USING BUILDING COMMISSIONING TO IMPROVE PERFORMANCE IN STATE BUILDINGS

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ABSTRACT

Using the commissioning process, states are beginning to improve and optimize their existing building stock as well as ensure that their new construction projects perform according to design. This paper reports on the progress a number of states are making in the area of commissioning for both new construction and existing buildings. It discusses the various programmatic approaches they are using to incorporate commissioning into state energy management programs and new construction projects. It also reports the results of a recent survey of members of the National Association of State Facility Administrators (NASFA) on their use and understanding of commissioning for new construction and existing buildings. The results of two commissioning case studies, one for a new construction project in the State of Montana and one for an existing building in the State of Tennessee are reviewed. Key Words: Commissioning, Survey.

administrators know about the concept of building commissioning for new construction projects, a survey of the membership of National Association of State Facility Administrators (NASFA) was conducted in late 1997. The inspiration to conduct the survey came as a follow up to a presentation on building commissioning given by Daniel Abitz of George Butler Associates (GBA) at the June '97 NASFA conference. GBA requested and received NASFA's permission to conduct the survey with the help of NASFA members Ron Wilkinson from the Montana A/E Division and Myron Reed from the Kansas Division of Architecture. Mr. Wilkinson and Mr. Reed are especially interested in gaining information on what level of education the NASFA members need regarding commissioning. This information will be used in developing future NASFA workshops and conference agendas.

481 surveys were mailed to all 50 states plus Washington DC, Samoa, Saipan, Guam, Puerto Rico, and the Virgin Islands. 111 completed surveys were returned for a response rate of 23%. Completed surveys were received from 39 states and from 3 of the 5 U.S. Territories. The survey consisted of seventeen questions. As is typical for most surveys, not all respondents answered all questions. Throughout this section of the paper, the number of respondents corresponding to reported percentages are in parenthesis. Respondents that answered no to question 4 "Are you familiar with commissioning and how it applies to the building industry?" were asked to stop and return their survey form. This reduced the number of respondents for the balance of the survey by 40%. The following summarizes the results of the survey:

Most respondents had construction or major renovations totaling over $250,000 during the last two years (96%, n=105). Eighty-four percent (n=87) reported the total square footage involved was 250,000 square feet or more. When asked how they anticipated this number would change, the

The majority of respondents are familiar with commissioning (60%, n=66). All respondents were asked what they would like to know about commissioning. They were offered seven topic choices in the form of questions and asked to check all that apply. The three questions most often chosen in descending order are:

1. What are the typical costs of commissioning?
2. What is the relationship between Construction Administration and commissioning?
3. What are some case studies of building commissioning projects and the benefits shown by those examples?

The question, "Why has commissioning been invented?" received the least indication of interest.

In the past two years, of those facilities constructed or having major renovations (over $250,000), 34% (n=23) of the respondents reported that their projects did not include any form of

commissioning. Fifty-eight percent (n=39) reported that some of their projects had received some commissioning, and only 7% (n=5) reported that most or many of their projects received some form of commissioning. When asked if the projects planned for the next 12 months (similar to their past projects) will include some form of commissioning, 19% (n=13) reported that projects would not include any form of commissioning. Fifty-five percent (n=38) reported that some of their projects would include some form of commissioning and 25% (n=17) reported that many to all projects would receive some form of commissioning.

The majority of the respondents are of the opinion that the commissioning agent or provider should be contracted directly by the owner (86%, n=60). For state facilities, 78% reported that the agency responsible for construction hires the commissioning agent (n=47).

Only 11% of the respondents (n=6) reported that Testing, Adjusting, and Balancing (TAB) is *always* performed by the commissioning agent on their projects. Twenty-three percent (n=13) reported the commissioning agent *never* performs this service. However, the majority (66%, n=37) fell in between these extremes, reporting that sometimes to usually the commissioning agent performs TAB.

Respondents were asked what systems they thought should be commissioned. They were offered 11 building system types and asked to check all that apply. The following lists the 4 system types receiving the most responses in descending order:

1. HVAC systems and temperature controls
2. Fire alarms
3. Security/Access control
4. Alarm interaction with mechanical systems

Building shell received the least responses.

The respondents were asked to give their opinion as to whether their projects were never, sometimes, usually, or always better as a result of the commissioning activities? Overall the respondents believed that commissioning activities usually or always improved their projects as follows:

- 51% felt that commissioning reduced the construction issues for the owner (n=20)
- 72% felt that building comfort is improved (n=31).
- 63% felt that commissioning reduced warranty period callbacks (n=25).
- 54% felt that maintenance staff calls are reduced (n=25).
- 83% felt maintenance staff training was improved (n=33).
- 66% believed that O&M manuals are improved (n=27).

The respondents were also asked to give their opinion as to what the biggest obstacles are to providing commissioning. Respondents viewed funding and education about commissioning as the greatest obstacles. Ability to demonstrate measurable benefits and availability of commissioning agents ranked slightly lower as obstacles.

COMMISSIONING AND THE STATE OF THE STATES

Like many private owners, state governments have begun to recognize the significant energy savings and other benefits that commissioning can yield. These savings free up state money for more constituent services. In addition, the improved building performance and O&M training resulting from commissioning can reduce states' potential liability for IAQ-related health problems among building occupants. The states listed below have officially begun to commission their facilities.

State of Florida

The Department of Management Services (DMS) for the State of Florida has used commissioning as a critical component in their projects since 1993. The DMS directly hires a commissioning provider for each new construction project. This allows the State to retain more control over projects and assure impartial testing of systems. Commissioning projects such as the new office complexes in Tallahassee and Jacksonville (770,000 sf) achieved significant cost avoidance and improvements in workplace performance and efficiency.

State of Montana

Montana has begun to commission new state facilities. The State prefers to hire an independent commissioning authority and tracks commissioning costs separately from construction costs. As a rule, the State budgets 2-2.5% of the mechanical construction cost and 1% of the electrical cost plus travel and per diem for building commissioning. This paper includes a case study demonstrating the evolving commissioning process for new state buildings in Montana.

Montana plans to expand their retrocommissioning activities underway in the Rebuild America Partnership to state buildings through the Alliance program. Workshops and

case studies will support both retrocommissioning of Rebuild Partners and state buildings.

State of New York

The Flex Tech program sponsored by the New York Energy Research and Development Authority (NYSERDA) offers commissioning to state buildings as one of the technical services. These services have been offered to both new and existing buildings since 1993 (original program through the New York State Energy Office). Beginning in 1997, commissioning services are also offered as part of a financing program available to state facility managers.

Northwest Region

The Northwest Energy Efficiency Alliance (Alliance) recently funded a project to integrate commissioning into Northwest state and local government buildings. The multiyear project includes workshops, case studies, enhanced development of commissioning services, and communications to public facility officials on the benefits of commissioning. States participating in the project include Oregon, Washington, Idaho, and Western Montana.

State of Oregon

The program underway in Oregon focuses on new and existing state buildings. A survey of state project managers has been completed, an introductory commissioning booklet and "commissioning tool kit" have been developed and distributed, and workshops conducted. Some state agencies (Department of Corrections and Department of Administrative Services) are commissioning a few of their buildings. Other agencies have not yet begun to commission their buildings. Oregon's activities as part of the Alliance project includes demonstration projects with quantification of benefits, training of facility and project management staff, dissemination of results, and establishment of state requirements and model policies.

State of Tennessee

The State of Tennessee is developing a retrocommissioning program for all existing state buildings. The retrocommissioning demonstration of the Chattanooga State Office Building was completed in 1997. As part of Tennessee's commissioning initiative, the State Building Energy Management Program will conduct the following activities:

- Develop a commissioning guideline and program design
- Implement additional demonstration projects which integrate commissioning with performance contracting
- Integrate commissioning with the Tennessee Rebuild America Partnership

State of Texas

The Texas State Energy Conservation Office has been involved in metering and monitoring existing state facilities for nearly 10 years. They target buildings in need of continuous commissioning by tracking data collected from monitoring numerous state buildings that have been retrofitted through the LoanSTAR program. The State Energy Conservation Office at Texas A&M University is sponsoring commissioning workshops for state agencies and school district building operators, because the state believes this training will increase energy savings. These workshops are presented by the Energy Systems Laboratory at Texas A&M University. Texas is also working to establish a front-end commissioning component for new construction. The state plans to make the development of a commissioning plan part of the review process for selecting architects and contractors. In addition, Texas plans to begin commissioning HVAC systems (after move-in) by a team that includes the building owner, architect and contractor. The State is currently developing a 330,000 sf office building and hopes to incorporate commissioning into its construction.

State of Washington

The Washington Department of General Administration requires commissioning on all state projects with a construction budget greater than $5 million. However, actual implementation of commissioning has occurred on few buildings. Similar to Oregon, Washington's participation in the Alliance project will focus on demonstrating the benefits of commissioning through quantification, developing case studies, and providing information to state facility and project managers.

COMMISSIONING CASE STUDIES

The following discusses the commissioning findings from two case studies. The first one not only looks at the commissioning findings but also the lessons learned by the state from commissioning a *new* classroom building at the University of Montana in Missoula. The second one includes the findings and estimated energy

savings from commissioning an *existing* state office building in Chattanooga, Tennessee.

Case Study 1: The Evolving Building Commissioning Process in Montana

The Gallagher School of Business Administration ("BA" building) is located on the University of Montana campus (the University) in Missoula, Montana. The building contains classrooms, lecture halls and offices arranged in four levels of 25,000 to 30,000 square feet (sf) each with a total square footage of 110,000 sf. The building HVAC system is a variable air volume design with outside air injection. It is complex for the size and usage of the building, using some 36 air handling units (AHUs-four dedicated to outside air injection), 84 fan terminal units (FTUs), 35 variable air volume boxes (VAVs), 30 pumps, 8 heat exchangers, 29 excess air ventilation, exhaust and pressurization fans and 18 unitary heaters. The system employs VAV operation in all zones, ground water heat rejection in conjunction with the chiller and also direct ground water cooling, chiller cooling heat reclaim, and a complete direct digital control (DDC) energy management and control system (EMCS).

Total building construction cost, not including design fees, is about $14,000,000 or about $125/sf., making the BA building a structure of above average expense. Mechanical costs are about $2.2 million and electrical costs are about $1.5 million, totaling about 26% of the total construction cost.

The Commissioning Process.

The BA building was constructed using the design-bid-build process, managed by the Montana Architecture and Engineering Division (the Division). The building design process was started early in 1992. Construction started in June of 1994 and continued until occupancy in July of 1996. Although the building was somewhat unfinished in July, the university insisted on occupancy and the building was fully occupied while the final stages of construction were in progress.

During the design stage of the project, the consultant had been instructed to add notifications in the specifications indicating the project would be commissioned. This verbiage was included in divisions 13 and 15 but nothing else was done until construction was nearly complete. Commissioning was not discussed with the contractor in any significant way throughout most of the project. As the end of the project approached, the Division decided to begin the commissioning process. A contract for commissioning was signed with the consultant in March of 1996 and the commissioning kickoff meeting was held in April of 1996. This allowed the consultant/commissioning firm (which had little or no prior commissioning experience) about four months before occupancy to perform the entire commissioning process on a building of well-above-average complexity.

Being the first commissioning project for both the Division and the consultant, the process of negotiating the fee was difficult and the end result, in retrospect, was a substantial under-funding of the work. By way of comparison, using a rule of thumb, the sum of 2% of the mechanical costs plus 1% of the electrical costs yields a nominal fee of approximately $59,000. Current practice in Montana is to allow travel, per diem, video-taping and similar extras on top of the nominal 2% and 1%, which might boost the currently accepted commissioning fee on a similar project to the $60,000 to $70,000 range. The fee allowed for the BA building was about $23,000. So, from the start, this commissioning project was under-funded and short on time. But what ensued was even worse.

At the commissioning kick-off meeting in April of 1996, the consultant had turned over to the contractor a three-ring binder containing several hundred pages of static inspection and functional test check lists which the contractor was asked to complete as proof that the system was correctly installed and operating. The consultant knew the commission budget was very limited and hoped to use this as a way of getting the commissioning done for the right price. The plan was to check selected aspects of these checklists during the normal punch list inspections to confirm that the contractor had filled out the sheets accurately. As much as the consultant tried to describe commissioning during the kick-off meeting, the contractor left the meeting apparently assuming that the several hundred pages of checklists were little more than just another punch list.

By mid-summer, all of the checklist pages had been completed by the various sub-contractors. Unfortunately, the *actual* punch list completed shortly after the commissioning list contained some 700 incomplete, unfinished or unworkable items. Furthermore, all test and balance reports submitted to the consultant were rejected as incomplete or so poorly documented that they were not credible.

The T&B firm was (and is) an independent company, NEBB and AABC certified. The T&B firm was selected by the plumbing sub-contractor and although the Division is not shown sub-contractor's bid amounts or sub-contracts, it appeared the T&B sub-contractor was paid correctly. The Division received no particular complaints from the T&B firm, such as complaints that they were not being paid or that their bid had been too low. They simply failed to perform in the manner required by the construction documents.

All of the above indicated that the consultant's completion of the commissioning checklists apparently had very little effect on the resulting quality of the project. At this point the consultant had spent over half of his commissioning budget of $23,000 and the University had several hundred pages of completed checklists of apparently little value.

Building Operating Problems.

Winter came early during the fall of 1996. The operation of the building was a disaster. HVAC complaints of every kind poured into the campus Facilities Services office, daily. Rooms were too cold and airflows were too high. Other rooms were too hot. A stairwell attic space temperature was measured at 22 F. Entry areas and stairwells were so cold that fire protection sprinkler heads froze, broke and flooded the spaces. An AHU was reported as inaccessible with the filter so dirty that it was being sucked into the fan by the airflow. VAV dampers were hunting at low flows and could not be controlled. Drafts were coming in through return air ducts and into offices. An odor was so bad in a lecture hall that the class had to be moved.

The consulting engineer/commissioning agent was trading letters with the out-of-state test and balance firm and making little or no progress in getting an acceptable test and balance (TAB) report and getting TAB problems rectified. Even worse, the consultant now said that because the completion of the building had been delayed, he no longer had staff available to perform even the little commissioning he could do with the remaining budget. Clearly something more had to be done to get the building at least stabilized and operating safely.

The Commissioning Process has Changed.

As a result of all of this, the Division made a radical change in the commissioning plan. In November of 1996, they negotiated an end to the commissioning the consultant had completed at that point and approached a newly formed commissioning specialty firm to do the work. At the same time, the budget was re-evaluated and a new budget of approximately $65,000 was established.

The firm proposed a detailed scope of work, broken down by system, which included most of the systems and most individual pieces of equipment. The scope was trimmed somewhat from complete mechanical commissioning to concentrate resources on systems serving areas which had the most complaints.

The total proposed fee for this work was just under $62,000. The Division accepted the proposal and sent out the contract in early January. The kick-off meeting was held during the last week in the month and was attended by the original design team as well as representatives of all of the subcontractors.

As the work proceeded through the next several months, the commissioning agent worked with the university staff to solve, or at least mitigate, problems as they were encountered. Small and clear-cut problems were fixed on the spot during the commissioning process, but most problems were recorded and organized for discussions with the contractor later. No significant changes were made by the commissioning team because the project had not received "final completion" status and was, at least technically, still under the control of the contractor.

Commissioning Findings.

In June of 1997 the preliminary findings of the commissioning were distributed. The findings of the commissioning team were lengthy. The more major findings are summarized as follows:

For the AHUs, 112 discrepancies were identified including the following:

- Schedule times were incorrectly programmed in the EMCS
- Damper sequences were incorrectly programmed
- Some fans were operating at excessive volume and their motors were being over-amped
- High efficiency motors had not been supplied as specified
- Hot deck temperature sensor was installed in the cold deck
- Variable frequency drives (VFDs) had received virtually no programming on the project

- No maintenance access panels on some AHUs
- Minimum outside air in some cases 20 to 30% as opposed to required 10%
- Minimum outside air set to 0%
- Nuisance trips on freeze 'stats
- VAV box parameters incorrect causing incorrect volume indications on computer

For the fan terminal units 24 discrepancies were identified, most of which were identified on multiple units. The discrepancies included the following:

- Poor maintenance access, no access to unit reheat coils for cleaning
- Automatic flow control valves too small
- Controls not correctly calibrated
- Averaging and reset temperature control strategy programmed incorrectly
- Supply air diffusers noisy and windy, fan terminal volume too high
- Scheduled minimum air volume at all units too low resulting in lack of control

For the cold water/ground water pumps 16 discrepancies were identified, including the following:

- No VFD programming for variable speed pumps
- Ground water/cold water pump coordination and sequencing is incorrect
- Specified cold water pump sequencing plan may be impossible to achieve
- Ground water pumps are operating off their design curves, must rebalance
- Reinjection valve pressure control sequence unworkable

For the chilled water/heating water systems 25 discrepancies were identified, including the following:

- Specified pump sequencing plan may be unworkable
- Flow sensors more than 10% out of calibration
- Three pumps programmed to stage rather than specified two pumps with one as back-up
- Pumps operating off published pump curves
- Heating water pumps balanced with three running instead of two as specified
- Condensate pump motors overamped
- Pumps below design flows with balance valves wide open

For the fire alarm systems, ten discrepancies were noted, four of which were identified on multiple units.

- Most zones had at least one fan which did not shut off when the zone was in alarm
- Smoke damper had linkage disconnected
- Naturally aspirated smoke detector has insufficient pressure (P) across ports to provide a sample
- Smoke detector located downstream of VAV box
- Smoke detector located upstream of return air branch

Correcting the Problems.

In mid July a meeting was held to discuss the disposition of the findings. All concerned parties were at the meeting including representatives of all sub-contractors. The discrepancies were reviewed and discussed, one by one, and responsibility assigned for the correction of each item. Most items fell to the temperature control (EMCS) contractor and the TAB contractor but there were assignments for everyone present, including the design consultant and the university staff.

Progress on correcting the problems identified during the commissioning process has been slow but steady. At the time of this writing (December 1997) approximately half of the discrepancies have been corrected and the consulting engineer has submitted all of the required corrections to the original pump sequencing plans to allow the reprogramming of the EMCS. The TAB contractor has been slow in performing throughout the project and the project team is continuing to work through the remaining TAB issues.

Lessons Learned.

Like any first experience, the Division learned a number of lessons from this commissioning experience. Among those are:

- Include the Contractor in commissioned projects

Include specific language in the design specifications indicating the project will be commissioned so that the contractor is part of the commissioning team right from the start. The Division now contracts with the commissioning agent before the design is complete and assigns the agent the responsibility of writing a division 17 in standard CSI format. Division 17 is to thoroughly describes the commissioning process, indicate which systems will be commissioned and describe which sub-contractors are required to be present during testing.

The agent also includes references in division 15 and 16 specifically indicating that commissioning will take place and directing the sub-contractors to division 17 for a complete description. Commissioning language is also included in division 1, which indicates that the project will be commissioned and that completion of commissioning is a requirement for substantial completion of the project. Commissioning is clearly described as not being a punch list and as not taking the place of TAB, normal construction administration or the normal punch list procedure.

After the award of the project, the commissioning agent contacts the contractor, discusses the commissioning process and forwards a commissioning schedule to the contractor for inclusion into the contractor's schedule. The submittal of the overall project schedule and the schedule of values by the contractor is a requirement for the payment of the first contractor pay request. These schedules are checked to confirm that commissioning appears in each.

As the early stages of commissioning take place in the form of static inspections and hydrostatic testing of piping, the contractor gets to know the commissioning agent and learns that the process is real and needs to be understood.

• Start the Commissioning Process During Design

As described above, the commissioning agent is part of the design team and builds quality into the project at every stage of construction. If the agent is brought into the project at the last minute, his work is compromised by a lack of time. The Division has seen good results from also assigning the agent the tasks of writing portions of the specifications relating to commissioning. In fact, the Division has expanded the duties of the agent in this area and now has the agent write portions of the specifications relating to O&M manuals and training as well. On a recently started project, the commissioning agent visited the operations staff at the site during the design process, interviewed them about training and O&M manuals and included their specific requirements in the appropriate specification sections.

• Adequately Fund the Commissioning Process

Costs of commissioning vary depending on the extent of the work. The Division has had good results from commissioning mechanical and electrical systems and doesn't do "whole building" commissioning. Usually a sampling of multiple identical units (such as VAV boxes and FTUs) is adequate to assure quality. Include notice in the specifications to the contractor that if discrepancies are found in a certain percent of the sample (say 15%), a new sample will be chosen next time and the additional commissioning expense will be paid for out of the contractor's retainage.

Rules of thumb on 2% to 2 ½% of mechanical construction cost and 1% of electrical cost work out to be about what the Division's commissioning agents are submitting in their proposals. The Division allows travel costs, per diem, and extras such as video-taping added to this cost.

The Division is continuing to research how much commissioning adds to the contract bid price and has begun to list this value in the bid submittal as a separate line item to track these costs. As described above, the contractor's cost of commissioning should also appear in the schedule of values and can be tracked that way, too. Experience to date had shown that the contractor might add about one third the amount of the commissioning agents fee to his own bid to allow for extra time taken by his sub-contractors. The Division hopes that eventually this amount will go to zero when the contractors learn that commissioning is in their best interest due to a reduction in warranty work.

• Use an Independent Third Party to Commission

As much as the Division respects the contractors and consultants who do our work, we believe it is impossible for anyone to completely and dispassionately check and correct their own work, especially when the correction results in extra work or rework for them. This is consistent with standard quality control practice in other industries around the world and would seem logical for the construction industry as well.

We have learned that commissioning is a process that means extra responsibilities for the Owner. The commissioning agent can not do it all without Owner oversight. For this reason we contract directly with commissioning agents, as opposed to contracting through the design architect or through the contractor. We track the work of the commissioning agent independently of the rest of the construction administration.

• Make Commissioning a Requirement for Substantial Completion

The overall main benefit of commissioning is to identify problems in the design and construction of the building *before the design/construction team has left the site.* The Division and our client

agencies agree that we are not concerned with penalizing our consultants and contractors for mistakes. Rather, we are very concerned that our operating staffs are not stuck with the mistakes and left to re-design or re-build parts of the building with their limited resources. We want the problems solved while the resources are on the site, and this means before substantial completion.

Although substantial completion means different things in different locales, the intent is the same: complete commissioning before the bulk of construction retainage is released. The best possible arrangement is to demand that commissioning be completed before occupancy. But even if this is not possible (sometimes the client agency is simply too demanding and too powerful), it still may be possible to complete commissioning prior to releasing construction retainage. The retainage is a powerful tool in getting problems corrected and getting a building ready to turn over to the operating staff.

Remember, completion of commissioning included completion of all training and all O&M manuals (the Division is also requiring O&M manuals sooner in the project, at a stage of 50% to 75% complete, so that training can take place simultaneously with commissioning).

• Use Remote Monitoring to Assist In and Understand the Commissioning Process

The Division is also experimenting with the remote monitoring of the building's EMCS host computer during the final stages of construction. This helps the Division understand how the building is working, helps define problems with more accuracy and provides a transition period to work with the building staff and improve their training. Monitoring is something that should be done by the Owner's engineering staff because it also provides invaluable insight into design details and improves the staff's ability to check and critique the next project.

• Consider Contracting Directly with the TAB Firm

On this project, the Test and Balance sub-contractor was farther removed from the general contractor than any other firm on the construction team. This makes it far too likely that T&B concerns will never get to the owner. The Division is currently configuring several test projects with the T&B contractor contracted directly with the Division and also with the T&B contractor contracted through the commissioning firm. Local T&B firms have been very appreciative of these changes and the Division is

Case Study 2: Commissioning New and Existing Systems in the Chattanooga State Office Building

Introduction.

In 1994, the State of Tennessee in its efforts to explore the benefits of building commissioning attended the second National Conference on Building Commissioning and began an initiative. The initiative seeks to educate and obtain a commitment from key administrative state government officials, explore the barriers to efficient buildings in Tennessee, and develop guidelines for implementing building commissioning programs and activities for the state. The State Building Energy Management Program (SBEM) under the Department of General Services (DGS) is primarily responsible for this effort. Although they have experienced both successes and set backs in making commissioning "business as usual" for the state, they remain convinced that commissioning activities are the catalyst for overcoming the barriers to efficiently operating and maintaining their buildings. This case study presents the findings from the State of Tennessee's commissioning demonstration project using the Chattanooga State Office Building[1]. This project was competed in 1997.

Project Scope and Objectives.

The initial scope of the project included commissioning for the existing building systems in the Chattanooga State Office Building.. However, as the project began to solidify, it was decided that commissioning would also include the new energy management control system (EMCS). The expanded scope allowed the project to demonstrate the commissioning outcomes for both a retrofit as well as for existing HVAC systems. Although some of the improvements implemented using the new EMCS could have been accomplished with the existing EMCS, it lacked several points of control necessary to support more sophisticated control strategies. This coupled with the fact that the specified training was never provided to the building staff and the vendor was continually unresponsive to the staff's requests for assistance caused the replacement.

Commissioning of a new installation cannot guarantee a vendor will be responsive once the job is finished, however, had the existing control

[1] Haasl, T. and Edmunds, D., *The Role of Existing Building Commissioning in the State of Tennessee's Energy Management Program,* Fifth National Conference on Building Commissioning Proceedings, 1997.

system been commissioned when it was installed, it would have ensured that the system initially operated and met design intent. It would have also ensured that the building personnel were trained as specified.

The following lists the commissioning project objectives:

- Obtain cost effective energy savings from commissioning building systems. This requires monitoring selected building systems.
- Identify and recommend operations and maintenance procedural improvements focusing on those measures that will sustain optimal energy performance and reduce operating costs.
- Identify HVAC related health and safety issues as they present themselves during the normal course of the commissioning work.
- Obtain background information for the development of a state-wide program design for commissioning all existing state buildings.
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Building Description.

The Chattanooga State Office Building, located in Chattanooga, Tennessee is a seven story, 175,000 square foot office building with an underground basement. The east wing of the building was constructed in 1950 and the west wing was constructed in 1970. The building uses natural gas for heating and electricity for cooling. New chillers along with a DDC energy management control system (EMCS) were installed in 1994. However, the EMCS was replaced with a new system during 1996-97 commissioning study.

The mechanical system is a built-up (two-pipe) system composed of 19 air handling units and approximately 418 under-window unit ventilators. The primary plant equipment is comprised of two steam boilers, a hot water heat exchanger, two 300 ton chillers and one open loop cooling tower. The main control for the HVAC equipment is accomplished with a DDC energy management control system.

Lighting control is accomplished by manual switches. The lighting for the office areas consists primarily of standard ceiling mounted fixtures containing two to four 34-Watt fluorescent lamps with incandescent lighting in the entry lobby.

For the most part, in-house facility staff members perform the preventive maintenance tasks for the HVAC systems. Service contracts exist for annual and semi-annual maintenance on the boiler and chiller plant equipment.

Commissioning Approach.

Through an on-site commissioning assessment process, investigators observed the building's present operation and maintenance strategies and practices in an attempt to find cost-effective improvements. The project did not include extensively identifying or implementing energy-efficient capital improvements. However, in the course of the commissioning process, any energy-efficient capital improvement that was thought to be effective, was offered as a recommendation for further investigation.

Commissioning of the existing systems included the following steps:

- Developing a building-specific commissioning plan
- Performing an on-site survey of the present maintenance practices and operating strategies
- Developing commissioning specifications for the new EMCS
- Performing short-term diagnostic monitoring of specific systems including the new EMCS
- Developing a "master list" of deficiencies for possible improvement
- Developing recommendations for the most cost-effective improvements
- Implementing the improvements
- Overseeing the commissioning of the new EMCS
- Performing post-improvement monitoring as needed
- Calculating the energy savings obtained
- Submitting a final report

During the monitoring period, portable dataloggers measured current, temperatures, pressures, and humidity for areas, systems, and equipment thought to exhibit the most opportunity for improvement. Once the monitoring data was analyzed along with the on-site assessment findings, a "master list" of recommended improvements was submitted to the owner's representative, facility manager, and other commissioning team members. Together they decided which improvements appeared to be most cost-effective to implement within the project's time frame. After implementing the improvements, another two weeks of monitoring data was gathered and analyzed to ascertain the effectiveness of the improvement regarding energy, demand, and comfort conditions.

Ultimately the cooling and heating savings calculations were done using the ASHRAE

modified bin method. Bin temperatures were also used to determine fan and pump energy savings. The short-term diagnostic monitoring data was used to inform the calculations. (For more discussion on using short-term diagnostics refer to the paper *Uncovering Hidden O&M Problems with Short-Term Diagnostic Testing* by Mark Arney et al. presented at the 1995 National Conference on Building Commissioning.)

Summary of Commissioning Findings.

The commissioning investigation identified 45 possible improvements. The opportunities fell into the following categories:

- Heating ventilating and air conditioning (HVAC) for both plant and distribution systems
- Controls (DDC)
- Miscellaneous (such as documentation, O&M planning, domestic hot water, etc.)

Of the possible 45 all of the opportunities leading to significant energy savings have been implemented. Table 1 shows the energy-related improvements and the potential savings opportunities. Most of these were accomplished by including equipment schedules and control strategies in the new EMCS along with commissioning for both the new system and the existing controlled equipment.

Although the improvements listed in Table 1 appear to be fairly simple, what are not apparent are the related improvements to the controlled equipment or the commissioning issues with the new system. For example, not only is the economizer control strategy improved through the EMCS but many related dampers and actuators were commissioned and repaired. The new-system commissioning also included checkout of sensor calibration and the proportional interface between the EMCS and the damper actuators. Without this integrated approach, only incorporating the improved operating strategy would have failed to deliver any value.

Table 1: Potential Annual Energy Savings from Selected Improvement for the Chattanooga State Office Building

	Improvement Description	*Issue	Savings ($/yr.)
1	**Add scheduling (automated) - plant equipment**	O/I	27,494
2	**Add scheduling (automated) - air handlers**	O/I	24,145
3	**Improve economizer operation for eight air handlers**	O/I	742
4	**Incorporate supply air reset for two air handlers**	O/I	1,285
5	**Reduce chiller lockout setpoint to 60^0 F**	O	579
6	**Reduce freeze protection setpoint to 35^0 F**	O	5,968
	Total Savings		**60,213**

* The "Issues" column categorizes the improvement as primarily either an operation (O) or maintenance (M) issue. The I following the backslash (\) indicates the problem stemmed from when the previous EMCS was installed..

The total savings of $60,213 is obtained by adding each improvement separately. In some cases, the high and low range is calculated, depending on which condition was used in determining the savings. In these cases, the mid-range value is reported. For example, the low-end savings for economizer operation are $495 per year and the high-end savings are $989 per year. Table 2 reflects the mid-range value of $742 per year.

Project Costs.

The total cost for the project, including the installation of the new EMCS and the commissioning of both the existing building systems and the new EMCS totals approximately $110,000. Using the savings figure of $60,000, this results in a simple payback of 22 months or less than two years.

Another way to look at cost is to consider the commissioning cost per square foot. With a commissioning budget of $50,000 and a square footage of 175,000, the commissioning cost equals 28.5 cents per square foot. At first glance this appears high. However when the project is put in perspective, i.e. a project that includes both the commissioning of a new system and the existing systems with all the extraneous costs attributable to a "demonstration project", the per square foot cost looks more reasonable. As the state of Tennessee pursues other project and becomes more self-sufficient at obtaining commissioning services, the costs should go down considerably.