

HVAC SYSTEMS COMMISSIONING MANUAL



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**SHEET METAL AND AIR CONDITIONING CONTRACTORS'
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SECOND EDITION 2013



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NATIONAL ASSOCIATION, INC.**

4201 Lafayette Center Drive

Chantilly, VA 20151-1219

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NATIONAL ASSOCIATION, INC.**

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FOREWORD

Commissioning includes the final act of verifying compliance with project specifications and the owner's project requirements. The term commissioning has evolved to represent a total quality management process in the construction trades. It includes demonstrating and verifying system and subsystem operational performance and is a detailed testing and documentation of building systems and components. Finally, it is the foundation of and includes training provided to facility managers to be used by building management throughout the operational life of the building. While commissioning can be applied to all components of a structure, this manual only focuses on the HVAC systems and the parties responsible for the proper design, installation, verification, operation, and maintenance of these systems.

HVAC systems are typically the most energy intensive systems in a building. HVAC systems can be the source of indoor air quality (IAQ) problems or the vehicle to the solution of those problems. Poorly designed, improperly installed, or inadequately maintained HVAC systems can cause high operating costs, occupant discomfort, affecting the long term financial viability of a building. The purpose of this manual is to introduce the commissioning process and to provide all stakeholders an understanding of the skills and expertise required to apply the concepts to the most critical element in most buildings—the HVAC system. Contractors who understand the process will be in position to offer this service to building owners and designers. Owners who understand the value commissioning adds to their building will demand it be an integral part of the construction process.

The original group tasked with developing the first edition of this standard, the SMACNA Building Services Committee, decided to introduce the commissioning process as a multi-level concept applicable to projects large and small, simple and complex. The current task force agreed with multi-level concept which is continued in this edition. The manual treats the subject in sufficient detail to provide a professionally run organization, with a commitment to the total quality management process, the tools to direct the activities of a commissioning team. The concept of commissioning an existing building which is sometimes called re-commissioning or retro-commissioning is covered in this standard. The commissioning process can be utilized in renovation and retrofit projects as well as part of an ongoing building maintenance program for any building.

New to this edition is a chapter on LEED® projects. As the United States Green Building Council is evolving and changing its system for rating buildings it is important that all parties involved in these types of projects be familiar with the changing requirements. LEEDv3 (2009) is the basis for the chapter on LEED® commissioning requirements.

The manual includes sample specifications and sample commissioning reports. Also included are samples of commissioning checklists for a wide variety of HVAC systems and components. Although these checklists are comprehensive, they are intended as guidelines to develop forms specific for the building or components being commissioned. Since each building and its systems are unique, forms used in the commissioning process are customized for the equipment and systems involved and to reflect the requirements of the commissioning authority.

This manual will be updated in the future as industry needs change and evolve. Continuing efforts will be made to provide the industry with the latest methods and engineering data from recognized sources, supplemented by SMACNA research, the services of local SMACNA chapters, and the growing experience base of SMACNA contractors.

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CHAPTER 1

PURPOSE AND SCOPE

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1.1 DEFINITION

Commissioning may be defined as: “the process of advancing systems from a state of static physical completion to a state of full, demonstrated, and documented working order, according to the owner’s project requirements and the design requirements, during which time the owner’s operating staff are instructed in correct systems operation and maintenance.”

In order to carry out the full commissioning process, it is necessary to plan and document it. Planning should begin as early as possible to ensure the owner’s project requirements are understood and suitable quality assurance strategies are utilized. The results of the quality assurance process should be documented to provide an auditable record of the process.

1.2 PURPOSE

Since the publication of the first edition of this manual, the use of the commissioning process in the building construction industry has grown dramatically. Many organizations have made building commissioning “business as usual” on each construction project. Building commissioning has been recognized as a critical process in the design, construction, and operation of a sustainable or “green” building. While the commissioning process has been expanded to apply to other systems, e.g., fire alarm, security, electrical, building envelope, the primary focus of building commissioning remains on heating, ventilating, and air conditioning (HVAC) systems. First, HVAC systems are among the most complex and interconnected of building service systems. Second, considerable energy is consumed in HVAC systems. Inefficient operation increases operating cost. Third, HVAC systems must be designed properly, then installed, operated, maintained, and serviced correctly, if both comfort and indoor air quality are to be attained and maintained.

The primary purpose of this manual is to provide guidance to contractors on how an effective HVAC systems commissioning process should be planned and carried out. A second purpose is to provide a clear explanation of the reasons for commissioning to make it understandable for a broad cross section of the industry. Contractors who understand commissioning are in a position to sell its use to owners, designers, and others.

Another purpose of the manual is to provide guidance on commissioning HVAC systems in existing buildings. Any existing building with poor temperature

control, dissatisfied occupants, excessive energy or maintenance costs, or other evidence of improper design or operation is a candidate for commissioning. Because there are many existing buildings with these characteristics, and owners often contact contractors directly for remedial work on them, provision of commissioning services for these buildings is a potentially important field for knowledgeable contractors.

This manual covers commissioning during the construction phase of a project in considerable detail. It puts particular emphasis on the commissioning agent, the commissioning authority, the commissioning plan, communication and coordination during construction, and commissioning documentation. This is to give the clearest possible guidance to contractors and others whose involvement is primarily during the construction phase of a project. In some cases, the contractor has the opportunity to join the process prior to the completion of design. When this occurs the contractor is able to contribute ideas and suggestions regarding quality and constructability during the design or pre-design phases. Understanding the commissioning process enables the contractor to engage more effectively early on.

This manual does not provide material specific to any particular building. The material within is intended to cover the entire commissioning process, providing not only organizational and procedural steps, but also the rationale behind them. This assists users of the manual to adapt the information to the successful commissioning of any type of building project.

1.3 SCOPE

The *HVAC Systems Commissioning Manual* is intended to cover the full range of HVAC equipment and systems typically found in commercial and institutional buildings.

The level of commissioning varies to suit the specific requirements of each project as determined by the owner.

The manual describes in detail the commissioning process for three different levels of commissioning. The manual provides guidance on the use and application of the commissioning process in the green building rating systems developed by the U.S. Green Building Council (USGBC). In addition, as an aid to users, it provides examples of delivery receipt, prestart checklists, and functional performance test checklists for many types of equipment and systems. These include:



- Hot water and steam boilers; with atmospheric or power burners; gas, oil, or combination gas/oil fired.
- Chillers; with reciprocating, scroll, screw, or centrifugal compressors; air-or water- cooled; with or without condensers; and including heat recovery models.
- Cooling towers, closed-circuit heat rejectors, and both air cooled and evaporative condensers.
- Hot water, chilled water, and condensing water pumps associated with the preceding.
- Constant volume, single zone air systems (including all components such as fans, coils, furnaces, condensing units, dampers, and controls, as applicable).
- Condensing boilers.
- Primary and secondary piping systems.
- Variable flow piping or pumping systems.
- Variable Air Volume (VAV) Systems (including various components such as terminal units and Variable Frequency Drives (VFD))



CHAPTER 2

INTRODUCTION

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2.1 HISTORICAL BACKGROUND

Over the years, buildings and their services have become more complex and varied. At one time, systems were simple, with few controls (mostly manual), and similar from building to building. After installation, a simple equipment start-up by the contractor was often all that was needed. The equipment, and thus the system, either worked or not. If not, diagnosis and correction was usually obvious and quick.

Building operators understood such simple systems and were able to keep them operating correctly. There were summer operating modes and winter operating modes. Everything in local zones was controlled by a thermostat. When energy consumption was not a concern, equipment oversizing often compensated for incorrect operation, and comfort conditions could be maintained.

Today, there is a wide range of equipment and systems used for building HVAC. These systems are often complex, particularly in their controls to implement energy savings strategies. They have come about in order to meet a whole series of conflicting pressures: capital cost constraints; more stringent building codes, particularly with respect to smoke control and energy; escalating energy costs; energy conservation standards for equipment; occupant demands for better comfort and good indoor air quality; and green building trends.

2.2 WHY COMMISSIONING?

The primary purpose of commissioning is to deliver a building where service systems function according to design intent and to meet the needs of the owners and occupants. To achieve this, it is essential to implement a commissioning process in which functional and environmental performance is tested; verified for all anticipated operating conditions; documented prior to occupancy; and maintained during the life of the building systems.

The simple start-up is no longer adequate. If today's building systems are going to function properly, they must be designed competently and installed correctly. On the installation side this means checking that all aspects of the installation are complete before start-up. Once started, system operation must be checked and verified in detail.

Building owners and operators must be provided with usable documentation regarding inspection, service, and maintenance requirements and be instructed on the importance of carrying them out. An effective,

ongoing service and maintenance program is essential for maintaining efficient system performance, providing occupant comfort, and extending equipment life.

Once that is done, operators must be trained in all aspects of the operation of the systems. This is critical because correct systems operation requires a basic understanding of the equipment's capabilities, limitations, and intended control sequences. Without documentation and instruction, operators do not have the resources to properly operate the building and its systems. In addition, due to smaller safety factors and more demanding occupants in today's buildings, there are fewer margins for error.

Unfortunately, in many cases, the construction industry has not updated its practices to meet the demands of today's mechanical systems, owners, and building occupants. In addition, many owners think they are getting and paying for a fully commissioned building when they are not. Application of information in this manual will enable contractors to understand how to upgrade their skills and update their commissioning practices to meet today's needs.

2.3 SMACNA'S RESPONSE

SMACNA exists to encourage and enable sheet metal and air conditioning contractors, and others in the industry, to improve their capabilities and the quality of the installations they produce. The development and distribution of standards and manuals and participation in training programs are a central part of this effort.

The HVAC contractor has traditionally had the responsibility of providing a complete and fully functioning installation. In essence, “fully functioning” also means “fully commissioned.” Thus, the traditional responsibility includes all the activities involved in planning the commissioning process and implementing it on site.

The commissioning agent is an integral part of implementing the commissioning process. Chapter 4 provides some information on commissioning agents, and section 4.3 details the skills and qualifications needed by them. HVAC contractors have to be prepared to retain external commissioning agencies, or to develop the required expertise internally, in order to undertake HVAC systems commissioning as described in this manual.

The owner and his designers determine the terms of reference, the scope of work, and the detailed



specification requirements, all as contained in the contract documents. If specific commissioning requirements are contained therein, it is the contractor's responsibility to meet them. The owner should have some means of ensuring the contractor carries out those responsibilities. This corresponds with Level 2 commissioning.

However, even when the contract documents do not contain any explicit commissioning requirements, commissioning can still be planned and carried out by the contractor. This is what is referred to as Level 1. In essence, Level 1 commissioning is the minimum that should be carried out by any responsible and knowledgeable contractor committed to quality work. This manual outlines how, if commissioning is done properly and expertly, a better product can be produced at little or no additional cost. In essence, Level 1 is simply quality control procedures that are embedded in how contractors produce and install duct or entire HVAC systems. Well thought out and adhered to Quality Control procedures can save time and money.

2.4 QUALITY MANAGEMENT

Commissioning is essentially a quality control process. Quality is built into a product by planning and forethought; it is not achieved by trying to fix problems after they have occurred. A quality product does not need to cost more to produce, but many changes to both processes and attitudes may be necessary to achieve the goal of quality products.

SMACNA is convinced that commissioning, as an integral part of the design and construction process, is one of the means of improving the quality of the HVAC systems that contractors turn over to owners. Helping the industry to improve its quality management performance is one of the goals of this manual. It focuses on a commissioning process, which is truly

integrated into the overall construction process, as a means of moving toward that end. If commissioning is planned and carried out properly, this increase in quality can be achieved with a reduction in construction cost. In other words, the time and cost of the commissioning process can be offset by the time and cost saved through improvements in efficiency.

Nevertheless, when a comprehensive commissioning process is required, the specifications must clearly define the work and level of effort required. The specifications must define the commissioning procedures to be followed and all related contractor responsibilities, including those of the commissioning agent. They must also define the scope of equipment, subsystems and systems to be commissioned. Only when process and scope are both defined, can contractors bid the work fairly and accurately. And finally, only when the owner's designer or commissioning authority enforces the specification objectively, will the process carry through to the end of the project to the benefit of both owners and contractor.

Unfortunately, a building is not a product for which prototypes can be built, tested, revised, and fine tuned before full production begins. Every building is unique. Furthermore, the construction industry is fragmented, involving a vast array of contractors, subcontractors, suppliers, tradesmen, test and balance specialists, controls technicians, equipment startup specialists, designers, inspectors, and owner's staff. With competitive bidding on every element, a lowest immediate cost mentality prevails for every item, at every level of bidding. In such an environment, it is very difficult for the contractor to consider an overall quality management approach, let alone achieve it. However, a quality management approach, incorporating a commissioning process as outlined in this manual, has the potential to produce a better product for the customer, possibly at a reduced overall cost.

CHAPTER 3

BENEFITS AND COSTS

3.1 BENEFITS

3.1.1 Overview of Benefits

The benefits of commissioning accrue to owners, designers, contractors, and occupants or tenants. Ultimately, however, the majority of benefits, in the form of a building that functions properly, accrue to the owner. To request commissioning beyond the basic Level 1 the owner must be convinced of these benefits.

Many, perhaps most, owners think they are already getting, and paying for, a completely functional building, when in fact they may not. Such owners may not be aware of the benefits available to them from commissioning. They need to be informed of these benefits by designers and contractors who understand both the practice of, and the rationale for, the commissioning process.

3.1.2 Benefits to Owners

Commissioning benefits owners by adding value to a project. This value can be measured in both hard costs and benefits and soft costs and benefits. The commissioning process can add value by ensuring that the owner's needs for the building have been thought through and documented carefully at the program phase. Design intent and the designer's basis of design can thus be more responsive to the owner's needs. When commissioned, the facility operates in accordance with design intent, maintains thermal comfort, operates efficiently, and produces a high level of occupant satisfaction.

Another benefit to owners is fewer unidentified deficiencies at turnover, particularly hidden ones resulting from incorrect functioning of controls. Thus, owners will not have to either pay for later correction or live with the problems. Living with the problems can result in diminished productivity by either occupants, maintenance staff or both, or increased operational costs due to inefficient operation of the systems.

Well commissioned systems are set up to function at maximum efficiency, minimizing energy and operating costs. In order to achieve this third benefit, knowledgeable building operators are essential. Owners must put sufficient priority on this aspect of their building operations and maintenance management. Operator involvement in the commissioning process itself can be an important familiarization and educational experience. But it must be followed up; particularly as staff changes take place over time.

In addition to the operational benefits already mentioned, knowledgeable operators bring other benefits to the owner. When there are problems, fast and accurate diagnosis is likely, leading to quicker and possibly less expensive corrective action. In dealing with occupants, trained operators can provide more accurate information on the nature of the problem and do so in a way which instills confidence in the owner's staff. Of course, the problems must be resolved. But when they are, the resulting happy occupant or tenant is a valuable asset to a building owner.

The United States Green Building Council (USGBC) has recognized that commissioning is critical to delivering a sustainable building to the owner. The Leadership in Energy and Environmental Design (LEED®) rating systems developed by the USGBC require commissioning on all new projects. Such a mandatory requirement is not made lightly and serves as an indication of the long-term benefits to the owner for a properly commissioned building.

3.1.3 Benefits to Designers

There are more demands on designers today than ever before. The changes in systems, energy concerns, Indoor Air Quality (IAQ) issues, increasingly stringent codes, Building Information Modeling (BIM), and the continually evolving controls technology are all responsible. Designers are asked to design systems which not only meet design conditions, but operate well at part loads, are accessible for service and maintenance, and are within the owner's budget.

When the commissioning process helps clearly establish the owner's goals in the programming phase, the designers can more effectively meet these goals in their design. This can reduce time spent on redesigns to meet fluid or ambiguous owner directives. As commissioning fosters an integrated design and construction process, input during design on how the building and its systems will actually be constructed can reduce future Requests For Information (RFIs) and potential in-field changes.

Designers also benefit from commissioning when they are involved with the functional performance verification and acceptance tests. These tests measure how the design performs dynamically in the field and can provide valuable feedback to help guide future designs.

3.1.4 Benefits to Contractors

Commissioning benefits to all parties are maximized when contractors are an integral part of the



commissioning process. Commissioning is a team effort, and the contractors are a vital part of this team. It is the contractor who is directly responsible for the quality of workmanship and care when all the systems come together in construction. A contractor who works with the process will reap a variety of both hard and soft benefits. Contractors who merely tolerate the process – or worse, try to avoid it entirely or work against it – will not see these benefits.

The benefits of commissioning to contractors can include the following:

- Improved construction planning and coordination,
- Few to no outstanding deficiencies at substantial completion,
- Quicker project completion,
- Better documentation of equipment startup, which aids warranty administration,
- More satisfied clients and owners after completion,
- Reduced callbacks, and
- Therefore, lower operating and maintenance service costs.

Each of these benefits is expanded upon in the following:

- The first benefit, an overriding one, is that commissioning can produce better planning and coordination. Having a commissioning plan and dedicated commissioning personnel committed to following through on it is important in this regard. Priority items, and responsibilities for them, can be identified and followed up. On-site communications are critical and are enhanced and facilitated by the commissioning personnel.
- A second benefit to contractors is fewer deficiencies at substantial completion. The various prestart checks and functional performance tests result in potential early identification of deficiencies from faulty equipment or incomplete or incorrect physical installation work including controls problems not detectable by physical inspection, but requiring dynamic testing. When

deficiencies are identified, the step by step logic of the commissioning checks and tests often isolates their causes and, therefore, who should be responsible for correction. If it is an installation problem, correction by the responsible trades while they are still on site is commonly possible. If it is a design problem, it can be referred with documented evidence to the designer. By identifying issues as early as possible, their resolution is often simpler and less costly both in terms of time, aggravation and dollars. All these factors are money and time savers for the contractor.

- Potential for more timely payment and project closeout.
- Commissioning results in improved documentation. The forms that are completed identify specific equipment and system start dates for warranty and payment purposes. In addition, documentation will usually confirm that correct equipment startup procedures were followed.
- The most important benefit is a satisfied client or owner after completion. This results from systems that are tested and verified to function as intended; in other words, the quality promised is delivered. Operators who, through their exposure to the commissioning process, have seen correct system operation and understand it, will not complain unjustifiably. On both counts, customer satisfaction is increased.
- Another benefit to the contractor is reduced callbacks. These can result from deficiencies discovered after substantial completion. As noted, commissioning provides a practical means to minimize callbacks. Callbacks can also result, when there is no real problem, because operators do not understand the operation or limitations of the design. When the commissioning process is carried out properly, more knowledgeable operators result, reducing this cause of callbacks.
- Finally, commissioning can reduce overall contractor costs. Planning and carrying out commissioning definitely has a cost, *see* Section 3.3), but these costs can be more than offset by the savings made possible by the process. Improved site labor utilization can

result from better site coordination. Tradesmen can be assigned to tasks truly critical to timely completion with some confidence that the necessary prerequisite work has actually been completed. Identification and resolution of deficiencies early and while construction is ongoing reduce the time and effort (and thus the cost) of getting trades back to site to correct them. Fewer callbacks reduce another source of cost.

3.1.5 Benefits to Occupants and Tenants

The dominant benefit in this category is increased employee productivity brought about by occupant satisfaction with the building and minimum time lost to complaints or absenteeism caused by ineffective or poor system operations. When commissioning has been carried out competently and thoroughly, the building systems function in an integrated fashion as designed and, with good maintenance, will continue to do so. Environmental conditions and IAQ will be in accordance with design intent, so a high level of occupant satisfaction with respect to these factors is to be expected. While definitive comparisons are extremely rare, it is a widely held belief that improved employee satisfaction results in improved productivity, with benefits vastly greater than costs from commissioning or other means of achieving the improved building conditions.

In owner-occupied buildings, benefits in this category could be considered among those received by owners. In tenant-occupied buildings, these benefits flow directly to the occupants, but, in a very real sense, they also go to the owners because, if the tenants are satisfied, retaining existing tenants and obtaining new ones will be easier.

3.2 BENEFITS OF COMMISSIONING EXISTING BUILDINGS

The commissioning process is not reserved for new construction projects. The process can and has been applied to existing buildings. In the past, the terms “recommissioning” and “retrocommissioning” have been used when referring to commissioning of existing buildings. The industry has moved away from these terms and instead simply uses the term “commissioning” whether it be for a new or an existing building. Commissioning should be a continuous process throughout the life of the building.

Commissioning an existing building can bring enormous benefits to owners, mostly by eliminating

avoidable cost or overcoming problems, such as occupant complaint or excessive vacancy. Some reasons for commissioning an existing building are:

- HVAC systems not functioning correctly,
- HVAC systems operating inefficiently, thus wasting energy and increasing cost,
- HVAC systems zoning and layout do not match current occupancy or usage patterns,
- Comfort needs of occupants not being met,
- IAQ problems,
- Occupant complaints, or
- Reduced occupant productivity.

Many of the noted conditions or problems can be interrelated. The following discussion provides additional information.

- HVAC systems that are not functioning correctly often contribute to occupant discomfort. Sometimes such situations are of such long standing, they have become accepted as normal. Nevertheless, the failure of the systems to function correctly is negatively impacting occupant productivity and likely resulting in increased energy use.
- Often, tenant alterations occur without corresponding adjustments to the HVAC system. As a result, the HVAC layout and zoning no longer match the current occupancy. This contributes to ventilation, temperature control, and other comfort problems.
- Systems not operating or maintained properly are often less efficient. There is an energy savings opportunity in proper operation and maintenance.
- When comfort needs are not being met, for whatever reason, there are almost always increased costs due to lower occupant productivity, increased energy use, or increased maintenance costs.
- Poor IAQ can be a building owner’s most severe problem. In extreme cases, buildings have been evacuated while corrective measures are identified and carried out. Clearly,



the direct cost of such an event is extremely high, and there is huge potential for indirect costs related to litigation and bad building having a “reputation” as a “sick building”. It is important to owners to avoid problems of this magnitude.

- Occupant complaints and reduced productivity are often related. Both, however, result in additional costs, one from investigations of causes of complaints and the other from reduced work output.

Unfortunately, most owners do not recognize they have problems or avoidable costs that would justify commissioning until they are so severe as to be overwhelming. Often, the best way to identify whether or not a building is a candidate for commissioning is to carry out a preliminary survey to evaluate the factors noted above. Knowledgeable contractors, particularly those with design expertise, are often in a good position to carry out such surveys and advise owners concerning the costs and benefits of commissioning an existing building. Where such commissioning is justified, the emphasis should be on the cost savings opportunities available.

Contractors can benefit from commissioning existing buildings in three ways. First, it is a potential source of new business, but only for those with staff having the necessary knowledge and skills, *see* Section 4.3. Second, because of the extreme importance of capable operations and maintenance in keeping buildings functional, it is an opportunity to sell owners on improved maintenance programs, preventative maintenance agreements, and educational programs that may provide knowledgeable operators. Third, to the extent owners of existing buildings recognize the benefits of commissioning, there will be an increase in the demand for improved commissioning in any new construction they undertake.

3.3 COSTS

3.3.1 Overview of Costs

Commissioning requires time and, therefore, has a cost. All commissioning costs are eventually borne by the owner, either directly or indirectly. It is important to remember, however, these costs are more than offset by benefits to the owner.

Total costs for Level 1 or Level 2 commissioning typically range between 2 and 5 percent of the HVAC construction cost. In general, these percentages tend to:

- Drop as the project size rises.
- Rise for more complex and sophisticated projects.
- Rise for projects located further away from major urban centers, and
- Rise as controls and interfaces between systems become more complex.

Each of the major parties to the commissioning process incur some of the total cost:

Costs to Owners. In Level 2 commissioning, the owner incurs costs for making staff or service contractors available for familiarization, instruction, and demonstration. Typically, for HVAC commissioning, such costs do not exceed 0.5 percent of the mechanical cost. In Level 1 commissioning, the owner imposes no specific commissioning requirements and, therefore, may not participate in the commissioning process; however, a wise owner will make operating staff available as noted for Level 2.

Costs to Designers. The principal commissioning cost incurred directly by designers is for additional on-site time to witness systems performance verification, if the owner has retained them to act as commissioning authority. For Level 2 HVAC commissioning, additional on-site time could result in costs of up to 0.5 percent of the mechanical cost.

Costs to Contractors. The direct costs of Level 1 or Level 2 HVAC commissioning incurred by the contractor, including the cost of the commissioning agent’s work, is typically in the range of 1 to 4 percent of the mechanical system cost.

Level 3 commissioning costs are higher than those for Level 2. The exact amount depends heavily on the degree of detail in the required test protocols, number of different components requiring Level 3 testing, and a host of other factors. This cost is incurred for additional owner staff time, additional designer time, additional contractor commissioning services, and (possibly) test fees to specialized agencies certified to carry out specialized testing work.

3.3.2 Existing Building Commissioning Costs

The costs to commission existing buildings vary greatly. A rough estimate of probable cost is between \$0.10 to \$0.25 per square foot of building area.

However, due to the wide range of activities that could occur during this commissioning process, the cost can range dramatically. This gives some indication of the possible tasks required in an existing building commissioning project.

However, it is important to note that existing building commissioning is driven not by its cost, but by the savings opportunities identified in the initial surveys leading to the decision to proceed with commissioning.



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CHAPTER 4

AGENT AND AUTHORITY

4.1 GENERAL

The terms, commissioning agent and commissioning authority are used in this manual. The terms provide a means of delineating the commissioning responsibilities of the contractor who is responsible for carrying out commissioning (commissioning agent) and those who organize, verify, and accept the results (commissioning authority) on behalf of the owner.

When different contractual arrangements exist, or when the owner assigns responsibilities differently, corresponding adjustments must be made to the roles and responsibilities described in this chapter

4.2 THE COMMISSIONING AGENT

For the purposes of this manual, the commissioning agent is defined as the persons or company responsible for carrying out implementation of the commissioning process. It is important to recognize that the commissioning agent's role is usually carried out by a team, rarely by one person, except on very small projects. In some respects, the term "commissioning agency" might be more appropriate; however, in this manual the term "commissioning agent" is used.

Usually, the commissioning agent's responsibilities are during the construction phase of a project. This arrangement is common in two circumstances. (1) For large complex projects it is common to have a commissioning authority that organizes the entire commissioning process. (2) For small projects that are not complex, there may be little involvement from the owner's commissioning authority and the commissioning agent will take the lead in both planning and implementation.

In situations where there is no third-party commissioning authority or the owner's commissioning authority so chooses, commissioning agents may be appointed during the design or pre-design phases. In such cases they have early input with respect to the planning of the commissioning process. Under these circumstances, the commissioning agent may have the lead in planning commissioning activities. The commissioning agent's responsibilities also include coordinating, documenting, and witnessing the on-site tests described in the commissioning plan.

The commissioning agency's function may be carried out by a separately retained company specializing in commissioning work or by properly skilled staff of the contractor carrying out the work.

4.3 SKILLS AND QUALIFICATIONS—COMMISSIONING AGENT

The ideal commissioning agent has most or all of the following qualifications, experience, and skills:

- A good knowledge of a variety of HVAC equipment and systems is important. This knowledge needs to include an understanding of the design basics behind each system and how each is typically controlled in order to perform as designed. It can be obtained from technical school, manufacturer's technical training programs, direct field experience, or design office experience.
- Experience in either the engineering or installation and field testing of controls systems for a range of HVAC and Building Automation Systems (BAS) is also needed. Knowledge of controls and BAS is important to overall system function and is closely related to HVAC systems knowledge.
- Training and experience in testing and balancing of air and hydronic systems proves valuable in on-site work.
- Good writing and documentation skills are essential for a number of commissioning tasks: (1) Preparation of an understandable and useful commissioning plan incorporating all the steps required, in the correct order, (2) Producing useful commissioning meeting minutes, and (3) Documenting test results as they are obtained. Knowledge of computer use for some of these tasks is essential for productivity, recordkeeping, effective use of master lists, and selecting information for dissemination.
- Planning and organizational skills tie-in with the writing and documentation skills just described. The ability to plan ahead and visualize the steps that must be taken in order to have a successful commissioning process is critical. This includes focusing on the details of what must be done, organizing those details into a coherent plan, which field personnel can understand and follow on the job-site, and not losing track of the overall goal. These skills also include an ability to prioritize, communicate to those involved, and follow through on required corrective actions.



- Excellent communications skills, with everyone involved in the project are necessary. These skills are important because the jobsite effectiveness of the commissioning agent often depends on good working relationships to achieve the needed cooperation. Previous jobsite experience and a considerable degree of maturity in conflict resolution are helpful in this regard, all targeted towards eliciting real cooperation and effective progress to project completion.

Relatively few individuals have all the skills and experience outlined above. For this reason, a team approach is often the most effective way for a commissioning agent to implement the commissioning process with each member contributing some of the skills needed.

It is important to remember that commissioning is primarily an organizational and planning task. Therefore, those skills are as essential to commissioning as the technical knowledge concerning the systems being commissioned.

4.4 THE COMMISSIONING AUTHORITY

The commissioning authority is defined as the persons or company responsible, on the owner's behalf, for

ensuring the commissioning process is properly carried out according to contract requirements throughout the project. During the construction phase, this includes witnessing functional performance tests and verifying acceptable performance. It also includes ensuring the required documentation is produced.

On small projects, the commissioning authority is often someone on the owner's staff, the design professional, or contractor. On larger projects the owner may retain a commissioning specialist to represent their interests with respect to meeting their requirements through commissioning.

In Level 3 commissioning, see Section 5.3.4, the specific types of system or installation may require very specialized knowledge. In such cases, the commissioning authority – and, for that matter, the commissioning agent, must have that knowledge to carry out their responsibilities competently. Therefore, the owner may bring in separate specialists or require its overall commissioning authority do so for overseeing the Level 3 commissioning work.

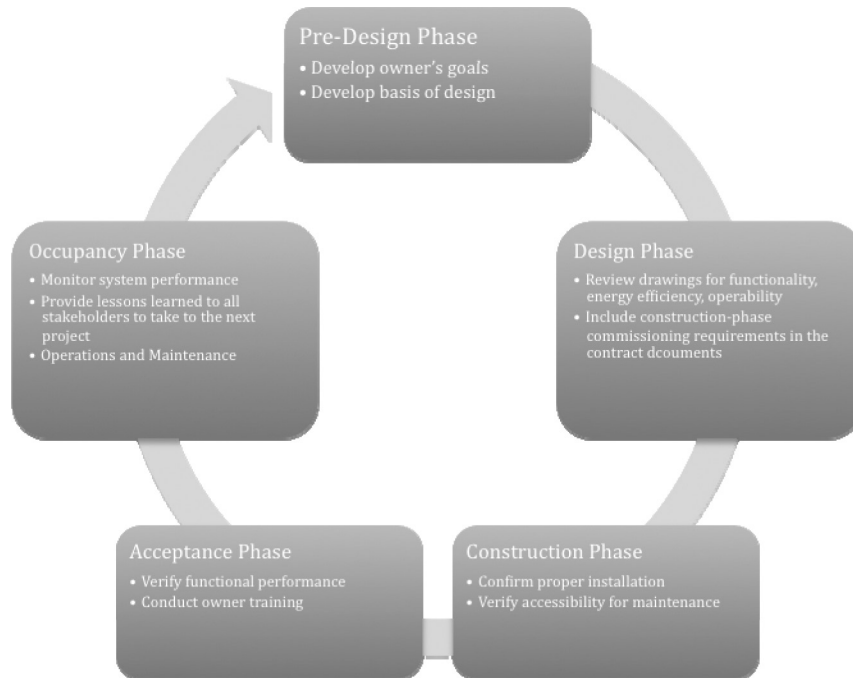
CHAPTER 5

OVERVIEW OF THE PROCESS

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5.1 GENERAL

As stated in Section 1.1, commissioning is a process that is most effective if it begins early in the development of a project and continues throughout the project to owner acceptance. However, “commissioning” is often confused as just being the functional testing of the equipment. The following figure illustrates the commissioning process as applied to a typical building project.



While there is only one commissioning process illustrated, it may be adapted to apply to a broad range of projects and systems. In order to be economically justifiable, commissioning must be organized to accomplish its desirable results at a cost consistent with commissioning's added value to the project. The value added to a project – and thus the appropriate time and cost commitment – will depend on the:

- Size, phasing, and duration of the project,
- Quantity of systems to be commissioned,
- Complexity of systems, and their controls, being commissioned,
- Degree of controls interface between different systems,
- Mission-critical nature of the processes controlled by the commissioned systems,

- Responsibilities of all contractors,
- Existence of acceptance test procedures mandated by code, manufacturer, or regulation, and
- Owner's project requirements (OPR) and acceptance criteria.

5.2 ORGANIZATIONAL OPTIONS FOR COMMISSIONING

There are two organizational options for commissioning:

Owner-directed Commissioning. When using this option, the owner provides a commissioning authority to develop, orchestrate, and document the commissioning process. This commissioning authority may be a member of the owner's staff or be retained through a commissioning agency. With owner-directed commissioning, there is an agency external to the typical design and construction parties (architect, engineer-of-record and contractor) involved in the design and construction process. This type of commissioning is advocated by many as providing a truly independent authority which is best able to represent the owner and ensure that its project goals are achieved throughout the design and construction phases.

Contractor-directed Commissioning. Under this option, the contractor plans and implements the commissioning process, either with a properly skilled group of its staff or by a commissioning agency acting as a specialist sub-trade. The contractor provides the commissioning documentation to the owner or owner's representative for review and acceptance as defined in the contract documents. Typically, this type of commissioning begins in the construction phase. However, in a design-assist contractual relationship, the contractor may play a role in the review of contract drawings with respect to the commissioning process. The owner or owner's representative is responsible for placing the specific commissioning requirements in the contract and ensuring that the other elements of the commissioning process in the Pre-Design and Design phases have been implemented.

SMACNA advocates the contractor-directed commissioning option for a number of reasons:

- The elements of the commissioning process are consistent with the implementation of total quality management principles. The commissioning process should be an integral part of the contractor's work and responsibility-using it to improve planning and organization.
- It reinforces that the contractor is responsible for providing a totally complete and functional installation according to the contract documents
- The owner's oversight and verification through its commissioning authority has a more direct and robust feedback path, thus better ensuring requirements are met. This same oversight protects competent contractors by demanding performance to a standard of acceptance consistent with contractual requirements. Competent contractors are able to perform to the required standard.

5.3 LEVELS OF COMMISSIONING

5.3.1 Introduction

The variations in project size, complexity, critical or highly specialized systems, and owner requirements suggest describing the commissioning process in terms of different "levels" of commissioning. Three different levels of commissioning are described in this manual:

1. Level 1: Basic Commissioning
2. Level 2: Comprehensive Commissioning
3. Level 3: Critical Systems Commissioning

5.3.2 Level 1—Basic Commissioning

Contractors committed to producing quality work may want to take steps to ensure they deliver on that quality commitment. Level 1 commissioning provides an organized process to help them reach that goal.

Generally, the contractor carries out Level 1 commissioning during the construction and acceptance phases of the project. Level 1 commissioning is intended to:

- Ensure the contractor meets a basic contractual requirement to produce a complete and fully functional installation in accordance with the contract documents.
- Help the contractor plan, organize, and coordinate that part of its work related to completing the installation and getting equipment and systems started properly, safely, and on schedule.
- Ensure that systems operation, including all control sequences, is verified and that functional performance as specified is achieved in all respects. This step assures that the systems begin operation in an energy efficient manner.
- Identify problems as they arise and as early as possible. Provide a mechanism for getting them corrected by whoever is responsible in a timely manner with follow-up to prevent problems from being neglected or repeated.
- Provide documentation to the owner showing that system installation and operation is according to the Owners Project Requirements (OPR).
- Demonstrate to the owner the system performance and functionality by operating the equipment and systems through the entire sequences of operation.
- Ensure that the equipment is installed in such a manner that it can be easily maintained in accordance with manufacturer's instructions for the expected life of the equipment or building.

- Provide a framework for giving training and demonstrations in correct systems operation to the owner's operating staff and for providing instructions and recommendations for a maintenance program of the completed systems.
- The preceding steps of commissioning the installation and startup should be followed by training for operations and maintenance to help assure that the building is more energy efficient and sustainable throughout its lifetime.
- Carry out all of the preceding in the most efficient manner possible and without increasing overall contractor costs for the project, even though there is some cost for the commissioning process itself.

In Level 1 commissioning, the benefits to the contractor have the potential to be greater than the costs incurred to plan and carry out the commissioning process.

5.3.3 Level 2—Comprehensive Commissioning

Level 2 commissioning applies when a higher level of oversight is desired throughout the design and construction process. The owner may delegate the commissioning responsibilities, in part, to the designer and, in part, to the contractor. The use of a third-party commissioning authority in Level 2 is at the discretion of the owner.

At the writing of this manual, Level 2 commissioning is essentially the level of commissioning required for a project pursuing LEED® certification.

The owner should have a commissioning authority to ensure the contractor carries out its commissioning responsibilities properly. In addition, the owner should have some mechanism in place to ensure the designer also carries out its responsibilities. These arrangements need to be defined and communicated to all affected parties.

Level 2 commissioning builds upon the components of Level 1 commissioning in the following ways:

- Begin the commissioning process in the pre-design phase of the project. The owner develops (perhaps with the assistance of a commissioning authority and others) and

publishes its OPR. This document defines the owner's goals for the project with respect to:

- Energy efficiency
- Indoor air quality
- Life-cycle costs
- Maintenance requirements and costs
- Operating procedures
- Control sequence
- Systems performance requirements

Note: The above are examples and are not intended to represent an all inclusive list.

- Develop the Basis of Design (BOD). This document is developed by the design team. It translates the OPR into specific design conditions and assumptions that will form the starting point of the design documents.
- Establish and publish a commissioning plan during the Pre-Design Phase that will be used during construction and acceptance to ensure the owner's goals established in the OPR are achieved.
- Create more comprehensive documentation of the commissioning process during construction. Commissioning forms may include the following:
 - Equipment delivery receipt checklists
 - Pre-start checklists
 - Start-up procedures and checklists
 - Pre-functional checklists
 - Functional performance test procedures
- Test the functionality of all normal operating and failure modes beginning at the component level and working up to the complete system level.
- Review operation and maintenance manuals to ensure that they provide the level of detail



necessary for the owner's maintenance staff to maintain the commissioned equipment.

- Develop a systems manual that describes and illustrates how the individual equipment works together as a system within the building.
- Provide more commissioning attention to interfaces between the HVAC systems and systems installed under other divisions of the work (for example, fire alarm or security).

5.3.4 Level 3—Critical Systems Commissioning

Level 3 commissioning is the most detailed and thorough application of the commissioning process. It is carried out in those facilities for which correctly functioning and performing systems are extremely important such as where life safety is involved.

Level 3 commissioning is driven by either specific owner requirements or by code or regulatory requirements. In some cases, Level 3 commissioning involves acceptance test procedures that are witnessed, and the results certified, by a regulatory official independent of both owner and designer. One example is certification testing of a fume hood to ANSI/AIHA Standard Z9.5.

Often, Level 3 commissioning goes beyond functional performance to include what could be termed operational or environmental performance. Correct functionality of an individual system is not enough. Higher level system performance tests must be conducted to verify and document that multiple systems interact correctly to achieve and maintain the specified environmental conditions. One example is specific room/corridor pressure relationships in a laboratory that must be maintained during all normal lab operations. Tests might include monitoring supply/exhaust air flows and room/corridor pressures while fume hood sashes are operated, supply airflows are varied, and the lab entrance door is opened and closed.

In Level 3 commissioning, the owner may decide to maintain direct control over the commissioning process, particularly when multiple trades are involved in the commissioning process and functional testing. In these circumstances the owner will only select a commissioning authority to orchestrate the process. Although cost may be a selection criterion, knowledge, experience with similar projects, effectiveness, and integrity are factors in selection. It is a situation

in which a partnering arrangement between an owner and an accomplished commissioning agent is appropriate.

Some examples and characteristics of “critical” systems are:

Fire Life Safety. Systems providing fire alarm signaling, fire suppression, smoke control, or evacuation or simply responding in some way to a fire condition (e.g., shut down, go to 100 percent exhaust, etc.).

Life Safety. Systems for hospitals (particularly operating rooms or isolation areas) or laboratories, in which dysfunction could threaten the health or safety of patients, staff, or visitors.

Automatic Backup or Standby. Systems important enough to justify standby or redundant equipment designed for automatic activation in the event of a failure of primary equipment. The means for detecting the failure, and for responding, must both be covered.

High Cost if Failure Occurs. The most obvious systems with respect to costs are those associated with industrial or process production shutdowns or failure to maintain product specifications, but this classification is also applicable to major computer operations.

Possible Impacts on Occupant Safety or Health. For example, critical care hospital facilities or biological containment laboratories.

Critical Data Services. Many data centers are critical to global financial transactions, house personal data that must be accessible at any time, or support similar business propositions. Data centers often have redundant power supplies and cooling systems and emergency backup generation.

5.3.5 Existing Buildings Commissioning

The commissioning process is not reserved for application to new construction projects. The process can and has been applied to existing buildings. In the past, the terms “recommissioning” and “retrocommissioning” have been used when referring to commissioning of existing buildings. The term “recommissioning” was used to describe the process of commissioning an existing building that had been commissioned during its original construction. The term “retrocommissioning” was used to describe the process of commissioning an existing building that had not been commissioned during its original construction. The industry has moved away from these terms and instead simply

uses the term “commissioning” whether it is for a new building or an existing building.

Commissioning an existing building can identify causes of operating problems, occupant complaints, or avoidable costs. It can then provide the operational and technical information to plan, carry out, and functionally test the corrective measures implemented. Problems that can be identified and corrected through commissioning include:

- HVAC systems not functioning correctly,
- HVAC systems operating inefficiently, thus wasting energy and increasing cost,
- HVAC systems zoning and layout not matching current occupancy or usage patterns,
- Improper interactions between various systems e.g. improper pressurization

Addressing the measures above can correct:

- Comfort needs of occupants not being met,
- Indoor air quality,
- High maintenance costs
- Excessive energy costs

A prospective owner may also be interested in retaining the services of a commissioning authority for the

Investigation Phase of existing building commissioning. As part of a building survey, the structured and organized approach inherent in the Investigation and Implementation phases of commissioning an existing building can produce valuable insight into the condition and capabilities of the HVAC systems in the building.

In commissioning a new construction project, all the relevant documents, shop drawings, balancing reports, and other information are generally available (or will be at the appropriate time during the process). However, when commissioning an existing building, this may not be the case. Therefore, in many cases, a major task of commissioning an existing building is to gather the necessary data about the building’s current systems.

Once the data is available, the processes are very similar to the commissioning processes previously described. The level of commissioning is contingent upon the owner’s goals and expectations on the detail and outcome of the process. Some differences are that the building is already complete, other trades are not usually involved, and the building may be occupied. These factors must be accommodated in the commissioning planning process.

Existing building commissioning is particularly relevant to contractors because, if they are doing service and maintenance work in the building, they may be aware of conditions justifying some degree of commissioning and are often in a position to make such commissioning proposals to the owner for consideration.



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CHAPTER 6

LEVEL 1, BASIC COMMISSIONING

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6.1 OVERVIEW

This chapter covers what the contractor and their commissioning agent must do to carry out basic commissioning procedures effectively. Nearly all the tasks listed in sections 6.2 through 6.5 are carried out by the commissioning agent, with the involvement of the HVAC contractor and his suppliers, sub trades, and other contractors (for example, electrical), whose work must be coordinated with that of the HVAC contractor.

The commissioning agent function may be carried out by a dedicated group within the HVAC contractor's organization or by a separate company acting in a sub trade relationship. The term "commissioning agent" will be used to describe the function, regardless of whether the contractor carries it out directly or through a separate company. Much of the benefit to contractors from commissioning arises from improved planning, scheduling, and coordinating of work. These benefits will only be achieved if the commissioning agent makes commissioning a top priority right through to acceptance of the completed installation.

6.2 PREPARATIONS

The schedule is a critical planning and communications tool. It lets each supplier, sub trade, and other contractor know when their work must be completed on a system-by-system basis in order not to delay commissioning and final acceptance.

The commissioning agent's first task is to pull together:

- The Owner's Project Requirements,
- Statement of design intent,
- Schedule information,
- List of equipment and systems needing to be commissioned,
- List of sub trades, suppliers, and other contractors (most commonly the electrical contractor) who will be involved in the commissioning process, and
- All submittal data and controls sequence descriptions needed to prepare commissioning checklists.

The commissioning agent prepares a commissioning schedule that identifies commissioning tasks and the estimated time each will require. This is coordinated

with the overall project schedule. Any conflicts need to be resolved prior to coming to implementing the commissioning tasks.

This schedule is usually a simple bar chart. Typical events and tasks on it include:

- Dates for completion of installation, ready for prestart checks, often on a system by system basis,
- Time allowance for prestart checks and startup, possibly on a system-by-system basis,
- Time allowance for correcting any prestart problems and rechecking,
- Elapsed time allowance for functional performance tests, possibly on a system-by-system basis, and
- Time allowance for correcting any functional problems and rechecking.

6.2.1 Equipment and System Prestart and Startup Checklists

The commissioning agent prepares equipment and system prestart and startup checklists. These checklists focus on critical items that suppliers, sub-trades, and other contractors must complete before startup can occur safely and operation under control can take place. These checklists should identify installation responsibilities and will generally cover:

- Equipment mounting and hook up,
- Electrical services,
- Controls installation, including safety controls, and
- Any other applicable prestart requirement, for example, pressure testing, pipe cleaning and water treatment, or boiler/gas/electrical inspections.

Appendix B contains examples of prestart and startup checklists for a range of equipment and systems.

For efficiency, these checklists should be produced from master lists, with modifications to suit the project-specific equipment or system. The use of computers to store masters and retrieve, edit, file, and print



these lists greatly speeds their production and improves their content, consistency, and legibility.

Rationale: These lists identify who must do what in sufficient detail to define responsibility. When combined with the schedule, they also pinpoint the time-frame when work must be done to stay on schedule.

6.2.2 Functional Performance Checklists

The commissioning agent prepares functional performance checklists. These checklists provide a system-specific, step-by-step process to test system performance against the specified control sequences. These checklists typically cover tests of:

- Each mode of operation, for example, unoccupied, morning startup, and occupied,
- The sequence of controls, for example, economizer operation and on/off, staging, or modulation of heating and cooling components to meet changing loads, and
- Safety or emergency controls, for example, freeze protection or power failure response.

These checklists are intended to facilitate efficient, effective contractor testing of systems' functional performance against specified requirements; therefore, they need to cover all specified functions. Care must be taken to ensure that the checklists are not overly complex and are easy to use on the jobsite.

Appendix D contains examples of generic functional performance test checklists for a range of equipment and systems. These checklists need to be revised to cover the exact control sequences and functional requirements for the system in question because they tend to vary greatly from project to project. However, these generic checklists do include most of the common control elements that need consideration (e.g., fans, pumps, coils, dampers, controls, valves, compressors, boilers, temperatures, static pressures, etc., as applicable). Thus, they will provide a good base from which to prepare project specific lists. As with prestart checklists, the use of computers to store masters and retrieve, edit, file, and print them greatly speeds production and improves content, consistency, and legibility.

Rationale: Working out the step by step procedure for testing systems operation ahead of time, and documenting it in lists, enables efficient testing in the field, makes documentation of results easy, identifies problems (and who is responsible for correcting them), and

provides evidence of acceptable performance, to the designer or owner.

6.3 COMMISSIONING PLAN

The schedule, *see* Section 6.2.2), the prestart/startup checklists, *see* Section 6.2.3, and the functional performance test checklists, *see* Section 6.2.4, together will form the commissioning plan. The timing of its preparation and the extent of its distribution is up to the contractor. Preparation as soon as the necessary information is available is recommended. The commissioning plan is key information for the other contractors and sub-trades to establish their schedule and scope of work regarding testing and startup.

Rationale: Early preparation, indicating elapsed time requirements and the optimum sequence of tasks, can help to identify any scheduling conflicts early, making resolution more likely. Subsequent schedule revisions are almost certain to be needed, but making revisions from a coherent schedule is much better than scrambling with no plan. Distribution to all parties with responsibilities related to the successful completion and operation of the HVAC installation is absolutely critical for commissioning to be successful.

Rationale: If everyone is not informed, there is reduced coordination. If they are informed, and make commitments accordingly, then the contractor has a better basis for demanding and receiving timely performance and results from his sub trades and suppliers.

An example of a commissioning plan for the HVAC systems in a small office building is in Appendix F. This example illustrates how the various elements of documentation should be organized in the plan for use onsite during the prestart/startup and functional performance test phases of the commissioning process.

6.4 PRESTART CHECKS

When installation of equipment and component parts of a system, or group of systems, is or should be complete, the commissioning agent coordinates and performs prestart checks according to the relevant checklists. The results are documented on the lists. If everything is satisfactory, then the equipment and system can be started up and put into operation, ready for functional performance testing.

If something is not satisfactory, the deficient, faulty, or incomplete items and the required corrective actions are noted on the checklist. The commissioning agent notifies the party responsible for correcting the

problem. This notification can be in the form of a copy of the checklist or an action report containing only items pertaining to that one party. Agreement on a deadline for completion should also be made. Commissioning agent follow-up is essential. Rechecks are done on those items, and, if the results are satisfactory, startup takes place.

6.5 FUNCTIONAL PERFORMANCE TESTS

When equipment and system startup has taken place, functional performance of specified controls sequences and system function can be tested. Prior to functional performance testing are

- successful startup,
- completed controls calibration, and
- sufficiently completed systems balancing to allow system operation in all modes of operation. In many cases systems must be fully balanced.

The order in which functional performance tests are carried out can be important, particularly in larger, multiple-zone systems. Generally, the zone terminal tests will be done first, then the central system, then any specified interactions with other HVAC systems, and finally any specified interactions with non HVAC systems (often these non HVAC systems, such as fire alarm, are in other divisions of the work). The optimum sequence of tests needs to be reflected in the functional performance test checklists.

Functional performance tests are carried out according to the procedure detailed on the checklists, and the results are documented on the lists. If performance is satisfactory, the system is ready for the next in the sequence of tests, or if all have been completed, the system is ready for turnover.

Some tests may need to be deferred due to weather, seasonal, or occupancy factors. For example, if the building is being completed in winter, it may be impractical to startup the refrigeration side of the HVAC equipment or to create a full cooling load. In such a case, the functional performance tests for the cooling functions may be deferred until it is feasible to obtain a full cooling load.

If something is not satisfactory, the deficient, faulty, or incomplete items and the required corrective actions should be noted on the checklist, copies made, and the

needed action communicated to the responsible party for correction. Agreement on a deadline for completion should be reached. Commissioning agent follow-up is essential. After corrections have been made, those items are retested, and, if the results are satisfactory, the next in the sequence of tests can be carried out. Once all functional performance tests have been completed with satisfactory results, the system is ready for turnover to the owner.

6.6 OPERATIONS INSTRUCTION AND DEMONSTRATION

Commissioning is of little lasting benefit if the operating personnel do not understand the systems and how to operate them properly. The contractor who carries out Level 1 commissioning services should include a well-organized series of instruction and demonstration sessions. It is important that the owner is informed of the operating and maintenance requirements of the HVAC systems and encouraged to participate and to implement a proper operations and maintenance program. The contractor can use this opportunity to offer a service contract proposal to the owner, using his commissioning expertise, intimate knowledge of the building's systems, and performance as evidence of his capabilities.

The instructional portion of this program should cover:

- Descriptions of each type of system in the building, including design intent, theory of operation, capabilities and limitations, modes of control, and sequences of operation,
- Particular attention to the controls system,
- Inspection, service, and maintenance requirements for each system, including any requirements for special skills and knowledge which may best be met by specialized service contractors,
- Operational monitoring and recordkeeping, including what should be monitored, what useful information can come from monitored data, and why that information is important to analyzing system operation.

The demonstration portion of this program should cover:

- Operation of each system, or a typical example when there are several similar ones in the building,



- Startup and shut down procedures, operation under all specified modes of control and sequences of operation, and the correct procedures under emergency (for example, power failure) or abnormal conditions, and
- Operational monitoring procedures.. This is particularly important in projects with DDC systems incorporating powerful trending and graphing features.

The contractor must ensure that the operations manuals are available at this time and consulted during the instructional sessions. This will greatly add to the effectiveness of the training program and use of the manuals in the ongoing operation of the building. A well implemented training program will increase the owner's perception of the professionalism of the contractor.

6.7 SUMMARY

All the checks and tests are carried out to suit the schedule requirements of the project. In larger projects some systems may be checked, started up, operated for functional performance tests, and proven complete before some other systems are even ready for startup.

On the other hand, on a small project, the entire on-site commissioning process, as described in sections 6.4 and 6.5, for every system in the building may be carried out in one or two days. Only completion of incomplete work and correction of deficient or faulty items would need later follow up and rechecking.

CHAPTER 7

LEVEL 2, COMPREHENSIVE COMMISSIONING

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7.1 OVERVIEW

This chapter provides a detailed description of typical Level 2 commissioning procedures. While Level 1 commissioning procedures occur only during the construction and acceptance phases of the project, Level 2 commissioning activities take place during all phases of the project:

Pre-design Phase.

Design Phase.

Construction Phase.

Acceptance Phase (a subset of the Construction Phase).

Occupancy Phase

Warranty Phase (a subset of the Occupancy Phase)

Typical Level 2 commissioning procedures are detailed in Sections 7.2 through 7.5, and are presented in roughly chronological order. They assume the owner retains design professionals to undertake the design, and then enters into a stipulated sum contract with a contractor for construction of the project. They also assume the HVAC systems commissioning agent will be working under the HVAC contractor's direction. Finally, the procedures assume the owner will retain either the HVAC designer or an independent agent to act as his commissioning authority. On the owner's behalf, the commissioning authority ensures that the owner's project requirements are achieved.

When different contractual arrangements exist, or when the owner assigns responsibilities differently, corresponding adjustments must be made to the roles and responsibilities described in this chapter

The Level 2 procedures suggested in this chapter are for an owner wishing a comprehensive commissioning process that will ensure a facility is designed to meet the Owner's Project Requirements (OPR), constructed in accordance with the design, and demonstrated to function fully in accordance with the design. In addition, these procedures include demonstrations and familiarization for operations personnel, either staff or contractors, so they can operate and maintain the facility correctly. The procedures conclude with tracking the HVAC system operation during the first year of occupancy and assisting the owner with necessary adjustments to meet the actual operating conditions of the facility.

For any specific project, the owner may have individual requirements varying from those in this manual. In such cases, the necessary adjustments must be made to accommodate those requirements.

7.2 PRE-DESIGN PHASE

The owner defines and documents his requirements for the commissioning process at the inception of the project. This document is referred to as the OPR. These usually involve some designer responsibilities and they must be included in the designer's scope of work.

The owner's requirements for, or related to, commissioning are usually for a process to ensure:

- The system design and specified equipment meets occupancy needs. This means that the owner must define occupancy needs.
- The system is installed and proven to function in accordance with the design. The actual system performance is documented to serve as a project record for reference by the future operating staff.
- There is effective operator training that is specific to the systems and equipment installed.

In the final analysis, the owner's goal is a successful, sustainable building which is operated effectively and efficiently.

The owner's occupancy needs for the building should be included in the OPR document for the project. With respect to HVAC design the following items are relevant:

- Space temperature and humidity criteria,
- Thermal zoning criteria,
- Thermal load generated by illumination requirements,
- Ventilation requirements and related indoor air quality criteria,
- Building energy use,
- Commissioning criteria, and
- Budget (first cost, operating cost, lifecycle cost).



The owner's commissioning criteria must be defined in sufficient detail to permit the designer to include contractor commissioning scope and responsibilities in the contract documents.

7.2.1 Commissioning Criteria

The OPR document should contain commissioning criteria information as follows:

Commissioning Scope. Which systems will be commissioned.

Commissioning Roles and Responsibilities. Who is responsible for what. This may include a preliminary event matrix and sequence of activities.

Time Requirement. It should indicate, in general terms, the elapsed time period over which the on-site commissioning activities are expected to take place. This provides some indication of the likely level of effort.

Commissioning Team. The commissioning team needs to be identified in generic terms. Typical members include the owner, the operator, the mechanical and electrical designers, the general contractor, the mechanical contractor and his controls specialist, test and balance (TAB) contractor, other relevant sub trades and suppliers, the electrical contractor, the commissioning agent, and the commissioning authority.

Acceptance/Verification Procedures. Such items as benchmarks, test protocols, and code requirements as they apply should be identified.

Operator Training and Familiarization Requirements. Specific training requirements for the building operating staff should be identified. This is especially important when new or unfamiliar systems are utilized to meet energy efficiency and indoor environmental quality goals.

Documentation. This needs to include commissioning plan content and submission, documentation of on-site commissioning checks and tests as they occur, training documentation, and the final commissioning report.

It is ultimately the owner who must set the commissioning criteria. However, they may make those decisions based on recommendations from the designers or from the construction manager or contractor, if the latter have been identified this early in the project (Pre-design Phase).

7.3 DESIGN PHASE

7.3.1 Basis of Design

If not included in the contract documents, the Basis of Design (BOD) is defined and documented by the designers, prior to starting the design phase itself. Design criteria, applicable codes and standards, design assumptions, and performance standards (which may relate to the design criteria) are all included. In addition, areas of the building or functions within requiring special attention in design or commissioning need to be identified.

7.3.2 Design Concepts

Various design concepts, that meet the OPR are typically developed. These design concepts need to consider commissioning issues as well. Examples include providing access for both commissioning and later maintenance and keeping systems, particularly their controls, as simple and easy for the operator to understand as possible.

7.3.3 Contract Drawings and Specifications

The contract drawings and specifications define what is to be installed. To help in commissioning, the contract drawings and specifications should include information to help the contractor understand how the systems were intended to function dynamically.

The following information should be included:

- Design criteria calculations and assumptions.
- Descriptions of the various HVAC systems in the project. This information should cover system type, major components, and how these systems interact with one another.
- System operational information for the HVAC systems in the project. This information should cover intended operation under both full and part loads, intended operation during different seasons or weather conditions, sequence of operations under different modes of operation, including startup, occupied, unoccupied, fire emergency, normal power failure, emergency power, normal power restoration, etc., as applicable.
- Flow and schematic diagrams and controls point matrix keyed to the systems descriptions above.