COMMISSIONING A MATERIALS RESEARCH LABORATORY

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Synopsis

This presentation will cover the process of commissioning a new 150,000 sq. ft. research facility at Sandia National Laboratories. The laboratory being constructed is a showcase of modern design methods being built at a construction cost of less than $180 per sq. ft. This is possible in part because of the total commissioning activities that are being utilized for this project.

Our unique approach to commissioning will be presented in this paper. The process will be followed through from the conceptual stage on into the actual construction portion of the laboratory. Lessons learned and cost effectiveness will be presented in a manner that will be usable for others making commissioning related decisions. Commissioning activities at every stage of the design will be presented along with the attributed benefits. Attendees will hear answers to the what, when, who, and why questions associated with commissioning of this exciting project.

About the Author

Jerry Savage has a Mechanical Engineering Degree from Stark Technical College in Ohio. He has worked as a laboratory designer and mechanical engineer since 1985. He has designed and built several optics laboratories and renovated a large portion of the Air Forces Weapons Laboratories. Some of these include the Starfire Optical Range and portions of the Chemical Laser Facility. Jerry has also served as design team leader for five years of tool installations and clean room modifications at Sandia’s Microelectronics Development Laboratory.

Jerry is currently employed by Sandia National Laboratories where he is working as the lead mechanical engineer for the Processing and Environmental Technology Laboratory. He is the author of Sandia’s commissioning specification and leads efforts in that direction. He has also worked with the Department Of Energy in preparing their training film on commissioning. He has been working for several years with the design team for the Gamma Irradiation Facility as well as other projects throughout Sandia.
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Background Information “We’ve All Been There”

We cannot get into a discussion about building commissioning without some background information on the project. Different types of buildings require different styles of commissioning. By that I mean that while most commissioning systems will have the same elements the emphasis given to each may be much different between, for instance, a laboratory and an office building. The level of complexity for a modern research laboratory absolutely requires a very tight and comprehensive commissioning system.

Like most of you, we have seen projects go wrong. The learning curve at Sandia National Laboratories that led us to implement commissioning was costly both in terms of money and credibility with our customers. As our building systems became more complex and our customer’s requirements more stringent, we were finding ourselves faced with mounting dilemmas. How do we satisfy our customer’s more stringent ES&H, code, schedule, and budget requirements while actually getting something built? We tried varied approaches that had different levels of success and failure. Usually at the end of the project we had buildings that were a compromise of intended use or required large expenditures of time and cash to satisfactorily complete. HVAC and exhaust systems didn’t work. Controls were not functioning anywhere near intended if they even worked at all. The buildings simply did not meet the users requirements or the intent of the designers.

We stood back and looked at what was going wrong. About this same time the rest of the industry began to stir as well. They were all facing similar problems. Some training programs began to emerge that organized means and methods to deal with these costly issues. Several of us at the labs went to ASHRAE commissioning seminars to retrieve these tools for ourselves. It was found that we all had some ideas and methods that were correct. Some parts of our start-up and design procedures were working well while others were dismal failures. We found that Commissioning systems could tie all the required elements together into something that should work.

We tried commissioning the next building, a component fabrication facility and combined research laboratory. Commissioning was included in the specifications and that alone should have saved us from our, by now, normal fate. Wrong! What we found was that there was a lack of understanding, or buy in, to this method. The contractor did not really buy in to the system and what was specified was found to be too weak. Our own design and construction team did not fully understand the rationale or realize the importance of commissioning as an integral part of the success of the project. After a substantial post mortem of this project, we were now more determined than ever to modify the commissioning specification and make it work for us.

At that point we found ourselves preparing to begin the PETL Project. This project was filled with potential. Potential for great risk of failure or opportunities to finally get the job done right. What you will hear now is the unfolding, pun intended, story of the commissioning of PETL.
Building Use and Design Information

PETL or the “Processing and Environmental Technology Laboratory” is a 150,000 sq. ft. materials research laboratory located in Albuquerque, New Mexico. The structure is of poured in place concrete waffle slabs and pre cast concrete exterior panels. The construction cost was $178 per sq. ft.

Lab Types
- Organic Chemistry
- Welding
- Thin Films
- Ceramics
- Corrosion

Equipment Types
- 46 VAV Fume Hoods
- SEM’s (Scanning Electron Microscopes)
- TEM’s (Tunneling Electron Microscopes)
- MRI’s (Magnetic Resonance Imager)

Design Features
- Central core of labs with perimeter offices
- UBC, H-6 laboratories with “Chemical Free Zones” for technicians
- Once through lab air
- Flexible lab utility arrangement
- Utility zoning
- Waffle slab construction to meet vibration criteria

SNL’s Unique Situation

Sandia National Laboratories, during the design phase for PETL, had a large staff of experienced facilities personnel at the projects disposal. We elected to use this staff to act as the commissioning authority team. While the Commissioning authority on paper is a single point of contact, he or she is actually the head of a large and very diverse team. Since these players all existed for us, we elected to take on this role. We felt that we would be able to act impartially in the user or owners behalf. The roles of the different players in this system can be seen in Figure A.
Figure A: Commissioning Overview Chart

Conceptual Design Phase

We started this phase with a Conceptual Design Report that had been produced by an independent AE Firm. This is a government requirement to get authorization to proceed with design. This could be called the programming phase. We had all the normal high level design programming meetings to set the design scope. These were held with all of the parties that would be involved throughout the project. These included the customer or users, AE, Sandia Design Team, Department Of Energy, Sandia Management, Sandia Maintenance, etc. Many other offline meetings were held with the various parties.
This would be the normal time to hire a Commissioning Authority and bring them onboard. We made the decision at this point that Sandia had the in-house capabilities to handle this role. For this reason we did not feel the need to have a comprehensive commissioning system or plan complete.

A separate line item was not called out in the cost estimates for commissioning. Commissioning costs were listed under each task, mostly in the mechanical areas. We will in the future have a separate line item in the estimates for commissioning activities. There are two major reasons for this. The first being that it will make it much easier to track the cost for commissioning activities. The latter, and I feel even more important, is to keep it paramount in everyone’s mind that commissioning is very important and that it is not just for mechanical systems.

**Commissioning Impacts “What did commissioning do for this phase”**

In our customer’s interest, and with their input, the commissioning team added value to the project in the following specific ways:

- Helped identify special or abnormal technical requirements of our customers
- Help define the applicable codes, DOE, and other government requirements
- Vehicle to input lessons learned
- Addition of a 10,000 ton hour Thermal Storage System to the nearby central chiller plant. This eliminated the need for chillers and towers for PETL. It also added the ability to save $200,000 per year in energy and maintenance. Simple payback is estimated to be less than a year
- Began defining the scope of commissioning for future phases
- Introduction of Vertical and Horizontal utility zoning

**Early Design Phase “Title I”**

Commissioning roles and responsibilities were further defined. The written commissioning specification was completed. At this point the team started to seek acceptance of the
specification within the Sandia facilities management structure. It was explained to these parties that this was a much different approach from anything that we had used before. This new specification put more of the responsibility on the contractor to ensure that the building would operate as intended. We had given the contractor the control of the Test and Balance work that Sandia had traditionally administered. The controls software responsibilities were also given to the contractor. Sandia was to review this work but not coordinate and control it. We felt that this would minimize the finger pointing that we had been seeing at the end of our construction contracts. We believed that you could not hold the contractor liable for work that he had no control over.

The DOE was also coming up to speed on the benefits of building commissioning about this same time. They issued an order requiring that all DOE projects be commissioned. We assisted the DOE with the production of a training film on commissioning that was subsequently simulcast to all DOE sites.

Commissioning Impacts “What did commissioning do for the early design phase”

- Separate air intakes for the air handling units were added to allow us to bypass the energy recovery unit and institute a standard economizer cycle

- An evaporative cooling section was added to the exhaust just upstream of the energy recovery unit that increased its efficiency in cooling mode by 15%

- The AE was told to take a 50% diversity factor on the laboratory make up air units as well as the exhaust system, as had been recommended by the laboratory designers. This resulted in a significant reduction in fan horsepower

- A new system of fume hood controls were recommended to the AE which reduced the cost of this system by approx. $125,000 while giving us more capability
Final Design Phase “Title II”

During this phase of the project our facilities department at Sandia was experiencing major change. These changes were due to the pressures mentioned above in the Background Information. Some of the members of the design team were now reclassified as Systems Engineers. While they were still matrixed to the project department their roles started to shift. This actually had little impact on the project since the new roles were designed to better serve our customers. This is what the team was already doing in the commissioning role. The difference was that now they would continue to own or be responsible for the building after the construction was complete. In essence, they were becoming a future customer of the project. A system of building managers was introduced along with a newly reformed maintenance system. Neither of these changes had much of an impact other than to reinforce what we were already doing. We modified the commissioning specification to accommodate the new roles and players and continued on.

As you will see in the following, the commissioning team was looking out for our customers future needs by getting increased efficiencies implemented in the design. These efficiencies would not have been part of the package from the AE. The reason being that it is in the best interests of the AE to be somewhat conservative with their design. They do not have the tie to the customer’s future operating costs that initiated these savings. An AE needs to protect itself from the liability of an undersized system. While they do meet the Energy Conservation numbers that we specified in their scope, they have very little incentive to surpass them.

Commissioning Impacts “What did commissioning do for the final design phase”

- A large portion of return air ductwork was determined to be unnecessary and removed.
- The requirement for the office walls facing the corridor to have a fire rating of one hour was removed.
- A more efficient multiple boiler system was specified with an efficiency rating of up to 98%.
- Laboratory HVAC system was further refined looking for problems earlier than normal.
- Exhaust duct static pressure was reduced by refining the duct system design. The duct construction pressure class, as well as future operating costs, were significantly reduced.
- Exhaust duct design was reworked to a modular design which was more efficient to operate as well as produce later by the contractor.
- The exhaust duct material was changed from stainless steel to a galvanized system with epoxy coatings and a customer agreed to future limitation. This change saved the project in excess of $800,000.
Construction Phase “Title III”

We entered the construction phase of the PETL project with a pre bid conference attended by all of the hopeful contractors. The commissioning specification was given its own line item in the presentation where it was introduced to the contractors as something to be aware of that was much different than usual. The contract was awarded and again the commissioning specification was called out specifically in the pre construction conference.

Our contractor proceeded to start the project and charged ahead with great intentions. All parties were hopeful that this portion would proceed smoothly. After all we had jointly participated in a partnering session and spirits were high.

The first signs of trouble, on the commissioning side, started to appear as the contractor was having difficulties procuring the test engineer. We finally agreed to their selection fully four months into the construction. The specified time limit for submission of the test engineer’s resume was 30 days. As construction progressed, the contractor continued to lose ground in getting the test engineers commissioning plan to us fully seven months late. This would have been a problem if we had included structural elements of the building as part of commissioning. We had previously elected to keep the structural elements out of commissioning and handle them under our normal specifications. The next, and probably the most important item to slip was the Commissioning Schedule. We never really received a commissioning schedule, let alone one that was integrated into the master schedule until the contractor started to see that they were not going to be able to get the project completed on time. They were now finally seeing that a well thought out commissioning schedule was required. PETL was much more complex than what they had planned on. They also found out that we were a very meticulous and demanding customer.

As you will see in the following construction phase commissioning impacts, all was not lost. The sections of the commissioning specification that were being followed or enforced were providing us with dividends. The Test Engineer and the Controls Subcontractor were proving to be valuable assets.

Construction Impacts “What did commissioning do for the construction phase”

- The Test Engineer brought attention to the contractors scheduling problems.

- The Sequence of operations section of the design was extensively reviewed and modified by the appropriate group which included the Design team, the test engineer, and the controls contractor. Many problems and potential problems were discovered in these meetings that would have been costly to fix later. Input was received from our maintenance staff as well as from our customers at these meetings.
The Commissioning Notebooks, required in the specification for future design and maintenance needs, were started to track and document the commissioning process.

Missing safety systems required to protect the ducting from over/under pressure were identified and the design changed to incorporate them.

Laboratory HVAC Min/Max control problems were identified which resulted in 12 air flow monitoring stations being resized. This would have been very costly later.

Baseline measurements for our pumps and fans were identified as being required during construction to ensure their long life. The measurements were taken.

A redesign of the first floor waffle slab was initiated in order for the contractor to be able to remove shoring six weeks earlier than otherwise possible. This allowed for work to progress in the basement helping with the overall schedule.

A Sandia public relations opportunity was implemented. A web site titled "PETL Pic’s of the Week" was put on our internal web. Answers to frequently asked questions about the Thermal Storage Tank were also posted in this section of the web. This is seen as the modern equivalent of the "construction wall hole" for the curious.

**Evaluation of Commissioning for the PETL Project**

The commissioning process used for PETL was always seen as a learning tool to move us forward in this area. It was never envisioned as being the perfect process. We intended to get it as close as we could and modify it as required for future projects. In that respect, we are considering the process a success. Major changes are slow to large organizations such as ours due in part to the sheer number of issues and people involved. We have taken a large step in the right direction with the goal of continued improvements. PETL should prove the merits of commissioning and clear the way for its use on future projects.

The commissioning portion of PETL is ongoing. The contractors are finishing up their portion of the work as I am presenting this paper. The Sandia Systems Engineers will continue the commissioning process through the next several seasons. The question of what was the overall contribution of commissioning to the PETL project is somewhat complicated to answer. Sandia had a design team in force on previous projects that performed many of the duties that are part of the formal commissioning process. We also perform Value Engineering on all of our projects with the results for the PETL project not being recounted, or credited, here. You will find, in the following, two separate tabulations for commissioning value. One for commissioning of PETL vs. no commissioning at all. The second for the differences of commissioning verses Sandia’s normal project approach.
Commissioning Value vs. No Commissioning

Total estimated commissioning costs for the PETL project are:

- Contractor cost of $200,000
- Sandia’s team cost of $800,000

Total: $1,000,000 or a little less than 4% of the construction cost

Avoided costs or savings. The clearly evident ones are:

- Eliminating portions of the return air ducting $50,000
- Changing the fume hood controller system 125,000
- Exhaust system material selection $300,000
- One hour firewall deletion 25,000

Total: $1,000,000

Energy savings and other lower maintenance costs will total about $300,000 per year. If you multiply this times the expected 40 year life of the building you arrive at a savings of 12 million dollars. Avoided damage, contractor call backs, and future maintenance efficiency items are difficult to put numbers to. Therefore, even though they are significant, we will not take credit for them here.

Commissioning vs. Sandia’s Normal Approach

All of the clearly evident savings seen on PETL to date fall in the “Commissioning Value vs. No Commissioning” category. As with most commissioning evaluations it is difficult to assess the avoided costs. Would we have damaged our HVAC ducts by over or under pressure? What would it have cost at the end of the project to change the code and get the controls working as intended had we not done such an extensive evaluation of the Sequence Of Operations? What would it have cost to not change out the airflow monitoring station when we did? We do not know how many or the cost of contractor call backs at this point since the building is just going into the occupancy phase. The documentation system of commissioning notebooks as well as video taped training sessions will avoid mistakes and not compromise the original design intent during future maintenance repairs or modifications.

I will conclude by saying that the results of commissioning are clearly evident even without taking credit for the avoided costs. Sandia will commission all future buildings. It just makes sense!