U.S. DEPARTMENT OF
Energy

BUILDING COMMISSIONING

The Key to Quality Assurance

• Rebuild America Guide Series •

Preface

Welcome to the Rebuild America Guide Series. This series of technical and business manuals is designed to meet the real-life needs of the Rebuild America community partnerships. These Guides provide clear and practical information on issues related to completing energy-efficient building retrofits. Each Guide will help the partnerships make educated decisions as they move through the retrofit process. The Rebuild America Guide Series is one of the products and services that the U.S. Department of Energy provides to America's communities to help them attain more efficient and affordable buildings.

Building Commissioning, The Key to Quality Assurance is designed to help Rebuild America partnership building owners and retrofit project managers understand and successfully oversee the commissioning process. This Guide was written for the U.S. Department of Energy's Rebuild America Program by Portland Energy Conservation, Incorporated (PECI). Editing, graphic design, and layout were provided by Energetics, Incorporated.

The Rebuild America Program recommends that its partners incorporate building commissioning into their projects to maximize building performance and energy efficiency. This Guide details such benefits to existing building systems and retrofit projects. Using this Guide will help building owners and project managers understand what the costs and benefits of commissioning are, how to benefit from commissioning their building, and why to select particular agents to act as a commissioning authority, or as commissioning team members.

Table of Contents

List of Acronyms

DDC	Direct Digital Controls
DOE	U.S. Department of Energy
EMCS	Energy Management Control System
EPA	U.S. Environmental Protection Agency
HVAC	Heating, Ventilating, and Air Conditioning
IAQ	Indoor Air Quality
RFP	Request for Proposal
RFQ	Request for Qualifications
TAB	Testing, Adjusting, and Balancing

List of Units

ft^2	Square feet
kWh	Kilowatt hours

Introduction

This Guide is written to aid building owners and retrofit project managers currently participating in the Rebuild America program. The Guide provides information on implementing building commissioning projects that will optimize the results of existing building equipment improvements and retrofits projects. It should be used in coordination with *Rebuild America's Community Partnership Handbook*. The *Handbook* describes, in detail, eight important steps necessary for planning and carrying out a community-wide energy-efficiency program. In step number 7 of the *Handbook,* commissioning is shown to be an integral aspect of implementing a building retrofit (See ***Steps for Your Partnership***, page 3). The commissioning process ensures that a facility is safe, efficient, comfortable, and conducive to the presumed activities for which it was constructed.

Rebuild America strongly encourages its partners to incorporate commissioning into their retrofit projects. By verifying the correct installation, functioning, operation, and maintenance of equipment, the commissioning process ensures that efficiency measures will continue to deliver benefits over the long term. Although commissioning can take place after the equipment has been installed, it is more effective when it takes place over the entire equipment installation process.

What is Building Commissioning?

Commercial buildings in the United States undergo frequent operational and occupancy changes. These changes challenge a building's heating, ventilating, and air-conditioning (HVAC) equipment and other mechanical and electrical systems to perform at optimal levels. Building commissioning is a systematic process that helps building equipment and integrated building systems provide peak performance. This Guide demonstrates the role of commissioning in assuring that equipment performs effectively to meet a building's current needs.

Building owners are spending more money on complex building systems than ever before, yet many find that they are not getting the specified level of performance. A study of 60 commercial buildings found that more than half suffered from control problems. In addition, 40% had problems with HVAC equipment and one-third had sensors that were not operating properly. An astonishing 15% of the buildings studied were actually

What Exactly is Building Commissioning?

Commissioning is 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.

missing specified equipment. Approximately one-quarter of them had energy management control systems (EMCS), economizers, and/or variable speed drives that did not run properly.[1]

Commissioning is a systematic process that begins, ideally, in the design phase of a building retrofit project and lasts at least one year after the project is completed.[2] However, it is never too late to commission a commercial building. Existing equipment can also be commissioned to ensure that it operates efficiently and meets the building owner's and occupants' current needs and expectations.

Commissioning is usually performed at a building owner's request. Often the owner may hire or assign a representative, who acts as a proxy, and spearheads the project. The box entitled ***Successful Building Commissioning*** on the facing page provides the discrete actions that must be taken in order to successfully commission a building.

Why is Commissioning Important?

Owning and operating a commercial building requires a substantial financial investment. Poor performance means building owners may be losing money. Excessive repair and replacement costs, employee absenteeism, inadequate indoor air quality (IAQ), and tenant turnover costs U.S. building owners and employers millions of dollars each year.

Building commissioning stops this unnecessary loss of money by restoring equipment and building systems to a high level of productivity. It ensures that a new building or system begins its life cycle at optimal productivity and improves the likelihood that the equipment will maintain this level of performance throughout its life. Building commissioning is the key to quality assurance in more than one way; it prevents problems from developing, anticipates and regulates system interactions, and implements a systematic method of meeting the building's mechanical, electrical, and control requirements.

The process of commissioning should not be confused with testing, adjusting, and balancing (TAB), the measurement of building air and water

[1] Piette, Mary Ann, "Quantifying Energy Savings from Commissioning: Preliminary Results from the Northwest," Presentation at the 4th National Conference on Building Commissioning, 1994.

[2] During the design phase, design-intent documentation is compiled. It provides an explicit description of how and why the equipment or building systems functions in the manner it does. Design-intent documentation provides guidance to the commissioning authority by detailing the concepts and criteria that the building owner considers important to the project.

Steps for Your Partnership

1 Form Your Partnership

Make a commitment to significantly reduce building energy use and cost in your community, and identify the organizations who will work together with you.

2 Collect and Examine Data

Define your targeted building stock and collect basic data on building characteristics, energy use, and energy costs.

3 Conduct Initial Screening

Conduct a simple screening of your targeted buildings to identify a candidate list of buildings that represent the best opportunities for energy savings.

4 Define Financing Options

Take a first look at costs, savings, and financing issues; develop rough cost estimates and funding options for both management and capital costs.

5 Develop an Action Plan

Define a practical action plan with your partners, using everything above to outline clear program goals along with management, financing, marketing, and business strategies to achieve them.

6 Evaluate Individual Buildings

Perform detailed energy audits on your best candidate buildings to define specific efficiency measures, their costs, and their savings potential.

7 Implement Your Program

Design, finance, install, and commission energy-efficiency retrofits. Consider holding community-wide education and training programs, and look into changes to codes and standards that can help your efforts.

Successful Building Commissioning

- Organize a commissioning team early in the retrofit process
- Prepare bid-specifications that clearly define commissioning expectations
- Hire a commissioning authority and contractors
- Work with the commissioning authority during the commissioning process
- Recommission as necessary

8 Verify and Report Results

Verify and document the savings you have achieved in order to enhance the credibility of your program, to improve it, and tell others about your results.

flows. The commissioning process, which is much broader in scope, involves functional testing and system diagnostics. Diagnostics and functional testing of equipment and systems helps determine how well building systems are working together. It also helps determine whether the equipment meets operational goals or needs to be adjusted to increase efficiency and effectiveness. A thorough commissioning effort results in fewer installation callbacks, long-term tenant satisfaction, lower energy bills, avoided equipment replacement costs, and an increased profit margin for building owners.

What DOE Will Do to Help

DOE formally recognizes the commitment of Rebuild America's partnerships by assigning a Program Representative as a primary point of contact. Program Representatives are available to assist in developing and pursuing building commissioning strategies.

A broad range of guidance materials, technical information, analytical tools, topic-specific workshops, and expert and peer contacts are available through DOE Program Representatives and DOE's support network of national laboratories. Further information about Rebuild America products and services can be found on Rebuild America's website at www.eren.doe.gov/buildings/rebuild.

How to Use this Guide

For those building owners and owners' representatives who have little experience in commissioning buildings, a chapter by chapter description of this six-chapter Guide is found below. A "Sample Prefunctional Checklist," and list of internet resources can be found in the appendices.

Chapter 1: Two Approaches

Chapter 1 discusses the two approaches to building commissioning found in this Guide. These two approaches include applying the commissioning process to: 1) existing building systems, and 2) retrofit projects. The chapter provides information on the commissioning phases associated with each type of efficiency project.

Chapter 2: Benefits

The immediate benefits of building commissioning discussed in this chapter include better performance of equipment and building systems and improved IAQ, comfort, and productivity. Long-term benefits discussed include reduced operation, maintenance, and equipment replacement costs.

Chapter 3: Investments and Paybacks

The third chapter is designed to give building owners a sense of the investments they must make to obtain worthwhile paybacks from building commissioning. At the end of this chapter several case studies of commissioning projects give the reader an understanding of the magnitude of cost savings associated with building commissioning.

Chapter 4: Selecting a Commissioning Authority

Chapter 4 outlines the major options the owner or owner's representative should consider when contracting a commissioning authority. It provides the basic minimum and optional qualifications that a commissioning authority should have. The advantages and disadvantages of hiring an independent third party, a mechanical or installation contractor, or a design professional are discussed.

Chapter 5: How to Commission a Building

The fifth chapter discusses the basic processes for commissioning a building and the roles and responsibilities of team members in the commissioning process. Step by step discussions of the two approaches to building commissioning, outlined in Chapter 1, are included. Lastly, tips and advice for determining the extent of commissioning efforts are discussed.

Chapter 6: Operation and Maintenance for Persistence

Chapter 6 describes the essential components of preventive maintenance, including consistent operation and maintenance, and comprehensive staff training. Implementing these processes in a consistent manner can make the benefits of commissioning last over the lifetime of a building's equipment and building systems. This chapter also discusses options for trouble-shooting and recommissioning equipment.

Chapter 1: Two Approaches

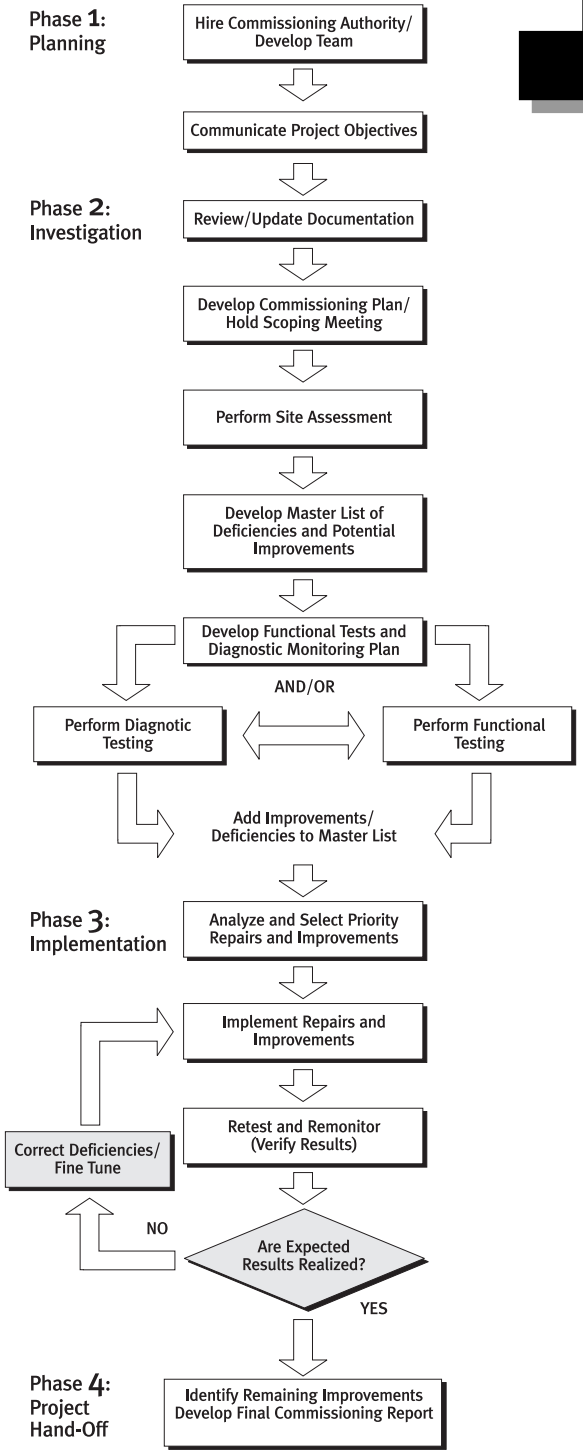
Overview

This Guide discusses two different commissioning approaches: commissioning as a means to improve the energy efficiency of existing building systems and commissioning as part of a retrofit project. An in-depth discussion of the two commissioning approaches can be found in Chapter 5.

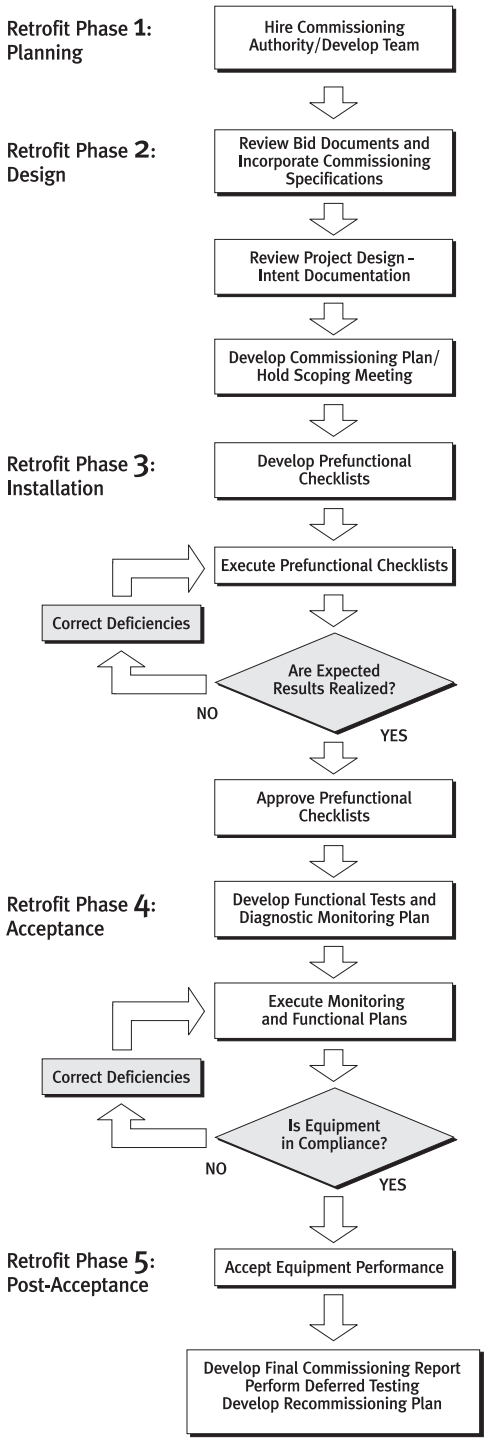
Commissioning Existing Building Systems

Commissioning existing building systems can provide impressive benefits, such as improving building operations and tenant comfort, reducing energy use, and increasing equipment life. Generally, the primary objective of commissioning existing building systems is to return the building's equipment to its original and intended operation, barring any legitimate changes made since installation. A second objective is to optimize equipment performance by adjusting the way the system is operated.

The process for commissioning existing building systems can be broken into four major phases, as depicted in the flow chart at the right.



Incorporating Commissioning into a Retrofit Project



When commissioning is incorporated into the retrofit project, owners are more likely to receive the expected energy savings from the retrofit. Commissioning during a retrofit project confirms that the new equipment being installed—and the existing building systems with which it interacts—are operating as intended. This confirmation is particularly important for mechanical equipment and controls, because their improper operation can influence performance and reduce the energy efficiency of related systems.

Commissioning a retrofit project often requires a greater commitment of time and money than commissioning an existing building system. In a retrofit project, the commissioning authority is required to integrate the commissioning process into every phase of the construction schedule.

The process for incorporating building commissioning into retrofit projects entails five major phases, as depicted in the flow chart at the left.

Chapter 2: Benefits

Overview

Building commissioning is an important tool that building owners can use to avoid the extra expense and diminished productivity associated with poorly functioning equipment and building systems. In both existing building systems and retrofit projects, the commissioning process detects problems and identifies solutions. Moreover, commissioning can prevent building problems by ensuring that interacting building systems are integrated and operating properly.

Until recently, the most frequently mentioned benefit of commissioning was the increase in energy efficiency and the resultant cost-savings that the commissioning process can help attain. While this is important, often the non-energy-related benefits far outweigh the savings derived from foregone energy expenditures. Other significant benefits of efficient system performance include the following:

- Improved performance of building equipment and building systems interactions
- Improved IAQ, occupant comfort, and productivity
- Decreased potential for building owner liability related to IAQ
- Reduced operation and maintenance costs

Commissioning ensures that existing building system and retrofit projects are designed to maximize the potential of the benefits mentioned above. Projects should be designed with these objectives in mind. Other benefits that should be considered include maximizing energy efficiency, easing maintenance, and meeting requirements for equipment warranties.

Improved Performance of Building Equipment and Systems

Commissioning confirms that building equipment and systems operate properly. Equipment that operates properly works more reliably and lasts longer. It also requires fewer service calls, and needs fewer repairs during its lifetime. Lastly, it uses less energy and demands less crisis maintenance from on-site staff (or expensive outside contractors). By reducing service-

calls and energy and maintenance costs, reliable equipment allows on-site staff to concentrate on their routine duties.

To achieve the improved building performance that results from commissioning a project, the commissioning team members must work as a unit. A case in point is the increased cooperation needed to perform cross-functional checks of the building's equipment and integrated systems' performance. When all the parties work well together during the commissioning process, the result is ultimately a better functioning building that suffers from fewer installation callbacks and litigation problems. In addition, commissioning oversight results in projects that are completed on time and within budget.

Commissioning oversight results in projects that are completed on time and within budget.

Improved Indoor Air Quality (IAQ), Comfort, and Productivity

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

Although little research has been completed to document the link between comfort and productivity in the office environment, comfortable employees are generally considered to be more productive than are uncomfortable employees. When occupants of an office building complain of discomfort, additional costs and lost productivity have been estimated to be significant. One such estimate[3] assumes that the typical building has one occupant per 200 square feet of space and an annual payroll cost of $34,680 per person (or $173 per square foot of office space). If one out of every five employees spends 30 minutes a month complaining about the lighting, the temperature, or both, the employer loses $0.11 per square foot in annual productivity. In a 100,000-square-foot building, this loss amounts to $11,000 per year.

[3] Trueman, Sr., Cedric (technical advisor for British Columbia Building Association), presentation to the National Electric Light and Power Association, 1989.

If comfort problems are severe enough to make employees ill, building occupants sustain additional productivity losses to cover sick time. Building operation costs also increase, as operators respond to more tenant complaints. Figure 1, below, shows a typical allocation of operating costs in a 140,000-square-foot office building.

Thus, comfort and productivity problems affect owners, whether they rent building space or occupy their own buildings. The cost of losing tenants is considerable. As shown in Table 1 on the following page, losing a tenant can mean a substantial loss of money when calculated for a five-year lease.

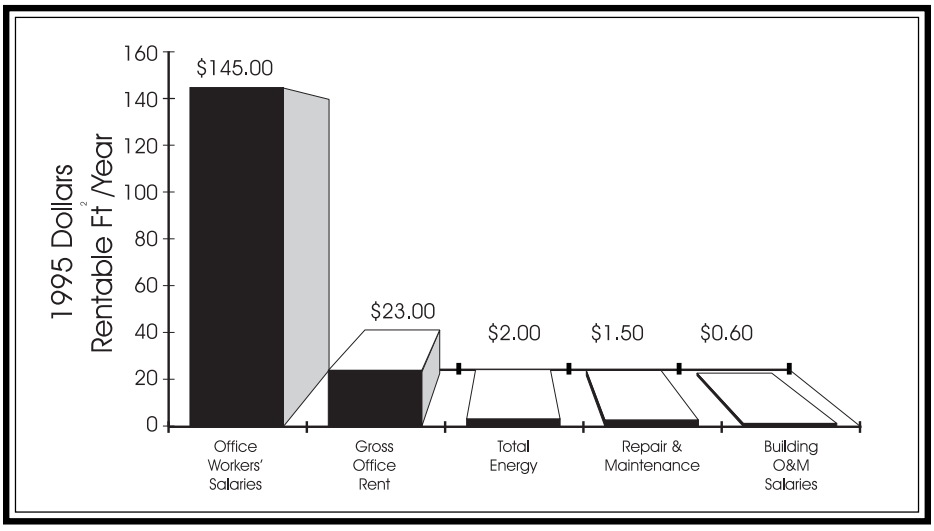


Figure 1. Operating Costs for a Commercial Office Building[4] (1995 Dollars per Rentable Square Foot)

[4] E Source calculation of 140,000 square-foot commercial building space according to Building Owners and Managers Association (BOMA) and Electric Power Research Institute (EPRI) data, 1990.

Table 1. Cost of Losing a Tenant in a Class A[5] Office Space[6] (1995 Dollars)

Five-year lease value	$297,500
Rent loss due to vacancy	$29,750
Improvements for new tenant	$52,500 - $70,000
Leasing commission	$14,875
Total cost of losing tenant	$97,125 - $114,625

The above example assumes a five-year lease totaling $297,500 ($17 per square foot) on a 3,500-square-foot office space. When a tenant leaves, this space will remain vacant an average of 6 months, for a total rent loss of $29,750. Improvements and build-outs to satisfy a new tenant usually run $15-$20 per square foot, or $52,500-$70,000 for a 3,500-square-foot office space. Moreover, the building owner often pays a leasing commission of 5% of the five-year lease value, or $14,875. Under these conditions, the total cost of losing one tenant could run from $97,125 - $114,625 or 32-38% of a five-year lease value.

Decreased Liability from IAQ Problems

"Sick building syndrome" and the court cases associated with it continue to make headlines across the country. For example, the government of Polk County, Florida, recently won nearly $26 million in damages for problems from a "sick" courthouse. Although the general contractor paid the award in this case, building owners can also feel the sting of IAQ lawsuits when occupants complain of illnesses resulting from building air quality. Even when owners are on the receiving end of litigation settlements, they and their tenants still suffer the inconvenience of acquiring other work space for use during the repair process—not to mention the inconvenience of the litigation process itself, which can drag on for months and even years.

Building commissioning protects owners by providing documented verification of a building's performance and operation—including a test of outside airflow rates, a primary factor affecting IAQ. If changes or additions are made to existing building systems after commissioning is complete, the owner or owner's representative should have them recommissioned to verify that such changes meet the air quality limits.

[5] Class A buildings are those that have the highest construction standards, as evidenced by state-of-the-art systems, and above-average finishes and fixtures. Class A buildings usually have the highest rents in a given area.

[6] Zier, David (Melvin Mark Company), ASHRAE presentation, 1995.

Recommissioning should take place throughout the life of a building, and performance documentation should be updated regularly. Recommissioning documentation provides owners with a record of building performance that can be used as evidence in the event of a lawsuit.

Commissioning also helps prevent many IAQ problems through its focus on training building operators in the proper maintenance of building systems. Properly run and maintained HVAC systems, with clean coils and air intakes and regularly changed filters, are less likely to contribute to IAQ problems. In order to avoid IAQ problems, operators should be trained to spot potential air quality and ventilation equipment trouble signs.

Reduced Operation, Maintenance, and Equipment Replacement Costs

By changing operation and maintenance practices, building owners can minimize life-cycle costs. Although equipment maintenance and replacement costs will always take up a portion of building budgets, proper operation and maintenance can prolong the life of equipment and save money for building owners. At a time when businesses are reinvesting in more cost-efficient, energy-saving building systems, the commissioning process establishes sound building operation and maintenance practices. Chapter 6 of this Guide provides information on training facility staff in operation and maintenance procedures.

The Bottom Line

The bottom line is that commissioning improves a building's value. A properly functioning building with reliable, well-maintained equipment is worth more than its noncommissioned counterpart. Commissioned systems and equipment also retain their value longer. Additionally, there is an ongoing demand for comfortable, healthy working space. Lastly, systems that function properly use less energy, experience less down time, and require less maintenance, thereby saving money for building owners.

The bottom line is that commissioning improves a building's value.

Chapter 3: Investments and Paybacks

Overview

Methods for measuring and reporting the costs and savings associated with commissioning vary by project. Nevertheless, commissioning costs are usually a very small portion of overall retrofit project budgets.

Commissioning is most cost effective when applied to equipment that is relatively large or that consumes high amounts of energy. When, however, the more numerous and small zone-level equipment is included in commissioning, costs can increase rapidly. For this reason, many existing building systems and retrofit projects are commissioned only when there is a great deal of room for improvement in system efficiency or other benefits. Table 2, below, lists the average range of estimated commissioning costs for retrofit projects.

Commissioning costs are usually a very small portion of overall retrofit project budgets.

Commissioning costs can vary considerably from project to project. Actual costs depend on the size and complexity of the project, and the extent and rigor of the commissioning specified. However, a general rule of thumb is that for most commercial office buildings, commissioning costs range from $0.10-$0.30 per square foot for existing building systems.

Table 2. Costs for Commissioning Selected Retrofit Projects (1994)

Scope	Cost Range
"Total-building" commissioning[7]	0.5-1.5% of total construction contract cost
HVAC and automated controls system	1.5-4% of mechanical contract cost
Electrical system	1-1.5% of electrical contract cost

[7] "Total-building" commissioning includes commissioning building controls and electrical and mechanical systems.

Savings from Building Commissioning

Methods for reporting the savings associated with commissioning vary and should correspond to the type of data the recipient of the report needs. Utilities have typically been interested in determining the kilowatt-hour savings. Building owners, however, are usually interested in learning how much money commissioning will save them in annual utility bills and operation and maintenance costs. Table 3, below, provides some examples of the cost and simple payback[8] from commissioning efforts for existing projects in various types of buildings.

Table 3. Existing Building System Commissioning Costs: Simple Payback[9]

Building Type	Commissioning Cost (1995 Dollars)	Annual Savings (1995 Dollars)	Simple Payback (Years)
Computer Facilities/Office	$24,000	$89,758	**0.3**
High-Rise Office	$12,745	$8,145	**1.6**
Medical Institution	$24,768	$65,534	**0.4**
Retail	$12,800	$8,042	**1.6**

Table 4, on the following page, shows the reported savings for certain types of buildings. When commissioning is done properly, both the energy and cost savings can be quite substantial.

[8] Simple payback is one method of calculating monetary benefits derived from commissioning. For more detailed information on calculating benefits, see *Financing Energy Efficiency in Buildings,* another manual in the Rebuild America Guide Series.

[9] Gregerson, Joan, "Cost Effectiveness of Commissioning 44 Existing Buildings", in *Proceedings of the National Conference on Building Commissioning*, 1997. Costs for Table 4 were collected over the following years: Computer Facilities - 1996, High-rise Office - 1995, Medical Institution - 1994, Retail - 1995.

Table 4. Annual Energy and Cost Savings from Commissioning Existing Building Systems Projects[10]

Building Type	Energy Savings	Cost Savings (1995 Dollars)
22,000 ft^2 office	130,800 kWh	$7,736
110,000 ft^2 office	279,000 kWh	$12,447
60,000 ft^2 high-tech manufacturing facility	336,000 kWh	$12,168

Commissioning Case Studies

Three case studies presented on the following pages are representative of recent commissioning studies from different building sectors in the United States. These case studies include building commissioning in a government building, in office buildings, and in hotels. They are included to give building owners an idea of the magnitude of savings that can be achieved through building commissioning in each type of building. The commissioning profiles on the following pages include:

- Chattanooga State Office Building, Chattanooga, Tennessee
- Parkway Fountains, Phoenix, Arizona
- Westin Hotels and Resorts

[10] Ibid. Note that cost figures reflect the varying electricity rates in different parts of the country.

Chattanooga State Office Building, Chattanooga, Tennessee[11]

The Chattanooga State Office Building is 175,000 square feet in area and contains systems that are typical of most Tennessee State buildings. Although the commissioning process for Chattanooga was originally intended to focus only on existing building systems, an energy management control system (EMCS) retrofit was scheduled at the same time. Thus, the State of Tennessee had the opportunity to demonstrate the effect of commissioning both existing equipment and new equipment during the same commissioning process. This objective was attained because of prudent planning. Because commissioning planning began early, the commissioning team was able to give the EMCS installation contractor ample time to integrate their specifications into the EMCS design.

Commissioning Opportunities

To date, 45 possible opportunities for improvement in the Chattanooga State Office Building have been identified. They fall under the following categories:

- HVAC for both plant and distribution systems
- Direct digital controls (DDC)
- Miscellaneous (such as documentation, operation and maintenance, planning, domestic hot water, etc.)

Investment and Payback

When the cost savings from the seven most significant improvements were combined, the resultant annual savings for the State of Tennessee were $61,000. In addition, the commissioning team has recommended eight future energy- and cost-saving capital improvements that have yet to be implemented. Commissioning yielded other benefits as well, including improved training for facilities staff, resolution of design problems, and documentation updates. The building is now undergoing post-commissioning monitoring.

The total cost for the project ran approximately $110,000, including installation of the new control system. The resultant savings give this project a simple payback of 20 months. The State of Tennessee, pleased with these results, is now developing a program to commission 135 existing state facilities.[12]

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[11] Figures are given in 1995 dollars.

[12] Haasl, Tudi and David Edmunds, "The Role of Existing Building Commissioning in the State of Tennessee's Energy Management Program," in *Proceedings of the National Conference on Building Commissioning*, 1996.

Parkway Fountains, Phoenix, Arizona

In 1995, Camidor Property Services began managing Parkway Fountains' office building in Phoenix, Arizona. Soon afterward, Camidor was invited to participate in the U.S. EPA/DOE "Tune-Up Study" of existing facilities. As part of the study, Parkway Fountains' building system was assessed for potential improvements. The initial assessment found that significant improvements were necessary.

Commissioning Opportunities

The following operational difficulties were detected in the office building:

- Lighting controls had been removed, so that lights remained on continuously
- Tenant improvements had resulted in the disconnection of thermostats and poor heat-pump scheduling
- The HVAC master control panel was set in manual position
- Outside air fans ran 24 hours a day, and their filters had not been changed in years
- Parking garage exhaust fans were not scheduled for reduced holiday and weekend operation
- Documentation of operation and maintenance and preventive maintenance plans were minimal

Investment and Payback

Camidor decided to focus its commissioning efforts on three areas: lighting, the master control panel, and scheduling changes[13]. As a result of making low-cost fixes in these areas, Camidor estimates that it will save $24,000 per year, or 15% of Parkway Fountains' annual utility costs. As even relatively new facilities are commissioned, Camidor is finding many more ways to save money through improved equipment and building systems performance.

[13] Blegen, Joseph. "Parkway Fountains Building Tune-Up," in *Proceedings of the National Conference on Building Commissioning*, 1996.

Westin Hotels and Resorts

Westin Hotels and Resorts manages properties both nationally and internationally. It commissions all new hotel construction projects and has begun to commission its existing building systems.

Commissioning Opportunities

In large part, Westin's commissioning efforts are based on the knowledge that the hotel industry must provide top-of-the-line living and working environments. Westin also recognizes that guests must be satisfied with their first stay at a Westin facility if they are to bring their business back to Westin. These factors, in addition to the desire to reduce equipment repair and energy costs, led Westin to begin commissioning its buildings in 1984.

Investment and Payback

To date, one of Westin's most successful commissioning projects is the 865-room, full-service, luxury hotel in Seattle, Washington. Approximately $100,000[14] was invested in commissioning this 800,000-square-foot site in 1983. From 1984 to 1992, annual energy costs dropped $300,000[15] over this eight-year

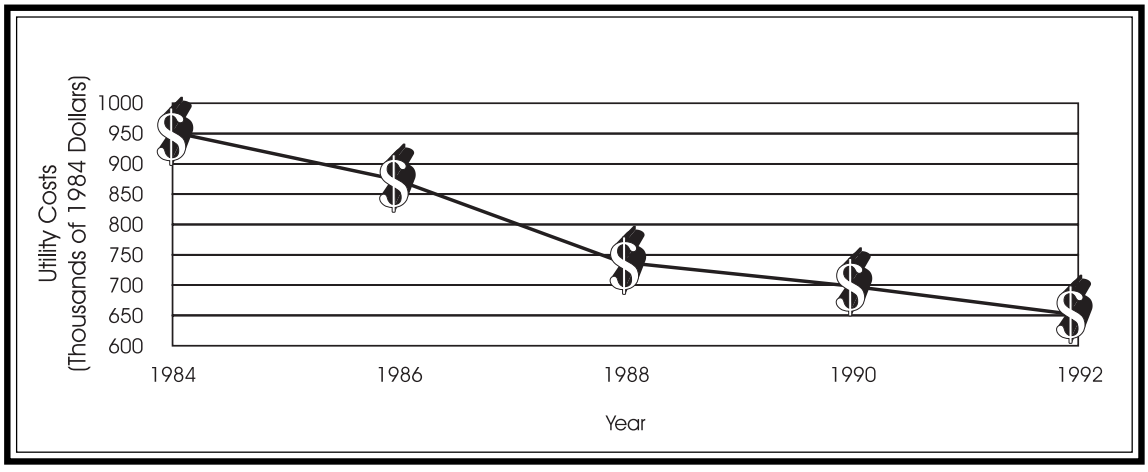

Figure 2. Westin Energy Costs after Commissioning

[14] $102,900 in 1995 dollars.
[15] $308,700 in 1995 dollars.

Westin Hotels and Resorts, continued

period due to commissioning and retrofitting equipment (see Figure 2 on the previous page). In addition, commissioning this hotel alleviated occupant discomfort, HVAC system deficiencies, IAQ problems, elevator malfunctions, fire, and safety hazards. Initially existing equipment was commissioned; next, new equipment (installed during retrofit projects) was commissioned; and finally, operation and maintenance practices were improved.

One of Westin's facility managers summed up the firm's commitment to commissioning its buildings:

"Without commissioning, we have no guarantee that our design intent is being met."

Chapter 4: Selecting a Commissioning Authority

Overview

One of the most important commissioning decisions building owners or owner's representatives can make is selecting who will act as the commissioning authority. Owners or owner's representatives can use a competitive request for proposal (RFP) to make the selection. A Request for Qualifications (RFQ) should first be sent to reputable firms that are experienced in commissioning. Based on the responses to the RFQ, owner's representative should develop a list of firms to receive an RFP. The RFQ should instruct individuals to discuss, in depth, their previous commissioning experiences and qualifications. Individuals applying for the position of commissioning authority should also be asked to describe their commissioning process. An individual with a comprehensive knowledge of the commissioning process will have an understanding that corresponds, in general, to the one on page 1 of this Guide.[16]

Commissioning Authority Qualifications

The commissioning authority should be selected by the owner or owner's representative. In general, a commissioning authority's minimum qualifications should include experience with developing the commissioning test plans (diagnostic, monitoring, prefunctional, and functional) and directly supervising the commissioning process. All relevant commissioning history should be evaluated in relation to the size of the project under bid and the status (e.g., whether existing building system or retrofit project) of the current undertaking. The ***Commissioning Authority Qualifications Checklist*** that follows presents selected guidelines for choosing a qualified commissioning authority. The commissioning authority should be directed to subcontract any work that is outside of his or her area of expertise.

[16] Individuals with little experience in the commissioning process may mistake commissioning for equipment start-up. Start-up refers to the process of using equipment for the first time in order to determine whether its primary functions work as intended. Commissioning goes beyond start-up to ensure that the new equipment conforms with design expectations in all modes and conditions of operation.

Commissioning Authority Qualifications Checklist

Recommended Minimum Qualifications

The recommended minimum qualifications for a commissioning authority include experience in the following:

- Designing, specifying, or installing commercial building mechanical-control systems or general HVAC systems
- Troubleshooting and/or performance verification of at least four comparable projects
- Responding conscientiously to the client's needs
- Meeting the owner's liability requirements
- Working with project teams and conducting "scoping meetings"
- Demonstrating good communication skills
- Commissioning at least two projects involving HVAC, mechanical, and lighting controls
- Writing functional performance-test plans for at least two projects

Optional Qualifications

Certain projects may require more or less experience, depending on their size, complexity, and specific building characteristics. Currently, there is no standard certification or licensing process for commissioning authorities. It is, therefore, up to each project manager to determine the appropriate qualifications. When applicable to the current project, optional qualifications for a commissioning authority include experience in the following:

- Managing at least two commercial construction or installation projects with mechanical costs greater than or equal to current project costs
- Designing, installing, and/or troubleshooting of DDCs and EMCSs
- Testing instrumentation
- Understanding of air/water testing and balancing
- Planning and delivering operation and maintenance training

Commissioning Authority Options

In general, there are three parties who may act as the commissioning authority. The commissioning authority can be any of the following:

- Independent third party commissioning authority
- Mechanical or installing contractor
- Design professional

Independent Third Party

Many owners who commission their buildings recommend using an independent third party as the commissioning authority. An independent commissioning authority, under contract to the owner, can play an objective role and ensure that the owner will truly get the building performance expected. The independent third party option offers the owner the most objectivity of any of the commissioning authority options discussed in this section. For large and/or complex retrofit projects, especially in buildings with highly integrated and sophisticated systems, potential savings resulting from objective commissioning are likely to outweigh higher costs associated with hiring an independent professional designer or engineer. For existing building systems, independent third party commissioning authorities are likely to find more opportunities for improvements and savings because they bring a set of "new eyes" to the building and have a low investment in the old way of doing things.

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Mechanical or Installing Contractor

When commissioning a retrofit project, a mechanical or installing contractor may act as the commissioning authority. This may be desirable when one mechanical contractor performs all of the mechanical work on the retrofit project, when the project specifications clearly detail the commissioning requirements, and when the building is less than 20,000 square feet.

It used to be standard practice for many mechanical contracting firms to conduct rigorous performance tests and systematic diagnostic procedures for equipment they installed. As construction budgets became tighter, this service was dropped from most installations. Although mechanical 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, a conflict of interest can arise when mechanical or installation contractors are required to objectively test and assess their own work, especially since repairing deficiencies found through commissioning can increase their costs.

Design Professional

A design professional is often required for large retrofits. Using this individual as the commissioning authority may be a good idea, provided that the project specifications detail the commissioning requirements. The advantage of using the design professional as the commissioning authority is that the design professional will already be familiar with the design intent of the project, which somewhat reduces the costs of management. Owners considering this option should bear in mind that commissioning costs are not generally included in a design professional's fees. Commissioning must therefore be specifically written into the design professional's bid specifications, so that firms can include this service in their bids. A potential drawback to this option is that the design professional may not have adequate experience in day-to-day construction processes and troubleshooting to adequately direct the commissioning authority.

Chapter 5: How to Commission a Building

Overview

This chapter discusses the roles and responsibilities of each member of the commissioning team. This team, which includes members of the design-construction team, is responsible for integrating the commissioning process into the retrofit project's construction phases. This chapter also includes step by step descriptions of the two approaches to building commissioning that were outlined in Chapter 1. Finally, the issue of how to know when the commissioning effort is sufficient is discussed.

Roles and Responsibilities of the Commissioning Team

A commissioning team should be created for integrating the commissioning process into both existing building system and retrofit projects. For commissioning existing building systems, the commissioning team may consist merely of the owner or owner's representative and the commissioning authority. In retrofit projects, members of the design-construction team are usually also on the commissioning team. In this case, the commissioning team is made up of the individuals who can help integrate the commissioning process into the retrofit project's construction phases. Members of the design-construction project team, like components of integrated building systems, need to interact in order to perform their tasks successfully. Commissioning actually facilitates this interaction because it sets clear performance expectations and requires communication among all involved parties.

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

Budget consideration and special project characteristics may expand or minimize the commissioning roles and responsibilities of the team members.

The commissioning authority can review the scope of commissioning and advise the owner on how best to consolidate tasks to fit the size and complexity of any given project.

Commissioning team members most often include the following:

- Owner, owner's representative, or project manager
- Design professionals/design engineer
- Commissioning authority
- Installing contractors and manufacturer's representatives
- Building operators
- Testing specialists
- Utility representative

The roles and responsibilities of each member are detailed below.

Building Owner or Owner's Representative

In some cases, the building owner solely manages the commissioning process. In other cases the owner's representative, who is often a property manager or facility manager, is given authority over project budgets and goals by the building owner. The owner or owner's representative translates the desired results of the commissioning project into concrete goals and communicates them to the project's designer and the commissioning authority. As the project proceeds, the owner's representative is often responsible for submitting interim progress reports to the building's owner. These reports detail the project's progress, and whether the commissioning authority and/or the design professional (in the case of a retrofit project) are meeting the owner's expectations. The owner's representative may have the following responsibilities:

- Determines the objectives and focus of the project
- Hires the commissioning authority and other members of the project team, preferably using a competitive RFP
- Determines the project's budget, schedule, and operating requirements
- Communicates the commissioning goals to the commissioning authority
- Assigns in-house staff commissioning roles and responsibilities
- Facilitates communication between the commissioning authority and other team members
- Approves start-up and functional test completion
- Attends building-training sessions when appropriate

Design Professionals

Design professionals may be involved in retrofit projects, but are seldom used for existing building system projects.[17] A design professional is often an engineer or architect who specializes in the mechanical design of building systems for large projects. The design professional's main commissioning task is to review and approve project documentation (shop drawings, operation and maintenance manuals, submittals, and as-built drawings). As part of the commissioning team the design professional may be asked to review the commissioning plan and functional performance test plans, document all new systems and controls, monitor installation activities, and observe functional testing.

Commissioning Authority

It is the commissioning authority's responsibility to work with all team members to accomplish the goals set forth in the commissioning plan. Although the scope of the commissioning authority's role varies for different types of projects (existing building systems or retrofit projects), the commissioning authority's primary tasks can include the following[18]:

- Developing a commissioning plan
- Gathering and reviewing existing building documentation
- Performing an assessment of operation and maintenance practices and energy use for existing systems
- Ensuring that documentation of design-intent for retrofitted equipment is adequate
- Assisting the owner's representative in developing commissioning specifications in the bid documents for retrofit projects
- Developing diagnostic and/or test plans
- Providing input on retrofit design features that facilitates commissioning and future operation and maintenance
- Writing prefunctional and functional performance tests
- Ensuring that team members understand their specified commissioning responsibilities
- Submitting interim progress reports to the owner's representative

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[17] When designing a retrofit project, the design professional collects the owner's needs and expectations and compiles this information in a document to establish the "design-intent." For more information on design-intent, see "Commissioning Retrofitted Systems" later in this chapter.

[18] Unless otherwise specified, these tasks apply to the commissioning authority's role in both existing building systems and retrofit projects.

- Overseeing all functional performance tests and contractor start-up tests, TAB, and duct pressure testing. For existing equipment, the commissioning authority may also perform some functional performance tests (when a warrantee issue is not involved)
- Writing a final commissioning report to document the evaluation of the system's capabilities with respect to the owner's needs and the documented design-intent
- Reviewing and commenting on technical retrofit-project considerations, from design through installation, to facilitate sound building operation and maintenance
- Reviewing operation and maintenance manuals

Installing Contractor and Manufacturer's Representative

An installing contractor or a manufacturer's representative may be responsible for performing a number of functions included in the commissioning plan. These include the following items:

- Conducting performance tests (under the supervision of the commissioning authority) especially in cases where the equipment's warrantee will be voided if the commissioning authority performs the tests
- Assisting with the development of the commissioning plan and schedule
- Adjusting building systems and documenting system start-up
- Training building operators in the operation and maintenance of systems
- Providing operation and maintenance manuals for the installed equipment

Building Operator

The building operator should assist with (or at least observe) as much of the functional testing as possible. This assistance improves his or her understanding of equipment and control strategies and also enables the operator to retest systems as part of ongoing operation and maintenance. Operators should also attend all training sessions.

Testing Specialists

If special testing is needed due to the complexity of the project, the specialists performing these tests should also be involved in commissioning. Test results and recommendations from these specialists are submitted to the commissioning authority for review. They may also review documentation relating to the systems they test, and train operators on the proper use of this equipment.[19]

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

Utility Representative

When a utility is involved in the commissioning process, the utility representative is often considered part of the commissioning team. Some utilities offer services that can complement the commissioning process. Others may even offer commissioning provider services. The owner's representative should contact the local utility to find out what services they can provide.

Steps in The Commissioning Process: Two Approaches

As discussed in Chapter 1, this Guide focuses on two distinct building commissioning processes. These include commissioning existing building systems and commissioning retrofit projects. Commissioning an existing building system entails diagnostic and functional testing as well as improving operation and maintenance on an existing piece of equipment or building system. It is generally a less complex and less time-consuming process than commissioning a retrofit project. Commissioning a retrofit project entails incorporating these same improvements, as well as others, into the equipment installation process. When planning to commission a retrofit project, owner's representatives should also consider commissioning their existing building systems in order to obtain maximum benefits from the commissioning process.

Projects that include commissioning in their planning phase usually are more profitable than those that do not. Building owners who include commissioning in the planning phase are more likely to have projects with higher benefit to cost ratios, and a safe and comfortable building. Making changes to a project during this phase is more efficient and less expensive than making the change once project implementation is under way.

Commissioning Existing Building Systems

Table 5, below, summarizes the steps involved in commissioning existing building systems. In this approach, the owner's representative is responsible for initial actions that pertain to commencing the commissioning process (such as hiring project team members), including actions in the planning and investigation phases. After the commissioning authority has been hired, he or she then advances the commissioning effort, including following through with actions in the investigation, implementation, and project hand-off phases.

Table 5. Steps in Commissioning Existing Building Systems

Phase 1: Planning

- ☑ Hire commissioning authority/Develop team
- ☑ Communicate the primary commissioning objectives to the commissioning authority

Phase 2: Investigation

- ☑ Review and update documentation
- ☑ Develop the commissioning plan/Hold scoping meeting
- ☑ Perform an operation and maintenance site assessment
- ☑ Develop a "Master List" of operation and maintenance deficiencies and potential improvements
- ☑ Develop functional tests and diagnostic monitoring plan
- ☑ Perform functional tests of systems and equipment

Phase 3: Implementation

- ☑ Analyze and select priority repairs and improvements
- ☑ Implement repairs and improvements
- ☑ Retest and remonitor

Phase 4: Project Hand-off

- ☑ Identify remaining improvements
- ☑ Prepare and submit a final commissioning report

Phase 1: Planning

The owner or owner's representative is responsible for spearheading the initial commissioning process. The initial steps in the planning phase consist of hiring the commissioning authority and communicating the primary commissioning objectives to the commissioning authority. These steps are described below.

☑ **Hire a commissioning authority/ Develop team**

As discussed in Chapter 4, one of the most important commissioning decisions a building owner or owner's representatives can make is selecting the commissioning authority. A number of agents, including an independent third party, mechanical or installing contractor, or design engineer can act as commissioning authority and should be hired through a competitive bidding process. The ***Commissioning Authority Qualifications Checklist*** (found in Chapter 4) presents selected guidelines for choosing a qualified commissioning authority.

☑ **Communicate the primary commissioning objectives to the commissioning authority**

It is important for the building owner or owner's representative to clearly communicate to the commissioning authority exactly what the objectives are for commissioning a building or system. The primary objectives of the commissioning process may include one or several of the following challenges:

- Reduce comfort calls from tenants/occupants
- Increase equipment life
- Obtain energy savings
- Improve indoor air quality (IAQ)
- Reduce staff time spent on emergencies
- Increase the value of the building
- Retain tenants/occupants
- Obtain a general overview of the building and systems

Phase 2: Investigation

The investigation phase should lead the commissioning team to a thorough understanding of goals, processes, and measures of success for the commissioning project. The steps include the following:

☑ **Review and update documentation**

The commissioning authority must obtain an overview of the building and systems to determine the general building operations and requirements. To expedite this activity, the owner's representative should compile a building documentation package for the commissioning authority to study prior to a "walk-through" to ascertain what system types exist, and how these systems are controlled. This packet may include the following items:

- Drawings relevant to the systems that are scheduled for commissioning
- Operation and maintenance manuals
- Testing, adjusting, and balancing (TAB) report
- Equipment list with nameplate information (including any energy-efficiency information)
- Preventive maintenance logs or plans
- Control-system documentation, such as sequences of operation, control diagrams, and points lists
- Energy-efficient operating strategies
- Utility-rate schedule and energy bill (electric and gas) information for at least the past 12 months

☑ **Develop the commissioning plan/Hold scoping meeting**

Once the commissioning authority and building staff clearly define the commissioning objectives and review the documentation, the commissioning authority develops the commissioning plan. The plan includes the following information:

- Commissioning objectives
- Scope of commissioning
- Commissioning team members' names, roles, and responsibilities
- Schedule of commissioning events
- Scope of investigation and testing

- Description of diagnostic monitoring and use of energy management control system (EMCS) trending[20]
- List of end products that will result from the commissioning effort

☑ **Perform an operation and maintenance site assessment**

The commissioning authority's goal in performing an operation and maintenance site assessment is to gain an in-depth understanding of how and why building systems and equipment are currently operated. For large or complex buildings and systems the commissioning authority generally develops a formal assessment document that includes a detailed building staff interview and an in-depth site survey of equipment condition. To expedite the assessment process, the owner's representative may assign a building operator to work with the commissioning authority. The designated operator should be knowledgeable in operating and maintaining the systems designated for commissioning. The operation and maintenance site assessment should identify key issues regarding the current system. Issues may include the following:

- Current design, operational intent, and actual control sequences
- Equipment condition issues (broken dampers, dirty coils, sensor calibration, etc.)
- Current schedule (time of day, holiday, etc.)
- The most severe control and operational problems
- The most severe comfort or trouble spots in the building

As the site assessment progresses, it may be cost-effective to have the assigned building operator make minor adjustments to the existing equipment.

☑ **Develop a "Master List" of operation and maintenance deficiencies and potential improvements**

Concurrent with the operation and maintenance site assessment (See **Perform an operation and maintenance site assessment**, above) the commissioning authority should begin to develop a master list of operation and maintenance deficiencies and opportunities for improvement. The master list summarizes all of the findings from the investigation phase and is the first step in developing a diagnostic monitoring plan. This list is active throughout the process and when deficiencies are discovered, they are added to the master list.

[20] Trending is an EMCS capability that allows data from control and monitoring points (such as temperature and current) to be tracked and collected over time.

The master list is a primary product of the commissioning effort. It will ultimately become an important decision-making tool for the operating staff to consult when diagnosing future degradation in operations. Every finding from the operation and maintenance site assessment, as well as adjustments or repairs made during the investigation phase should be noted on the master list. Additionally, the list should be revisited after a diagnostic monitoring plan is developed and implemented (See **Develop functional tests and diagnostic monitoring plan**, below). The master list should itemize the following:

- Name of the system or piece of equipment
- Description of the deficiency or problem
- Solutions being considered
- Status of implementation

☑ Develop functional tests and diagnostic monitoring plan

The purpose of developing and implementing a diagnostic monitoring plan is to collect further information on when and how the building equipment and systems are actually operating. A diagnostic monitoring plan helps the commissioning authority analyze the information found on the master list (See **Develop a "Master List" of operation and maintenance deficiencies and potential improvements**, above). It also enables the collection of specific data that can support or refute the observations made during the site assessment (See **Perform an operation and maintenance site assessment,** previous page).

The commissioning authority develops and implements a diagnostic monitoring plan using either the building's EMCS trending capability (acceptable as long as the system's sensors have been recently calibrated) and/or portable data loggers. Generally, diagnostic monitoring gathers data for a minimum of two weeks, including a typical weekend. The commissioning authority analyzes data, compares it to the operation and maintenance site assessment information to see if discrepancies exist, and records deficiencies on the master list.

☑ Perform functional tests of systems and equipment

It may be necessary to functionally test the system or equipment in question during the investigation process. A functional test consists of a series of written steps that place a piece of equipment through all modes of operation under a variety of conditions. Functional testing may be done as part of diagnostic monitoring or in lieu or diagnostic monitoring. In some cases, diagnostic monitoring may indicate that a problem exists but may not reveal the cause of the problem. In these cases, functional testing may be used in concert with diagnostic monitoring or trending to pinpoint the source of the problem.

When dataloggers are not available or the EMCS is inadequate for trending, functionally testing the system manually may be the only remaining option. Manual testing involves putting the system or piece of equipment through a series of tests that check its operation under various modes and conditions using hand-held instruments to verify proper operation. Any and all functional testing information should be compiled and appended in the final report.

Phase 3: Implementation

When the investigation process is complete, the process of implementing commissioning improvements begins. From the perspective of the commissioning authority, the implementation phase consists of two steps. The steps include the following:

☑ **Analyze and select priority repairs and improvements**

To set priorities for operations and maintenance improvements, the commissioning authority, in conjunction with the owner's representative, consults the master list (developed in the investigation phase). Some engineering analysis may be necessary to determine which improvements will save the most energy and cost the least to implement. A simple payback of 18 months or less is not unusual for the selected improvements. Financial cost-benefit methods that include life-cycle costing may also be used to determine the most cost-effective improvements.

☑ **Implement repairs and improvements**

The overarching goal for commissioning existing building systems is to implement cost-effective improvements. Unless improvements are actually put into place, the commissioning process remains incomplete. Depending on staff time and expertise, the commissioning process may be carried out by in-house operation and maintenance staff. In some cases implementation may need to be outsourced. For example, hiring a controls contractor may be necessary if in-house staff lacks the expertise or access required to make control strategy changes at the program level. For selected equipment, these improvements may include the correction of incorrect sequences or the addition of energy-efficient control strategies. The commissioning authority may also provide a list of recommended training topics for building staff.

☑ **Retest and remonitor**

It is often important to retain the commissioning authority through the implementation process, whether implementation is done in-house or outsourced. The commissioning authority may supervise implementation of the improvements, depending on the complexity of the tasks. Also, it is necessary (and highly recommended) to retest some of the equipment and systems, either manually or through remonitoring, to ensure that the improvements are working as expected and that they positively affect other systems and equipment as well as the building occupants.

Phase 4: Project Hand-off

The project hand-off phase is the final phase of commissioning existing building systems. Although building improvements have already been made at this point, the commissioning authority has a responsibility to continue to see the project through this final phase. Project hand-off includes identifying future energy-efficiency improvements and preparing and submitting a final report. Perhaps most importantly, this phase provides a time in which the commissioning authority's knowledge of the particular building system's operation and maintenance is transferred to the individuals who are charged with continuing upkeep. This transfer of knowledge is a prerequisite for adequate system functioning and preventive care. The project hand-off phase consists of the following two steps:

☑ **Identify remaining improvements**

During the normal course of commissioning, the commissioning authority reviews equipment and system efficiency, condition, and age for operation and maintenance improvements. Although commissioning existing building systems does not involve implementing large capital improvements, commissioning is often the first step toward identifying possible energy-efficient improvements. Therefore, the commissioning authority generally recommends a list of possible energy-efficient capital improvements before project hand-off. Long-term and capital-intensive energy-efficiency improvements may include energy-efficient lighting retrofit (interior and exterior lighting, exit lighting, etc.), the addition of lighting sweep controls, daylight harvesting, variable frequency drives, and carbon-dioxide (CO_2)-based ventilation control.

☑ **Prepare and submit a final commissioning report**

The commissioning authority prepares a comprehensive final report for the building staff, owner's representative, and/or the building owner. The final report generally includes the following information, along with an executive summary:

- Project background
- Building/systems description
- Summary list of deficiencies and their solutions
- Commissioning plan
- Master list of improvements
- Description of which improvements were implemented and a cost-savings analysis
- EMCS trending plan and logger diagnostic/monitoring plan and results
- Completed functional tests and results
- List of recommended capital improvements

Commissioning Retrofitted Systems

Commissioning a retrofit project usually entails a larger scope of work than commissioning existing building systems. This is because commissioning a retrofit project entails not only commissioning existing building equipment and systems, but also commissioning the new equipment installation. The commissioning process must be skillfully interwoven with the retrofit construction schedule to produce the best results. The commissioning authority is responsible for integrating the commissioning plans into every phase of the retrofit schedule. A retrofit project follows the typical construction phases listed below.

- Planning
- Design
- Installation
- Acceptance
- Post-Acceptance

Table 6, on the following page, lays out the retrofit project construction phases and the corresponding commissioning tasks. In practice, commissioning tasks may not correspond exactly to this schedule.

Table 6. Retrofit Project Construction Phases and Corresponding Commissioning Tasks

Retrofit Project Task	Commissioning Tasks
Retrofit Phase 1: Planning	
• Choose the retrofit project construction design team	☑ Hire the commissioning authority/ develop team
Retrofit Phase 2: Design	
• Develop design and bid documents	☑ Review bid documents and incorporate commissioning specifications ☑ Review project design-intent documentation ☑ Develop commissioning plan/ hold commissioning scoping meeting
Retrofit Phase 3: Installation	
• Install equipment • Start-up equipment	☑ Develop prefunctional checklists ☑ Execute prefunctional checklists/ correct deficiencies ☑ Approve prefunctional checklists (demonstrating new equipment is ready for functional testing)
Retrofit Phase 4: Acceptance	
• Submit final equipment documentation • Perform operator training • Accept retrofitted building	☑ Develop functional test and diagnostic monitoring plans ☑ Execute monitoring and functional test plans/ correct deficiencies ☑ Accept equipment performance
Retrofit Phase 5: Post-Acceptance	
• Perform ongoing operations and maintenance and periodic recommissioning	☑ Develop final commissioning report ☑ Perform deferred testing (if any) ☑ Develop recommissioning plan (optional)

The commissioning activities associated with each phase of a retrofit project are briefly described below.

Retrofit Phase 1: Planning

The retrofit planning phase is the best time to start integrating the commissioning process into a retrofit project. During this phase, the owner's representative may hire a designer or contractor. Aside from performing typical design tasks, design-team members may be asked to participate on the commissioning project team. Therefore, design-team members should be committed to commissioning, monitoring commissioning work, reading commissioning reports, and acting on recommendations for fixing deficiencies. The single step in the planning phase is described below.

☑ **Hire commissioning authority/ develop team**

When commissioning a retrofit, the planning phase is the ideal time to select a commissioning authority. Early selection allows the commissioning authority to play an advisory role during the conceptual process and increases "buy-in" for commissioning from other team members. Early integration of the commissioning authority into the team facilitates a cooperative working environment. If an existing system was commissioned prior to the retrofit, the owner's representative should consider hiring the same commissioning authority for the retrofit project, since he or she already knows the building.

Retrofit Phase 2: Design

The goal of commissioning during the design phase is to ensure that the efficiency and operational concepts for building systems are included in the final design. The commissioning steps that are integrated into this retrofit project phase are listed below.

☑ **Review bid documents and incorporate commissioning specifications**
☑ **Review project design-intent documentation**
☑ **Develop commissioning plan/hold commissioning scoping meeting**

The bid specifications developed during the design phase define the design intent for each system and include commissioning requirements for the installing and mechanical contractors and others. Specifications should

include any special equipment and instrumentation that will be necessary during performance testing. Specifications should also describe the contractors' responsibilities in preparing operation and maintenance manuals for equipment installed. The commissioning authority reviews bid documents and all other design-intent and contract documents for inclusion of commissioning details.

The design-intent documentation explicitly describes how and why the equipment or building systems function as they do. These documents guide the commissioning authority by detailing the concepts and criteria that the building owner considers important to the project. They also help each party, at each respective stage, understand why certain building systems were selected to meet functional requirements.

The design-intent document covers the following:

- General system description
- Objectives and functional use of each system, equipment, or facility
- General quality of materials and construction
- Occupancy requirements
- Indoor environmental quality (space temperature, relative humidity, IAQ, noise level, illumination level, etc.)
- Performance criteria (general efficiency, energy, and tolerances of IAQ objectives)
- Budget considerations and limitations
- Restrictions and limitations of the facility's systems

The commissioning authority attends selected design-team meetings to review the project's design and note potential system performance problems. The commissioning authority may, depending on the owner's objectives, recommend changes to improve energy-efficiency, operation and maintenance, and equipment reliability. Making changes during the design phase, rather than after the installation phase begins, saves money.

The commissioning plan details the objectives for every stage of the retrofit project. The plan outlines the schedule for team members to follow, and describes how the commissioning plan fits the retrofit-project schedule.

The design phase also includes a commissioning scoping meeting. At this meeting, the commissioning authority shares the draft-commissioning plan with project team members. The roles and responsibilities of the project team members are outlined and the commissioning plan and schedules are reviewed. After team members provide comment on the draft commis-

Commissioning Retrofits Funded through Energy Service Performance Contracts

An increasing number of building owners are working with ESCos to upgrade their energy-consuming equipment. Because ESCos provide financing for retrofit projects in exchange for a portion of the project's savings, the success of these projects, from both the owner's and the ESCo's point of view, can hinge on the energy-saving effects of commissioning. ESCos that incorporate commissioning into their contracts are more likely to deliver expected savings and performance for the building.

sioning plan and schedule, the commissioning authority uses their suggestions to finalize the commissioning plan. The final commissioning plan includes the following:

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

During this phase, the commissioning authority can also play a significant role in developing a building's operation and maintenance program by suggesting improvements to the current program. The authority should interview the facility manager to determine whether operating staff is able and available to operate and maintain building equipment and systems. The commissioning authority also reviews the design documents and drawings to ensure that equipment is accessible for maintenance.

Retrofit Phase 3: Installation

The steps the commissioning authority is responsible for completing during this phase include the following:

- ☑ **Develop prefunctional checklists**
- ☑ **Execute prefunctional checklists/correct deficiencies**
- ☑ **Approve prefunctional checklists**

The commissioning authority is responsible for developing prefunctional checklists, and also approves and oversees the execution of these checklists. These activities may be integrated with equipment start-up procedures. Using the prefunctional checklist, the commissioning authority documents deficiencies that may affect functional testing during the acceptance phase of the project. These reports may be submitted to the owner, depending on the contract arrangements for the project. It is important to establish a clear line of command for delivering correction orders. Tracking contractors' responses to these instructions is critical to the success of the commissioning effort.

It is critical that the commissioning authority approves the prefunctional checklist and that deficiencies are remedied before functional testing can occur in the acceptance phase.

Retrofit Phase 4: Acceptance

During the acceptance phase, the commissioning authority performs the following steps to assure the owner's representative of satisfactory equipment operation:

- ☑ **Develop functional test and diagnostic monitoring plans**
- ☑ **Execute monitoring and functional test plans/ correct deficiencies**
- ☑ **Accept equipment performance**

The diagnostic plans and the functional test plans are completed during this phase of the project. Monitoring and testing is performed to verify that the equipment is operating according to the design intent and owner's operational requirements. Ideally the commissioning authority should involve building staff in the testing process to improve operator understanding of the proper operation of equipment and systems. The experience also provides operators with valuable hands-on training in running and troubleshooting the equipment they will manage.

The diagnostic monitoring plan and functional performance are modified, if necessary, during the acceptance phase to reflect any changes in installations. The commissioning authority then uses the tests to document and verify the proper operation of equipment and systems according to the contract documents. Most often, the commissioning authority directs the tests, but the responsible manufacturer's representative or contractor, particularly the controls contractor, performs actual equipment operation during the tests. Requesting the installing contractor perform the operation is a wise preventive measure in cases where the warrantee may be voided.

If corrective measures are required, the commissioning authority makes sure that they meet the owner's criteria and the design intent. Acceptable performance is reached when equipment or systems meet specified design parameters under full-load and part-load conditions during all modes of operation as outlined in the commissioning test plan.

Once functional performance testing and diagnostics are complete, and any deficiencies are remedied, the commissioning authority approves the tests and submits the completed test to the owner's representative for review.

The acceptance phase is complete when the new installation moves from the static state to the dynamic state free of deficiencies. The design/construction team transfers control of the new systems to the building operators during the acceptance phase. Part of this transfer involves training building operators in the operation and maintenance of the new equipment and systems. The installing contractor or manufacturer's representative usually conducts this training.

As part of the commissioning responsibilities, the commissioning authority may oversee the training sessions that installing contractors or manufacturers' representatives conduct. The commissioning authority also verifies that operation and maintenance manuals are complete and available for use during the training sessions. Finally, if any modifications to operation and maintenance practices occur, the authority ensures that the appropriate revisions to the manuals are made. Training should be mandatory for building staff responsible for operating and maintaining complex building equipment, especially for EMCS.

The owner's representative may wish to videotape the training. As discussed in later chapters, videotaping sessions often provides extra incentives for trainers to ensure the quality of these sessions. Video-production contractors and vendors can assist the owner's representative in documenting the training.

The owner should accept the retrofit project only after the equipment has achieved acceptable performance under specified design parameters (full-load and part-load during all modes of operation) as outlined in the commissioning test plan.

Retrofit Phase 5: Post-Acceptance

After acceptance, the building is in the hands of the owner and operators. Even though the project is considered complete, some commissioning tasks continue throughout the life of the building. These tasks include ensuring that equipment and systems continue to function properly. Any changes in equipment and building usage should be documented. It may be appropriate to continue working with the commissioning authority at the beginning of this phase. The commissioning authority may review and recommend methods for carrying out these functions. In addition, the commissioning authority completes the following tasks:

- ☑ **Develop final commissioning report**
- ☑ **Perform deferred testing (if any)**
- ☑ **Develop recommissioning plan (optional)**

After completing functional performance testing and diagnostics, the authority writes a final commissioning report, which includes all project documentation, and submits it to the owner for review.

Any testing that was delayed because of site or equipment conditions or inclement weather should be completed during this phase. Any seasonal testing that was not performed should also be completed during the post-acceptance phase. When performing deferred testing during post-acceptance, the commissioning authority must take care to meet the terms of new equipment warranties. As part of the commissioning specifications, the owner's representative should require that contractors provide the commissioning authority with a full set of warranty conditions for each piece of new equipment.

Owners should consider recommissioning their facilities periodically to ensure that performance levels continue to meet design intent. If building operators have been involved in the original commissioning effort and received training, then they may be able to conduct the recommissioning process themselves.

How Much Commissioning is Enough?

Because commissioning all building systems is rarely practical or even necessary, owners need to determine how much commissioning is appropriate and most cost-effective for their project. Factors that influence this decision include the following:

- Complexity of the building systems
- Building type and size
- Project type, whether existing building system or retrofit project, or both
- Budget available for commissioning
- Building's tenant or occupant demographics
- Facility's use or purpose; for example, medical, laboratory, and other high-tech facilities will almost always require more rigorous scopes for commissioning activities than a typical commercial space
- Owner's objective in commissioning the building; those owners commissioning for IAQ may choose to employ a more rigorous scope of commissioning activities

The complexity of the systems and the controls often dictates the extent of commissioning necessary for either existing building system or retrofit projects. The risk of performance problems increases with project complexity. Complex systems include those with sophisticated controls and control strategies, complicated sequences of operation, or a significant interaction with other systems and building equipment.

For example, an upgrade from incandescent lighting to T-8 fluorescent lamps with electronic ballasts is not a complex project, and probably would need little more than an inspection before start-up. If, however, the lighting upgrade also included lighting controls (such as sweep controls, occupancy sensors, and daylighting controls) the project would be considered complex and would benefit from commissioning. All projects that include controls, EMCS, pneumatic equipment, integrated systems, HVAC-related plant equipment and air distribution systems should be commissioned. Following are examples of energy-efficient equipment that experts commonly place on their "must-commission" list:

- Lighting sweeps or daylighting controls
- Energy management systems and control strategies
- Variable speed drives in motors
- Ventilation air control
- Building pressurization control
- Refrigeration floating head pressure in compressors
- Refrigeration anti-condensate heater controls
- Capacity controls for heating and cooling plant equipment

All projects that include controls, EMCS, pneumatic equipment, integrated systems, HVAC-related plant equipment and air distribution systems should be commissioned.

But how much commissioning is enough? Certain types of equipment tend to require less commissioning, *under most conditions*, than do others, but every project is different. Every building is unique, and building owners and occupants may have specific building performance needs. No hard and fast rules universally determine the appropriate level of commissioning. Therefore, an experienced commissioning authority is the best resource for defining the most appropriate, cost-effective scope of commissioning for a project.

Other Commissioning Tasks for Contract Consideration

A quality operations and maintenance program can ensure that the savings from commissioning persist over time. Building owners or managers may want to consider including operations and maintenance program elements in the commissioning authority's contract. These elements include the following:

- An operations and maintenance plan outline, including examining and enhancing the current maintenance service contract procedures
- A list of required operations and maintenance documentation and methods for the building or systems, including full written sequences of operation for all equipment
- An energy-efficiency plan and policy, including strategies for obtaining management buy-in
- Guidelines for implementing a preventive maintenance plan
- A comprehensive training plan or recommendations for appropriate building staff to attend training. Training can include general operation and maintenance concepts for specific equipment and systems, including both building operators and facility managers or owners
- Guidelines and recommendations for incorporating an energy accounting and tracking system
- A list of operational strategies for the owner's representative to incorporate in the future
- An operations assessment program and systems tune-up and recommissioning schedule

Commissioning ensures that a building is performing as intended at the time that commissioning occurs.

When Does Commissioning End?

Commissioning ensures that a building is performing as intended at the time that commissioning occurs. By that definition of performance, maintaining a certain level of performance would require that commissioning never end. While this expectation is not practical, operation and management staff should recommission selected building systems on a regular basis, perhaps every 2-3 years depending on building use, equipment complexity, and operating experience. A commissioning authority can recommend an appropriate interval for recommissioning a building and systems. Between recommissionings, staff should implement sound operation and maintenance practices to ensure that the savings from commissioning continue for as long as possible.

Chapter 6: Operation and Maintenance for Persistence

Overview

Consistent operations and preventive maintenance, including troubleshooting of building systems, safeguard the most positive and persistent effects of commissioning. Keeping buildings functioning properly is a necessity, especially where indoor environments are directly linked to occupant safety and staff productivity.

To ensure that the benefits gained from commissioning persist over time, sound operation and maintenance practices must be in place and practiced regularly. Furthermore, if regular checks and maintenance on building systems are convenient, maintenance can often be done in-house. The following are examples of design recommendations that simplify operation and maintenance:

- Ground floor access to the chiller room through a connected loading dock
- Roll-up doors of sufficient size to permit removal and replacement of chillers without having to disassemble equipment
- Clearance on all sides of the chiller to allow for maintenance
- Hoist or crane equipment positioned over banks of chillers
- Valves that permit the isolation of an individual chiller without having to shut down the entire air-conditioning system
- Walkways around elevated equipment
- Roof access with adequate openings via stairs, not ladders
- Gauges, thermometers, and test ports (in sufficient numbers) on piping and equipment

Successful operation and maintenance planning begins early in the commissioning process. Increasingly, building owners are recognizing the importance of soliciting design recommendations from operation and maintenance staff. Consultations with the building's operation and maintenance staff regarding any new practices and policies are imperative. Establishing and implementing a preventive maintenance program for all building equipment and systems should include instituting the following measures:

- Periodic reviews of operating parameters, schedules, and sequences of operation
- Monthly utility bill reviews for unexpected changes in building energy use or tracking precise use with energy accounting software use
- Scheduled or unscheduled maintenance tracking for each piece of equipment (periodic reviews of maintenance documents will often indicate whether certain pieces of equipment require tuning)
- Building documentation updates to reflect current building usage and any equipment change-outs
- Operator training needs assessments on an annual basis

Training

Perhaps the most essential component of operation and maintenance is having a well-educated staff. Operation and maintenance manuals are powerful documents for training the facility's current staff and new staff members. For a building to function at its optimal level, building operators and managers must have the skills to perform quality operation and maintenance.

Instruction should meet the level of need and ability in the current operation and maintenance staff. Ideally, the bid documents should specify training session topics, such as those listed on the following page.

Building operation staff will gain a permanent and inexpensive on-site training aid if the project manager videotapes training sessions—especially the start-up and shut-down procedures for equipment. New staff can view the videos as part of their training.

When maintenance is provided by a facility manager lacking a technical background, the commissioning authority can still coordinate with contractors to ensure that the manager is educated about the capabilities, intended function, and required maintenance of the building systems. This training should enable the facility manager to respond to occupant complaints in a manner that is consistent with the system's design intent. The facility manager should have access to a list of resources for timely and accurate maintenance assistance.

Suggested Training Topics

- Descriptions of equipment and systems installed and their warranties or guarantees
- Equipment start-up and shutdown procedures, operation in normal and emergency modes, seasonal changeover, and manual/automatic control
- Requirements and schedules for maintenance on all operation- and maintenance-sensitive equipment
- Health and safety issues
- Special tools and spare-parts inventory to facilitate operation and maintenance
- Emergency procedures
- Operation and adjustment of dampers, valves, and controls
- Hands-on operation of equipment and systems
- Common troubleshooting problems, their causes, and corrective actions
- Review of operation and maintenance manuals and their location on-site
- Building walk-through
- Review of related design-intent documents
- EMCS operation and programming
- Control sequences and strategies
- Thermostat programming
- Relevant commissioning reports and documents
- When and how to recommission building systems
- Maintenance work order management system
- Sound energy-management practices

Operation and Maintenance Manuals

When appropriate, commissioning bid specifications should explicitly state that contractors will be required to provide training for staff and provide comprehensive operation and maintenance manuals, including written control sequences and diagrams for each piece of equipment. The commis-

sioning authority reviews these manuals to ensure compliance with the commissioning specifications. Operation and maintenance manuals should contain the following information:

- Name, address, and telephone number of installation contractor
- Model number of the equipment
- Product data
- Test data
- Performance curves (for pumps, fans, chillers, etc.)
- Installation instructions
- Operation requirements
- Preventive maintenance requirements
- Parts lists
- Procedures for troubleshooting equipment that are specific to its unique design and application

If the authority believes it would be beneficial, the operations and maintenance manuals can also include additional information that has been gathered during the commissioning process. This information may include the following:

- Equipment submittals
- Design-intent documents
- Control strategies and sequence of operations (normal and emergency)
- Copies of the commissioning tests (prefunctional checklists and functional performance test forms)

Contractors should provide at least three copies of each operation and maintenance manual. The master copy should reside in the facility manager's office. A second copy should be used as a field copy from which selected pages may be removed for use during site work. The last copy resides in the owner's or management firm's office. Some companies "hard bind" the master copy, so that no one inadvertently removes and misplaces pages. If an outside firm will maintain and operate building equipment, a fourth copy should be provided to them as a reference. Because outdated manuals are not useful, amendments to any one copy should be added to or replaced in all copies.

Troubleshooting

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

Because the commissioning authority and design professional will have become very familiar with the building system in question by the end of the project, the owner's representative may want to consider contracting with one or both of them for the first year of operation to provide troubleshooting assistance on an as-needed basis. This contract could be written in a "fee-for-service" or an "amount-not-to-exceed" manner. Owners may find that it is more cost-effective to purchase troubleshooting services from the commissioning authority or design professional, because their knowledge of the building systems and design saves time in diagnosing problems.

In the long run, owners may also find it beneficial to train operation and maintenance staff in energy accounting. In addition to tracking the building's energy use, energy accounting can also provide a red flag that indicates when problems or potential problems exist with equipment operation.

Preventive Maintenance

Preventive maintenance is the cornerstone of all operations and maintenance practices. The commissioning authority can assist the project manager or facility manager in developing a preventive maintenance plan for a building's controls and electrical and mechanical systems. This effort should be minimal because the preceding commissioning process gathered most of the information required for developing a preventive maintenance plan. Operating and maintenance manuals will provide any additional information. Preventive maintenance can save the owners' representatives time and money by helping to provide the following:

- Preventing losses of equipment, time, productivity, and resulting revenue
- Extending equipment life

- Identifying equipment degradation
- Decreasing the owner's potential for liability

Perhaps the most cited reason for performing preventive maintenance is the energy savings and corresponding cost savings that it provides. For example, replacing worn fan belts on a regular basis can save 2-4% of the energy used to run the fans. Cleaning air filters and cooling coils regularly can save 1-3% of the building's energy use for cooling. These basic activities cost very little to perform, but can add up to dramatic savings.[17]

Another benefit of preventive maintenance is early detection of degradation in the system's components. Incidence of failures will be lower if building staff follow appropriate operations and maintenance procedures and proper reporting and documentation practices. For example, if an equipment component shows signs of imminent failure, the responsible person can immediately place a work order for replacement parts. This process prevents failures from occurring and permits scheduling of repair or replacement work when it is convenient for the building's occupants. Preventive maintenance can save money by reducing the number of emergency service bills.

Preventive maintenance of integrated building systems can also make buildings safer and can reduce an owner's potential liability. For example, a properly functioning air-handling system is required in case of fire. The potential for liability is lower when ventilation systems are part of the fire sprinkler and smoke-detection systems and operate as intended. Proper maintenance of these systems considerably reduces the chances of small accidents becoming full-blown emergencies.

[17] Manufacturers develop and recommend preventive maintenance procedures to prevent equipment failure and lenthen equipment life. When estimating equipment life, manufacturers assume that preventive maintenance of the equipment and system will occur regularly.

Appendix A: Sample Prefunctional Checklist

This section includes a sample prefunctional checklist for a packaged air conditioning system. This checklist is intended as an example that could be used as a "boilerplate" form and adapted to fit specific projects.

Sample Prefunctional Checklist for Packaged Air Conditioning System

Building:	Commissioning Authority:	Phone:
Date:	Contractor:	Phone:

Project Information

Building Name	
Building Contact Name	
Phone	
Commissioning Authority Name	
Address	
Phone	

Equipment

Equipment Name	
Type	
Manufacturer	
Model Number	
# of Identical Units	

Unit Number	Serial Number	Location

- Does the installed equipment match the model type specified?
  ☐ Yes / ☐ No

Documentation

Documentation Available on Site (check all that apply):

☐ Manufacturer cut sheets

☐ Submittals

☐ Manufacturer product design data (curves)

- ☐ Operation and maintenance manuals
- ☐ EMCS points list
- ☐ Hard copy of EMCS program
- ☐ Installation manual
- ☐ Water treatment report
- ☐ As-built drawings
- ☐ Schedules
- ☐ Balance report
- ☐ Written control strategies
- ☐ Other (list):_____

- Is the documentation complete according to specifications?
  ☐ Yes / ☐ No

Purpose of the Performing this Test or Checklist (e.g., routine or emergency maintenance):

Equipment Description (model number, size, general function)

Nameplate Information

(Volts, Amps, Phase, BTUs, Efficiency, etc.)

General Checklist

Enter comment number (i.e., 1,2,3, etc.) in appropriate box below if item is missing or deficient. A description of deficiency should be listed by corresponding number in the box entitled "Deficiencies" directly following this chart.

Checklist Item	Unit #				
General condition appears good					
Casing condition good: no dents, leaks, door gaskets tight					
Attached duct work is properly sealed (boot in good condition)					
Pipe fittings complete and pipes properly supported					
Condensate drain in place and properly trapped					
Protective shrouds for belts in place and secure					
Alignment of motor driven components correct					
Correct refrigerant charge					
Correct oil level					
Compressors and piping were leak tested					
Crankcase heater on when unit is off					
Disconnects in place and labeled					
All electric connections tight					
Proper grounding installed					
Auxiliary heaters operate					
Control system interlocks functional					
Safeties installed					
Smoke detectors in place					
All dampers stroke fully and easily					
Dampers close tightly					
Enthalpy control and sensor properly installed					
Related thermostats are installed					
Related EMCS points are installed					
OSAT, MAT, SAT, RAT sensors properly located and secure (OSAT shielded). State which sensors are installed.					

Checklist Item	Unit #				
Supply fan belt: acceptable tension and condition					
Supply fan: acceptable noise and vibration					
Supply fan area clean					
Supply fan rotation correct					
Filters clean and tight fitting					
Construction filters removed					
Indoor coils clean and in good condition					
Unit starts and runs with no unusual noise or vibrations					
Condenser fan rotation correct					
Condenser fan acceptable noise and vibration					
Condenser fan clean and in good condition					
Condenser coils clean and in good condition					
Other (list): _____					

Deficiencies

List, in detail, deficiencies noted in the ***General Checklist*** above.

General Comments

Signature _____ Company _____ Date _____

Commissioning Authority

Appendix B: Internet Resources

The following internet sites contain useful information pertinent to the Rebuild America Program. They also include sites describing resources available from the U.S. Department of Energy, other federal agencies, and a sampling of key associations.

Resources from U.S. DOE

Building Technology Center (Energy efficiency research, demonstrations, and technology transfer)
www.ornl.gov/ORNL/Energy_Eff/btc.html

Center of Excellence for Sustainable Communities (Information on sustainable communities)
www.sustainable.doe.gov/

Energy Efficiency & Renewable Energy Clearinghouse (General information and resources)
www.eren.doe.gov/

Federal Energy Management Program (FEMP) (Among other information, full text of GSA "Draft Building Commissioning Guide")
www.eren.doe.gov/femp/facbuild.htm

Energy Fitness Program (Support and procedures for energy performance contracting)
www.ornl.gov/EFP/

Rebuild America (Technical support and financing advice for community partnerships)
www.eren.doe.gov/buildings/rebuild/

Resources from Other Federal Agencies

Energy Star Buildings Program (Program descriptions and financing for energy-efficient buildings)
www.epa.gov/energystar.html

Housing and Urban Development (Housing rehabilitation, mortgage insurance and more)
www.hud.gov/

President's Council on Sustainable Development (Policies and strategies for sustainable communities)
www.whitehouse.gov/PCSD/index.html

Resources from States, Utilities, and Associations

Association of Higher Education Facilities Officers (Strategies for universities and colleges)
www.appa.org/

Florida Design Initiative
www.fcn.state.fl.us/fdi/fdi-home.htm

National Association of State Energy Officials (State programs with links to their sites)
www.naseo.org/

National Association of Energy Service Companies (Energy performance contracting)
www.naesco.org/

National Environmental Balancing Bureau
www.mcaa.org/nebb/bsc-man.htm

Northwest Energy Efficiency Alliance (Market transformation incentives – interim site)
www.nwalliance.org/projects/current/buildcom.html

Oregon Office of Energy (Among other information, contains the full text of "Commissioning for Better Buildings in Oregon")
www.cbs.state.or.us/external/ooe/cons/bldgcx.htm

Portland Energy Conservation, Inc.
www.peci.org/

Texas A&M Energy Systems Lab
www-esl.tamu.edu/

University of Washington
www.weber.u.washington.edu/~fsesweb/

Glossary

CLASS A BUILDINGS

Buildings that have state-of-the-art systems as evidenced by above-average finishes and fixtures. Class A buildings usually have the highest rents in a given area.

COMMISSIONING

Commissioning is the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained according to owner's operational needs.

COMMISSIONING PLAN

A written document describing the scope of work, commissioning process, roles of each team member, and the commissioning schedule.

DAYLIGHT CONTROLS

An electronic control that reduces interior lighting to take advantage of the natural light coming into a space.

DESIGN INTENT

Generally a written document that describes, in detail, how and why building systems function. This is generally developed by the design engineer.

EQUIPMENT STARTUP

The process of successfully starting equipment for the first time, to prove that it operates. It is performed by the installing contractor.

OCCUPANCY SENSORS

Lighting switching devices that respond to the presence or absence of people in a given area by turning lights on or off.

PREFUNCTIONAL TESTING

Testing that is done according to a checklist (generally developed by the commissioning authority) that verifies that new equipment and all its components are functioning as intended. Prefunctional testing is conducted in preparation for functional testing. A prefunctional checklist is often incorporated into the startup process.

SICK BUILDING SYNDROME

A syndrome that is often experienced by building occupants as a result of indoor air quality problems due to such factors as inadequate fresh air flow and ventilation.

SCOPING MEETING

A meeting that occurs prior to installation of new equipment or commissioning of existing equipment. At this meeting the commissioning roles and responsibilities are discussed and the commissioning schedules are agreed upon.

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