PART 2: Commissioning Guide for Design Professionals

Commissioning is a quality-assurance process for new construction and installations that helps ensure that building equipment and integrated systems perform as owners and designers expect. Commissioning implements a systematic process to verify and cross-check performance from pre-design through warranty, increasing the likelihood that a newly constructed building will meet client expectations. In return for investing in commissioning, the building owner can save money during construction and throughout the operation and maintenance of a quality building. The designer can be an essential part of the commissioning process, helping to facilitate successful commissioning, and promoting overall client satisfaction.

What *Is* Building Commissioning?

Commissioning is a systematic process of ensuring that building systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs.[1] Ideally, the process begins in the pre-design phase with the development and documentation of owner's project requirements and design intent acceptance criteria, and continues through design, construction and the warranty period with actual verification through review, testing and documentation of performance. Commissioning integrates many traditionally separate project activities, including aspects of design peer review, equipment startup and verification procedures, control system calibration, testing, adjusting and balancing, O&M manual preparation and facility staff training and functional testing.

[1] ASHRAE, *Guideline 1-1996: The HVAC Commissioning Process*, American Society of Heating Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia, 1996.

Why Commission Your Projects?

Consider a common commissioning problem with a VAV terminal unit. The unit is installed as part of a remodeling project (thus, served by an existing system) and it is not maintaining the required space comfort conditions. When the commissioning provider investigates the problem, he finds a group of qualified contractors/tradesmen who have all done their specific tasks.

- The tinner hung the unit, connected the ducts, installed the diffusers and balanced the system.
- The pipe fitter connected the reheat coil, insulated the lines and balanced the water system.
- The controls contractor installed the controller, verified wiring connections and calibrations, and installed the software.
- The designer extended the existing systems—as instructed—to serve the new loads, and the systems and equipment the designer specified have been installed as shown and connected to the existing systems.
- The building operator is running the existing systems to the best of his ability and really doesn't know if they are capable of handling the new load.

Everyone has done their part to the letter of their contract, yet the space is not comfortable. No one has taken ownership of the interactive parts *as a system* and looked beyond the boundaries of their contract for a cause and solution to the problem. This is the heart of commissioning—to take a big picture, systems oriented perspective on the project, develop an understanding of the interactions of the systems and then develop solutions.

COMMISSIONING BRINGS A BIG PICTURE, SYSTEMS ORIENTED PERSPECTIVE TO PROJECTS.

Today, commissioning typically begins with the selection of a commissioning provider. The commissioning provider may be an individual or a firm. The owner may also choose to use a designated in-house staff member, or the services of the designer or construction manager to implement the commissioning process. The first task of the commissioning provider is to work with the team of project stakeholders to develop the projects commissioning plan. The commissioning provider helps ensure that the building owner's project requirements are properly documented. The provider also promotes O&M and energy efficiency improvement opportunities during the design phase.

For instance, a designer may document the reasons for combination fire/smoke dampers and their ratings where a duct passes through a particular fire separation. A commissioning provider could advocate for accessibility for these devices and promote the use of energy-efficient configurations (airfoil blades vs. conventional blades, and damper out of the air stream vs. damper in the air stream).

The commissioning provider and/or designers then incorporate commissioning requirements into their specifications. During construction, the commissioning provider inspects building systems and components for compliance with contract documents and related acceptance criteria. When the project is near completion, the provider and appropriate contractors conduct rigorous functional tests. In most cases, the commissioning provider will also coordinate and provide oversight for the start-up process. At the end of the commissioning process, building operators receive training and ideally a systems manual, that documents the key information to ensure proper O&M of the building.

A properly commissioned facility has several advantages over a non-commissioned building. These can include fewer change orders during the construction process, fewer call-backs, long-term tenant satisfaction, lower energy bills, lower O&M costs, lower equipment replacement costs and an improved profit margin for building owners once the building is occupied. Commissioning also assures that the building's operational staff is properly trained to run the building as the designer intended.

Commissioning can help optimize energy-efficient design features and improve overall building performance. Design professionals can use this proven, systematic approach to reduce change orders and liability exposure, and ensure that the building owner receives a building that functions according to the owner's project requirements.

DESIGNERS CAN USE COMMISSIONING TO REDUCE CHANGE ORDERS AND LIABILITY EXPOSURE.

A Brief History

Over the past 20 years, the construction industry has changed dramatically in the United States. Older building systems were less complex, requiring less sophisticated equipment to perform successfully. Control systems, even sophisticated ones, were generally electro-mechanical because electronic and digital technology was not considered cost effective in the commercial buildings industry. Low energy costs made the more complex HVAC systems, like variable air volume (VAV) fan systems, less attractive than the energy intensive but easy-to-operate constant volume reheat fan systems. The low energy costs provided little incentive to schedule equipment and systems, and the continuous operation of systems often masked operational problems or simply eliminated them. In addition, building envelopes allowed greater air infiltration because energy costs were lower and efficiency was not a priority. At the same time, designers and contractors that delivered higher quality buildings commanded higher fees.

Today, energy efficiency receives more attention. Buildings have more sophisticated controls and equipment and building envelopes are tighter. Most significantly, the transition from a design-bid-build to a bid-design-build contract process has increased the pressure on the design community to reduce fees and consequently curtail the extent of their work.[2] New construction design fees typically are governed by a percentage of the capital

[2] Nolfo, Andrew, "Commissioning and the Design Build Process," in *Proceedings of the National Conference on Building Commissioning*, 1998.

cost of the facility. Focusing on capital costs, rather than the life-cycle costs associated with a facility, encourages owners to ignore long-term considerations such as O&M costs, energy efficiency, ease of use and occupant productivity.[3] It also discourages designers from investigating innovative system alternatives that could cut long-term costs and improve the overall performance of the building.

The construction process is an increasingly complex maze of specialized tasks. In most cases, the architect or general contractor controls the project. Specialized mechanical and electrical design work is subcontracted out, leading to a disjointed construction process. But despite this added complexity, project budgets are shrinking, leaving little room for error. Construction teams have relatively little money for "contingencies" when problems occur. Mistakes that might have been corrected with teamwork are now overlooked in the name of completing the job on time and within a budget. It used to be standard practice for many contracting firms to conduct performance tests and systematic check-out procedures for equipment they installed. As construction budgets have become tighter, this service has been dropped from most projects. The net result can be poor building performance and increased operating costs. When problems occur, the building owner and/or tenants may file litigation against the construction and design teams for what they perceive as inadequate product delivery. Many owners do not understand that they are not currently paying for the level of quality assurance that commissioning provides. Given today's sophisticated building systems, tight construction budgets and short construction timelines, owners need to use the commissioning process to help deliver buildings that perform as intended.

Who Takes Advantage of Commissioning?

Commissioning is standard practice for many facilities at the Walt Disney Company, Sprint, Kaiser Permanente Health Care, the Boeing Company and other firms.

The commissioning process has been successfully demonstrated in both the government and private sectors. Executive Order 12902 requires all federal agencies to "establish and implement facility commissioning." Several state governments are developing policies to establish commissioning infrastructures. The California Energy Commission (CEC) is helping to develop and promote the practice of commissioning within California's construction industry. Private corporations have embraced commissioning after recognizing that better building performance reduces their energy and long-term maintenance costs, reduces their liability and improves occupant productivity. Commissioning is standard practice for many facilities at the Walt Disney Company, Sprint, Kaiser Permanente Health Care, the Boeing Company, Hewlett Packard, Chevron Oil, Target Stores and Westin Hotels.

[3] Tamblyn, Tom, "Commissioning a School: A Case Study," in *Proceedings of the National Conference on Building Commissioning,* 1994.

Why Should Designers Be Involved?

Commissioning offers designers an opportunity to view the entire building delivery process, to work through design questions in a team environment, see the results of their designs and, ultimately, provide a higher quality product to their customers. In turn, designers who participate in commissioning should command higher fees for providing these services. In traditional construction compensation models, the designer's fee is based indirectly on a percentage of the building's cost. The designer gets no reward for extra effort to make the building perform better, or perform more efficiently, or to make construction less costly. This is not desirable for owners, designers, or anyone interested in energy and resource efficiency. Commissioning provides an opportunity to rethink this compensation model. By systematically documenting efficient design, construction and performance, commissioning saves money in construction and subsequent operations. Implementation of the commissioning process often necessitates expanded designer services—services that ensure better building performance and satisfied customers.

Innovation in design can be intimidating. Every building design is unique, even seemingly "standard" designs. In essence, each building is a prototype, yet it is expected to perform as if it had been built before. Commissioning can provide a safety net to review and support the design, whether it is a new design or a reworking of a tested design. Commissioning allows designers to observe the implementation of their designs in the field. Without commissioning, the best design ideas may be negated in the field due to change orders or contractor oversight. Through the commissioning process, the designer will see proof that his or her designs are implemented.

Commissioning allows designers to observe the implementation of their designs in the field.

The commissioning process encourages everyone involved in a building project to function as a team, from design initiation through building acceptance and warranty. It allows owners and operators to decide how they want their building to function, and to convey these expectations clearly. It offers the design and construction professionals a systematic process to develop and complete the project based on these expectations. Many owners accept that in return for investing more in a design process that includes commissioning, they will receive a completed building that meets their quality expectations at a lower ultimate cost. By shifting a portion of total project costs from construction and first-year fine-tuning to the commissioning provider and the design team, the owner can potentially save significant sums of money.[4] Owners who have experienced the benefits of commissioning are typically willing to pay more for design services on future projects that include commissioning.

[4] 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.

What Does This Guide Include?

This guide addresses commissioning issues from the designer's perspective. Assuming that readers have a basic knowledge of the commissioning process,[5] the guide describes how designers can use commissioning to enhance their services and maximize client satisfaction. Readers will gain an understanding of how commissioning can benefit designers, the role of designers in various commissioning activities, and how designers interface with other commissioning team members. The guide also offers tips for marketing commissioning services to clients, commissioning plan outlines and sample owner's project requirements documentation. Sample commissioning specifications and other commissioning resources can be found in the EDR CD-ROM of Building Commissioning Guidelines.

Acronyms List

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BCA	Building Commissioning Association
DDC	Direct Digital Control
EDR	Energy Design Resources
EMS	Energy Management System
HVAC	Heating, Ventilation and Air-Conditioning
LEED	Leadership in Energy and Environmental Design
O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Administration
PID	Proportional plus Integral plus Derivative
RFI	Request for Information
RFP	Request for Proposal
RFQ	Request for Qualifications
TAB	Testing, Adjusting and Balancing
USGBC	U. S. Green Building Council
VAV	Variable Air Volume

Commissioning and Green Buildings

Building owners are increasingly concerned with issues of resource efficiency, environmental impact, and occupant health and productivity. They are beginning to request that their facilities be designed and constructed with "green" features that minimize

[5] For a description of the commissioning process, see Part One of this guide: *Introduction to Building Commissioning*.

environmental impact and maximize occupant productivity. Certain federal, state and local government agencies, as well as a number of private owners, now require their facilities to meet a "green" standard.

Commissioning is especially important for green buildings because these projects use new construction techniques and materials. Green buildings often employ systems that use renewable resources such as solar energy or wind power and low-energy HVAC systems with natural ventilation or evaporative cooling. They may also employ systems that conserve water through rainwater and gray water recovery. All of these technologies can make a significant contribution to the sustainability of a project, but they add complexity to building design and construction, as well as commissioning, since the technologies are less thoroughly understood. Commissioning can help ensure that the green ideas and concepts of the designer are developed for the individual needs of the facility and clearly articulated within the design documents. In addition, commissioning can verify that the green design features perform adequately once the building is completed.

Commissioning a green building includes ensuring that:

- The design meets the desired green building certification criteria.
- Green materials are adequately specified and installed.
- The green products or features will not have a negative impact on other building systems or ongoing O&M.
- The design decisions and rationale behind them are adequately documented.
- Specifications and drawings are clear and complete.
- Specific performance criteria are developed for each green feature, if appropriate.
- The appropriate O&M documentation and staff training is provided so facility staff can properly maintain the green features.

The United States Green Building Council (USGBC) has developed Leadership in Energy and Environmental Design (LEED), a green building rating and certification system to provide guidance to designers. Under LEED, buildings earn points in six general categories: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, and Innovation & Design. Buildings can earn a bronze, silver, gold or platinum rating.

COMMISSIONING IS A PREREQUISITE FOR LEED RATING ELIGIBILITY.

The USGBC requires six commissioning tasks as prerequisites for LEED rating eligibility.[6] These "Fundamental Building Systems Commissioning" requirements for mechanical systems are:

- Hire a commissioning provider for the project.
- Collect and review the owner's project requirements and basis of design documentation.
- Include commissioning requirements in the construction documents.

6 U.S. Green Building Council, *LEED Reference Guide*, Version 2.0, 2000.

- Develop and use a commissioning plan.
- Verify the installation, functional performance, operational training and maintenance documentation for each commissioned system.
- Complete a commissioning report.

Although these steps are part of any good commissioning process, the need to document these steps for LEED purposes and coordinate with other members of the LEED team may add costs to the commissioning work. In addition, LEED requires that the functional testing of the heating and cooling systems occur during the heating and cooling seasons respectively. While this is desirable, it is not mandatory for a non-LEED commissioning process, and thus, it may incur additional commissioning costs.

An additional credit toward a LEED rating can be earned by completing all five of the following tasks:

- Conduct a focused review of the design before the construction document phase.
- Conduct a focused review of the construction documents just prior to completion.
- Conduct a selective review of contractor submittals of commissioned equipment.
- Develop a Recommissioning Management Manual.
- Establish a contract for a near-warranty-end or post-occupancy review.

Recent experience has shown that many owners and construction project managers assume that the LEED process and the commissioning process are identical—that the commissioning provider is handling all LEED requirements and coordination. This is not usually the case. LEED requires commissioning of all credit-earning mechanical systems and energy-efficiency measures under the Energy and Atmosphere and the Indoor Environmental Quality categories. However, it does not stipulate that the commissioning provider will handle all LEED-related design and coordination issues, such as LEED document coordination, specification, implementation or engineering. Such coordination is beyond the scope of the commissioning associated with a LEED project. While the commissioning provider is a good candidate for performing this coordination, it should not be assumed that he or she will be providing this coordination simply because they have been engaged to perform the commissioning work. The specifications for a LEED project must clearly stipulate which parties will be responsible for which LEED activities. A matrix like the one below can help make sure that each party understands his or her role in the process.

Sample LEED Certification Responsibilities Matrix

Designate the party responsible for each credit activity in the spaces on the matrix below—the first two lines are filled in as an example. Note that the prerequisites and credits listed below are a selected sample, not a complete list, of LEED activities.

TABLE 4

LEED Credit Category	Coordination of Documents	Specification/ Engineering	Implementation	Commissioning
Energy and Atmosphere				
EA Prerequisite 1 (Fundamental commissioning)	LEED Coordinator	Commissioning Provider	Commissioning Provider	Commissioning Provider
EA Prerequisite 2 (Minimum energy performance)	LEED Coordinator	Mech. Designer	General Contractor	Commissioning Provider
EA Prerequisite 3 (CFC Reduction in HVACR equip.)				
EA Credit 1.0 (Optimize energy performance)				
EA Credit 3.0 (Best practice commissioning)				
EA Credit 5.0 (Measurement & verification)				
EA Credit 6.0 (Green power)				
Indoor Environmental Quality				
EQ Prerequisite 1 (Minimum IAQ performance)				
EQ Prerequisite 2 (Envrmntl. tobacco smoke control)				
EQ Credit 1.0 (C02 monitoring)				
EQ Credit 6.1 (Controllability of Systems)				
EQ Credit 7.1 (Thermal comfort)				
EQ Credit 8.2 (Daylight and views)				

How Designers Benefit from Commissioning

Becoming involved in a commissioning process offers many benefits to the designer:

- The team approach promotes project success.
- Coordination between designers, contractors and owners improves building performance.
- Designs become more realistic, robust, practical and achievable in the field.
- Designers spend less time answering questions from the construction team, due to improved communications.
- Problems are detected and corrected early, keeping projects on time and within budget.
- The designer gains an ally on the project (the commissioning provider).
- Commissioning reduces the likelihood of claims against the designer.
- Increased customer satisfaction can lead to higher fees and more repeat business.

A Team Approach

In recent California focus group studies, building owners and their representatives repeatedly stressed that a major obstacle to achieving optimal building performance is the lack of communication between the design team and construction team. Without proper communication between designers and contractors, the original owner's project requirements are likely to be "lost in translation" as a project moves from concept to completion. (Documenting the owner's project requirements is a critical component of commissioning and is discussed in more detail later in this document.) Commissioning links the traditionally fragmented phases of the design and construction processes by facilitating a team approach and encouraging the project team to view the building process holistically. Owners, designers and contractors meet to review plans, document intent, identify acceptance criteria and clarify issues before they become in-the-field problems.

Commissioning can create a cooperative team approach to a project. If the commissioning provider facilitates a collegial relationship among all team members, the project team is likely to resolve issues effectively, with the least amount of wasted time and money. In contrast, a group of professionals who do not work as a team may resort to "finger pointing" and defensive tactics when issues arise.

Coordination Among Designers, Contractors and Owners

Commissioning can foster greater cooperation among the professionals involved in a project and provide a platform for cross-checking the performance of a building's equipment and systems. On many projects, a lack of coordination among the design, installation and operational team members can lead to systems that function inefficiently or fail to function

at all. For example, the mechanical systems found in many commercial buildings are oversized,[7] a result of uncertainty over future loads and the use of excessive safety factors. This leads to unnecessary energy use to run these systems. It can also lead to an unnecessary and significant increase in first costs, which ripple through the project. A larger-than-necessary fan may mean a larger motor, which can mean a larger starter or variable speed drive, which can mean a larger distribution feeder, which can mean a larger electrical service. The commissioning process encourages the review of performance requirements and the design to ensure that appropriately-sized mechanical systems are specified and installed.

Commissioning can also ensure that design details, especially those related to commissioning, are not changed in the field. In-the-field decisions (such as substituting a saddle joint for a manufactured tee, or changing the pitch of the roof slightly) can drastically affect building performance. One cannot expect the contractor to be aware of the ramification of making such changes if he or she is not familiar with the motivation behind the design specifications. Moreover, changes can affect the ability to test building performance—essential for a successful commissioning—and O&M—process.

COMMISSIONING CAN FOSTER GREATER COOPERATION AMONG THE PROFESSIONALS INVOLVED IN A PROJECT AND PROVIDE A PLATFORM FOR CROSS-CHECKING THE PERFORMANCE OF A BUILDING'S EQUIPMENT AND SYSTEMS.

Finally, commissioning sees that designs account for continued building performance by providing adequate access to systems and equipment that may require maintenance, replacement or retesting. Doors and access panels should be sized and situated appropriately, where they are not obstructed by last-minute changes in construction plans or by field changes. By establishing and sustaining team communication, as well as functionally testing systems and equipment, commissioning can help team members ensure that systems are sized correctly and function as designed.

Designs Work in the Field

Bringing designers and contractors together to solve problems improves the work of both. Designers learn the practical aspects of implementation, leading to designs that are easier to construct and maintain and that are more energy-efficient in the field. Contractors learn the importance of each design detail—why they should not substitute a saddle joint when the designer specified a manufactured tee, or why two seemingly identical pieces of equipment can mean very different levels of energy-efficiency.

By becoming involved in the commissioning process, designers learn the practical implications of their designs. Designers see how their designs address real world problems such as energy efficiency, constructability and maintainability. All too often, a technically superior design is plagued by implementation problems. A designer may create a

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

sophisticated design and address every conceivable problem. However, if the design is beyond the available construction, operation and maintenance capabilities in the field, the building will not perform as intended.

> For example, consider PID control algorithms. Current DDC equipment can do PID control on almost any control loop. Designers often specify PID control for everything from the central system control loops to the space temperature control loops, although tuning a PID loop (as compared to a proportional-only loop) is quite complex. A proportional-only loop can be set up in less than an hour and will work predictably after that. A PID loop can take hours or days to tune and may require seasonal adjustments. If not properly adjusted, it can become unstable and drive other loops into instability. This wears out equipment, significantly affects the building environment and often wastes energy. The advantage of the PID loop over the proportional-only loop is that it eliminates the proportional offset, offering more precise control. If the loop is applied to a discharge air temperature control system, this can mean a significant savings in energy and a significant improvement in performance, and the PID is probably worth the extra tuning effort. On the other hand, to control space temperature—where occupants will adjust the set point as a function of how they feel—PID control is an unnecessary layer of complexity in this case.

By getting involved in the commissioning process, the designer has the opportunity to witness the problems associated with tuning a PID loop. A designer who has never encountered this problem might specify it for everything, unaware that this could result in significant increases in construction and operating costs, and ongoing performance issues. Thus, the designer involved in commissioning will learn to produce designs that achieve optimal performance under real world constraints.

The commissioning process gives the designer an opportunity to get out in the field to see the result of their efforts—an opportunity that doesn't usually exist, at least in a billable mode. This benefits the overall construction process because ultimately, the designer knows the project drawings and specifications better than anyone. Often, designers can look at a situation in the field and, based on knowledge of the assumptions behind the design, solve a problem in minutes that might have taken the contractor or the commissioning provider hours to address.

Designers Save Time

The commissioning process promotes well-documented designs and collegial relationships, both of which reduce the time designers spend answering questions from the construction team. In a commissioning process, the designer, with assistance from the owner and the commissioning provider, documents the owner's project requirements, acceptance criteria and basis of design at the inception of the project. Clarity from the outset reduces ambiguity, smooths the process of design review and produces construction documents

that convey exactly what is to be built. In addition, the commissioning process includes regularly scheduled meetings with the entire commissioning team. If a question arises during construction, the construction team can consult the design documentation or engage designers in an ongoing dialogue without waiting for small questions to become big problems.

Early Detection Saves Money

The commissioning process encourages parties to communicate and solve problems earlier in the construction process, while there are still low-cost or no-cost solutions available.

> For example, a design for a grocery store included a rooftop air-handling unit. The commissioning provider pointed out that the air intake was close to the loading docks, where the unit would draw in exhaust from the trucks. The design team decided to change the position of the rooftop unit, avoiding hundreds of thousands of dollars in lost worker productivity, potential health complaints, litigation fees and lower sales over the life of the building.[8] If they had attempted to correct the problem after construction, the cost (to filter the air or relocate the unit) would have been exorbitant.

By saving the owner money on construction and first costs, commissioning can free up money to be spent on design. Commissioning incorporated into the design phase of projects can significantly reduce change orders. This, in turn, reduces the requests for project delays and decreases the use of the owner's contingency funds for change orders.[9] Commissioning can also reduce first costs (see preceding oversizing scenario) and ongoing operating costs through better access and maintainability, improved efficiency and smarter resource use. Better access to equipment can have a significant impact on long-term costs and efficiency. For instance, if a chiller room is easily accessible, the costs to upgrade to better or more sustainable refrigeration technology when it becomes available are not prohibitive. If, on the other hand, it costs $50,000 in temporary ramps, rigging and access accommodations to install a $30,000 chiller, then chiller replacement will be delayed until it is an absolute necessity. Thus, commissioning during design can help projects meet schedule and budget goals—and the resulting facilities continue to save money in lower operating costs over the life of the buildings.

By saving the owner money on construction and first costs, commissioning can free up money to be spent on design.

[8] Altwies, Joy. "Quantifying the Cost Benefits of Commissioning," in *Proceedings of the National Conference on Building Commissioning*, 2001.

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

THE COMMISSIONING PROVIDER BECOMES THE DESIGNER'S ALLY, HELPING TO ENSURE THAT DESIGNS ARE WELL DETAILED AND REALIZED IN THE FIELD.

Designers Gain an Ally

Designers without previous commissioning experience may feel that commissioning adds an unnecessary layer of oversight. However, if the process unfolds as intended, the commissioning provider becomes the designer's ally, helping to ensure that designs are well detailed and realized in the field. A designer's internal process of design review includes reviewing load calculations, verifying design details, verifying coordination among the various design specialties, reviewing control system sequences, verifying specifications, spot checking equipment selections and reviewing the final check set. A commissioning provider reviews the design specifically for commissionability and operability. For example, a commissioning provider will check that the design includes access for testing and O&M procedures—reading gauges, entering doors and panels, and inspecting and replacing filters.

> On one job, a commissioning provider discovered that a single sensor in a six-foot-high mixed-air plenum was installed at the top of the plenum. Due to stratification of air within the plenum, the sensor indicated the mixed air temperature was at set point 55°F when in fact the average air temperature was 48°F. A second sensor was installed to produce an average temperature reading, avoiding endless building control nightmares. Thus, commissioning had a significant impact on system performance, energy efficiency and occupant comfort.

The commissioning provider can also help make sure that contractors do not make equipment or component substitutions that might affect the final performance of the design or alter the owner's or designer's original intentions.

Reduced Claims

By taking care of problems before the owner occupies the building, commissioning can significantly reduce the likelihood of errors and omissions claims against the design/construction team. In 1996, the Design Professional Insurance Companies (DPIC) studied 44 of their claims on buildings that were not commissioned. The average settlement was $584,000 or roughly 1 percent of the total construction costs.[10] Common themes that ran through many of these claims were a lack of coordination among parties (owner, designers, contractors and operational staff), equipment changes during the construction phase of the project and improper maintenance practices once the building was occupied. All of these issues could have been addressed by building commissioning.

Some designers might argue that they carry insurance to cover these types of losses. However, the damages of a lawsuit extend far beyond the expenses covered by insurance.

[10] Thomson, Jeane P. "Can Commissioning Impact Professional Liability Claims?" in *Proceedings of the National Conference on Building Commissioning,* 1997.

Each firm in the DPIC study lost the time and expenses to investigate and prepare their defense, paid out large insurance deductibles and lost the opportunity to earn future revenues from the affected clients.

Increased Customer Satisfaction

As indicated earlier, commissioning increases the likelihood that a project will meet the client's expectations. Satisfied clients will be more inclined to hire the design team again and more willing to pay more for a proven product. Designers will have documentation that paying more for commissioning and commissioning-related design activities will save money on construction and future facility operations.

Benefits During Construction

Although designers and owners benefit most when commissioning begins during the design phase or earlier, designers can also benefit from a commissioning process that begins during construction. A commissioning provider who comes into a project during the construction phase can bring a valuable new perspective and help solve start-up problems faced by 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 owners. By documenting the owner's project requirements and witnessing their implementation, the commissioning provider also can provide feedback to the designer. This improves future designs and earns customer good-will and satisfaction. A building owner who is satisfied at final turnover is more likely to contract with the design team again and, in turn, becomes an excellent reference.

Reduced Litigation Exposure

Every new building is essentially a prototype—unique and untested until it is built. With proper project planning, adequate time to develop and review the design, an able construction team to implement the design, and adequate training for the operators who run and maintain the building, occupants can be comfortable and productive over the life of the building. However, in today's construction environment, low design budgets, highly complex building systems, increased specialization and fast track construction timelines have become the norm. These factors can result in building systems that have not been adequately designed, fully tested or made to function as intended. In some cases this can result in unsatisfactory building performance, or worse, complete system failures.

There are many reasons a building may fail to perform as expected. Perhaps the owner's project requirements are not clear; perhaps the design is inadequate, or an adequate design lacks clarity; perhaps the design is misinterpreted or inadequately constructed. And at any

point in the design and construction process, simple human error may occur. A well-developed commissioning process mitigates each of these situations. Commissioning promotes the clear definition of owner's project requirements, achievable acceptance criteria, a clearly documented design, specifications that accommodate testing, and thorough documentation of system testing and its results. Commissioning not only proves the adequacy of the design, but also documents that at one time the design performed as intended. It also promotes the continuance of that performance via operations staff training and access to improved facility documentation, such as system manuals.

COMMISSIONING CAN PROVIDE ADDITIONAL DOCUMENTATION THAT AN ADEQUATE STANDARD OF CARE WAS USED DURING DESIGN.

Owners use lawsuits to contest inadequate building performance and system failure problems. Designers in turn have tried to protect themselves from these lawsuits while facing the increased pressures of completing their projects with fewer resources. While commissioning offers a quality assurance process for the owner, it also safeguards designers by improving the quality of their designs, which improves the final built product. Commissioning also provides additional documentation that an adequate standard of care was used in their design process.

Michael Hornreich, an attorney who specializes in construction litigation, believes that commissioning provides a basis for better communication and documentation between the building owner and the construction team. "Commissioning seeks to have the owner recognize at the beginning of their project what the overall project costs will be to properly design and construct a building to their desired performance parameters. Within a well-defined commissioning process, the owner is directly involved in helping the designer and the commissioning provider answer the following questions:

- "What is the desired product (i.e. owner's project requirements with acceptance criteria)?"
- "How will the work be inspected during installation?"
- "How will the performance be evaluated?"
- "What are the warranty obligations?"
- "How will the system need to be maintained?"

"The challenge of using this is not checking off discussion points, but rather using each point to force a deliberate approach to making decisions."[11] This communication, and the documentation that results, helps improve the outcome of the project and provides evidence that the performance expectations of the owner were met at building turnover. This documentation can also help reduce or eliminate future judgments because it demonstrates that proper care was taken during the design and construction process.

[11] Hornreich, Michael, "The Practical Legal Aspects of Commissioning Building Systems–Why Owners Should Pay for Commissioning Services," in *Proceedings of the National Conference on Building Commissioning,* 1994.

Increased Designer Profits

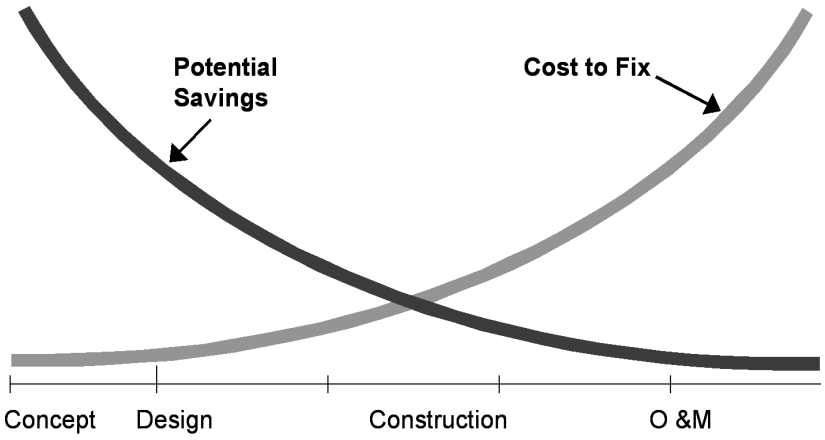
A designer's first impression might be that commissioning will add work to projects without additional compensation. As partners in the commissioning process, designers do take on some additional tasks and responsibilities. However, the services provided by the design team as part of the commissioning process (such as documenting design decisions, assuring that the contract documents reflect commissioning requirements and participating in commissioning meetings) will not only increase design revenue but will, in many cases, reduce or eliminate problems that have caused cost overruns and conflicts on non-commissioned projects. Commissioning results in a product that meets owner expectations, thus potentially reducing liability claims. After receiving a commissioned, well-performing building at turnover, owners are more likely to recognize the designer's efforts to deliver high-quality design services, and they will be more likely to hire that team on future projects.

Building owners who subscribe to the commissioning process are more willing to pay more for these design activities because they know that they will save money in the long run. Owners who are reluctant to invest the extra money will be persuaded after their first successful project involving commissioning. When they receive a building that works exceptionally upon turnover, they will realize they can afford to pay designers more.

Because commissioning can identify potential problems earlier in the design or construction process, it can result in a lower overall construction budget, fewer change orders, fewer contractor call-backs and lower operating costs. The earlier in the process that commissioning begins, the more potential savings are realized, freeing up more of the budget for design and commissioning services. The following figure shows how the savings potential of commissioning varies over the course of a project.

Cost and Savings vs. Project Timeline

FIGURE 4



Who Provides Commissioning Services?

Many people believe that commissioning is best performed by an independent third party who works directly for the owner. There are several reasons for this. First, most firms working in the design/construction field do not have the commissioning experience to properly plan and execute the majority of commissioning tasks. A qualified outside provider brings experience from a number of projects and may have expertise that in-house staff may not have, such as engineering analysis experience or diagnostic skills. Second, an outside provider is better able to identify problems that might have been missed by those intimately involved with the project. An outside provider offers a fresh perspective and new ideas to resolve problems and will not have a conflict of interest when reporting findings to the owner. Third, an outside provider has no investment in doing things "the old way." An outside provider can help project team members see the value in using new methods to perform old tasks.

It is also possible for someone affiliated with the design or construction team to act as the commissioning provider if they are properly experienced. The Building Commissioning Association (BCA)[12] recommends that when the commissioning provider is not an independent party under contract directly with the owner, then he or she should develop a formal plan for managing the potential conflict of interest. One method to manage (but not eliminate) these potential conflicts of interest is to institute parallel and simultaneous reporting of all findings to the owner's representative and contract manager for the commissioning services.

Provider Qualifications

To properly plan, schedule and execute a successful commissioning project, the chosen provider should have broad experience working as a team member in other commissioning projects. Additionally, a commissioning provider must have excellent communication and conflict management skills. On any commissioning team, there are likely to be differences of opinion. The commissioning provider's most challenging task is crafting the diverse opinions of all team members into an action plan that identifies possible conflicts and resolves them to the satisfaction of all involved.

[12] The BCA is a professional organization of independent commissioning providers, founded in 1998, that promotes high professional standards in the commissioning industry. For more information, see the Building Commissioning Association Web site at www.bcxa.org.

In general, for complex projects, a commissioning provider who will personally develop the commissioning test plans and directly supervise the commissioning work should meet the qualifications in the following checklist. These qualifications are focused on HVAC and control systems. Where electrical and other systems will be commissioned, the commissioning provider's experience in these areas should also be considered. However, often the prime commissioning provider will work with other consultants to 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 and other systems being commissioned.
- History of responsiveness and proper references.
- Meets owner's liability requirements.
- Experience working with project teams, managing projects and conducting scoping meetings.
- Experience commissioning at least two projects of similar size and of similar equipment to the current project; one in the last three years. This experience includes the writing and execution of verification checks and functional 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 O&M training.
- Background in building contracting.
- Overall understanding of all building systems including building envelope, structural and fire/life safety components.

Independent commissioning providers, who often have design engineering or operations training, should have the recommended minimum qualifications. Hands-on experience with building systems is especially critical. It is important to involve an independent provider as early in the project as possible. This allows the provider to review the owner's project requirements, begin scheduling commissioning activities and begin writing commissioning specifications into bid documents for other contractors.

Who Manages the Commissioning Contract?

The commissioning process is a team effort involving all of the traditional stakeholders of the construction process plus a commissioning provider with the specialized knowledge and experience to help plan and direct the commissioning activities. The traditional contractual relationship among the owner, design team and construction team remains the same. The only change is the addition of language outlining the design and construction teams' responsibilities to ensure that the appropriate commissioning activities take place. A separate contract for commissioning services can be managed by the owner/project manager, the architect or the contractor. Each option has its advantages and disadvantages. The final decision will probably depend on the complexity and the specific needs of the particular project.

Independent Third Party Under Contract to the Owner

Many owners who have commissioned their buildings recommend using an independent third party who reports directly to the owner. An independent commissioning provider, under contract to the owner or to the owner's project manager, can play an objective role and ensure that the owner will get the building performance he or she expects. For large and/or complex projects, especially in buildings with highly integrated, sophisticated systems, future savings from commissioning often outweigh the slightly higher costs of 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 phase, the commissioning provider can suggest more improvements and savings at the stage when changes can be made on paper. This approach is preferable to waiting to fix the problems through the change-order process while the building is under construction.

Architect or Design Engineer

On many construction projects, the owner delegates to the architect or design firm the responsibility of managing expenditures and approving payments to the various design engineers and contractors. If the owner has developed rigorous commissioning requirements and specifications, the firm may also be asked to manage the commissioning provider's contract. In some cases, if the managing architectural or design engineering firm has a qualified field engineer who does not have responsibility for the design of the project, he or she may even be charged with overseeing the commissioning activities (witnessing tests, etc.). This option has some advantages because the architect or mechanical designer is already familiar with the owner's project requirements and doesn't need to spend time getting up to speed. Overseeing the commissioning is not included in a design professional's basic fees, so the owner must pay the designer for managing the contract. To manage the

potential conflict of interest created by having the commissioning services managed by the design firm, all findings of the commissioning process should be directly reported to both the designer and to the owner.

Contractor

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.

If an owner has a good relationship with the general contractor, he or she may 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 owner has a technical staff that is qualified to oversee the test engineer. Still, many general contractors prefer to work with an independent commissioning provider because they are objective and they help oversee the quality of the subcontractors' work. This improves client satisfaction and ultimately reduces callbacks.

Commissioning and Design-Build Projects

At one time, construction projects were primarily designed and constructed using a design-bid-build process. The building owner contracted architects and engineers to develop a set of building plans and specifications based on his or her project requirements. Once these documents were completed, they went out to bid and the owner selected a contractor from the pool of respondents. Much of the discussion in this guide assumes this traditional design-bid-build approach. However, this section briefly touches on the design-build process.

Over the last 20 years, a new method of design and construction has appeared in the building industry. Largely contractor driven, design-build project delivery is an attempt to contain costs and improve construction timelines. In theory, selecting a combined design and construction team in one bidding process can result in lower overall project costs and shorter construction timelines. In reality, many owners have been dissatisfied. In some cases, owners didn't understand the implications of different quality levels of building materials and mechanical equipment. In other cases, the general contractor who won the design-build contract did not understand or give importance to the design process and so did not allocate proper funding for the design of appropriate building systems.

To avoid the potential pitfalls of the design-build process, owners must develop a strong set of design/performance criteria before placing their project out to bid. They should hire an experienced independent commissioning provider to help develop the criteria and work with the owner's representative, to determine whether the criteria are met. During the pre-bid meeting, owners must make the general contractors aware of their performance requirements and commitment to the commissioning process. With these precautions, a design-build project can be successfully commissioned, and the designer's role in the commissioning process will be the same as their role in commissioning a design-bid-build project.

If the owner decides to add commissioning into the design-build project after the project has gone out to bid, designers will find that their role differs somewhat. They may be charged with documenting the building owner's project requirements and acceptance criteria while the project is under construction and developing an addendum to the project specifications that includes commissioning. Designers may need to request more money to cover documentation tasks that were not in the original scope of work. In addition, designers can expect to encounter more RFIs and change orders than they would if commissioning had been part of the project from the beginning.

Project Phases and Commissioning

Commissioning activities occur during each phase of design and construction. Throughout all project phases, commissioning activities promote clear communication and teamwork. Ideally, commissioning begins in the pre-design phase and continues through design, construction and warranty. This provides the most overall benefit. In each phase, a commissioning provider works with various project team members to coordinate the commissioning process, with the aim of ensuring system integration and promoting overall quality assurance. In practice, commissioning often begins during the construction phase.

A description of the commissioning activities in each project phase is outlined below.

1. Pre-design Phase

Pre-design is the optimal time to begin the commissioning process. The initial commissioning team should be convened to lay the groundwork for the team effort and to plan for commissioning at later phases. In pre-design, the team includes at least the owner/project manager, commissioning provider and designers. The contractors and building operators should be added as they are hired.

One of the most significant tasks that occurs during commissioning begins during pre-design: developing project documentation necessary for commissioning—sometimes referred to as

design intent documentation. This documentation forms the foundation of the commissioning process, and its contents evolve over the course of a project. Because this documentation is not produced consistently and is not typically easily accessed for design and construction projects, there is some debate in the industry as to what exactly it should include. However, industry experts agree that this enhanced level of project documentation is critical to producing buildings that perform well and meet owner requirements. ASHRAE is currently working to better define this aspect of commissioning for its upcoming revision of the Commissioning Guideline.

For the purposes of this publication, this design intent documentation includes owner's requirements for the project, design intent acceptance criteria for each requirement, and references to the portions of the design basis and design narrative that relate to each requirement. These pieces of documentation are described in more detail later in this section and in the Design Phase section.

Design Intent documentation forms the foundation of the commissioning process.

The main commissioning tasks of the pre-design phase are outlined below. These tasks are especially critical for large or complex facilities (such as labs, hospitals, office buildings with innovative systems or special usage or IAQ requirements). Some of these tasks may be scaled down for smaller, less complex projects.

Commissioning Provider Selection. The project manager sends out requests for proposals or requests for qualifications for the commissioning services and contracts with a commissioning provider or designates one from the owner's, designer's or construction manager's organization. When a commissioning provider is involved from the beginning of a project, he or she can identify design strategies that facilitate later commissioning activities and offer commissioning-focused review of design documents. In addition, if the commissioning provider is involved from the start, the project team will accept him or her as someone who really understands and is invested in the project. The team's positive attitude about commissioning will result in a more successful commissioning effort. See Provider Qualifications on page 54 for recommended selection criteria.

Design Phase Commissioning Plan. The commissioning provider begins to develop a design phase commissioning plan, including recommended schedule and staffing requirements, documentation processes, and lists of potential checks and tests that should be considered. The plan will be enhanced as the design progresses. See Appendix 4 for a commissioning plan outline.

Owner's Project Requirements: Development and Review. Owner's Project Requirements, along with their related acceptance criteria, are the most critical piece of design intent documentation. The commissioning provider or design team may assist the owner in developing the owner's project requirements (OPR), or at a minimum, ensure that they are clearly documented. The OPR is an explanation of the ideas, concepts and criteria that the owner deems important. The owner or the owner's programming

representative typically develops this document, but the designer is often responsible for ensuring that it is clear and comprehensive. Designer responsibility in this area depends on their contract and their relationship with the owner. Some designers routinely develop this type of documentation; some rarely do so. The important factor—in terms of successful commissioning and in the performance of the building—is that the owner designates either the designer or the commissioning provider to spearhead the development of the OPR.

As the design progresses, the designer, owner and commissioning provider enhance the OPR by adding basic acceptance criteria to each item. As these criteria evolve over the course of a project, the commissioning provider and designer update the documentation. Appendix 5 contains an example of OPR .

Owner's Project Requirements

The owner's project requirements should generally describe the project both physically and functionally, and they should begin to set the performance requirements for design, construction and operation. The level of detail will vary with the size and complexity of the project, the building use needs and sophistication of the owner, and the experience of the design team. The owner's project requirements should describe how the project will be used and operated, and should present measurable goals and objectives when possible. They may also state specific contractual performance requirements or energy consumption targets, if the owner establishes them. The owner's project requirements set the criteria for all subsequent design decisions. Appendix 5 contains a sample format for developing this documentation.

2. Design Phase

During the design phase, the commissioning provider performs a commissioning-focused design review, ensures that the owner's project requirements are clearly documented and followed, and checks that commissioning for the construction phase is adequately reflected in the bid documents. Design-phase commissioning facilitates construction-phase commissioning and provides additional design review in areas of special concern to the owner. Note that commissioning during design is not intended to provide quality assurance for the entire design process; however the owner may choose to enlist the commissioning provider to perform a more rigorous design review, depending on the commissioning provider's experience and qualifications. Rather, it ensures that the final design includes all efficiency and operational concepts for building systems developed during pre-design.

A primary commissioning task for designers during this phase is continuing to develop the design intent documentation with assistance from the commissioning provider and the owner. (Depending on the commissioning provider's scope of work, the commissioning provider may take the lead on this task with assistance from the designer.) The main commissioning tasks during the design phase are outlined below.

Commissioning Scoping Meeting. The commissioning provider holds a scoping meeting at the beginning of the design phase. At this meeting, the commissioning provider outlines the roles and responsibilities of the project team members and reviews the commissioning plan and schedule. Team members comment on the plan and schedule, and the commissioning provider uses these suggestions to revise the commissioning plan.

Commissioning Plans. The commissioning provider updates the design-phase plan and develops a preliminary construction-phase plan to guide development of the commissioning specifications. The plan contains a list of the systems and specific equipment to be commissioned, along with the general modes to be tested and the probable testing methods. In addition, the plan more fully defines various team member responsibilities, O&M documentation, training and scheduling. Appendix 4 contains a design phase commissioning plan outline.

Design Intent Acceptance Criteria. The designer works with the owner to establish acceptance criteria for each item in the OPR. These criteria should be "project-specific and measurable in a practical way."[13] The criteria may include measurement and verification methods, such as functional testing or construction observation. The designer, commissioning provider and owner must be careful to clearly link each OPR item to its corresponding acceptance criteria. See Appendix 5 for an example of acceptance criteria associated with Owner's Project Requirements.

Who Develops Design Intent Documentation?

Developing the Owner's Project Requirements and Design Intent Acceptance Criteria is a team effort that involves the owner, design team and commissioning provider. Either the designer or the commissioning provider may be responsible for leading this effort. Their specific roles and level of effort should be specified in their contracts. Designers embarking on projects that will be commissioned should work with the owner as early as possible to define their role in this area. For instance, designers may take the lead in documenting OPR for the owner (with review by the commissioning provider), but the commissioning provider may take the lead in assigning acceptance criteria for each OPR (with review by the designer). Obviously, many combinations of roles are possible. This makes it essential for designers and commissioning providers to get clear direction, ideally in their contracts, from the owner.

Basis of Design. The design team develops documentation of the assumptions behind design decisions that were made to meet the owner's project requirements. The basis of design describes the systems, components, conditions and methods chosen to meet the

[13] Stum, Karl, "Understanding Owner Project Requirements Documentation (Design Intent)" in *Proceedings of the National Conference on Building Commissioning,* 2001.

requirements. For example, it describes which codes, temperature parameters and occupancy levels were used to size and select the systems. Some reiteration of the owner's project requirements may be included. The portions of basis of design that directly relate to the OPR are referenced in the design intent documentation.

Design Narrative. The designer compiles the design concepts and design basis into a design narrative document that the commissioning provider reviews for clarity, completeness and compliance with the owner's project requirements. Portions of the design narrative that directly relate to the OPR are referenced in the design intent documentation.

THE COMMISSIONING PROVIDER DOES NOT APPROVE THE DESIGN, BUT MAKES RECOMMENDATIONS TO FACILITATE COMMISSIONING AND IMPROVE BUILDING PERFORMANCE.

Design Review. The commissioning provider attends selected design team meetings and formally reviews and comments on the design at various stages of development. He or she notes potential system performance problems, energy-efficiency improvements, indoor environmental quality issues, O&M concerns, and other issues, depending on the scope of commissioning and needs of the project. The commissioning provider does not approve the design, but makes recommendations to facilitate commissioning and improve building performance. For example, the commissioning provider reviews designs to ensure that equipment is accessible for maintenance. It is the responsibility of the project manager to evaluate and discuss all findings with the design team and implement those approved. Of course, legal responsibility for the design ultimately rests with the Engineer of Record. The commissioning provider should work with the designer to incorporate commissioning requirements in such a way as to minimize liability issues for the designer.

Commissioning Specifications. The commissioning provider develops (or assists the designer to develop) detailed commissioning specifications to be included by the design team in the final contract document. Specifications should include any special equipment or instrumentation that must be installed for obtaining measurements during functional testing. Extra monitoring points, test ports and gages can make a building more "commissioning-friendly." These features facilitate commissioning and can reduce commissioning costs. They also make it easier for operating staff to monitor building performance and troubleshoot problems in the future. Appendix 6 contains sample specification language requesting additional monitoring points, test ports and gages, as well as a list of potentially valuable monitoring points to include. Finally, the commissioning specifications should also describe the responsibility that contractors have for preparing O&M manuals and for training facility staff.

Contract Documents. The design team is responsible for producing the formal contract or bid documents. Ideally these documents should include a complete set of mechanical, electrical and structural drawings, as well as a detailed set of specifications with equipment performance requirements and comprehensive sequences of operation. An update of the design record may be included as an attachment. The commissioning provider reviews these bid documents, including updated design narratives, for consistency with the owner's project requirements, testing and commissioning requirement, and acceptance criteria.

O&M Planning. The commissioning provider can help develop a building's O&M program or suggest improvements for a program already in place. The provider can interview the facility manager to determine whether sufficient personnel resources are available to ensure continued building performance once the building is operational. The commissioning provider and owner also begin planning for O&M staff participation in functional testing as part of their training.

COMMISSIONING DURING THE CONSTRUCTION PHASE IS MOST EFFECTIVE WHEN COMMISSIONING HAS BEEN PART OF THE PROJECT SINCE THE DESIGN PHASE OR EARLIER.

Pre-bid and Pre-construction Meetings. Although these meetings are not uniquely commissioning tasks, commissioning needs to be emphasized here so that all of the bidders and project participants are aware of commissioning and its role in the project. These meetings set the tone for working with the contractors on the commissioning effort.

3. Construction Phase

Commissioning during the construction phase is most effective when commissioning has been part of the project since the design phase or earlier. The project team can use the documents developed during the building's design to ensure that systems are installed, testable and maintainable as intended. The main construction phase commissioning tasks are listed below. As in the pre-design phase, the promotion of clear communication is one of the most important roles of commissioning.

Construction Phase Commissioning Plan. The commissioning provider updates the construction phase commissioning plan to include a list of all systems and specific equipment to be commissioned; the process to be followed; communications, reporting and documentation protocols; and an estimated schedule for the commissioning process.

Construction Phase Commissioning Kick-off Meeting. The commissioning provider coordinates a construction phase commissioning kick-off meeting. The meeting should include the project manager, construction manager, design team, commissioning provider, and representatives from the general contractor and mechanical, electrical, controls and TAB subcontractors. At this meeting, the commissioning provider outlines the roles and responsibilities of the project team members, specifies procedures for documenting commissioning activities and resolving issues, and reviews the preliminary construction phase commissioning plan and schedule. Team members, including designers, comment on the plan and schedule, and the commissioning provider uses these suggestions to complete the final commissioning plan.

Issues Log. The commissioning provider develops a record of issues and findings that require further attention. The log is updated regularly and shared with the project manager, construction managers and contractors for discussion and resolution during construction meetings.

Submittal Review. The commissioning provider reviews contractor submittals of equipment to be commissioned, comments on each submission and forwards them to the project manager or designer. The review allows the commissioning provider to check for adherence to the owner's project requirements and acceptance criteria.

Prior to formal O&M manual submittals, the commissioning provider requests a list of installation and start-up procedures, O&M information, equipment performance data, control drawings and other specific information. The data is used to write verification checklists and functional test procedures. Project manager support for obtaining these additional documents from the contractors is critical.

Coordination Drawing Review. The commissioning provider may assist the project manager in monitoring the development of coordination drawings to ensure reasonable harmonization among the trades.

Change Order Review. To monitor impacts on commissioning and owner project objectives, all RFIs and change orders applicable to the commissioned systems should be submitted for review to the commissioning provider.

Construction Observation. The commissioning provider and the designer should visit the construction site periodically. The provider notes any conditions that might affect system performance or operation. The designer notes any instances where the design is not properly implemented. For more information on field observation, refer to the design brief on Field Review, available on the Energy Design Resources Web site at www.energydesignresources.com.

Verification Checklists. Verification checklists (sometimes referred to as start-up checklists, construction checklists, or prefunctional checklists) transfer the information in the specifications and drawings to the workers in the field. Verification checklists are used to ensure that equipment is properly installed and ready for functional testing. The contractor or commissioning provider creates a checklist for each piece of equipment, consisting of simple questions that must be answered as the installation progresses. Sometimes, the commissioning provider just oversees this process and the contractor is charged with actually developing the checklists. The contractors usually complete these checklists. The commissioning provider approves and may oversee start-up and the use of verification checklists, often through a spot-check process. If a spot check reveals a problem, then they review more checklists. The commissioning provider makes sure that any deficiencies are remedied before functional testing begins.

Functional Testing. The commissioning provider develops and witnesses the functional tests to document and verify the proper operation of equipment and systems according to the building specifications, plans and change orders, and architect's instructions. Often,

the commissioning provider meets with the contractors and suppliers to assure that the tests they develop are comprehensive and safe to execute. But the actual test is written by the provider and tailored to the building or system. Subcontractors carry out the test procedures. Equipment or systems must meet specified design parameters under full-load and part-load conditions during all modes of operation, as described in the commissioning test requirements of the specifications. If corrective measures are required, the commissioning provider makes sure that they do not jeopardize the owner's project requirements or the acceptance criteria. The owner and designer normally are consulted for strategies to resolve these types of issues.

O&M Manuals Review. The commissioning provider and designers review the O&M manuals and verify that they are complete, clear and available for use during the training sessions.

Training Review. Ideally, enhanced training requirements are included in the specifications. The commissioning provider augments the training provided by contractors and manufacturers with an overview, questions list and other types of training to ensure that the operating staff is fully conversant with the operation of the building in all circumstances. In some cases, the designer gives a systems overview as part of building operator training.

The designer may present a systems overview as part of building operator training.

Final Commissioning Report. After completing functional testing, the provider writes a final commissioning report and submits it to the owner for review. The report summarizes the commissioning effort, specifically addressing the projects success in meeting the project acceptance criteria. The report also includes the commissioning provider's feedback on each piece of commissioned equipment and system relative to installation and start-up, function, performance, O&M documentation and staff training.

Systems Manual. In addition to the final report, some commissioning projects require the completion of a systems manual: a more comprehensive documentation package to assist the owner in understanding, operating and maintaining the building's systems. This manual may be the most important document the commissioning process generates. ASHRAE's *Guideline 1-1996: The HVAC Commissioning Process* recommends that the Systems Manual include:[14]

- An index of all commissioning documents with notations as to their storage locations.
- The final commissioning report.
- Initial and final owner's project requirements and acceptance criteria documents.
- As-built documents.

[14] ASHRAE, *Guideline 1-1996: The HVAC Commissioning Process* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia, 1996.

- A description of systems, including their capabilities and limitations.
- Procedures for all normal, abnormal and emergency modes of operation.
- Sequences of operation as actually implemented, with control systems data including all set points, calibration data, etc.
- The location of all control sensors and test ports.
- Seasonal start-up and shutdown procedures.
- Control schematics and computer graphics.
- Complete terminal interface procedures and capabilities of the DDC system.
- Recommended operation record-keeping procedures including sample forms and trend logs.
- Maintenance procedures.

THE DESIGNER OFTEN CONTRIBUTES THEORETICAL INFORMATION FOR THE SYSTEMS MANUAL.

The commissioning provider is typically in charge of developing the Systems Manual. In compiling the relevant documentation, the provider may request specific pieces of information from the designer. For instance, the designer often contributes theoretical information for the systems manual (excerpts from the design narrative and design basis) and may also provide sequences of operation.

Other Written Work Products. The commissioning provider may write various reports during construction to document testing progress and deficiencies that may affect future building performance. These reports may be submitted to the owner, design engineer, project manager or contractors, depending on the contract arrangements for the project. (A clear process for delivering correction orders to the responsible contractors and tracking their responses should be established before the construction phase.)

Final Acceptance or Substantial Completion. Final acceptance (also referred to as substantial completion) occurs when the building moves from the static construction state to the dynamic operating state. The design and construction team transfers control of the building to the owner and building operators during this phase. Part of this transfer involves training building operators. At this stage all project documentation is provided to the owner and operating staff, including the final commissioning reports and the systems manual.

4. Post-acceptance/Warranty Phase

Upon turnover, the building is in the hands of the owner and operators. Although the project is considered complete, some commissioning tasks from the initial commissioning contract continue throughout the typical one-year warranty period.

Seasonal Testing. Seasonal testing is conducted to verify proper operation, at minimum, during both winter and summer. Although some testing of heating and cooling systems can be performed under simulated conditions during the off-season, natural conditions provide

more reliable results. (LEED certification requires testing the equipment under actual operating conditions at or near design, thus it requires seasonal testing.) Any testing that was delayed because of site conditions, equipment status or inclement weather needs to be completed during warranty. When performing post-occupancy testing, the commissioning provider or test engineer must be careful not to void any equipment warranties. The commissioning provider should work with the owner to ensure that all warranty conditions are obtained from the contractors before testing. (Designers can assist in this task by stipulating in the specifications that contractors must provide these documents. Owners should also note this stipulation during pre-bid meetings.) Some warranty provisions may require that the installing contractor actually perform the testing, under the supervision of the commissioning provider.

Warranty Review. The commissioning provider may also return a few months before the expiration of the contractor's one-year warranty to review system operation and interview facility staff. Acting as the owner's technical resource, he or she can assist facility staff in addressing any performance problems or warranty issues.

Recommissioning. Building owners may consider recommissioning their facilities periodically to ensure that equipment performance levels continue to meet their project requirements. If building operators were involved in the original commissioning effort, and if they received training, they may be able to conduct the recommissioning process themselves. Designers who have long-term relationships with their clients may assist in troubleshooting during the recommissioning process.

Designers who have long-term relationships with their clients may assist in troubleshooting during the recommissioning process.

Commissioning Team: Roles and Responsibilities

Commissioning is a team process in which members of the project team each play defined roles. The commissioning team often includes the building owner or project manager, commissioning provider, design professionals, general contractor, subcontractors and manufacturer's representatives. For LEED projects, the LEED coordinator should also be a member of the commissioning team. (Although LEED certification requires commissioning, the commissioning process does not automatically cover all LEED issues or LEED coordination.) The team may also include facility staff, testing specialists or utility representatives. It is important to remember that the commissioning team does not manage the design and construction of the project. It merely promotes communication among team members to identify and resolve issues in a collegial and systematic fashion.

The responsibilities of each team member are outlined below. Budget considerations and special project characteristics may expand or reduce the commissioning roles

and responsibilities. The commissioning provider can review the scope of commissioning and advise the owner on how to consolidate roles and tasks to best fit the size and complexity of the project.

The Design Professional

AT A MINIMUM, THE DESIGNER'S ROLE IS TO EMBRACE THE CONCEPT OF COMMISSIONING AND SPECIFY THE PROCESS IN THE PROJECTS BID DOCUMENTS.

At a minimum, the designer's role is to embrace the concept of commissioning and specify the process in the projects bid documents. (The commissioning provider sometimes provides the specification language.) If the design professional is hiring the commissioning provider, he or she should do so as early in the design process as possible. Likewise, if the design professional is providing the commissioning services, he or she should begin commissioning as early as possible. (See the earlier section, "Who Provides Commissioning Services," for a discussion of possible conflicts of interest.)

Outlined below are the basic commissioning-related tasks of the design professional at each phase of commissioning:

Pre-design

- Assist with developing or reviewing the owner's project requirements document.
- Attend the commissioning scoping meeting.
- Review the draft design phase commissioning plan submitted by the commissioning provider.
- Work closely with the commissioning provider to keep the overall project and the commissioning tasks on schedule (in some cases).

Design

- Review and comment on the commissioning plan.
- Document or review the owner's project requirements for all systems.
- Assist with the development of acceptance criteria.
- Write system descriptions and record design basis information.
- Respond to issues raised by the commissioning provider during design review.
- Review and incorporate the commissioning-related specifications for construction (developed by the designer and/or the commissioning provider).
- Map the location of the incorporated commissioning specification items to facilitate their review by the commissioning provider.
- Attend the pre-bid meeting to answer bidder questions in general and to emphasize the importance of commissioning to the success of the design.

Construction

- Attend the pre-construction meeting to answer contractor questions in general and to emphasize the importance of commissioning to the success of the design.
- Clarify design issues related to system operation and owner's project requirements.
- Conduct periodic field visits to assure proper implementation of the design.
- Assist in resolving construction and operational deficiencies illuminated by commissioning.

- Prepare and submit final as-built documentation for inclusion in the O&M manuals (sometimes it is more effective to delegate this to the contractors, especially if they are doing detailed coordination drawings or fabrication drawings).
- Review and approve the O&M manuals.
- Present a systems overview during facility staff training (if requested).
- Review commissioning plans, functional test plans (optional, but highly desirable on complex projects).
- Witness selected functional testing (optional, but highly desirable on complex projects).
- Prepare content as necessary for the Systems Manual. See page 65-66 for a list of items to include in the systems manual.

Warranty

- Coordinate resolution of design non-conformance issues identified during warranty-phase commissioning.
- Participate in review close to warranty expiration (optional).

The following section discusses some of the above responsibilities in more detail.

Selected Commissioning Tasks for Designers

Working with the Commissioning Provider. The designer may be called on to handle overall coordination of the commissioning during design. This includes scheduling and coordinating the meetings of the commissioning team. Designers who assume this role also ensure that commissioning issues are part of design team meeting agendas and that the leads for each task understand their commissioning responsibilities and execute them. By working closely with the commissioning provider, the architect helps keep the project on schedule.

Documenting the Owner's Project Requirements. The owner's project requirements explain the ideas, concepts and criteria that the owner considers important. It should cover the following for each system, major component, facility and area:

- Specific corporate policies and required codes, standards and/or guidelines to be followed.
- Objectives and functional use of the facility, system, or equipment.
- General quality of materials and construction.
- Occupancy requirements.
- Indoor environmental quality requirements (such as space temperature, relative humidity, noise level and illumination level).
- Energy performance goals.
- Budget considerations and limitations.
- Restrictions and limitations of the system or facility.
- Critical system functions important to the owner.

Documenting Acceptance Criteria. The owner, commissioning provider and designer work together to assign appropriate, specific acceptance criteria to each OPR item. (As discussed previously, either the designer or the commissioning provider will lead this effort.) For instance, if a space temperature requirement is listed in the OPR, the acceptance criteria might require that the system be functionally tested to demonstrate its ability to meet that criteria. Appendix 5 contains an example of how Acceptance Criteria link to the Owner's Project Requirements.

Documenting Basis of Design. The basis of design is the documentation of the rationale behind design decisions that were made to meet the owner's project requirements. It includes:

- Specific descriptions of systems and methods for meeting owner's project requirements.
- Equipment maintainability information.
- Fire, life and safety information: a general strategy narrative and detailed sequences.
- Energy performance statistics.
- Ventilation strategies and methods.
- Complete sequences of operation, including setpoints and control parameters.
- Schedules.
- A list of applicable codes and standards.
- Primary load and design assumptions.

For example, for a rooftop air conditioning unit, the basis of design describes why the system was chosen above others. It records details of size, efficiencies, areas served, capacity, setpoints, control type, noise and vibration criteria, sequences of operation under all modes of operation, control strategies and other relevant information. Appendix 5 contains a sample format for documenting the owner's project requirements and their related basis of design.

The architect or the commissioning provider documents the owner's initial project requirements. If the architect takes the lead on this task, the commissioning provider reviews the OPR, and vice versa. The architect then coordinates the creation of the full design documentation by the design team. Each member of the team provides the written basis of design and detailed sequences of operation for the areas of design that are their responsibility. The following parts of the owner's project requirements and basis of design should be selected from the project documentation and included as an integral part of the bid specifications or as an attachment to the specifications:

- A design narrative describing the system in general.
- The objectives of each system and its functional use.
- The full sequence of operations under all modes and conditions.
- The setpoints and operating parameters.
- Performance criteria and applicable codes and standards.

Incorporating Commissioning into Specifications. There are two approaches for incorporating commissioning in the specifications. The first approach is to write separate sections for commissioning within each applicable division (for example, Division 15 for HVAC, Division 16 for electrical) as well as a separate division for commissioning (Division 17). The second approach is to integrate commissioning specifications into existing applicable divisions. Each has its advantages. Under the "separate" approach, the commissioning provider can write complete sections and pass them to the architect for inclusion in the specifications. This is more common practice, and it is easier for the architect because he or she does not actually write the commissioning specifications. However, this approach may give the appearance that commissioning is a large additional task, and it may result in higher bids. Under the "integrated" approach, the designer must work closely with the commissioning provider to weave the commissioning specifications into existing sections. This may make commissioning less intimidating to contractors, and may result in lower bids.[15] If the integrated approach is taken, the designer must map the location of the commissioning-related specification items, so that commissioning provider can review them without reading through the entire specification package.

Regardless of who writes the commissioning specifications and whether they are separate or integrated, they must provide information to help bidders understand the commissioning process and their role in it. The specifications provide the process and requirements for executing the commissioning work. For example, the mechanical design engineer works with the commissioning provider to develop commissioning guide specifications for pre-functional and functional test plans. The commissioning specifications provide the bidders with a clear description of the scope of verification testing. They detail what to test and under which conditions, acceptance criteria and acceptable test methods. They include requirements for documentation, reporting and general scheduling. The specifications should also outline the relationship among start-up, pre-functional checklists, manual functional performance tests, control system trend logs and stand-alone data logging. The inclusion of example tests and checklists is recommended.

Reviewing and Commenting on the Commissioning Plan. The designer reviews and comments on the commissioning plans for both the design and construction phases. These plans, developed by the commissioning provider, are not static documents, but evolving outlines of the commissioning process. They provide direction for the commissioning process during design and construction, and guide the development of the commissioning specifications by the architect (or commissioning provider) during the latter part of the design phase. The construction phase plan resolves issues that could not be fully developed during design, such as scheduling, participation of various parties, actual lines of reporting and approvals, and coordination. The commissioning provider develops

THE SPECIFICATIONS MUST PROVIDE INFORMATION TO HELP BIDDERS UNDERSTAND THE COMMISSIONING PROCESS AND THEIR ROLE IN IT.

[15] Altwies, Joy, in "Commissioning and Green Building Design," a National Conference on Building Commissioning Pre-conference Workshop, May 2001.

separate plans for design and construction, but the plans share the following features:

- A description of the objectives of the particular phase of commissioning.
- A list of players and their contact information.
- An outline of the management structure.
- A list of roles, responsibilities and tasks for each of the players.
- A timeline of the process and scheduling: meetings, reviews, tests and submission deadlines.
- Specific details about design or construction reviews.
- A list of systems and components being commissioned.
- Documentation and reporting formats for designs or construction phase activities.
- Plans for reporting findings and resolving conflicts.

Appendix 4 contains commissioning plan outlines. See the EDR CD-ROM of Building Commissioning Guidelines for sample commissioning plans.

Commissioning Provider

The commissioning provider's role is to promote a positive team approach to facilitate a quality project. The commissioning provider works closely with the owner or project manager, the designers and the contractors to document the quality design and construction process systematically. The commissioning provider's primary tasks include:

- Documenting or reviewing the owner's project requirements and acceptance criteria.
- Reviewing drawings and specifications for design features that facilitate commissioning and future O&M.
- Assisting the designer in developing commissioning specifications for the bid documents (or writing the specifications for the designer to include in the bid documents).
- Developing a commissioning plan.
- Reviewing construction start-up checklists.
- Writing functional and performance tests.
- Submitting regular reports to the building owner or project manager.
- Witnessing selected contractor start-up checklists and all functional and performance testing.
- Reviewing contractor and manufacturer training plans before facility staff training.
- Reviewing O&M manuals for completeness.
- Writing a final commissioning report and a systems manual that details the most important operation parameters and equipment instructions.

Interaction with the Design Team. From pre-design through warranty, the commissioning provider makes sure the building is designed, built and operable as the owner intended. To this end, the commissioning provider works with the design team to see that the owner's project requirements are well documented and that designs facilitate commissioning and future O&M activities.

At the end of design development, the commissioning provider reviews the design with the other design team members. As discussed earlier, the provider is not responsible for overall design review; the provider's review focuses on whether the design is commissionable. The commissioning provider may also consider energy efficiency, O&M needs, indoor environmental quality, constructability, coordination issues between trades and disciplines, functionality for tenants, environmental sustainability and life-cycle costs.

The construction-phase commissioning process can be easier and more effective if certain features are included in the design. The commissioning provider may bring these to the attention of the design team so that they can incorporate these features into the construction documents. Some of these features are:

- Easy access for entering, inspecting and maintaining the interior of ducts, plenums, vessels and other equipment; observing and replacing filters; removing coils; equipment removal and maintenance or replacement; service clearances; and National Electrical Code (NEC) required clearances.
- Isolation valves, dampers, interlocks, piping, etc. that allow for manual overrides, failure simulations, season changes and other testing conditions.
- Sufficient monitoring points in the EMS to facilitate performance testing, LEED measurement and verification requirements, and O&M. See Appendix 6 for specification language requesting these points as well as a list of potential monitoring points to include.
- Pressure gauges, thermometers, pressure-temperature ports and flow meters in strategic areas to verify system performance, meet LEED measurement and verification requirements, and facilitate ongoing O&M.
- Specification of the location and criteria for the systems sensors.

Along with the traditional design team members, the commissioning provider reviews the full set of construction documents and specifications when the project is approximately 50 percent and 95 percent complete, budget allowing. These reviews are a requirement for the additional LEED point for commissioning. The commissioning provider compares the design with the owner's project requirements. He or she is not responsible for design concept, design criteria or compliance with codes. The provider does not verify the designer's calculations, proof schematics or perform a constructability review unless specifically assigned. For example, the commissioning provider does not verify appropriate pipe or duct sizing, but may comment on unusually tight or restrictive duct layouts and bends, or a poor location of a static pressure sensor. As in the design development review, the commissioning provider reviews the design for commissionability and should only review design in areas where he or she has expertise. These reviews of construction documents are written and forwarded to the design team members who issue a written response. Suggested areas for review are:

The commissioning provider reviews the design for commissionability and should only review design in areas where he or she has expertise.

- Commissioning specifications.
- Equipment and system commissionability.
- O&M facilitation.

- Control system design and control strategies.
- O&M documentation.
- Building operator training requirements.
- Component and system energy efficiency.
- Indoor environmental quality.
- Environmental sustainability.
- Functionality for tenants.
- Life cycle costs.

Through this process of design review, the commissioning provider becomes the designer's ally, ensuring that the systems the designer designed will produce a quality building that meets the owner's usage and performance requirements.

Other Team Members

This guide addresses the distinction and interaction between the roles of the commissioning provider and the design professional. The roles of the other team members involved in commissioning are described in the Introduction to Building Commissioning. (See pp. 20-22 of the introduction guide for a description of the Building Owner/Project Manager, General Contractor, Installing Contractors, Subcontractors and Manufacturers, Facility Manager and Building Operator roles in commissioning.)

Marketing Commissioning Services to Your Clients

Designers are uniquely qualified to promote commissioning to their clients. They can attest that commissioning links high-quality design services to an efficient construction process and results in a smooth turnover and a building that performs as intended. In a traditional non-commissioned project, the implementation of the design is largely left to the contractors. If owners were willing to pay for quality designs, why would they jeopardize that investment by failing to ensure proper implementation?

A successful marketing message promotes the many benefits to owners, including the potential for overall project cost savings and ongoing operational savings. Common sense tells us that resolving issues on paper is less expensive than resolving them in the field. Furthermore, a building that is efficient and easy to maintain is likely to see lower operating costs. Evidence suggests that commissioning can significantly reduce a building's energy use, saving thousands of dollars per year over the life of the building. Buildings that perform as intended make for productive, healthy occupants. As building owners look for additional ways to improve their bottom line, commissioning can be marketed as a risk management tool.

When the commissioning process is successful, the change orders, requests for information, scheduling problems and conflicts are reduced. In fact, they may be so minimal that the owner may think the commissioning process was unnecessary. It is imperative to point out to the owner that the relatively problem-free project was a direct result of the commissioning process.

Excessive repair and replacement costs, employee absenteeism, indoor air quality problems, design and construction team liability and tenant turnover cost U.S. building owners and employers millions of dollars each year. Building commissioning is one way to improve the outcome of a construction project, providing a critical link between high-quality design services and a building that performs as intended.

Commissioning Case Studies

There are numerous examples of costs that have been avoided through the commissioning process. First, commissioning can avoid the costs of resolving problems after installation: costs for repair, replacement, reinstallation, and the professional services to fix mis-sized, misplaced, or otherwise inappropriate equipment. Second, commissioning can avoid the costs of the adverse effects of unresolved problems: costs for energy, maintenance, revenue loss and employee productivity loss.[16] Furthermore, a successfully commissioned building that performs as designed is more attractive to tenants, saving owners the expenses associated with tenant turnover.

Case studies of commissioning projects are available on the EDR CD-ROM of Building Commissioning Guidelines and also at some of the Web sites listed at the end of this publication.

16 Altwies, Joy. "Quantifying the Cost Benefits of Commissioning," in *Proceedings of the National Conference on Building Commissioning,* May 2001.

Procedural Guidelines, Specifications and Functional Tests

*Denotes documents available on electronic disk.

[RCX] = dedicated solely to retrocommissioning;

[rcx] = contains some data on retro-commissioning.

D = for design phase, C = for construction phase.

All CAPS Source denotes document is more comprehensive than lower case.

Source	Guide-lines	Guide Specs	Sample Tests
Appendix VII Idaho New Building Commissioning Guidelines, State of Idaho, 2000. Available at: http://www2.state.id.us/adm/pubworks/archengr/app7nbcg.pdf	YES	No	No
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)	No	No	*Yes
Procedural Standards for Building Systems Commissioning, National Environmental Balancing Bureau (NEBB), 1999. (301) 977-3698.	Yes d,c	Some d,c	Some
A Practical Guide for Commissioning Existing Buildings, PECI and Oak Ridge National Labs (ORNL), 1999. NTIS (800) 553-6847 *[RCX]*	YES	No	No
Model Commissioning Plan and Guide Commissioning Specifications, USDOE/PECI, 1997.NTIS: # DE 97004564 (800) 553-6847. or download from http://www.peci.org/cx/mcpgs.html	*Some D,c	*YES D,C	*YES
Building Commissioning Guide, U.S. GSA. & USDOE, 1995, revised in 1998 (Ver. 2.2). Ver. 1 by Enviro-Management & Research, Inc. Version 2.2 available on the web: http://www.eren.doe.gov/femp/techassist/bldguide.pdf	*Yes D,C	No	No
The HVAC Commissioning Process, ASHRAE Guideline 1-1996, 1996. ASHRAE Publications Dept., 1791 Tullie Circle, NE, Atlanta, GA 30329. (404) 636-8400 http://www.ashrae.org	Yes d,C	Some d,c	No
Functional Test Protocol Library, Pacific Gas & Electric Company, 2001. Available on the EDR CD-ROM of Building Commissioning Guidelines (for ordering information visit www.energydesignresources.com) or by calling 925-866-5329	No	No	YES
The Building Commissioning Handbook, The Association of Higher Education Facilities Officers (APPA), written by John Heinz and Rick Casault, 1996. APPA, 1643 Prince Street, Alexandria, VA 22314. (703) 684-1446 http://www.appa.org	YES d,C	YES C	No
Beyond Lighting DSM: Life After Green Lights, Montgomery Co., MD, 1995. *[RCX]* Existing building commissioning case study with sample process and detailed procedures. 70 pgs. (301) 217-6000	Yes	No	Yes
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	Some d,c	Some d,c	No
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	No	*YES C	No
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://depts.washington.edu/fsesweb/fdi2001/15_mech/doc/19-15t.doc	No	*YES C	Some

Source	Guide-lines	Guide Specs	Sample Tests
Commissioning Guidelines, Instructions for Architects & Engineers, State of WA., 1995. Dept. of General Admin., Div. of Engin. & Arch., (360) 902-7272	Yes d,c	No	No
C*ommissioning of HVAC Systems,* seminar/workshop training materials, Univ. of Wisconsin, Madison, 1994. (800) 462-0876 or (608) 262-2061	Some C	Some C	Some
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 www.ashrae.org	Yes C	No	No
Commissioning Smoke Management Systems, ASHRAE Guideline 5-1994. ASHRAE Publications Dept., 1791 Tullie Circle, NE, Atlanta, GA 30329. (404) 636-8400 www.ashrae.org	Yes d,c	No	No
Standard HVAC Control Systems Commissioning and Quality Verification User Guide, U.S. Army Const. Engineering Research Labs, 1994. Facilities Engineering Applications Program, U.S. Army Engineering and Housing Support Center, Ft. Belvoir, VA 22060-5516. FEAP-UG-GE-94/20	No	No	Yes
Contractor Quality Control and Commissioning Program—Guidelines and Specification, Montgomery Co. Gov., St of Maryland, 1993. (301) 217-6071	*Yes c	*YES C	*Some
HVAC Systems Commissioning Manual, Sheet Metal and Air Conditioning Contractors' National Association (SMACNA), 1993. SMACNA, 4201 Lafayette Center Dr., Chantilly, VA 22021	Yes c	Some c	Some
Commissioning Guide, Public Works Canada, Western Region, 1993. (403) 497-3770	Some d,c	Yes d,C	No
Guide Specification for Military Construction—Commissioning of HVAC Systems, Dept. of the Army, U.S. Army Corps of Engineers, 1993. Washington, DC 20314-1000	No	*Some c	*Yes
Building Commissioning Guidelines, Bonneville Power Administration/PECI, 1992. (503) 230-7334	YES d,C	Some c	Some
HVAC *Functional Inspection and Testing Guide,* U.S. Dept. of Commerce and the General Services Administration, 1992. NTIS: (800) 553-6847	No	No	YES
AABC *Master Specification,* Associated Air Balance Council. (Primarily for how the TAB fits into the commissioning process) AABC National Hdqrs, (202) 737-0202	No	*Yes d,C	No

Commissioning Overviews and Case Studies

Building Commissioning: The Key to Quality Assurance. USDOE Rebuild America / PECI., 1998. *[RCX]* Commissioning retrofits and existing buildings: overview, process and case studies. 68 pgs. 1-800-363-3736.

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. *[rcx]* New construction overview, benefits, process and case studies. 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. *[rcx]* Commissioning overview and report of 175 building case studies. 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.*

Commissioning the Physics/Astronomy Building Control System (U. of WA). Bonneville Power / Phoebe Caner, 1996. Commissioning case study and report with lessons learned. ~110 pgs. (503) 230-7334.

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://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*) *[rcx]*
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/ (retro-commissioning process and software, for purchase) *[RCX]*
University of Washington	http://depts.washington.edu/fsesweb/fdi2001/15_mech/doc/19-15t.doc Univ. Cx guide specs distributed throughout the specs. Vol's 1-4)
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 doc's. Search on "commissioning.")
Whole Building Design Guide (NIBS)	http://www.wbdg.org/ National Institute of Building Sciences (find commissioning information by searching on "commissioning"

For further information please contact Pacific Gas and Electric Company's Savings By Design Program at 1-800-468-4743 or visit their Web site at http://www.savingsbydesign.com. Information is also available at www.energydesignresources.com.

Reference Notes

ASHRAE Guideline 1-1996. American Society of Heating Refrigerating and Air-Conditioning Engineers. Atlanta Georgia. 1996.

Association of State Energy Research and Technical Transfer Institutes. *How to Achieve Top Performance in Your Building: Commissioning Benefits, Process and Performance, 1998.*

Altwies, Joy. "Commissioning and Green Building Design." National Conference on Building Commissioning Pre-conference Workshop. May, 2001.

Altwies, Joy. *"Quantifying the Cost Benefits of Commissioning." Proceedings of the 9th National Conference on Building Commissioning*. May, 2001.

Dunn, Wayne. *"Roles and Responsibilities." Proceedings of the 3rd National Conference on Building Commissioning*. May, 1995.

Hornreich, Michael. *"The Practical Legal Aspects of Commissioning Building Systems—Why Owners Should Pay for Commissioning Services." Proceedings of the 2nd National Conference on Building Commissioning*. May, 1994.

Nolfo, Andrew. *"Commissioning and the Design Build Process." Proceedings of the 6th National Conference on Building Commissioning*. May, 1998.

Savage, Jerry. *"Commissioning a Materials Research Laboratory." Proceedings of the 8th National Conference on Building Commissioning*. May, 2000.

Tamblyn, Tom. *"Commissioning a School: A Case Study." Proceedings of the 2nd National Conference on Building Commissioning*. May, 1994.

Thomson, Jeane P. *"Can Commissioning Impact Professional Liability Claims?" Proceedings of the 5th National Conference on Building Commissioning*. May, 1997.

U.S. Green Building Council, *LEED Reference Guide,* version 2.0, 2000.

York, Dan. "Commissioning Green Buildings." *Proceedings of the 6th National Conference on Building Commissioning*. May, 1998.

Commissioning

The process of ensuring that systems are designed, installed, functionally tested and capable of being operated and maintained according to the owner's operational needs [based on ASHRAE Guideline 1-1996]. This term is used in regard to new construction or major capital improvements/retrofits.

Commissioning Plan

A living document that outlines the roles and responsibilities for each commissioning team member throughout the design, construction and turnover phases of a project.

Commissioning Provider

An independent third party or a member of the design/construction team that is responsible for coordinating the commissioning process, facilitating the development of the design intent documentation and commissioning specifications, verifying the completion of the prefunctional tests, writing and verifying the functional performance tests, overseeing the building operator training and writing the final commissioning report.

Commissioning Team

The key members of each party involved with a construction project designated to provide insight and carry out tasks necessary for a successful commissioning project. These members can include the building owner or owners representative, commissioning provider, design professionals, installing contractors, facility operators, testing specialists and utility representatives.

Continuous Commissioning

An on-going process to resolve operating problems, improve comfort, optimize energy use and recommend retrofits. Performance is monitored and assistance provided as needed to maintain continued optimum performance.

Design Basis

A written document describing the rationale and assumptions for calculations, decisions, schemes and system and assemblies selected to meet the Owner's Project Requirements and to satisfy applicable regulatory requirements, standards and guidelines.

Design Intent Acceptance Criteria

Those specific criteria required to demonstrate that the owner's project requirements and designer's basis of design have been met. Criteria may include project and design goals, budgets, limitations, schedules, environment and performance requirements, owner directives and supporting information.

Design Narrative

A written description of the concepts and features the designer intends (during schematics) to incorporate into the design or what they have incorporated (during the balance of design) to meet the Owner's Project Requirements and associated Performance Criteria.

Functional Test Procedure

A procedure identifying the appropriate steps to test, verify, and document the operation and performance of a specific system.

Owner's Project Requirements

A written document, sometimes called the "design intent statement," outlining the owner's expectations of how the facility will be used and operated. Each OPR will have specific design intent acceptance criteria attached to it.

Recommissioning

A periodic event that reapplies the original commissioning procedures in order to keep the building operating according to design or current operating needs.

Retrocommissioning

An event in the life of a building that applies a systematic investigation process for improving and optimizing a building's O&M procedures. Retrocommissioning occurs post-construction and typically focuses on energy-using equipment. It may or may not emphasize bringing a building back to its original operational goals, as expressed in the Owner's Project Requirements.

Scoping Meeting

A meeting at the beginning of the commissioning process, ideally during the design phase, where the commissioning provider outlines the commissioning roles and responsibilities of the project and reviews the commissioning plan and schedule.

Sequence of Operation

A narrative describing the how the mechanical, electrical and control systems are intended to operate during startup, shutdown, unoccupied, manual, fire, power failure, security lockdowns and other modes of operation.

Specifications

A written package of standards and procedures that dictates the contractors responsibilities for delivering the final completed construction project.

Verification Checklist or Procedure

A procedure identifying the appropriate steps to verify the functional test-readiness of a specific piece of equipment. This is also known as a pre-functional test procedure or checklist.