COMMISSIONING AND MAINTENANCE

INTRODUCTION

Building owners spend more on complex building systems than ever before, yet many find they are not getting the performance they expect. A 1994 study of 60 commercial buildings found that more than half suffered from control problems. In addition, 40% had problems with HVAC equipment and one-third had sensors that were not operating properly.[1] An astonishing 15% of the buildings studied were actually missing specified equipment. And approximately one-quarter of them had energy management control systems, economizers, and/or variable-speed drives that did not run properly. Problems also frequently occur on the envelope, structural, and electrical systems of many new buildings.

Schools are investments, and every new school is unique. In essence, each school design is a prototype expected to perform as if it were something that had been built before. Combining a new school design with modern technology, a tight construction schedule, and a fixed budget can lead to a building that does not perform as anticipated.

Building commissioning is one way to improve the outcome of a construction project. Neither the design team nor the district desires a poorly performing school. Unfortunately, school districts frequently are the ones left to deal with the resulting financial implications, including excessive repair and replacement costs, student absenteeism, indoor air quality problems, and construction team liability. Building commissioning can ensure that a new school begins its life cycle at optimal productivity and improves the likelihood that it will maintain this level of performance.

Commissioning is a quality-assurance process that increases the likelihood that a newly constructed building will meet district expectations. Commissioning can optimize the energy-efficient design features and improve overall building performance. Districts can use this proven, systematic approach to reduce change orders and liability exposure, and to ensure that they receive buildings that function according to their original project requirements (design intent).

WHAT EXACTLY IS BUILDING COMMISSIONING?

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent, and the school's operational needs. Ideally, this is achieved by beginning in the pre-design phase with design

[1] Piette, Mary Ann. "Quantifying Energy Savings from Commissioning: Preliminary Results from the Northwest," in *Proceedings of the National Conference on Building Commissioning*, 1996.

intent development and documentation, and continuing through design, construction, and the warranty period with actual verification through review, testing, and performance documentation. The commissioning process integrates and enhances the traditionally separate functions of design peer review, equipment startup, control system calibration, testing, adjusting and balancing, equipment documentation, and facility staff training, as well as adds the activities of documented functional testing and verification.

Commissioning is occasionally confused with testing, adjusting, and balancing. Testing, adjusting, and balancing measures building air and water flows, but commissioning encompasses a much broader scope of work. Commissioning typically involves four distinct "phases" in which specific tasks are performed by the various team members throughout the construction process. The four phases are pre-design, design, construction, and warranty. As part of the construction phase, commissioning involves functional testing to determine how well mechanical and electrical systems meet the operational goals established during the design process. Although commissioning can begin during the construction phase, districts receive the most cost-effective benefits when the process begins during the pre-design phase at the time the project team is assembled.

A properly commissioned school can result in fewer change orders during the construction process, fewer callbacks, long-term occupant satisfaction, lower energy bills, and avoided equipment-replacement costs. Commissioning also assures that the building's operational staff is properly trained, with correctly compiled operation and maintenance manuals delivered at project turn-over.

COMMISSIONING APPROACHES

In recent California focus group studies, building owners and their representatives repeatedly stressed the lack of communication between the design team and construction team as a major problem. This lack of communication means that the original design intent of a project is unlikely to be carried through to project completion. (Documenting design intent — the expectations for building performance — is a critical component of commissioning and is discussed in more detail later.) Commissioning provides a means of linking the traditionally fragmented phases of the design and construction process, because it encourages the project team to view the process holistically. The commissioning process encourages parties to communicate and solve problems earlier in the construction process. Beginning proper commissioning during the design phase can help identify and solve problems that later may turn into performance problems, occupant comfort complaints, indoor air quality issues, and decreased equipment life.

Although commissioning works best when it begins during design, projects already under construction can still benefit from commissioning. Bringing a commissioning provider into a project during the construction phase can be invaluable in helping solve start-up problems that have stumped both designers and contractors. The commissioning provider can also document the start-up and functional testing results, thereby reducing future liability exposure for the

designers and district. The provider also oversees operation/maintenance staff members training, thus improving the operating procedures of the facility.

BENEFITS OF COMMISSIONING

Until recently, the most frequently mentioned benefit of commissioning was its energy-related value: building commissioning ensures that the energy savings expected from the design intent are implemented correctly. While these benefits are significant, the non-energy-related benefits of commissioning far outweigh them. Examples include:

- Proper and efficient equipment operation
- Improved coordination between design, construction, and occupancy
- Improved indoor air quality, occupant comfort, and productivity
- Decreased potential for liability related to indoor air quality, or other HVAC problems
- Reduced operation and maintenance costs.

Proper and Efficient Equipment Operation

Commissioning verifies that equipment is installed and operating properly. Equipment that operates as intended lasts longer, works more reliably, and needs fewer repairs during its lifetime. By promoting equipment reliability, commissioning can reduce service, energy, and maintenance costs. Equipment that operates properly tends to use less energy, require fewer service calls and replacement parts, and demands less "crisis maintenance" from onsite staff (or expensive outside contractors), allowing them to concentrate on their normal duties.

Improved Coordination Between Design, Construction, and Occupancy

Commissioning can result in greater cooperation among the professionals involved in the project and provides a platform for cross-checking the performance of a building's equipment and combined systems, which ultimately leads to fewer callbacks and litigation problems.

A good design includes systems that are sized correctly, rather than the oversized mechanical systems found in many commercial buildings.[2] On many projects, a lack of understanding and coordination between the design, installation, and/or operational team members can lead to systems that function inefficiently. Commissioning allows for a broad perspective and consistent focus throughout the design and construction process on whether the building will function as intended and identifies the best long-term solutions for problems that arise during the project. Commissioning can facilitate improved integration and communication among team members throughout these phases and can also ensure that correctly sized systems function as intended and specified.

Many districts mistakenly believe that adding commissioning quality assurance procedures to their design process will delay the project's schedule and increase costs. Many who have

[2] York, Dan. "Commissioning Green Buildings," in *Proceedings of the National Conference on Building Commissioning*, 1998.

incorporated commissioning into the design phase of their projects have discovered that commissioning can significantly reduce change orders,[3] which in turn reduces the requests for project delays and decreases the use of contingency funds for change orders. Thus, beginning commissioning during design can actually contribute to the on-time and on-budget completion of projects. It should be noted that these benefits will not be realized if the commissioning process begins during the equipment start-up phase of a project.

Improved Indoor Air Quality, Comfort, and Productivity

The benefits of high performance schools are all dependent on how well the building performs.

Surveys indicate that comfort problems are common in many U.S. buildings. A recent OSHA report noted that 20% to 30% of commercial buildings suffer from IAQ problems. Building occupants complain of symptoms ranging from headaches and fatigue to severe allergic reactions. In the most severe cases, occupants have developed Legionnaire's disease, a potentially fatal bacterial illness. The National Institute of Occupational Safety and Health surveyed 350 buildings with deficient IAQ and found that more than half of the complaints stemmed from HVAC systems that were not operating properly.

Building commissioning is a tool districts can use to avoid the expenses and productivity losses associated with poor IAQ and student/teacher discomfort. Because commissioning assures that HVAC and other building systems are installed and operating properly, commissioned buildings tend to have fewer comfort-related problems.

Liability Related to Indoor Air Quality

Building commissioning protects schools in more than one way. First, it provides documented verification of a building's performance and operation. Ventilation rates are a good example of a primary factor that affects indoor air quality. HVAC commissioning typically includes testing these flow rates under varying load conditions to assure that the ventilation systems are operating properly. If a school has deficiencies, the commissioning provider documents the original condition and records the repairs made. Commissioning should be repeated throughout the life of the school, and performance documentation should be updated regularly. This documentation provides districts with a record of building performance that can be used as evidence in the event of a lawsuit.

Commissioning also helps prevent many IAQ problems through its focus on training the teachers and staff in the proper maintenance of building systems. Properly run and maintained HVAC systems, with clean coils and air intakes as well as regularly changed filters, are less likely to contribute to IAQ problems. In addition, trained school staff can spot potential air quality and ventilation problems before they develop.

Both local and state government agencies have begun using commissioning as a tool to ensure that indoor air quality standards are being met when a building is constructed.

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[3] Savage, Jerry. "Commissioning a Materials Research Laboratory," in *Proceedings of the National Conference on Building Commissioning*, 2000.

Reduced Operation, Maintenance, and Equipment Replacement Costs

Operation, maintenance, and equipment replacement costs will always consume a portion of building budgets. However, more operation and maintenance departments are realizing that they can minimize life-cycle costs by changing their practices. That is, proper operation and maintenance can actually save money compared to poor practices, and many businesses are reinvesting their operation and maintenance savings in more efficient building systems. The commissioning process establishes sound building operation and maintenance practices, and trains operators in carrying out these practices. (Some of these practices are discussed in more detail in the Operation and Maintenance for Persistence section of this chapter.)

The Bottom Line

Commissioning improves a building's value. Properly functioning buildings with reliable equipment kept in good condition are worth more than their non-commissioned counterparts. Commissioned systems and equipment retain their value longer. Additionally, an ongoing demand exists for comfortable, healthy working space. Finally, systems that function properly use less energy, experience less down time, and require less maintenance, thereby saving money for districts.

COSTS OF BUILDING COMMISSIONING

Currently, no standard method of reporting the costs and savings associated with commissioning exists. For many projects, commissioning costs are not separated from other project costs. For projects where these costs have been tracked separately, various methods have been used to report both the costs and associated benefits. The table below lists some of the most common cost-estimation methods. No matter which estimation method is used, however, commissioning accounts for only a very small portion of overall construction and retrofit budgets.

Table 43 — Estimated Commissioning Costs for New Equipment [4]

Commissioning Scope	Estimated Cost Range
Whole building (controls, electrical, mechanical) Commissioning from design through warranty	0.5% to 3% of total construction cost
HVAC and automated controls system only	1.5% to 2.5% of mechanical contract
Electrical system only	1% to 1.5% of electrical contract

SAVINGS FROM BUILDING COMMISSIONING

Districts and their servicing utilities are interested in the energy (kWh) savings achieved from commissioning energy systems and equipment. Additionally, they are also interested in how much the commissioning will save them in operation and maintenance costs. Just as commissioning costs can vary from project to project, so do commissioning savings. Savings

[4] Estimated costs adopted from PECI Data and Ron Wilkinson's article "Establishing Commissioning Fees," ASHRAE Journal-February, 2000.

will depend on the scope of the commissioning. Table 44 shows the reported savings for three different types of commercial buildings commissioned during the past few years. When commissioning is done properly, the savings can be quite substantial for schools as well.

Table 44 – The Savings from Commissioning New Equipment (Mechanical Systems)[5]

Building Type	Annual $ Savings	Annual Energy Savings
110,000-ft^2 Office	$22,320	279,000 kWh
22,000-ft^2 Office	$13,080	130,800 kWh
60,000-ft^2 High Tech Manufacturer	$26,880	336,000 kWh

Many districts question how they can pay for commissioning with a limited design and construction budget. Because commissioning can identify potential problems earlier in the design or construction process, the result is a lower overall construction budget, fewer contractor callbacks, and lower operating costs during the first year of operation. By transferring those potential savings to the design and commissioning team budgets, the total project costs can be equivalent to a project that is not commissioned, as illustrated in Figure 52 below.

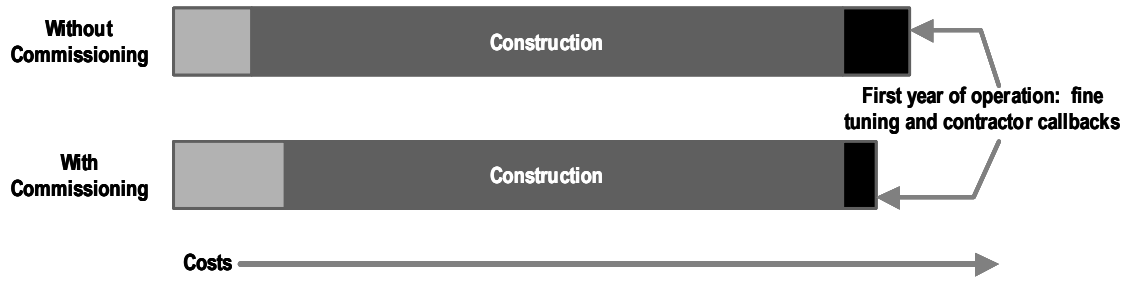

Figure 52 – How to Pay for Commissioning-One Option

Shift 2% of total project costs to the commissioning provider and 3% to the design team.[6]

SELECTING A COMMISSIONING PROVIDER

One of the most important commissioning decisions is selecting the commissioning provider and determining who will hold the commissioning provider's contract. Two primary methods exist for selecting a commissioning provider: competitive bid and selection by qualification. The Building Commissioning Association (BCA) can provide a list of commissioning providers. Contact information for the BCA can be found in the resources section at the end of this chapter. In the Request for Qualifications, be sure to ask for details on previous, relevant commissioning experience, including the depth of commissioning experience (what some call

[5] Annual energy savings calculated from three Northwestern United States commissioning projects. Cost savings estimates based on a blended 2000 California kWh rate of $0.10 for smaller office buildings and $0.08 for larger offices and industrial facilities.

[6] The Farnsworth Group, as presented in "How to Achieve Top Performance in Your Building: Commissioning Benefits, Process and Performance," a workshop series by the Association of State Energy Research and Technical Transfer Institutes, 1998.

commissioning is no more than traditional equipment startup).[7] Make sure that the provider's definition of commissioning corresponds to the one at the beginning of this chapter. Recommended commissioning provider qualifications are discussed in more detail in the following pages. Based on the responses, develop a list of firms to receive a Request for Proposal that details exactly what services the construction project will need to be properly commissioned. Districts can also select a commissioning provider based on qualifications and rate schedules, rather than by competitive bid. This process warrants careful interviewing and contact with the providers' current or past clients.

Any of the following parties can be selected to manage the commissioning provider's contract:

- Project Manager
- Architect/Design Engineer
- Contractor.

Each option has its advantages and disadvantages. The final choice will depend on the complexity and the specific needs of the particular project. As building commissioning has evolved and more practitioners with different ideas have entered the field, a group of interested parties worked to form the BCA, a professional association, in 1998. According to the BCA website (http://www.bcxa.org/), "The BCA's goal is to achieve high professional standards, while allowing for diverse and creative approaches to building commissioning that benefit our profession and its clients. For this reason, their focus is on identifying critical commissioning attributes and elements, rather than attempting to dictate a rigid commissioning process". The association believes that "the basic purpose of building commissioning is to provide documented confirmation that building systems function in compliance with criteria set forth in the project documents to satisfy the owner's operational needs." Paramount to this is the understanding that if the commissioning provider is not an independent party under contract directly with the district/owner then he or she must develop a formal plan for managing the potential conflict of interest. One method that has been used successfully to manage, but not eliminate, these potential conflicts of interest is parallel and simultaneous reporting of all findings to the district's representative and contract manager for the commissioning services.

Independent Third Party Under Contract to the District/Owner

Many districts/owners who have commissioned their buildings recommend using an independent third party as the commissioning provider. An independent commissioning provider can play an objective role and ensure that the district will truly get the building performance expected. For large and/or complex projects, especially in buildings with highly integrated, sophisticated systems, future savings from commissioning outweigh the slightly higher costs with an additional contract. Independent third party commissioning providers bring a fresh perspective to the project as they collaborate with the design team. By joining the project team during the design, the commissioning provider can identify more opportunities for

[7] " Start up" refers to the process of starting up equipment to determine whether it operates. Commissioning goes beyond start up to ensure that new equipment performs in conformance with design expectations in all modes and conditions of operation.

improvements and savings early on when changes can be made on paper. This approach is preferable to waiting to fix the problems through the change-order process as the building is being constructed.

Independent commissioning providers, who are often trained as design engineers, should have the qualifications listed under "Commissioning Provider Qualifications," plus they should be able to write commissioning specifications for bid documents. Hands-on experience with building systems is especially critical. It is important to involve the independent authority as early in the project as possible. This allows the authority the opportunity to review the design intent for the project, begin scheduling commissioning activities, and begin writing commissioning specifications into bid documents for other contractors.

Architect or Engineer Overseeing the Commissioning Process

If commissioning requirements in the project specifications are rigorous and detailed, districts may consider having the architect manage the contract of a commissioning provider. When the architect or the mechanical designer has qualified field engineers on staff and those engineers do not have responsibility for the design of the project, the architect or engineer may be considered for directly overseeing the commissioning process. One advantage of using the architect or mechanical designer is that he or she is already familiar with the design intent of the project. Districts considering this option should bear in mind that commissioning is not included in a design professional's basic fees. Districts should require that all findings of the commissioning process be directly reported to both the designer and to the district as they occur to manage the potential conflict of interest created by having the commissioning services under the designer. Districts must also recognize that even if this option is not chosen and an independent third party is used, designers might increase their fees slightly to offset the additional time requirements to coordinate their work with the commissioning provider.

Contractor

It used to be standard practice for many contracting firms to conduct performance tests and systematic checkout procedures for equipment they installed. As construction budgets became tighter, this service was dropped from most projects. Although contractors may have the knowledge and capability to test the equipment they install, they may not be skilled at testing or diagnosing system integration problems. In addition, some contend that it is difficult for contractors to objectively test and assess their own work, especially since repairing deficiencies found through commissioning may increase their costs. For districts that only wish to have the commissioning process begin during the construction phase, it may be appropriate to use the installing contractor as the commissioning provider in cases where:

- The building size is less than 20,000 ft^2.
- The project specifications clearly detail the commissioning requirements.
- The district has skilled staff that can review the contractor's commissioning work.

Another option for districts that have a good relationship with the general contractor is to require that the general contractor hire a test engineer to commission the equipment. This scenario can work well when specifications and contract documents clearly detail the

commissioning requirements and when the district has technical staff that is qualified to oversee the test engineer. Still, many general contractors welcome the opportunity to work with an independent commissioning provider, because of the objectivity they bring and because they assist in ensuring that the subcontractors perform their work properly, improving client satisfaction and ultimately reducing callbacks.

Commissioning Provider Qualifications

Currently, there is no broadly recognized and approved certification or licensing process for commissioning providers. Therefore, it is up to each district to determine the commissioning provider's qualifications appropriate for a given project. See the sidebar for guidelines on selecting a qualified commissioning provider.

Regardless of who is chosen to act as the commissioning provider, there are certain minimum qualifications any commissioning provider ought to have, and the following list is by no means all-inclusive. Certain projects may require more or less experience, depending on size, complexity, and specific building characteristics. Direct the commissioning provider to subcontract work in which he or she lacks sufficient experience.

Commissioning Provider Qualifications Checklist

In general, for complex projects, a commissioning provider who will personally develop the commissioning test plans and directly supervise the commissioning work should meet these qualifications. These qualifications are focused on HVAC and control systems. Where electrical and other systems will be commissioned, the firm's experience in these areas should also be considered. However, often the prime commissioning provider will team with other subconsultants to provide a team that can expertly address all the systems being commissioned. In such cases, the management skill of the prime commissioning provider is also important.

Recommended Minimum Qualifications

Experience in design, specification, or installation of commercial building mechanical and control systems, as well as other systems being commissioned.

Experience commissioning projects within the last three years with similar size building systems.

History of responsiveness and proper references.

Meet district's liability requirements.

Experience working with project teams, project management, conducting scoping meetings, and good communication skills.

At least two projects involving commissioning of buildings of similar size and equipment to the current project. This experience includes writing functional performance test plans.

Optional Qualifications

Direct responsibility for project management of at least two commercial construction or installation projects with mechanical costs greater than or equal to current project costs.

Experience in design installation and/or troubleshooting of direct digital controls and energy management systems, if applicable.

Demonstrated familiarity with metering and monitoring procedures.

Knowledge and familiarity with air/water testing and balancing.

Experience in planning and delivering operation and maintenance training.

Building contracting background.

Overall understanding by the commissioning team of all building systems including building envelope, structural, and fire/life safety components.

THE COMMISSIONING TEAM

Members of a design-construction project team, like components of integrated building systems, need to interact in order to perform their tasks successfully. Commissioning actually facilitates this interaction, because it sets clear performance expectations and requires communication among all team members.

Any project involving commissioning should begin with a commissioning scoping meeting, which all team members are required to attend. At this meeting, the roles of each team member are outlined, and the commissioning process and schedule are described.

Commissioning team members most often include the district representative or project manager, commissioning provider, design professionals, installing contractors, and

manufacturer's representatives. The team may also include facility staff and possibly testing or diagnostic specialists and utility representatives. The commissioning team does not manage the design and construction of the project. Its purpose is to promote communication among team members and to identify and resolve problems early in the process. To that end, the design professional and district representative are key members of the commissioning team.

Of course, few situations are ideal. Budget considerations and special project characteristics may expand or minimize the commissioning roles and responsibilities described below. Districts should consult with their commissioning providers about potentially combining some of the following roles. The commissioning provider can review the scope of commissioning and advise the district on how to consolidate roles and tasks to best fit the size and complexity of the project.

District Representative

The district's most significant responsibility is to clearly communicate expectations about the project outcome. The district's expectations are used by the designer to establish the design intent of the project and by the commissioning provider to evaluate whether this intent is met. Other responsibilities of the district representative include:

- Determining the objectives and focus of the project.
- Hiring the commissioning provider (if using an independent third party) and other members of the project team.
- Determining the project's budget, schedule, and operating requirements.
- Working with the commissioning provider to determine commissioning goals.
- Facilitating communication between the commissioning provider and other project team members.
- Approving start-up and functional test completion (or delegating this task to a construction or project manager).
- Attending building training sessions when appropriate.

Commissioning Provider

The commissioning provider's primary tasks include:

- Ensuring the completion of adequate design intent documentation.
- Providing input on design features that facilitate commissioning and future operation and maintenance.
- Assisting in developing commissioning specifications for the bid documents.
- Developing a commissioning plan that includes equipment and systems to be commissioned.
- Ensuring that team members understand their specified commissioning responsibilities; work to promote a positive, solutions-based team approach; and facilitate bringing a quality project to completion.
- Developing diagnostic and/or test plans for systems to be commissioned.
- Writing construction, functional, and performance tests.

- Submitting regular reports to the district representative.
- Witnessing selected contractor start-up tests, air and water testing and balancing, and duct pressure testing.
- Overseeing all functional and performance testing of systems.
- Reviewing and commenting on technical considerations from design through installation, to facilitate sound operation and maintenance of the building.
- Reviewing contractor and manufacturer training plans prior to delivery to facility staff.
- Reviewing operation and maintenance manuals documentation for completeness.
- Writing a final commissioning report documenting the final evaluation of the systems' capabilities to meet design intent and district needs.
- Developing a systems concepts and operations manual that details the most important operation parameters and equipment instructions.

Design Professionals

The responsibilities of the design professionals will vary with the interests of the designers and the needs of the project. The primary commissioning-related responsibilities of design professionals are to document the design intent for all systems, if this was not completed in pre-design; to write system descriptions and record design basis information; answer questions and issues brought up by the commissioning provider during design; and to make sure that commissioning is included in the bid specifications. If the design professional is hiring the commissioning provider, he or she should do so as early in the design process as possible. During construction, the designers are tasked with clarifying design issues related to system operation and design intent and to assist in resolving construction and operational deficiencies illuminated by the commissioning process. For complex projects, the designer may review commissioning plans, functional performance test plans, and may witness select functional testing. If this is the case, the design professional's proposal should include funds to cover these activities. As mentioned before, the design firm may be responsible for hiring and overseeing the commissioning provider.

Installing Contractors and Manufacturer Representatives

Contractors and manufacturer representatives are responsible for performing commissioning functions described in the specifications. These may include assisting with developing the commissioning schedule, conducting performance tests (under the supervision of the commissioning provider or facilities staff) of the systems they install, adjusting systems when commissioning indicates this is needed, and documenting system startup. Contractors and manufacturer representatives are also responsible for training building staff in the proper operation and maintenance of systems, and providing operation and maintenance manuals on the equipment they install.

Facility Manager/Building Operator

The building operator should assist with (or at least observe) as much of the functional testing as possible. To achieve even greater impact on the commissioning process as early as possible, the district should try to hire its new operator or assign an existing operator who will

be responsible for this building to become closely involved with the construction commissioning team. The insights of an operator in the final phases of design can be quite beneficial. Often times there are details of the design that can be adjusted and modified at no cost yet will provide significant benefits to the ongoing operation of the building. Specific examples might include point-naming conventions, alarm messages, and graphic layouts of the energy management system. The operator can also help in interfacing any existing facilities management software, district standards, and equipment preferences into the project. As this employee observes the commissioning tests, the operator's understanding of the equipment and control strategies will improve. It also trains the employee to be able to retest systems periodically as part of ongoing operation and maintenance. The operator should also attend training sessions provided by manufacturer's representatives and/or contractors.

Testing Specialists

If the complexity of the project requires special testing, the specialists performing these tests should also be involved in commissioning. Test results and recommendations from these specialists should be submitted to the commissioning provider for review. They may also be required to review documentation relating to the systems they test and to train operators on the proper use of this equipment.[8]

COMMISSIONING PHASES

The commissioning process helps facilitate and connect each step of the construction process. Commissioning enhances communication among project team members and ensures that they all understand the project goals. This allows the project team to identify problems early, before they can affect later phases of the project and cause delays.

Predesign Phase

The predesign phase is the ideal time for the district to select a commissioning provider. Early selection allows the commissioning provider to play an advisory role during the conceptual process, suggesting ways to make the overall building more energy efficient and identifying key design strategies that can facilitate operation and maintenance. Involving the provider early can also increase buy-in for commissioning from other team members because the provider is involved from the beginning. Otherwise, the team may view the commissioning provider as an outsider who does not really understand the project. During this phase, the commissioning provider may assist in developing the district's goals or, at minimum, ensuring that these goals are clearly documented and distilled into a design intent narrative.

The design intent narrative, typically developed by the district, is an explanation of the ideas, concepts, and criteria that are important. It should generally describe the project both physically and functionally, and it should set the performance requirements for the design, construction, and operation. The level of detail will vary with the project's size and complexity,

[8] Dunn, Wayne. "Roles and Responsibilities," in *Proceedings of the National Conference on Building Commissioning*, 1995.

the district demands, and the design team's experience. The design intent should describe how the project will be used and operated, and should present known goals and objectives as measurable metrics when possible. It may also state specific contractual performance requirements or energy consumption targets, if the district establishes them. The design intent sets the criteria for all subsequent design decisions.

Expected Deliverables

Districts who decide to commission their buildings should expect to receive the following written deliverables:

Commissioning plan and schedule detailing each step of the commissioning process and each team member's role and responsibilities.

A diagnostic and functional test plan detailing the objective of each test, how each test will be accomplished, and noting expected performance parameters.

A list of findings and potential improvements identified by the commissioning provider for design phase and construction phase activities.

A training plan recommending specific topics and training schedules.

At the completion of the project, a final commissioning report detailing all of the commissioning provider's findings and recommendations, including copies of all functional performance testing data.

A systems concepts and operations manual which gives a description of each system with specific information about how to optimally operate and control the system during all modes of operation such as during fire, power outage, shutdown; etc., including special instructions for energy-efficient operation and recommissioning.

Energy savings and implementation cost estimates for recommendations developed in the process are also deliverables in retro-commissioning projects.

Design Phase

The goal of commissioning during the design phase is to ensure that the efficiency and operational concepts for building systems that were developed during programming are included in the final design. The main commissioning tasks during this phase are compiling and reviewing design intent documents if not already developed, incorporating commissioning into bid specifications, and reviewing bid documents. During the beginning of design, the designer develops the design concepts that he or she proposes to use to meet the district's program and intent. The designer also documents the assumptions (design basis) used in the design for sizing and selecting systems (i.e., codes followed, temperature parameters, and occupancy loads). The design concepts and design basis are compiled into a design narrative document that the commissioning provider reviews for clarity, completeness, and compliance with the design intent. As the design progresses, the design narrative is updated and compared against the design intent.

The bid specifications developed during the design phase include commissioning requirements for the contractors. Specifications should include any special equipment or instrumentation that must be installed for obtaining measurements during performance testing. They should also describe the responsibility that contractors will have for preparing operation and maintenance manuals and for training facility staff. The commissioning provider reviews these bid documents, updated design narratives, and all other design intent and contract documents.

The optimum time to hold the commissioning scoping meeting is during the design phase. At this meeting, the commissioning provider outlines the roles and responsibilities of the project team members with respect to commissioning and reviews the commissioning plan outline and schedule. Team members provide comment on the plan and schedule, and the commissioning

provider uses these suggestions to complete the final commissioning plan. The final plan will include:

- The scope or level of commissioning
- Commissioning schedule
- Team member responsibilities
- Communication, reporting, and management protocols
- Documentation requirements of each team member
- Detailed scope of testing
- Detailed scope of monitoring
- Recommended training format.

The commissioning provider attends selected design team meetings and formally reviews and comments on the design at various stages of development. They note potential system performance problems, and may provide input on energy efficiency, indoor environmental quality, maintainability, commissionability, sustainability, and life-cycle cost, depending on the skills of the commissioning provider and design team and interests of the district. Making these changes during the design phase, rather than after construction begins, reduces costly change orders, which saves money in the long run. It is important for the district to understand that the commissioning provider does not approve the design. He or she makes recommendations to facilitate commissioning and improve building performance in a collegial manner in concert with the designated design team.

During this phase, the commissioning provider can also play a significant role in developing a building's operation and maintenance program or suggesting improvements for a program already in place. The provider interviews the facility manager to determine operating staff ability and availability to operate and maintain building equipment and systems. Careful consideration is given to whether the proper level of staffing resources is available to fully implement a successful long-term operation and maintenance system to ensure continued building performance. The commissioning provider also reviews the design documents and drawings to ensure that equipment is accessible for maintenance.

Construction Phase

During this phase, the commissioning provider reviews contractor submittals of commissioned equipment and the operation and maintenance manuals and may write test plans for each system and piece of equipment to be commissioned. The provider also visits the construction site periodically and notes any conditions that might affect system performance or operation.

During the construction phase, construction checklists — sometimes referred to as "pre-functional tests" and usually completed by the contractors — are used to ensure that equipment is properly installed and ready for functional testing. The commissioning provider approves and may oversee start-up and the use of construction checklists, as well as making sure that any deficiencies are remedied before functional testing begins.

The commissioning provider should involve the building operation staff in the construction checklist procedures and functional testing as much as possible. Doing so improves staff understanding of the proper operation of equipment and systems. It also provides operators with valuable hands-on training in running and troubleshooting the equipment they will manage.

The commissioning provider may write various progress reports during construction that document testing progress as well as deficiencies that may affect future building performance. These reports may be submitted to the district, design engineer, project manager, or contractors, depending on the contract arrangements for the project. (Establishing a clear process prior to the construction phase for delivering correction orders to the responsible contractors and tracking their responses is critical to the success of commissioning.)

The commissioning provider uses the functional tests to document and verify the proper operation of equipment and systems according to the building specification plans and change orders, as well as the architect's instructions. Most often, the commissioning provider directs the tests, but the subcontractors, particularly the controls contractor, perform the actual equipment operation during the tests. If corrective measures are required, the commissioning provider ensures they meet the district's criteria and the design intent, involving the owner and architect to resolve responsibility or strategy when necessary. Acceptable performance is reached when equipment or systems meet specified design parameters under full-load and part-load conditions during all modes of operation, as outlined in the commissioning test plan.

After completing functional testing, the provider writes a final commissioning report and submits it to the district for review. In addition to the final report, some commissioning projects include a more comprehensive documentation package to assist the district in understanding, operating, and maintaining their systems. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) calls this package a systems manual and recommends that it include:[9]

- Index of all commissioning documents with notations as to their storage locations
- Commissioning report
- Initial and final design intent documents
- As-built documents
- Description of systems, including capabilities and limitations
- Operating procedures for all normal, abnormal, and emergency operation modes
- Sequence of operation as actually implemented, with control systems data including all set points and calibration data
- Location of all control sensors and test ports
- Seasonal start-up and shutdown procedures

[9] ASHRAE Guideline 1-1996-*American Society of Heating Refrigerating and Air-Conditioning Engineers*, Atlanta GA, 1996.

- Control schematics and computer graphics
- Complete terminal interface procedures and capabilities of the Direct Digital Control (DDC) system
- A list of recommended operation record-keeping procedures, including sample forms and trend logs
- Maintenance procedures.

The construction phase is complete when the facility has moved from the static construction state to the dynamic operating state essentially free of deficiencies. Control of the building may have been transferred from the design/construction team to the district and building operators prior to completing this phase. Part of this transfer involves training building operators how to operate and maintain the equipment and systems. Preferably, this training begins during the construction/installation phase, as discussed above.

The commissioning provider is responsible for interviewing the project manager and operation and maintenance staff to determine their training needs. With the district representative, the provider then selects the appropriate topics, level of detail, sequence of training, and training methods. Training may include both classroom sessions and hands-on site demonstrations of proper equipment operation and maintenance.

In addition, the commissioning provider oversees training sessions as specified in the bid documents that installing contractors, designers, and manufacturers' representatives will conduct. The provider also verifies that operation and maintenance manuals are complete and available for use during the training sessions. The commissioning provider may arrange for videotaping of the training and coordinate this videotaping with vendors. Videotaping training sessions often provides an extra incentive for vendors to ensure the quality of the sessions.

Warranty Phase

Upon turnover, the building is in the hands of the owner and operators. Even though the project is considered complete, some commissioning tasks from the initial commissioning contract continue throughout the typical one-year warranty period to ensure that full operation of building systems is achieved.

Any testing that was delayed because of site or equipment conditions or inclement weather, will be completed during warranty. Although some testing of heating and cooling systems can be performed under simulated conditions during the off-season, natural conditions usually provide more reliable results. Seasonal testing is conducted to verify proper operation during, at minimum, both winter and summer.

When performing testing during post-occupancy, the commissioning provider or test engineer must be careful not to void any equipment warranties. The district should require that contractors provide the commissioning provider with a full set of warranty conditions for each piece of equipment to be commissioned. Some warranty provisions may require that the installing contractor actually perform the testing, under the supervision of the commissioning provider.

The commissioning provider may also be tasked with returning a few months prior to the expiration of the contractor's one-year warranty to review system operation and interview facility staff. Acting as the district's technical resource, he or she assists the facility staff in addressing any performance problems or warranty issues.

It is a good idea for districts to consider recommissioning their facilities periodically to ensure that equipment performance levels continue to meet design intent. If school staff has been involved in the original commissioning effort, and if they received training that included the components listed in the Suggested Training Topics sidebar, they may be able to conduct the recommissioning process themselves.

When Does Commissioning End?

Commissioning ensures that a building is performing as intended at the time that commissioning occurs. This means that to maintain this level of performance, commissioning, in a sense, never ends. Certainly no one could reasonably expect building operation staff to perform functional tests on equipment and systems daily. However, operation and management staff should be encouraged to recommission selected building systems on a regular basis, perhaps every two to three years depending on building usage, equipment complexity, and operating experience. The commissioning provider can recommend an appropriate interval for the building and systems. In the meantime, implementing regular, sound operation and maintenance practices ensures that the savings from commissioning last.

OPERATION AND MAINTENANCE FOR PERSISTENCE

Sound operation and maintenance practices can help keep the school operating at commissioning levels. Some of these practices include:

- Establishing and implementing a preventive maintenance program for all building equipment and systems.
- Using commissioning documentation such as commissioning checklists and functional tests as a basis for periodic equipment testing.
- Reviewing monthly utility bills for unexpected changes in building energy use.
- Using energy accounting software to track building energy use.
- Tracking all maintenance, scheduled or unscheduled, for each piece of equipment. Periodic reviews of these documents will often indicate whether certain pieces of equipment require tuning up.
- Updating building documentation to reflect current building usage and any equipment change-outs.
- Establishing an indoor air quality program for the building.
- Assessing operator training needs annually.

Good Operation and Maintenance Begins During Design

Like commissioning, successful operation and maintenance begins in the design phase of a project. Soliciting input from operation and maintenance staff during the early stages of building

design can facilitate good operation and maintenance practices. The more convenient it is for staff to perform regular checks and maintenance on building systems, the better building performance needs can be met and costly maintenance can be avoided. In addition, the installing contractor's responsibilities concerning operation and maintenance should be clearly detailed in the project contract specifications during the design stage, so that the contractor can adjust the bid price accordingly. For instance, specifications should explicitly state that contractors will be required to provide information needed to facilitate the commissioning process and to coordinate activities with the commissioning provider as needed. The specifications should also require the contractor to provide comprehensive operation and maintenance manuals for equipment and provide training for staff.

Operation and Maintenance Manuals

The contractor prepares operation and maintenance manuals for each piece of equipment. The commissioning provider reviews each manual for compliance with the specifications as part of the commissioning process. Operation and maintenance manuals should contain:

- Name, address, and telephone number of installing contractor
- Product data
- Test data
- Performance curves (for pumps, fans, chillers, etc.)
- Installation instructions
- Operation requirements
- Preventive maintenance requirements
- Parts lists
- Troubleshooting procedures specific to the equipment design and application.

If the provider believes it would be beneficial, additional information, already gathered during the commissioning process, can also be included in the operation and maintenance manuals. This information may include equipment submittals, design intent documents including control strategies and sequence of operations (normal and emergency), and copies of the commissioning tests (pre-functional checklists and functional performance test forms).

Operation and maintenance manuals are useful reference tools for current facilities staff and can also be used as a training resource for new staff members. The operation and maintenance manuals should be placed in three-ring binders. Contractors should be required to provide at least three copies of each manual to the district. Typically, one copy becomes the master copy, and remains in the facility manager's office. "Hard binding" the master copy so that pages cannot be removed and misplaced is recommended. The second copy functions as a field copy, and selected pages from it may be removed for use during site work. The third copy resides at district offices. If building equipment will be maintained and operated by an outside firm, a fourth copy should be requested and provided to them as a reference. Because manuals lose their usefulness if they are not kept up to date, any pages added to them, such as checklists or preventive maintenance work orders, must be included in each copy.

Training

Perhaps the most essential component of operation and maintenance is training. Unless building operators and managers are given the skills to perform quality operation and maintenance practices, there is no hope that a building will continue to perform optimally.

As with all training, instruction should be structured to meet the needs of building operator staff. Training session topics should ideally be specified in the bid documents.

By videotaping each training session, including the hands-on start-up and shutdown procedures for equipment, building operation staff gains a permanent and inexpensive onsite training aid. When new staff is hired, they can view the videos as part of their training.

For buildings where a facility manager without a technical background provides maintenance, the commissioning provider can still coordinate with contractors to ensure that the manager is educated about the capabilities, intended function, and required maintenance of the building systems. This education should enable the facility manager to respond to occupant complaints in a manner that does not circumvent the systems' design intent. It is important to provide a list of resources for the manager to call for maintenance assistance when necessary.

Once a building is operating and occupied, problems occasionally develop that were not apparent during the commissioning process. These problems often occur during the first year of operation after construction or renovation. Sometimes the service contractor or operating staff can effectively troubleshoot and solve the problem. However, if a problem becomes chronic (for example, repeated comfort complaints), or if operating staff is unable to solve a problem in a reasonable amount of time, the district should request expert troubleshooting assistance.

Because the commissioning provider and design engineer are very familiar with the building systems, the district may want to consider contracting with one and/or both of them for the first year of operation to provide troubleshooting assistance on an as-needed basis. In traditional construction projects, the mechanical engineer is only responsible to help correct problems if their contract stipulates a warranty period and the problems are "design" related. The district may find that it is more cost-effective to purchase troubleshooting services from the commissioning provider or engineer, because their knowledge of the building systems and design saves them time in diagnosing problems. This contract could be written in a "fee-for-service" or an "amount-not-to-exceed" manner.

Suggested Training Topics

Descriptions of equipment and systems installed and their warranties or guarantees.

Equipment start-up and shutdown procedures, operation in normal and emergency modes, seasonal changeover, and manual/automatic control.

Requirements and schedules for maintenance on all operation and maintenance-sensitive equipment.

Indoor air quality, health, visual comfort, acoustic comfort, and safety issues.

Recommendations for special tools and spare parts inventory.

Emergency procedures.

Operation and adjustment of dampers, valves, and controls.

Hands-on operation of equipment and systems.

Common troubleshooting problems, their causes, and corrective actions.

Review of operation and maintenance manuals, and their location onsite.

Building walk-through.

Review of related design intent documents.

Energy management control system operation and programming.

Control sequences and strategies.

Thermostat programming.

Relevant commissioning reports and documents.

When and how to recommission building systems.

The maintenance work order management system.

Sound energy management practices.

In the long run, districts may also find it beneficial to train operation and maintenance staff in energy accounting. In addition to tracking the building's energy use, energy accounting can also indicate problems or potential problems with equipment operation.

Preventive Maintenance

Another important operation and maintenance practice is preventive maintenance. Preventive maintenance can save school districts time and money by:

- Maintaining facility operation
- Extending equipment life
- Identifying equipment degradation

- Preventing losses of equipment, time, productivity, and resulting revenue.

Effective maintenance and operations procedures are fundamentally important to sustaining the performance of all building systems. Student health and productivity can be affected when building systems fail to operate as designed. Sub-standard maintenance or incorrect operation of building systems usually results from a combination of factors. First, maintenance budgets are often the first to be reduced or eliminated when money becomes tight. Second, designers and contractors typically provide the building staff minimal or no training about how the building systems are supposed to operate or be maintained. Finally, schools eventually lose their institutional knowledge of the building systems because of staff turnover and lack of communication.

When estimating service life, manufacturers usually assume regular preventive maintenance of the equipment and system components. Many preventive maintenance procedures recommended by manufacturers are intended to extend the life of the component and the system as a whole. Lack of preventive maintenance reduces equipment life.

Identifying degradation of the system's components is another benefit of preventive maintenance. A proper facility operation and maintenance system that includes reporting and documentation reduces the incidence of failure. For example, if a component of the system is identified as potentially failing to operate as intended, a work order for replacement parts can

Energy Accounting

Energy accounting is a method of tracking a facility's energy use over time. Many facility managers seeking peak performance in their building have found that energy accounting software gives them a better understanding of their utility expenditures. Each month's usage and expenditures are input into a software program. The software then tracks the usage while normalizing for temperature changes over the period being analyzed. The energy "accountant" can then watch and see whether the facility performs as expected or uses more energy than expected over time. If higher than expected usage occurs, further investigation can identify the occupancy and/or usage changes, equipment problems, or other unknown problems that have increased the energy bills.

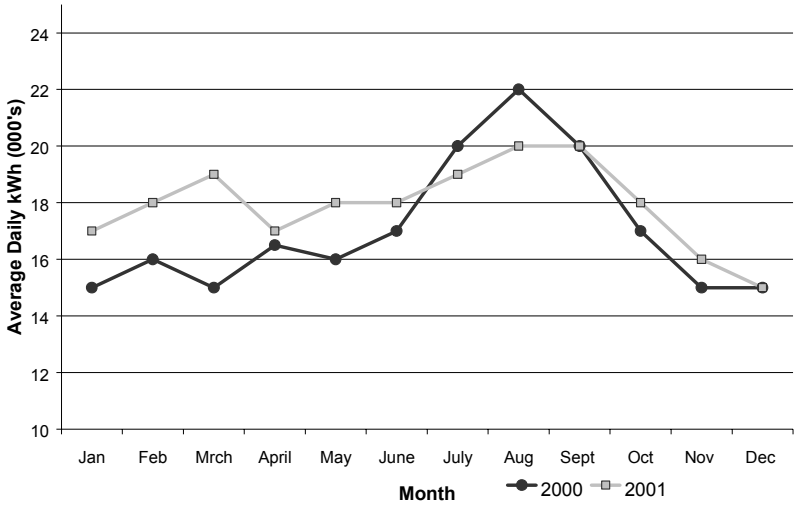

Figure 53

be set up immediately and work scheduled during unoccupied hours. Preventive maintenance can reduce the number and cost of emergency corrective maintenance bills.

Performing regular preventive maintenance can result in energy and cost savings. For example, simply replacing worn fan belts on a regular basis can save 2% to 4% of the energy used to run the fans. Cleaning air filters and cooling coils regularly can save 1% to 3% of the building's energy use for cooling. These basic activities cost very little to perform, but can add up to dramatic savings.

Preventive maintenance also makes buildings safer and can reduce potential district liability. Increasingly, building ventilation systems function as part of an engineered smoke-control system and, therefore, proper maintenance can decrease liability.

Developing a Preventive Maintenance Plan

The commissioning provider can help the district or facility manager develop a preventive maintenance plan for a building's HVAC and electrical systems. Most of the information required for developing a preventive maintenance plan is gathered as part of the commissioning process or can be obtained from the operation and maintenance manuals.

Preventive Maintenance Software Modules

Many major controls contractors also offer preventive maintenance modules for their software that will track and automatically advise operation and maintenance staff when equipment maintenance needs to occur. These systems can offer good value because the controls system already knows a lot about many of the building systems. To set these systems up properly to be operational when the building is first occupied, the district should allow some extra budget for a facilities operator to assist in set-up during construction. This will also allow the operator to become familiar with the system and maximize its benefits once the building is occupied.

A preventive maintenance plan consists of a checklist of tasks that are performed at manufacturer-recommended intervals (usually measured in hours of equipment run time). This checklist is usually kept in the form of a log and is updated manually when tasks are performed. In buildings that use computerized maintenance management systems, the equipment that requires preventive maintenance should be entered into the system. If the computerized system is used for generating preventive maintenance work orders, update the system when work is performed and keep hard copies of completed work orders in a file or notebook. Another low-cost measure to consider is programming the energy management system to track and archive equipment run times. This option is easy and inexpensive if done when the initial system programming takes place, and it should be outlined in the original equipment specification in the contract.

The preventive maintenance plan for each piece of equipment should include the following fundamental information, gathered during the commissioning process:

- Unique equipment identification number
- Name plate information
- Manufacturer's name
- Vendor's name and telephone number
- Equipment location

- Date installed
- Expected equipment life
- Expected annual energy use.

Preventive maintenance should be performed according to manufacturer requirements. Consult the manufacturer's operation and maintenance manual for each piece of equipment for requirements such as frequency, chemical treatments, proper lubricants, special tools, etc. This information should also become a part of the preventive maintenance plan.

The preventive maintenance work order form or task list for each piece of equipment should have a verification section with at least two signature lines: one for the technician performing the preventive maintenance and one for the supervisor verifying that the maintenance was performed.

Outsourcing Preventive Maintenance

If a new piece of equipment does not require frequent maintenance, and current staff time is committed, a contract for outside help may be less costly than hiring and training full-time staff. If a sophisticated new piece of equipment is purchased, compare the cost of training in-house staff to the cost of hiring a trained outside contractor to perform maintenance on the equipment to determine the best option.

In buildings where operating staff is not available or trained to perform the required preventive equipment maintenance, districts may obtain a service contract from the vendor, installing contractor, or a maintenance service contractor. Ensure that the service contract covers all of the manufacturer's recommended preventive maintenance procedures as described in the operation and maintenance manuals. After each site visit, require the contractor to provide an invoice or preventive maintenance form stating clearly which preventive maintenance activities or repairs were performed. Keep these forms onsite in a file or three-ring binder for future reference. Regardless of who actually performs the preventive maintenance, the district is responsible for making sure that the preventive maintenance plans are complete.

Maintenance contracts tend to be site-specific, but in general, there are two basic types of services.

- **Preventive maintenance contract.** Normally, this type of contract does not cover the cost of replacement parts, but does include labor and supplies. The equipment owner is responsible for parts replacement. The duration of a preventive maintenance contract is usually one year. Frequency of site visits may depend on the equipment being serviced. Corrective maintenance may or may not be included.
- **Guaranteed service and repair contract.** Large maintenance contractors usually offer this type of contract. Under this arrangement, the contracting firm not only maintains but also replaces failed components. It is essentially an insurance policy with a low deductible, and typically is a multi-year contract. The cost for this type of contract is comparatively high.

Regardless of the type of contract used, it is important to carefully evaluate the cost for the service, quality of service, and the existing contractor's familiarization with the facility's

equipment and operating procedures when the contract is up for renewal. Because any new contractor will face a learning curve when taking over a facility, it might not be a wise decision to choose a new contractor just because they offer a lower price. Careful consideration of the quality service already received and successful renegotiations with the existing service contractor might provide better long-term value.

LIST OF COMMISSIONING REFERENCES AND RESOURCES

Procedural Guidelines, Specifications and Functional Tests Last Updated: 10/25/01
*Denotes documents available on electronic disk.
Legend: ● Comprehensive Information ◘ Average Information/Partial Information ○ No Information

Source	Design		Construction		Sample Tests
	Guidelines	Specs	Guidelines	Specs	
Appendix VII Idaho New Building Commissioning Guidelines, State of Idaho, 2000. Available at: http://www2.state.id.us/adm/pubworks/archengr/app7nbcg.pdf	○	○	○	○	○
Building Commissioning Assistance Handbook Appendices. Seattle City Light, 1999. Standardized functional test procedures. http://www.ci.seattle.wa.us/seattle/light/conserve/business/bdgcoma/cv6_bcam.htm	○	○	○	○	*●
Procedural Standards for Building Systems Commissioning, National Environmental Balancing Bureau (NEBB), 1999. (301) 977-3698.	◘	◘	◘	◘	◘
A Practical Guide for Commissioning Existing Buildings, PECI and Oak Ridge National Labs (ORNL), 1999. NTIS (800) 553-6847.	●	○		○	○
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Beyond Lighting DSM: Life After Green Lights, Montgomery Co., MD, 1995. Existing building commissioning case study with sample process and detailed procedures. 70 pgs. (301) 217-6000.	◘	○	○	○	◘
Engineering and Design Systems Commissioning Procedures, U.S. Army Corps of Engineers, 1995 (ER 1110-345-723). Dept. of the Army, U.S. Army Corps of Engineers, Washington, DC 20314-1000.	◘	◘	◘	◘	○
Commissioning Specifications, C-2000 Program, Canada, 1995. C-2000 Program, Energy Mines & Resources, Energy Efficiency Division, 7th Floor, 580 Booth St., Ottawa, Ontario, Canada K1A 0E4.	○	○	○	*●	○
Model Construction Document Specifications and A/E Services Contract Clauses, Bonneville Power Administration/John Heinz, U. of WA, 1995. 503-230-7334. Also available on the Univ. of Washington web site at: http://www.depts.washington.edu/fsesweb/fdi2001/15_mech/doc/19-15t.doc.	○	○	○	*●	◘
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Source	Design		Construction		Sample Tests
	Guidelines	Specs	Guidelines	Specs	
Laboratory HVAC Systems: Design, Validation and Commissioning, ASHRAE collection of 11 papers, 1994. ASHRAE Publications Dept., 1791 Tullie Circle, NE, Atlanta, GA 30329. (404) 636-8400. http://www.ashrae.org/	○	○	●	○	○
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HVAC Systems Commissioning Manual, Sheet Metal and Air Conditioning Contractors' National Association (SMACNA), 1993. SMACNA, 4201 Lafayette Center Dr., Chantilly, VA 22021.	○	○	◘	◘	◘
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HVAC Functional Inspection and Testing Guide, U.S. Dept. of Commerce and the General Services Administration, 1992. NTIS: (800) 553-6847.	○	○	○	○	●
AABC Master Specification, Associated Air Balance Council. (Primarily for how the TAB fits into the commissioning process) AABC National Hdqrs, (202) 737-0202.	○	*◘	○	●	○

Commissioning Overviews and Case Studies

Building Commissioning: The Key to Quality Assurance. U.S. DOE Rebuild America/PECI, 1998.

Commissioning retrofits and existing buildings: overview, process, and case studies. Dedicated solely to retro-commissioning. 68 pgs. (800) 363-3736.

Beyond Lighting DSM: Life After Green Lights, Urban Consortium Energy Task Force of Public Technologies, Submitted by Montgomery County Government, MD, Div. of Facilities and Services, 1998. Existing building commissioning case study with sample process and detailed procedures. 70 pgs. (301) 217-6000.

Commissioning For Better Buildings in Oregon. Oregon Office of Energy/PECI, 1997.

New construction overview, benefits, process, and case studies. Contains some data on recommisioning. 44pgs. (503) 378-4040 or download at: http://www.energy.state.or.us/bus/comm/bldgcx.htm

What Can Commissioning Do For Your Building? PECI, 1997.

Commissioning overview and report of 175 building case studies. Contains some data on recommisioning. 12pgs. (503) 248-4636.

Commissioning Four New Science Laboratory Buildings (U. of WA). Bonneville Power Admin./Phoebe Caner, 1997. Commissioning case studies with detailed "lessons learned" information in all sections. ~70 pgs. (503) 230-7334.

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A web site dedicated to providing access to documents dealing with the Guidelines for Total Building Commissioning is being developed under the auspices of the National Institute of

Building Sciences. The site is maintained by the Florida Design Initiative and is organized around the individual technical guidelines that will comprise the complete set of Guidelines for Total Building Commissioning. http://www.sustainable.state.fl.us/fdi/edesign/resource/totalbcx.

Implement Building Commissioning, published by U.S. Department of Energy, Rebuild America, EnergySmart Schools program (Washington, DC, 2000); available at: http://www.eren.doe.gov/energysmartschools/om_implement.html. Defines building commissioning; discusses the selection of a commissioning agent; the benefits, approaches, and components of commissioning; and lists resources.

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Four case studies. Seattle City Light. http://www.ci.seattle.wa.us/seattle/light/conserve/business/bdgcoma/cv6_bcam.html.

Web Sites Containing Commissioning Documents

Building Commissioning Association	http://www.bcxa.org/
Florida Design Initiative	http://www.state.fl.us/fdi/index.html. Ongoing articles & forum.
National Institute of Health Model Commissioning Guide	http://www.des.od.nih.gov/farhad2/Commissioning/nih_cx_guide/ComGuideTitle.htm
NEBB	http://www.nebb.org/. Certification program and manuals.
Oregon Office of Energy	http://www.energy.state.or.us/bus/comm/bldgcx.htm Benefits of Cx, case study, the full text of *Commissioning for Better Buildings in Oregon*. Contains some data on recommissioning.
PECI	http://www.peci.org/ NCBC information, downloadable *Model Cx Plan and Guide Specifications*, Cx and O&M resources.
Seattle City Light	http://www.ci.seattle.wa.us/seattle/light/conserve/business/bdgcoma/cv6_bcam.htm Standardized test procedures and case studies.
Texas A&M Energy Systems Lab	http://www-esl.tamu.edu/. Retrocommissioning process and software, for purchase. Dedicated solely to retrocommissioning.
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USDOE / FEMP	http://www.eren.doe.gov/femp/techassist/bldgcomgd.html. Full text of GSA/USDOE *Building Commissioning Guide;* early version of *Model Cx Plan and Guide Specifications*.
USDOE	http://www.eren.doe.gov/. Links to commissioning documents. Search on "commissioning."
Whole Building Design Guide (NIBS)	http://www.wbdg.org/. National Institute of Building Sciences. Find commissioning information by searching on "commissioning."