days. The concept was clear that we needed to run this building without any big hiccups for 21 days before we turned it over to the researchers. It took us 54 days and four test starts before we achieved success.”

During the first seven days of the 21-day test period, the most complex operational and failure scenarios were exercised. It was during this initial period of challenging the systems that the most critical shortfalls were identified. Conducting a seven-day test prior to the regular test provides added assurance that any unexpected responses in the systems will be repaired before the 21-day test begins. Testing guidelines must be developed to detail what systems must be tested and what criteria constitutes a failure.

Lessons Learned

"The design of the Colorado State project required the adaptation of traditional building products to containment use, which proved challenging to the team," says Sholders. "In hindsight, there are certain strategies we would have expanded on or employed to assist with the challenges. For example, we would have created additional testing scenarios to prove that the adaptation of these materials was going to function as intended and we would have started this process much earlier."

The testing protocol must be developed very early in the construction and must match the specification criteria for those components. Therefore, when the actual functional tests occur, those assemblies have already been tested to the same criteria.

Functional mock-ups are essential in developing and proving the adaptation of building materials to containment use. Dedicated quality control oversight must focus on critical containment components. Limit the number of zone penetrations by using surface-mounted services. Test to a pressure that includes a safety factor.

In regards to redundant systems, use hard wire interlocks between associated air handlers and exhaust, use dual stage failure sequence to recognize failures sooner, ensure software reset when power fails, and remember that the weakest link is the redundancy of the building automation system.

When checking the pressure cascade integrity, identify the exhaust set point when the air handler fails to control negative pressure, install automatic bubble-tight dampers on supply and exhaust, use visual indicators at doors, and establish a contingency response plan in case of failures.

It is important to be realistic in determining how many people will be needed to staff the facility and what type of experience levels will be needed. Having a back-up contingency staffing plan and periodically re-commissioning systems can be beneficial to long term use and success of the research within.

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Biographies

Stephen Keiss has been a Colorado State University representative/project manager for 15 years. He is responsible for the complete management of construction projects and capital improvements from project inception/programming, design, construction, commissioning, warranty, and beyond.

Randall Larsen, AIA, LEED AP, is president of The FWA Group, an architecture firm specializing in the design of research and education facilities. Since 1979, he has specialized in laboratory and research-and-development facilities throughout the United

States and Canada. His work is concentrated in higher education, health science centers, and the biopharmaceutical industry.

Michael Sholders is an operations manager with Hensel Phelps Construction Co., currently assigned as manager of preconstruction services. Prior to his current position, he served as a senior conceptual estimator. He is a 1967 civil engineering graduate of UCLA and has served as an officer in the Civil Engineer Corps for the U.S. Navy. He has owned a commercial general contracting business and a millwork manufacturing business. He has worked at Hensel Phelps for 15 years, is a designated design-builder with the DBIA and is a LEED-accredited professional.

Paul Stasiewicz leads Affiliated Engineer's national commissioning practice, an internal division of the firm which provides commissioning services as a third-party entity. As a consultant, he has applied his expertise in assisting facility owners and managers in all phases of the facility life cycle. This includes the development and implementation of cost-effective facility management strategies, construction project commissioning, and quality assurance initiatives in project design, construction, and facility management.

This report is based on a presentation given by Keiss, Larsen, Sholders, and Stasiewicz at the Tradeline *2008 International Conference on Biocontainment Facilities* in April.

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Construction Considerations: Construction phase considerations should include interstitial collision management planning using computer modeling, the early rough-in of equipment, addressing air- and water-tight integrity challenges, and eliminating rework by mocking up one room in the containment zone. (*Photo courtesy of Affiliated Engineers Inc*.)

Staffing Plan: Be realistic in determining how many people will be needed to staff the facility and what type of experience levels will be necessary. Having a back-up contingency staffing plan and periodically re-commissioning systems can be beneficial to the long-term successful operation of a facility. (*Photo courtesy of Affiliated Engineers Inc*.)

Zone Penetrations: Limit the number of zone penetrations by using surface-mounted services. Check the compatibility of the sealant with decontamination agents and joining materials. (*Photo courtesy of Affiliated Engineers Inc*.)