Refrigeration Commissioning Guide *for* Commercial *and* Industrial Systems



Commissioning Refrigeration Systems in

- Food Retail and Convenience Stores
- Small Retail Stores
- Food and Beverage Facilities
- Food Distribution Centers
- Industrial Plant Applications

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for Commercial and Industrial Systems

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Preface

The Business Case for Commissioning: A Message to Owners

Refrigeration Commissioning Guide for Commercial and Industrial Systems provides value to owners and managers of commercial and industrial facilities that use refrigeration systems by ensuring that project requirements are met and owners' expectations are achieved.

Refrigeration systems account for a significant portion of commercial building energy use and are often the largest energy end use in food and beverage facilities. A U.S. Department of Energy (DOE) study estimates commercial refrigeration uses 1.23 quads (1.23×10^{15} Btu) (1.30 EJ) per year, which is approximately 7% of commercial building energy use. Nearly 70% of this commercial refrigeration use consists of supermarkets and other custom-designed refrigeration systems (DOE 2009).

Supermarkets are the largest example: a U.S. Environmental Protection Agency (EPA) study estimates that supermarkets typically use approximately 3,000,000 kWh of electricity per year, with 60% of that energy use attributed to refrigeration (EPA 2007). Portland Energy Conservation, Inc. (PECI) predicts that commissioning in existing grocery stores would result in 7% to 25% energy savings per year (PECI 2010). Based on these estimates, this commissioning guide, if widely adopted, would lead to substantial U.S. national energy savings.

Custom refrigeration systems are complex and individually designed for each facility. Deficiencies in the system design found at start-up are not easily resolved and, as a result, maintenance managers or operators deal with unnecessary shortcomings and expenses over the life of the facility. The value of commissioning is to establish a consistent stepwise process that helps "get it right the first time," resulting in refrigeration systems that "work right" and minimize maintenance and energy costs.

Thousands of refrigeration systems are installed every year in facilities ranging from convenience stores to large, sophisticated frozen food distribution centers. Properly commissioned systems reduce energy costs, are easier to maintain, help minimize liabilities from refrigeration leaks, and reduce loss of product due to system failures or unreliable performance.

Commissioning of refrigeration systems is currently uncommon. One reason is the belief that commissioning results in added cost and time without

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sufficient or measurable value. Certainly, commissioning is an investment, but it provides significant financial value in several ways. First, systems operate more reliably with lower maintenance cost and lower energy cost when commissioning is applied as described in this Guide. Second, incorporating commissioning can reduce first cost through improved understanding of system performance and lead to better equipment design and installation methods.

Using this Guide will help achieve cost-effective and cost-efficient refrigeration systems for new projects, expansions, remodels, and existing systems that simply need a tune-up. For commercial facility owners and managers, this means improved profitability through lower operating and service costs as well as reduced product loss. For industrial plants, this means improved "up time" and improved labor productivity in addition to reduced operating cost.

The commissioning process is holistic and considers life-cycle performance, including the long-term operating (utilities and servicing) costs of the refrigeration system. ***Commissioning*** **is not another term for** ***start-up*****.** The commissioning process starts with the initial planning and design and continues through construction, installation, start-up, and the first year of system operation. Commissioning also sets the stage for ongoing servicing and maintenance of performance. This Guide provides the process and methods to help achieve these desired results: expected performance and reliability with the lowest life-cycle cost.

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Acknowledgments

Refrigeration Commissioning Guide for Commercial and Institutional Systems was developed to provide guidance to refrigeration system owners, project/design managers, and refrigeration system service providers. This Guide is the result of the collaborative effort of dedicated professionals who unselfishly volunteered countless hours to give refrigeration system owners and the refrigeration industry consistent validation processes that can be used to bring order to the unorderly.

The primary authors were the members of ASHRAE Special Project Committee 137 and provided the expertise and experience necessary to develop the document. They represented manufacturers, contractors, and end users of refrigeration systems.

The project would not have been possible without the financial support of the U.S. Department of Energy (DOE) and National Renewable Energy Laboratory (NREL) as well as the invaluable support of ASHRAE. In addition, DOE's Better Buildings Alliance provided the project committee with the technical services of Rebecca Legett and Robert Zogg of Navigant Consulting, Inc. I would also like to thank Paul Torcellini of NREL for his support and help with the development of the document.

I would also like to personally thank all the members of the project committee for their diligence, creativity, persistence, and willingness to take time to support the development and review of this Guide. They worked extremely hard to put together practical and fundamental information covering the aspects of commissioning applicable to a holistic approach. Their expertise and differing views greatly enriched this Guide. The authors brought many decades of experience, success, and failure to the text to achieve a significant milestone for the refrigeration system owner and the refrigeration system industry. I appreciate the patience of the committee members' families during the development process, and I gratefully acknowledge the support of the committee members' employers, including CTA; DC Engineering, PC; Edmonds Engineering Company; Hillphoenix; National Renewable Energy Laboratory; PECI; Safeway, Inc.; Source Refrigeration and HVAC; Target

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Richard Royal
Chair, ASHRAE Special Project Committee 137

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1

Introduction

Refrigeration Commissioning Guide for Commercial and Industrial Systems provides user-friendly, how-to guidance for commissioning of custom-engineered refrigeration systems in commercial and industrial facilities. The intended audience of this Guide includes system owners, architects, design engineers, contractors, facility managers, and maintenance service providers, as well providers of commissioning services.

Commissioning is a process for ensuring that a facility or system is designed and operated as intended. Commissioning helps achieve larger goals of sustainable design and operations, life-cycle cost-effectiveness, efficient use of capital, minimizing overall maintenance costs and utility costs, long equipment life and reliability, and meeting performance expectations. ASHRAE addresses commissioning in two other publications: ASHRAE Guideline 0, *The Commissioning Process* (2005), describes a general commissioning process applicable to any facility or system and ASHRAE Guideline 1.1, *HVAC&R Technical Requirements for the Commissioning Process* (2007), addresses how the commissioning process is applied to heating, ventilating, and air-conditioning (HVAC) systems, with some discussion of refrigeration systems.

While Guideline 0 and Guideline 1.1 provide useful information, they do not readily address the needs of refrigeration systems. Refrigerated facilities are both numerous and among the most energy-intense commercial buildings. *Refrigeration Commissioning Guide for Commercial and Industrial Systems* builds on the concepts and process outlined in Guideline 0, providing specific methods and approaches to achieve comprehensive commissioning of commercial and industrial refrigeration systems.

Development of this Guide began after multiple discussions within ASHRAE concerning the value and need for such a publication and after consideration of many factors, such as the customized nature of refrigeration systems as contrasted to packaged HVAC systems and the typical methods of designing and contracting for refrigeration work. These are two of the factors that have resulted in very limited commissioning of refrigeration systems in current practice. The value of commissioning is clear to those designing and operating for improved sustainability in refrigerated facilities. To meet the

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apparent need and demonstrate the value of commissioning in the marketplace, it became clear that refrigeration experts should define the needs, determine the appropriate processes, and develop a guide specifically tailored for the commissioning of refrigeration systems.

THE NEED FOR COMMISSIONING

Refrigeration systems for most commercial and industrial facilities are custom-engineered for each application, with individual equipment selected and matched to meet project needs and designer preferences. In contrast, a rooftop cooling unit or a packaged water chiller is factory built as a package subject to standards and certification as a combined system, with performance and specifications fully described and catalogued. While factory packages still need commissioning, the more customized nature of refrigeration is an important factor in defining how refrigeration commissioning will be accomplished. Refrigeration system designers choose the type of refrigerant, control valves, compressor technology, method of oil management, capacity control measures, type of condensing (air or water cooled), and control system design and strategies. Supermarket store-planners determine which display cases will be used, what configuration will be laid out, and what merchandise will be in the cases. Temperature, load, and evaporator layout can be completely unique from project to project, requiring that compressors, condensers, evaporators, valves, and receivers be designed specifically for each project. Various control system providers and programmers contribute their products and services to the completed system, which adds another layer of customization. There are not only numerous manufacturers of compressors, condensers, cases, coils, and controllers but also numerous owners and contractors with their unique specifications—resulting in the possibility for infinite variations.

As with most construction projects, speed to market is critical. While many companies have well-established specifications and criteria, limited design time can make design coordination difficult. For example, to start pursuing permits for a new facility, a preliminary refrigeration design may be completed early in the process. That design is then distributed for bidding and construction several months later. When the equipment is received directly from the providers, the contractor must integrate everything on site. This process can result in the design's intent being lost. The commissioning process can help to preserve that intent for manufacturers and programmers.

Historically, the design and construction of commercial and industrial refrigeration systems have not followed the approach where the architect is responsible for all design engineers and a general contractor is responsible for all contractors. Refrigeration design has typically been separate from the architect's responsibility. The entire refrigeration scope may be assumed by a design-build contractor responsible for engineering the systems, providing the equipment, and performing the installation. The owner may have multiple design, equipment, and installation providers, all under separate contracts. Owners with multiple facilities may establish detailed criteria, design the refrigeration systems in house, rely on an original equipment manufacturer (OEM), or use a design consultant with refrigeration specialization. Because much of the commercial refrigeration business involves repetitive construction (e.g., multifacility operations), refrigeration design often evolves from one project to the next following a general criteria or relies on the experience

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ENERGY SAVINGS FROM COMMISSIONING AS RELATED TO RETAIL SALES DOLLARS—A CASE STUDY

Background: A study of several recently opened stores owned by a large supermarket chain revealed that each store had major shortcomings in the operation of its refrigeration and control systems. The chain has a large development department that includes architects, engineers, project managers (PMs), construction managers, and others, so the store designs were based on a well-developed set of specifications and criteria drawings and should have all been operating the same way. Further investigation revealed that the contractors for the subject stores had not followed the plans and specifications.

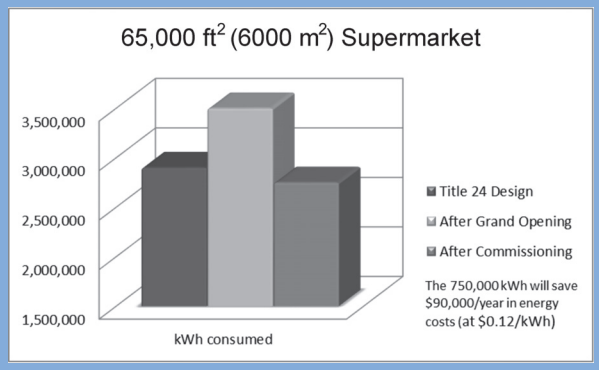
Problem: One specific store in California had been open for more than a year at the time of the study. The store had been designed to meet California Title 24 standards (CA 2013a, 2013b) and the store design had been evaluated by a leading engineering firm using energy modeling software. The modeling had shown that with all efficiency measures working properly the store energy use would be 2,800,000 kWh/year. However, the actual energy use for this store during the first year of operation was 3,500,000 kWh/year.

Lessons Learned: The Energy Management team developed and implemented a strategy to retrocommission the store systems. The result was a reduction in annual energy usage of 750,000 kWh and annual cost savings of $90,000, bringing the system more in line with the expectations generated by the model (see the figure).

Support for changes to address this issue at other stores and in future new construction required attention from retail management. But, the value of these savings is difficult to grasp when the focus is on sales dollars. Translating the savings into equivalent sales dollars shows that the average supermarket would have to sell approximately $4,500,000 in groceries (or about 10 weeks' worth of sales) in order to make up the dollar value of 750,000 kWh in energy savings. Additional savings would also result from reduced maintenance and/or a possible increase in sales from improved conditions in the store.

The magnitude of the savings demonstrated the cost-effectiveness of a new construction commissioning process that clearly defines expectations and verifies that equipment and controls are performing according to expectations. Subsequently, other stores in the chain also experienced savings ranging from 4% to 24% after similar retrocommissioning.

Commissioning should start before design so that expectations are met at the start of operation rather than errors being discovered and having to be fixed only after excessive energy consumption is realized.



Energy Usage in Kilowatt-Hours as Designed, Before and After Commissioning

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of "what works" and ensures product temperature requirements are met. Design practice, equipment sizing, and performance expectations are highly dependent on the experience of designers and contractors. Most refrigeration components (unlike HVAC equipment) are not certified to a rating standard, and generally equipment catalogs do not reference a test standard. Rules of thumb and experience factors are inherent throughout the design, construction, and operation of systems and are related to the built-up nature of nearly all refrigeration systems and related control systems.

Several retail chains have in recent years changed from reliance on vendor- or contractor-provided engineering to employing a refrigeration design consultant and incorporating refrigeration with the other mechanical engineering responsibilities (e.g., HVAC, plumbing). This approach adds refrigeration to the traditional mechanical, electrical, plumbing (MEP) design consultants and creates a mechanical, electrical, plumbing, and refrigeration (MEPR) team responsible to the owner and architect. In addition, it has become more prevalent for the general contractor to assume responsibility for the refrigeration subcontractor. To address the fragmentation of the process, commissioning seeks to provide a common thread with the purpose of creating high-performance refrigeration systems that meet specifications as well as minimize energy consumption while increasing reliability and maintainability.

PURPOSE AND SCOPE

The purpose of this Guide is to outline a commissioning process for refrigeration systems that can be readily adopted by a wide range of owners, designers, and contractors of commercial and industrial refrigeration systems in the United States and globally. The Guide is designed to start at project conception and extend through the first year of operation. Moreover, it also establishes a basis for a continuous improvement process lasting throughout the life of the facility.

This Guide is intended to improve and supplement existing design, construction, and operational practices. Since most companies have successfully refined their practices to achieve on-time and on-budget projects, commissioning must be carefully considered and adopted such that the existing responsibilities for design, supplier compliance, and contract completion are not diminished. Table 1-1 shows the people involved in commissioning a project and describes their roles or interests in the process.

A key concept in the Guide is that the commissioning work is a process or function that entails multiple entities and individuals over the course of a project—commissioning is not simply the work of a single commissioning authority (CxA). The Guide is designed to be flexible and to acknowledge the varied methods of designing and contracting refrigeration work across industry segments and from company to company. The Guide can be easily adopted in part or in whole, without assuming one contracting method over another. Users of the Guide will need to determine the elements that are appropriate to their projects, interests, and capabilities and define the responsibilities within available company and project team resources.

This Guide does not attempt to comprehensively address system design, detailed construction specifications, construction methods, or detailed routine start-up procedures (e.g., oil and refrigerant charging methods), and it does not include safety topics.

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Table 1-1 Potential Participants in the Commissioning Process

Owner	In general, "owner" relates to "who is paying the bills" and has the greatest interest in life-cycle cost and getting value from the system. Examples include the following: • Individual owner of business who may be very involved with project specifics, such as an independent store or specialty food manufacturer owner • Owner not directly involved with project specifics, such as a property investment/management firm funding an expansion of a refrigerated warehouse • Large company or chain where the owner is represented by an employee or a third-party agent
Tenant	The tenant directly or indirectly pays for operating costs. Some projects are built to suit the needs for a particular tenant based on medium- or long-term arrangements.
Engineering Team	Refrigeration design engineer(s), including the following: • Consulting refrigeration engineer • Engineer(s) for design-build contractor • Refrigeration equipment supplier(s) • Individual acting as Engineer of Record, as required Other engineers and disciplines, including the following: • Thermal envelope designer, in the case of a refrigerated warehouse • Control system designer, vendor, or contractor • Electrical engineer, related to refrigeration equipment and controls integration with other systems
Contractors	Refrigeration contractor(s), including the following: • One contractor providing and installing refrigeration equipment and controls • A separate controls contractor • A separate contractor for walk-ins or thermal envelope and doors
Safety and Code Consultants	Depending on the type of project, the location, and the type of equipment, additional consultants or specialists may be responsible for safety concerns and complying with safety regulations. Special concerns arise from certain system types (such as ammonia systems).
Commissioning Service Providers	Commissioning services may be provided by the following: • Independent third-party commissioning consultants who manage and coordinate the overall commissioning process (see the sidebar "Best Practices for a Commissioning Authority: Independence, Perspective, and Understanding" in Chapter 2 of this Guide) • A member of the design team • The design-build refrigeration contractor • Technical commissioning specialists who provide third-party testing and verification to implement the technical aspects of commissioning
Operations and Maintenance Personnel	Operations and maintenance personnel are responsible for keeping the equipment operating and maintaining temperature limits. They may be in house or outside contractors and may be different after the warranty period. The operations interests for a facility can vary widely: • Chain supermarkets often have an operations division that prefers a standardized view of refrigeration focused on reliability, maintainability, and energy performance. • An industrial project may require close coordination by plant operators, maintenance personnel, and production staff, particularly on an existing facility expansion. • For a new facility, the on-site operations staff may be involved late in the process, only as they are hired or assigned to the location.
Energy and Sustainability Consultants	Various parties may be involved with energy efficiency and sustainability, including the following: • Corporate departments measuring facility performance with metrics such as energy, water, and sustainability • Energy efficiency consultant engaged by owner • Utility and related program consultants for incentives and design assistance programs • Labeling and certification program consultants (e.g., bEQ, LEED®, Green Globes, ENERGY STAR®)
Other	Projects with new or special equipment, systems, or technology may include an associated representative to assist with design integration and commissioning. An Information Technology representative may be necessary to support data communications and management of information resources required to meet commissioning objectives.

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The Guide emphasizes refrigeration systems commonly used in commercial and smaller industrial facilities (e.g., retail food stores, halocarbon systems for warehouses, and small food facilities, etc.). While the commissioning processes outlined will also apply to commissioning of large industrial ammonia-based refrigeration systems and large built-up central compressor plants, specific technical procedures related to large industrial and ammonia systems are not addressed in this Guide.

The phases of commissioning described in *Refrigeration Commissioning Guide for Commercial and Industrial Systems* are, in order:

1. Planning and Design
2. Construction and Installation
3. Start-Up and First-Year Operation

This Guide is intended to be used within a variety of construction and contracting arrangements, including the following:

- Design-build projects by refrigeration contractors
- Owner-designed projects installed by a refrigeration contractor
- Projects designed by the owner's consultant and installed by a refrigeration contractor

This Guide is expected to be used frequently by design-build contractors, who manage the commissioning process largely on the owner's behalf and/or execute the technical procedures. While the benefit of an independent third-party perspective may not be achieved with this approach, this reflects the reality of the industry and how many commercial and industrial projects are contracted as well as the fact that a great deal of the relevant expertise resides with design-build contractors. For this reason, the Guide is designed to accommodate a "self-managed" method as well as apply to commissioning activities performed by consultants and independent third parties. Additional perspective on third-party commissioning authorities is provided in the Chapter 2 sidebar "Best Practices for a Commissioning Authority: Independence, Perspective, and Understanding."

This Guide is designed to address the characteristics of typical refrigeration applications and systems, including the following:

- Refrigeration systems must perform (maintain temperatures) at all hours of operation, in contrast to air-conditioning systems, which may be designed to meet temperatures a certain percentage of hours. The consequences of failing to maintain temperatures are therefore more problematic in refrigeration systems than in air-conditioning systems. Thus, safety factors are a practical necessity for refrigeration systems, though the amount of safety factor realized by the installed equipment and systems is rarely quantitatively tested.
- Refrigeration systems are custom built from components rather than factory-assembled packages. As such, each system is unique and performance is greatly affected by component interactions and control methods. Compressors and condensers are selected to meet the needs of multiple loads and multiple application conditions, with control valves and electronic control systems often selected and applied by parties different than the provider of the major components.

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- Retail chain stores and other large users commonly purchase equipment directly from multiple vendors to increase competition and obtain the best-in-class product for each use. Equipment may be specified and purchased under blanket bidding/purchase agreements.
- The owner (or engineer) often defines the manufacturer and the type of operating controls energy management system (EMS) that will be included with the equipment from one or more OEMs and installed by one or more contractors and then addressed by another controls contractor to include HVAC and lighting. This increases the integration challenges and can contribute to uncertain responsibilities and a lack of coordination between system design features, control system capability, and programming.

As previously stated, this Guide is intended to address the needs of all custom-designed refrigeration systems, including those for industrial applications, retail food stores, and other commercial applications. However, retail food stores provided the largest source of examples concerning design, construction, and facility operations, and the examples vary by business size (including national chains, independent chains, and individually owned stores), responsibility for design and design methods, contracting choices, and type of maintenance operations. Historically a large portion of refrigeration design in this sector has been provided by manufacturers and design-build contractors, along with a smaller portion of owner-designed and consultant-designed refrigeration and HVAC systems. Plus, supermarkets are remodeled and expanded over the life of the facility, providing multiple opportunities to realize benefits from commissioning. Using examples from this wide range of industry characteristics has resulted in a Guide that is expected to be adaptable to other industrial and commercial refrigeration applications.

Because commissioning is undertaken to achieve a project that meets owner expectations, this Guide is designed on the assumption that the owner (or owner's representative) will provide the assignment, directions, and overall impetus for commissioning. Commissioning will be most successful when all project participants fully understand the commissioning process and take initiative and action in their areas of responsibility and expertise.

There are two major aspects of the Guide: the commissioning process and the technical procedures used in commissioning. The process could be considered the "business of commissioning" while the procedures are the "nuts and bolts" (i.e., how to commission).

In some cases, these constructs may overlap or not be perfectly separated. Users of the Guide may choose to draw the line between the process and technical procedures in a manner that best suits their businesses and facility designs and construction methods. This Guide provides examples of only the most common technical procedures; individual Commissioning Plans should include the identification and development of project-specific technical procedures to ensure effective component- and system-level commissioning.

HOW TO USE THIS GUIDE

Refrigeration Commissioning Guide for Commercial and Industrial Systems traces the development of refrigeration systems from concept through design, construction, and start-up. Chapters 2, 3, and 4 cover the phases of commissioning: Planning and Design, Construction and Installation, and

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Start-Up and First-Year Operation. Each chapter includes a flowchart with steps outlined that users can follow to ensure that the end result will meet the expectations of the owner as well as a roles and responsibilities table that breaks out the possible interested parties and their involvement in the commissioning process. Sidebars are dispersed throughout the Guide to offer real-world examples to strengthen points and provide additional ideas and insights. The appendices provide resources for viewing the roles and responsibilities of people involved in commissioning for all phases in one table (Appendix A), an example Commissioning Plan (Appendix B), an example acceptance plan (Appendix C), and technical procedures that describe activities that may be conducted when commissioning refrigeration systems (Appendix D). Also included is a glossary of terms commonly used in refrigeration commissioning practice.

During the development of this Guide there was much discussion regarding the need for consistent terminology within the refrigeration industry, and the committee spent some time coming to a consensus on the terminology and acronyms used in this Guide. Though there is no separate acronyms section included, the acronyms are indicated throughout the text when the terms are used and they are included in the glossary entries.

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2

Commissioning during Planning and Design

INTRODUCTION

Objectives

The core objective of commissioning during planning and design is to ensure that a project is designed to be "commissionable." Starting the commissioning process in this phase helps to establish a framework by which commissioning is embedded in the project from the beginning. Specifically, it ensures that the Owner's Project Requirements (OPR) are the foundation of the project and that all subsequent phases of the project are based on this well-defined set of requirements. This chapter describes the key documents developed and activities undertaken in this phase to help ensure the project achieves the goals defined in the OPR and to facilitate commissioning of the project.

Process

The main commissioning activities during the Planning and Design Phase are the development or compilation of several key documents: the OPR, the Basis of Design (BoD), and construction documents (CDs). The Commissioning Plan is developed and refined concurrent with development of these documents. As explained in ASHRAE Guideline 0 (2005), the OPR describes *what* the owner's requirements are for the project, the CDs show *how* the requirements are tangibly met, and the BoD ties the two together.

Although these documents are developed during the Planning and Design Phase, they must be revisited and revised as needed throughout the project. For example, if a requirement in the OPR cannot be met, the designer must specify why in the BoD, detail what was done instead, and seek approval from the owner to have the OPR revised. In this regard, the OPR, BoD, and CDs, along with the Commissioning Plan, will be living documents throughout the life of the project. As the project progresses and new team members become involved in the project, these foundational documents must be made available and presented with clear expectations so that everyone involved may be held accountable.

As much as possible, the procedures, documents, guidelines, and forms to be used during the construction, start-up, and first-year commissioning activities should be identified during the project design, realizing that some details may change based on final design, equipment, and vendor selections. An