



New Construction Building Commissioning Best Practice

Building Commissioning Association

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Section 1 Introduction

1.1 Overview and Purpose

- A. The Building Commissioning Association (BCA) is comprised of owners, engineers, architects, contractors, commissioning providers and users of commissioning services in their day-to-day operations. Members represent a broad cross-section of interests and are associated with many sectors of the facilities and construction community. The BCA states that the basic purpose of commissioning is *"to provide documented confirmation that building systems function in compliance with criteria set forth in the Project Documents to satisfy the owner's operational needs."*
- B. As new construction commissioning has matured as an industry practice, various organizations, guidelines, protocols and certifications have been created to define and clarify the commissioning process. Some fundamental elements of the process have been enhanced, modified redefined or de-emphasized and new elements added. Some elements are not well implemented or understood. Subsequently, the BCA felt that writing a best practices document would help distill the long list of guidelines and longer list of tasks into primary activities that represent the ideal commissioning process, applicable to most building types and projects.
- C. The BCA is committed to defining best practices in the building commissioning industry and to providing documents that describe these practices and offer practical solutions to issues and concerns in the industry. Best Practices documents that communicate sound processes and a generally accepted ideal standard of care have been developed by the BCA for both existing buildings and new construction. These Best Practices have been shown over time to be justified in a wide variety of systems and building types.
- D. The definition of best practice creates a benchmark against which the market can gauge quality and professionalism. This Best Practice allows the BCA and other organizations to objectively evaluate commissioning initiatives, processes, guidelines, training curricula and certifications, etc. It



facilitates improved implementation of high quality building commissioning processes and promotes standardization of commissioning. This document complements the BCA Essential Attributes, which set a minimum standard, while the Best Practice helps define top quality.

1.2 Scope and Level of Detail

- A. The New Construction Building Commissioning Best Practice is intended to cover the general new construction commissioning process that is applicable to most systems. It is necessarily non-specific in most cases, but where a practice seems unclear by its varied application, more detail is given. For example, the document will give a general statement about the best practice of functional testing, but won't delve into the particulars of the best practice functional testing of any specific piece of equipment. The document describes the recommended process of commissioning, but does not offer guidance on the systems that should be commissioned or the specific rigor that should be applied since these are project specific. Details of most of the elements and means and methods for their application can be found in the documents referred to in the online BCA Resources Center. (See Resources Section)

1.3 Best Practice

- A. The term *best practice* generally refers to the best possible way of doing something. There is no single universally "best" way to apply commissioning in all circumstances. "Best" is taken in context of reasonable cost and schedule limitations; desires for objectivity and rigor; differing building and equipment types, project size, and complexity. The *best* practice is done to achieve *optimal* results.

1.4 Development Process

- A. The BCA's New Construction Building Commissioning Best Practice was developed and refined over a two year period by a Task Force of selected BCA practitioners with deep commissioning experience and volunteers from a broad cross-section of regions across the USA.
- B. The Task Force utilized the following primary reference sources: ASHRAE Guideline 0-2005 and Guideline 1.1-2007, the USGBC LEED rating system,



and the BCA Essential Attributes and Valuable Elements of Commissioning. The Task Force had the latitude to vary from these and other reference documents, but in the end was essentially consistent with them. Other reference sources included the BCA Commissioning Handbook, BCA training curriculum, the NEBB Procedural Standards for Whole Building Systems Commissioning of New Construction, and the NIBS Whole Building Design Guide.

- C. The Task Force used their experience as commissioning professionals to create not simply a merging of the referenced sources, but a listing of those elements in the resources that are considered to represent best practice. Even if a practice was rarely done, it may have been considered a best practice and is therefore included. If a practice is very innovative and effective, but expensive and difficult to implement with readily available technology, it is not listed as a best practice, although in future best practice versions it may be. Some practices recommended in some of the guidelines were not considered best practice, although they could be valuable in certain situations and are only mentioned in a qualified manner in the BCA's Best Practice document.
- D. The Task Force Best Practice was sent out to the BCA membership at large for their review and input. The Task Force responded to comments and incorporated those that they felt were warranted. The BCA Board of Directors then approved the final version.



1.5 Updates

A. As the commissioning industry matures and practicing professionals continue to gain experience, the list of "best practices" set forth here will be refined and modified. Accordingly, suggestions through the respective commissioning organizations are invited.

1.6 Industry Concerns and Best Practice Solutions Sidebar

In 2008, the BCA surveyed its members to identify major issues of concern, areas for improvement, observations about where the industry is going, and where potential pitfalls or roadblocks for the advancement of commissioning for new construction might exist. The BCA Task Force analyzed each concern, using their own experience as commissioning professionals, and provided Best Practice solutions. These concerns and the Best Practice are found throughout this document and are located in the sidebar. The full list of concerns and solutions are also found in Appendix B.

1.7 Acknowledgments

The Best Practice Task Force acknowledges the thoughtful and essential contributions made by the members of the BCA in providing invaluable input and commenting on the various drafts as we worked to complete this document.

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Section 2 Pre-Design

2.1 Introduction/Overview

- A. Commissioning ideally begins in the pre-design phase.
- B. The Pre-Design Phase lays the groundwork for the project and defines the plan for commissioning. During this phase the commissioning team is assembled and the Owner's Project Requirements (OPR) and the building program are developed. All decisions made in ensuing phases should be made with reference to the OPR.

2.2 Objectives

- A. Identify the Commissioning Team.
- B. Develop the OPR.
- C. Define the initial commissioning scope and budget.
- D. Develop the initial commissioning plan.
- E. Verify that the building program is consistent with the OPR.

2.3 Commissioning Team

- A. Owner/ Owner's representative
- B. Commissioning Authority (CxA)
- C. Design team
- D. Operating and Maintenance Personnel (when available)
- E. Construction Team Personnel (when available)
- F. End Users (when available)

2.4 Pre-Design Activities

- A. Owner designates a party to act as their project representative for commissioning related activities.
- B. Owner selects /designates a Commissioning Authority for the project.
1. *The CxA is in charge of the commissioning process and makes the final recommendations to the owner regarding functional performance of the commissioned building systems.* *BCA Essential Attribute*
 2. *The CxA is an objective, independent advocate of the Owner. If the CxA's firm has other project responsibilities, or is not under direct contract to the Owner, a conflict of interest exists. Wherever this occurs, the CxA discloses, in writing, the nature of the conflict and the means by which the conflict shall be managed.* *BCA Essential Attribute*
 3. In addition to having excellent written and verbal communication skills, the CxA *has current engineering knowledge and extensive hands-on field experience regarding:* *BCA Essential Attribute*
 - a) *Building systems*
 - b) *The physical principles of building systems performance*
 - c) *Building systems start-up, balancing, [functional] testing and trouble shooting.*
 - d) *Operation and maintenance procedures*
 - e) *The building design and construction process*
- C. Develop the OPR for the project.
1. The OPR defines the expectations, goals, benchmarks and success criteria for the project. The OPR must be developed with significant owner input and ultimate approval. The CxA typically assists the Owner in identifying the facility's requirements regarding such issues as energy conservation, indoor environment, staffing training and operation and maintenance.
 2. An effective OPR incorporates input early in the project from the Owner, design team, operation and maintenance staff and end users of the building and is updated throughout the project.

Industry Concern

What makes a Commissioning Authority qualified?

Best Practice Solutions

- Experience as the Commissioning Authority on similar projects.
- Independent Owner Advocate
- Excellent written & verbal skills
- Engineering knowledge of building systems and design.
- Extensive hands on field experience in construction, O&M, testing and troubleshooting.
- Related education, commissioning certification and/or professional licensure.

See Industry Issue 10 in the Appendix for more detailed information.



- a. An effective OPR is developed utilizing accepted methods for obtaining input (e.g. questionnaires, or Nominal Group Technique, workshops, etc.)
- b. The elements of an effective OPR are verifiable.

D. Define the commissioning scope, schedule and budget. The design schedule should include the commissioning activities. The commissioning scope identifies the systems to be commissioned and outlines the activities and the rigor of the commissioning process.

For each project, the commissioning purpose and scope shall be clearly defined in the CxA contract. BCA Essential Attribute

The CxA recommends the commissioning roles and scope for all members of the design and construction teams and that the scopes are clearly defined in:

1. *Each design consultant's contract*
2. *The construction manager's contract*
3. *General Conditions of the Specifications*
4. *Each division of the specifications covering work to be commissioned*
5. *The specifications for each system and component for which the supplier's support is required BCA Essential Attribute*

E. Incorporate commissioning into the project budget and schedule. The project budget should be adequate to support the commissioning activities and the construction schedule should provide sufficient time to accomplish all commissioning activities. Budgets are impacted by the extent and rigor of the commissioning scope. Using professional judgment to determine how many of each system or assembly are evaluated and verified and to what degree should be done carefully and by experienced and qualified personnel. This judgment is a type of sampling and may be considered for the following commissioning tasks: design review, submittal review, field installation observation, construction checklist verification, functional testing of multiple identical pieces of equipment, trend log analysis and operation and maintenance (O&M) manual review. The more rigid random statistical

Industry Concern

The OPR and BOD are frequently not developed nor utilized for a project

How to develop an OPR and who is responsible for its development is a common barrier.

Best Practice Solutions

- Utilize a proven method to obtain and document OPR input.
- Assign a champion and utilize a good facilitator
- Begin early, before schematic design, and keep the OPR up to date throughout the project.
- Verify and measure success of OPR achievement throughout project by comparing the design documents against the OPR.

See Industry Issue 1 in the Appendix for more detailed information.



sampling may be superior in certain cases, but there is not agreement among commissioning practitioners as to the efficacy of this method in many situations, and therefore is not recommended generally as a best practice. The owner should clearly define the desired level of sampling, objectivity and rigor in the CxA request for proposals (RFP). CxAs should identify their level of sampling in their proposals, when not explicitly dictated in the RFP.

F. Develop the Commissioning Plan. *Each project is commissioned in accordance with a written commissioning plan that is updated as the project progresses. The commissioning plan.* *BCA Essential Attribute*

1. *Identifies the systems to be commissioned*
2. *Defines the scope of the commissioning process*
3. *Defines commissioning roles and lines of communications for each member of the project team*
4. *Estimates the commissioning schedule*

The Commissioning Plan developed during the Pre-Design Phase should address in detail the development of and the ongoing management of the OPR, the development of the Basis of Design (BOD) and the design review process. Other elements of the Plan are normally developed in later phases.

G. Develop the Issues Log format and protocols. The Issues Log format should be developed to facilitate the documenting, tracking and resolution of commissioning related issues. Issues Logs typically contain at a minimum a detailed description of the issue, date identified, party responsible for corrections, issuing agent and completion status. *All... findings are documented and distributed as they occur.* *BCA Essential Attribute*

H. Review the Building Program. The Commissioning team reviews the building program documents and determines whether they are consistent with and support the Owner's Project Requirements.

I. Prepare the Pre-Design Phase Commissioning Report. At the conclusion of the Pre-Design Phase a report is developed that compiles the commissioning related documentation from the Pre-Design Phase.

Industry Concern

There is a lack of clarity surrounding the appropriate use of "sampling".

Best Practice Solutions

- CxA reviews with the Owner the resulting rigor, objectivity, cost, time and risk of potential sampling approaches.
- Sampling should not be done in high risk, life safety and complicated systems
- Define the sampling process in the commissioning plan and specifications

See Industry Issue 6 in the Appendix for more detailed information.



Section 3 Design Phase

3.1 Introduction/Overview

A. During the design phase, the commissioning process confirms that design documentation (plans, specifications, Basis of Design (BOD), etc.) are consistent with each other, include commissioning requirements and meet the Owner's Project Requirements (OPR).

3.2 Objectives

- A. Communicate the commissioning requirements to other project team members.
- B. Verify, through review, that the design documentation is consistent with the OPR and BOD.
- C. Ensure that commissioning requirements are included in the construction documents.
- D. Build engagement and cooperation among the project team members.

3.3 Commissioning Team Members

- A. Owner Representative
- B. User Representatives
- C. Commissioning Authority (CxA)
- D. Design Team
- E. Construction Team

Industry Concern

Owners and the Building Industry as a whole do not always understand the Commissioning Authority's (CxA) role for the design review.

Best Practice Solutions

- The Engineer of Record is ultimately responsible for the projects design and makes the final decision regarding the design.
- CxA comments should reflect a consulting, not a directing role.
- CxA limits their comments to their scope (Cx facilitation versus a peer review).
- Owner arbitrates designer / CxA issues.

See Industry Issue 11 in the Appendix

3.4 Design Phase Activities

- A. Update the commissioning plan. If a plan has not been developed, create one as described in the pre-design phase. Updates to the plan during design may include more detail about the construction phase schedule and responsibilities, new project team members and communication protocols. The commissioning plan should be consistent with the specifications.
- B. The commissioning plan should be provided to the contractor as a supplement to the construction documents to augment the commissioning specifications.
- C. Conduct a design phase commissioning kick-off meeting to review the commissioning plan and activities with the commissioning team.
- D. Review the OPR for completeness and clarity. The OPR should be included as a supplement to the construction documents
- E. Ensure the OPR and BOD documents are updated to reflect any Owner-approved changes made during the design process.
- F. Perform periodic commissioning-focused reviews of the design submissions using experienced qualified personnel.
 1. Design reviews shall be documented by comment statements appropriate for the level of completeness of the design. The CxA is respectful in wording their comments.
 2. The commissioning reviews focus on verifying that the OPR and BOD are met relative to facilitating the commissioning process. In particular, the reviews confirm that there are adequate access points, test ports, monitoring capabilities and points, and control features. Reviews also verify that energy-efficiency, operation, control sequences, maintenance, training and O&M documentation requirements are consistent with the OPR and BOD. Depending on the review scope desired by the Owner, extended depth to the commissioning reviews beyond commissioning facilitation may be part of the project. These could include checking and making suggestions for improvements relative to the

Industry Concern

CxA Design Reviews are being inconsistently performed.

CxA may be brought in late to project and intent and role of design review unclear.

Best Practice Solutions

- Ideally include three reviews and three review back checks.
- Review level should be appropriate for the stage of design completion.
- Reviewer should have appropriate level of expertise.
- Review comments and response to comments should be documented.

See Industry Issue 2 in the Appendix



design concept, bidding, coordination, performance, constructability, sizing calculations, life cycle cost analysis, and code, standards and guideline compliance. This extended review normally comes short of a full formal peer review.

3. Of particular importance is to perform a thorough review of the control logic, sequences of operation and integration issues of the dynamic equipment prior to late construction documents phase when changes can still be made. The review comments are resolved and necessary changes and clarifications are made to the design documents. Making recommendations for a rigorous controls submittal is also warranted.
 4. The ideal number and timing of reviews varies from project to project. Larger and more complex projects warrant more reviews. The CxA should discuss with the Owner the advantages and disadvantages of more review (impacts to the design schedule, costs, benefits, etc.). On most projects there should be at least three reviews and a back-check at the beginning of each subsequent phase. These three reviews occur at system selection or concepts phase, during design development phase and during mid-construction documents phase). Fewer reviews may be warranted for smaller or simple projects.
 5. The design team should provide written response to each of the design review comments. These responses should be returned to the CxA and issues resolved, with the CxA, design team and Owner all understanding the agreed upon path forward on each comment. This resolution should be documented prior to the design team moving significantly into the next design phase.
 6. At the next design submission the CxA back-checks the comments from the previous review, i.e., confirms that the agreed-upon resolution for each comment from the previous review has been incorporated into the plans and specifications.
- G. Determine and document the Owner's training requirements and provide them to the design team for inclusion in the construction documents. This

Industry Concern

The integration and functionality of control systems is problematic.

Best Practice Solutions

- Owner desired control interfaces and functionality should be defined in the OPR and early in the design.
- A controls integration coordination meeting should occur in design and be fully detailed in the construction documents.
- Controls integration coordination needs to continue through the submittal process and construction.
- Controls integration needs to be verified through construction checklists and functional testing.
- Involve all relevant vendors/contractors to resolve integration issues.

See Industry Issue 12 in the Appendix for more detailed information.



should include requirements for the CxA to provide training on the purpose and use of the Systems Manual.

- H. Develop commissioning specifications to ensure that commissioning requirements are included in the construction documents.
1. In the specifications, describe all contractor related commissioning responsibilities. For clarity and information, list the CxA and other non-contractor team member responsibilities (Construction Manager (CM), Owner, design team). Clearly delineate between the contractor responsibilities and the responsibilities of the rest of the team.
 2. Include requirements for:
 - a. Submittals
 - b. Commissioning Meetings
 - c. Commissioning schedule development
 - d. Construction checklist development and execution
 - e. Functional test procedure format and development
 - f. Startup process
 - g. Measuring instrument calibration requirements
 - h. Test readiness confirmation
 - i. Functional testing process - including management, execution and documentation
 - j. Balancing report review and reading validation
 - k. Issues log process
 - l. Deferred functional testing
 - m. Training verification
 - n. O&M manuals
 - o. System Manual requirements
 3. Include an equipment-specific functional testing scope for each piece equipment or type of assembly or system. Include test form format requirements, test rigor, any sampling allowed, trending requirements, etc. Functional testing requirements should also list the modes to be tested, under what conditions and give the acceptance criteria. Identify what testing is and is not part of the



formal commissioning process. Delineate between commissioning functional testing and contractor quality control and other testing specified elsewhere in the specifications (e.g., duct and pipe pressure testing, generator load bank testing, etc.)

4. Provide one or more representative functional test forms to illustrate the scope and rigor of the functional testing and allow the contractor to bid the work.
5. Develop construction checklists if the necessary documentation is available. If not, provide a few representative checklists to allow the contractors to bid the work.
6. Coordinate with the design team on other sections of the specifications that mention functional testing or commissioning-related activities so they are consistent with the formal commissioning sections. Cross reference between sections.
7. Include how completion of commissioning activities relates to occupancy permits and project closeout.
8. The CxA works to build cohesiveness and cooperation among the project team by clearly communicating the commissioning process and the role of each party.

Section 4 Construction Phase

4.1 Introduction/Overview

A. Successful construction phase commissioning is a well coordinated quality assurance process that encompasses installation, start-up, functional testing and training. During the construction phase the commissioning team works to ensure that equipment, systems and assemblies are properly installed, integrated, and operating in a manner that meets the Owner's Project Requirements (OPR). Functional testing and documentation provide valuable performance benchmarks, acceptance criteria and a baseline for the future operation and ongoing commissioning of the facility.

4.2 Objectives

- A. The Commissioning Plan (Cx Plan) and the OPR, BOD are updated.
- B. Commissioning team members understand their roles and responsibilities for the construction phase commissioning activities.
- C. Equipment, systems, and assemblies are properly installed, maintainable, and functioning properly as required to meet the OPR.
- D. The operations and maintenance (O&M) personnel are provided with complete and proper systems operating documentation.
- E. The O&M personnel, and occupants as needed, are properly trained. Training documentation is created to facilitate ongoing training.

4.3 Commissioning Team Members

- A. Owner's representative
- B. Commissioning Authority (CxA) and sub-consultants
- C. Design team
- D. Construction Management Representative
- E. Contractors
- F. Building occupant or user group representatives
- G. Personnel responsible for the building's operation and maintenance.

Industry Concern

Construction observation by Commissioning Authority can be too infrequent.

Best Practice Solutions

- Owner should understand importance of field observations.
- Adequate field observations should be included in Cx Scope of Work.
- Couple field observations with regular project & Cx meetings.
- Consider abbreviated field report to document Cx visits.

See Industry Issue 4 in the Appendix for more detailed information.



Industry Concern

Generic checklists are being utilized in lieu of project specific

Best Practice Solutions

- Supplement standard checklists with project specific information.
- Obtain input from the design, construction, and operation team.
- Complete checklist with aid of the construction team.

See Industry Issue 3 in the Appendix for more detailed information.

4.4 Construction Phase Commissioning Activities

- A. Update Cx Plan, BOD, and the OPR to reflect changes made to the project.
- B. Integrate the Commissioning Schedule into the construction schedule. The CxA works with the contractor to integrate the Cx activities into the construction schedule, with adequate time to complete all commissioning activities.
- C. Conduct construction phase commissioning kick-off meeting. The kick-off meeting is most effectively held when the contractors have mobilized to the site. The Cx plan is reviewed, along with roles and responsibilities, schedule, and deliverables.
- D. Review submittals. The CxA reviews submittals of commissioned equipment concurrently with the design team. Reviews normally focus on issues relative to commissioning facilitation.
- E. Hold a construction phase controls integration meeting. A construction phase controls integration meeting between the CxA, the designers, the controls contractor, and the building operator is held after the controls submittal review and prior to submittal approval. The goal of this meeting is to facilitate resolution of review comments, and verify that the controls system and system sequences are complete, verifiable, coordinated and meet the OPR.
- F. Develop the master list of commissioned equipment. This list may also be utilized by the owner for O&M purposes.
- G. Complete development of project specific Construction Checklists. The checklists should be completed utilizing the approved construction submittals and installation manuals to make the checklists specific to the installed equipment. Construction Checklists should be given to the contractor for review and comment prior to beginning installation.
- H. Develop functional testing procedures and test data forms. The preliminary functional test procedure forms are developed, usually by the CxA, after the controls submittals are approved. The contractor and designers review the forms and provide comments back to the CxA. The functional test procedures forms are completed and given to the



contractor as soon as possible after acceptance of the submittals, prior to controls programming and equipment start-up. Contractors run equipment through these tests using the forms to verify that the systems are ready for later functional testing with the CxA.

- I. Maintain Issue Log. The CxA maintains an Issues Log to document and track commissioning items that do not comply with the construction documents and OPR.
- J. Conduct regularly scheduled commissioning coordination meetings. The number of meetings will vary widely depending on the commissioning scope and the project complexity. However, the CxA scope should include enough commissioning coordination meetings to keep the CxA involved in the project to help the contractors follow the Cx Plan.
- K. Construction Checklists. The contractor executes the Construction Checklists and other required startup documentation.
- L. Conduct regularly scheduled site visits: Verify Construction Checklists. Review equipment, systems and assemblies installation. The site visits are often held in concert with the commissioning coordination meetings. An objective of the commissioning site visits is to verify proper installation early and prevent systemic problems.
- M. Assist project team with resolution of issues. ***The commissioning authority provides constructive input for the resolution of system deficiencies.*** *BCA Essential Attribute* The CxA verifies that the resolution is compatible with the OPR.
- N. Review Start-up Reports. The CxA reviews contractor and special agency equipment start-up and quality control testing documents and witness selected or critical startups and contractor quality control tests (e.g., duct and piping system pressure tests, generator load bank tests, etc.).
- O. Review the Testing, Adjusting and Balancing (TAB) plan and report. The TAB plan and report should be reviewed by the CxA concurrently with the designer and comments and recommendations provided to the designer. The TAB report is typically verified by field measurements through sampling techniques prior to or during functional testing as appropriate.
- P. Functional Test Readiness. The CxA confirms test readiness through the construction phase activities (field observation, review of start-up reports

Industry Concern

The functional testing process is sometimes inadequately performed

Best Practice Solutions

- The testing scope work should be well defined for all parties
- Follow the BCA Essential Attribute for functional testing
- Encourage O&M involvement in functional testing for training benefits
- Confirm all sequential details thru controls integration meetings.
- Utilize trend data as a supplement to functional testing.

See Industry Issue 5 in the Appendix for more detailed information.



and construction checklists, observation of control system and equipment operation, including trending and when required review of contractor's pre-tests of system operation) or receiving a letter of readiness prior to beginning the functional testing program to ensure that the functional testing process will run smoothly

Q. Coordinate, execute and document functional testing. *The functional testing program objectively verifies that the building systems perform interactively in accordance with the Project Documents. Written, repeatable test procedures, prepared specifically for each project, are used to functionally test components and systems in all modes of operating conditions specified for testing. These tests are documented to clearly describe the individual systematic test procedures, the expected systems response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion.* *BCA Essential Attribute*

1. The commissioning team is responsible for executing all functional tests. The CxA or CxA designated Cx Team member coordinates, witnesses and documents the functional tests as defined in the commissioning plan and specifications.
2. Perform deferred functional testing during Occupancy and Operations phase as required so tests are performed during proper weather or operating conditions.
3. Systems and assemblies that fail to meet the passing criteria shall be retested until accepted by the commissioning team.
4. When a central building automation system (BAS) is part of the project, trend logs of temperature, flow, current, status, pressure, set points etc. are utilized to confirm proper operation over time of all systems possible. This augments the manual functional testing.
5. When critical data is not available through a BAS, monitoring and recording of performance data is accomplished by using stand-alone data loggers.

Industry Concern

As-built documentation turned over to O&M personnel is not complete or useful.

Best Practice Solutions

- O&M personnel should be involved in determining O&M content.
- The O&M Manual content must be properly defined in the OPR and in the contract documents.
- Approved submittals including performance data accessories and options needed to be clearly indicated.
- Complete record documents including specifications need include all change-order, ASI, and as-installed information.



R. Review contractor as-built documents, warranties and O&M Manuals. *Verify that the operations & maintenance manuals comply with the contract documents.* *BCA Essential Attribute*

S. Compile the Construction Phase Commissioning Report. *Every commissioning project is documented with a commissioning report that includes:*

1. *An evaluation of the operating condition of the systems at the time of functional test completion,*
2. *Deficiencies that were discovered and the measures taken to correct them,*
3. *Uncorrected operational deficiencies,*
4. *Functional test procedures and results,*
5. *Reports that document all commissioning field activities as they progress, and*
6. *A description and estimated schedule of required deferred [functional] testing.* *BCA Essential Attribute*

T. Prepare a Systems Manual. The Systems Manual provides the information needed to understand and properly operate, the building systems and assemblies. It should be understandable to people unfamiliar with the project. The Systems Manual documentation is provided by the CxA, Owner, Designers, and Contractors. It is important that the documentation requirements are included in the construction documents and the designers' contracts.

The Systems Manual contains the following, as appropriate for the building and its systems:

1. Overview; Index and Executive Summary
2. Basic Operation
3. Ongoing Commissioning
4. Additional Elements – Items such as the O&M Manuals and As-Built documentation are sometimes included as a subset of the Systems Manual.

See Appendix C for more detailed information about System Manual content.

Industry Concern

The Systems Manual and Final Cx Report, if provided, are often inadequate and do not contain all necessary documentation.

Best Practice Solutions

- Develop the Systems Manual outline in the OPR.
- Include contractor requirements in contract documents
- Build the Systems Manual contents throughout the project

See Industry Issue 8 in the Appendix for further discussion



- U. Verify training of the owner O&M personnel and end users. *Verify that the training for the owner's operating staff is conducted in accordance with the project documents.* *BCA Essential Attribute*

The key objective of the owner's operating staff training is to convey knowledge and skills required to effectively and efficiently operate the facility. This includes an understanding of the OPR and BOD as well as training on the purpose and use of the Systems Manual. The CxA reviews the contractor's submittals of the training content, materials, and instructor qualifications to verify that the training will meet the requirements of the commissioning plan and the contract documents. Trainees complete a basic training evaluation form providing feedback regarding effectiveness. The owner may elect to have the CxA participate in key training sessions and/or use other methods to confirm that the training was delivered effectively.

Industry Concern

The O&M personnel training can be ineffective at assuring efficient operation

Best Practice Solutions

- Define training needs early (in design)
- Include active participation from maintenance staff, CxA, designers, contractors and equipment vendors.
- Perform systems level training in addition to component level training.
- Include Systems Manual and Syllabus

See Industry Issue 7 in the Appendix for further discussion



Section 5 Occupancy and Operations Phase

5.1 Introduction/Overview

A. The Occupancy and Operation Phase normally begins at Substantial Completion. This last phase of the New Construction Commissioning focuses on finalizing all uncompleted functional testing, training and project documentation while fine tuning building performance prior to project completion.

5.2 Objectives

- A. Complete any deferred functional testing and training.
- B. Complete systems and commissioning documentation.
- C. Verify successful turnover to operations and maintenance (O&M) personnel.
- D. Evaluate and optimize building performance.
- E. Update and implement the plan for commissioning the building over time (Ongoing Commissioning).
- F. Evaluate project success

5.3 Commissioning Team

- A. Owner/ Owner's Representative
- B. Operation Personnel
- C. Commissioning Authority
- D. Contractors
- E. Design Team

5.4 Occupancy and Operations Activities

- A. Maintain and update the Issues Log.
- B. Verify completion of outstanding O&M personnel training. Conduct deferred training of the O&M personnel. Evaluate the effectiveness of the training program and make a recommendation as to the need for supplemental training.
- C. Provide occupant training. Provide orientation and training to occupants relative to elements of the building systems and the assemblies they interact with.
- D. Conduct a Lessons Learned Workshop. A workshop should be conducted to discuss and document project successes and identify opportunities for improvements for future projects. Ideally key representatives from the project design, construction, commissioning and operations and maintenance teams participate.
- E. Optimize systems. The CxA identifies opportunities for fine-tuning system performance such as optimizing schedules, sequences, and set-points in addition to other no-cost/low-cost changes. The CxA may assist in implementation of the changes.
- F. Complete seasonal and deferred functional testing. When thorough testing of loading, staging and capacities can't be completed during the initial functional testing, testing is deferred to the appropriate season or load condition during occupancy.
- G. Update the Systems Manual. The Systems Manual should be updated with deferred functional testing and deferred training material. Operations personnel are informed how to keep the Systems Manual up to date as changes occur throughout the life of the building.
- H. Begin implementation of the Ongoing Commissioning Program. The Ongoing Commissioning Program includes the repeating of the functional testing portion of the commissioning process on a periodic basis, or ongoing monitoring and trending with associated automatic or manual diagnostics, or a combination of these methods. The magnitude, order and frequency of the re-testing of components and systems are dictated by the likelihood of performance degradation. The program should include



continuous monitoring of the more energy intensive systems and those more prone to performance problems. Utilization of periodic or continuous automatic fault detection monitoring should also be considered.

- I. Conduct an Operation and Maintenance staff survey. Conduct a staff survey or interview 4 to 8 months after move-in. The O&M personnel should be surveyed to evaluate building equipment controls and performance. The results are used during the Building Operations Review.
- J. Conduct an occupant survey. A survey is presented to the occupants 6 to 18 months after move-in to confirm that a satisfactory indoor environment has been achieved for a substantial majority of the occupants. Surveys should address the following elements: thermal comfort, indoor air quality, lighting and day lighting, and acoustical quality. Additional elements may be evaluated when dictated in the Owner's Project Requirements.
- K. Perform a Building Operations Review. The CxA conducts an on-site review of building operations 10 months after substantial completion, typically near the end of the warranty period. The Building Operations Review includes a review of the results of the Occupant and O&M personnel surveys, a review of work orders related to commissioned systems and the review of trend logs and equipment operation. Issues identified during the review are documented along with a proposed solution and identification is made of the responsible party for correction, as well as any need for additional training. Issues under warranty of the original construction contract are provided to the contractor for resolution. The Commissioning Report is updated to reflect the Building Operations Review and other changes or additions that occur during the Occupancy and Operations Phase.
- L. Benchmark Building Energy Performance. After implementing optimization changes, energy performance and independent variables such as time of day, weather, hours of operation and percent occupancy should be monitored for 6-12 months. Correlations should then be developed between whole building energy use and the variables. Similarly, for larger buildings, correlations for the primary end-uses and major equipment should be developed (heating hot water, fans, DX compressors, chiller plant, lighting, etc.).

Industry Concern

The near-warranty-end review, if performed, often omits evaluation of key performance metrics

Best Practice Solutions

- Confirm that equipment setpoints are being met and are following schedules
- Utilize occupant satisfaction surveys
- Document warranty and operational issues and develop resolution plan
- Evaluate energy consumption trends, assist with energy tracking protocols

See Industry Issue 9 in the Appendix for further discussion



M. Evaluate building energy performance. After the building energy performance benchmarking period, a Building Energy Performance Review should be conducted which evaluates energy use in at least two ways: 1) Comparison to building stock indices. 2) Comparison to benchmarks and correlations developed specifically for this building.

1. At the end of one year of occupancy the building's energy performance should be compared to appropriate indices such as Energy Star, ASHRAE, regional energy use indices, the OPR, etc. Though this method is only approximate it can identify anomalies that indicate where further investigation of building performance is warranted and improvement is possible.

2. Once a system is benchmarked and correlated, and after at least another season of occupancy, the systems' and building's energy performance should be compared to the benchmarks and correlations developed during the first year. Anomalies should be investigated. Optionally, a building energy model may be calibrated to as-built and as-operated conditions to evaluate building performance, when there is sufficient budget and interest, though results often have wide error bands.

N. Implement New Construction Commissioning When Appropriate. As changes or additions are made to the building the new construction commissioning process is applied.

O. Update the OPR. Throughout the life of the building as alterations are made or as building usage changes, the OPR may need to be updated in order to reflect current conditions and requirements.



Appendices:

Appendix A: Definitions

Appendix B: BCA Issues to Address

Appendix C: Systems Manual

Appendix D: BCA Essential Attributes

Appendix E: Resources



Appendix A: Definitions



Acceptance:

Acceptance is a formal action, to declare that some aspect of the project meets defined requirements, thus permitting subsequent activities to proceed

Architect/Engineer (A/E):

See Design Team

Automated Fault Detection:

A technology that monitors components, equipment and/or systems and recognizes when they are failing, they have failed or when environmental conditions have drifted outside optimal capability range. The technology may potentially optimize operation and/or notify personnel, possibly ensuring timely identification and correction of operating and service issues.

Back Check:

A back check is a verification that an agreed upon solution to a design comment has been adequately addressed in a subsequent design review.

Basis of Design:

Basis of Design (BOD): A document that records concepts, calculations, decisions and product selections used to meet the Owner's Project Requirements and to satisfy applicable regulatory requirements, standards and guidelines. The document includes both narrative descriptions and lists of individual items that support the design process. Also known as the Design Criteria.

Benchmarks:

Benchmarks are the comparison of a building's energy usage to other similar buildings and to the building itself. Developing standards and goals for energy management is a good way to motivate people to improve towards the goal of optimal energy performance. For example, ENERGY STAR Portfolio Manager is a frequently used and nationally recognized building energy benchmarking tool.

Building program:

A document prepared by the owner or architect that describes the facility's space and function requirements.



Commissioning Authority (CxA):

An entity identified by the Owner who plans, schedules and coordinates the commissioning team to implement the Commissioning Process.

Commissioning Plan:

A document that outlines the organization, schedule, allocation of resources and documentation requirements of the commissioning process.

Commissioning Process:

A quality-focused process for enhancing the delivery of a project and includes verifying and documenting that the facility and its systems and assemblies are planned, designed, installed, tested, operated and maintained to meet the Owner's Project Requirements.

Commissioning Report:

A document recording the activities and results of the commissioning process. Usually developed from the final Commissioning Plan with all of its attached appendices.

Commissioning Review:

The commissioning review is a collaborative review of the design professionals design documents for items pertaining to the following: owner's project requirements; basis of design; operability and maintainability (O&M) including documentation; functionality; training; energy efficiency, control systems' sequence of operations including building automation system features; commissioning specifications and the ability to functionally test the systems.

Commissioning Specifications:

The contract document that details the objective, scope and implementation of the commissioning process as developed in the Commissioning Plan.

Commissioning Team:

A team comprised of the CxA, Owner, A/E, Construction Manager/General Contractor, Contractors, maintenance and operations personnel, and occupants. Individuals, each having the authority to act on behalf of the entity he or she represents, explicitly organized to implement the commissioning process through coordinated action.



Construction Checklists:

A form used by the contractor to verify that appropriate components are onsite, ready for installation, correctly installed, set up, calibrated and functional.

Contract Documents:

The documents binding on parties involved in the construction of this project (drawings, specifications, change orders, amendments, contracts, Cx Plan, etc.

Contractor:

The general contractor's or subcontractor's authorized representative.

Construction Documents:

Construction documents include all building plans, specifications, general conditions of the contract and supporting documents (such as change orders and submittals) used for the completion of a construction project.

Construction Manager (CM):

The owner's representative managing the construction project. Often the construction manager and the general contractor are the same entity.

Construction Team:

A team comprised of Construction Manager/General Contractor, sub-contractors and equipment vendors & suppliers.

Data Logging:

The monitoring and recording of temperature, flow, current, status, pressure, etc. of equipment using stand-alone' data recorders.

Deferred Functional Testing:

Tests that are performed after substantial completion, due to ambient load or occupancy conditions, not allowing a thorough test during the initial testing period.



Functional Test:

The testing of the dynamic function and operation of components, equipment and systems using manual (direct observation) and monitoring (data-logging/trending) methods.

Functional Test Procedure:

A written protocol that defines methods, steps, personnel, and acceptance criteria for tests conducted on components, equipment, assemblies, systems, and interfaces among systems.

Issues Log:

A formal and ongoing record of problems or concerns – and their resolution – that have been raised by members of the commissioning team during the course of the commissioning process.

Lessons Learned Workshop:

A workshop conducted to discuss and document project successes and identify opportunities for improvements for future projects.

Manual Test:

Testing using hand-held instruments, immediate control system readouts or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the 'observation').

Monitoring:

The recording of parameters (temperature, flow, current, status, pressure, etc.) of equipment operation using data loggers or the trending capabilities of control systems.

Nominal Group Technique:¹

A formal, structured brainstorming process used to obtain the maximum possible ranked input from a variety of viewpoints in a short period of time. The typical approach is a workshop session where a question is presented, the attendees record their responses individually on a piece of paper, the individual responses are recorded on a flip chart without discussion in a round robin fashion, all of the responses are discussed, and then the participants rank their top five responses.



Ongoing Commissioning:

The application of commissioning related process activities on an ongoing basis to ensure that operations are being met to support the ongoing improvement of system performance. The Ongoing Commissioning Plan details how these activities and goals will be achieved.

Operations and Maintenance (O&M) Manual:

O&M manuals describe key components of each system or piece of equipment and explain how they should be operated and maintained for optimum performance.

Owner's Project Requirements (OPR):¹

A written document that details the requirements of a project and the expectations of how it will function. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

Owner's Representative or Project Manager (Owner):

The contracting and managing authority for the Owner who oversees the design and/or construction of the project.

Peer Review:

A formal in-depth review separate from the commissioning review processes. The level of effort and intensity is much greater than a typical commissioning facilitation or extended commissioning review.

Sampling:

Performing observation, review, testing or other verification on only a fraction of the total number of identical or near identical pieces of equipment, drawings, events, etc. Sampling techniques include random statistical sampling and less formal professional judgment methods.

Seasonal Testing:

See Deferred Testing



Systems Manual:

A manual organized by system which contains the information needed to optimally operate the building systems. Much of the Systems Manual is not found in traditional vendor O&M Manuals. For reference, ASHRAE includes all maintenance and design documentation in their definition of Systems Manual. See Appendix C for further details.

Trending:

Monitoring over a period of time with the building automation system.

Verification:

The process by which specific documents, components, equipment, assemblies, systems, and interfaces among systems are confirmed to comply with the criteria described in the Owner's Project Requirements or other project documents.

Warranty Period:

Period of time in which the contractor is responsible for equipment repairs following turnover to the owner. The warranty period is defined in the construction contract.



Appendix B: BCA Issues to Address



Introduction

In 2008, the BCA surveyed its members to identify major issues of concern, areas for improvement, and other observations about where the industry is going and where potential pitfalls or roadblocks for the advancement of commissioning for new construction might exist.

The following twelve key issues of industry concern were identified and have been evaluated, discussed and debated by the New Construction Best Practices Task Force. Best practice solutions are offered from the practical experience and lessons learned of the Task Force members.



ISSUE 1

Industry Concern

The OPR and BOD are frequently not developed nor utilized for a project

How to develop an OPR and who is responsible for its development is a common barrier.

Best Practice Solutions

- Utilize a proven method to obtain and document OPR input.
- Assign a champion and utilize a good facilitator
- Begin early, before schematic design, and keep the OPR up to date throughout the project.
- Verify and measure success of OPR achievement throughout project by comparing the design documents and the installed systems to the OPR.

Issue 1: The Owner's Project Requirements (OPR) and the Basis of Design (BOD) are frequently not being developed by the Project Team nor utilized for the commissioning process.

I. What are the barriers?

- Typically no one has contractual responsibility to develop the OPR and the BOD and it historically has not been integrated into industry standard contracts.
- The OPR and BOD should be developed early, ideally before schematic design, which in many cases pre-dates the Commissioning Authority involvement.
- There is a lack of good standards, examples and approaches for creating a quality OPR and BOD.
- The value of the OPR and BOD is not understood.

II. Why is this important?

- Provides a focused, concise, holistic and verifiable method of documenting the owner's needs and requirements.
- Provides for improved communication between the owner and the project team; many times the owner's requirements are either undocumented or, if documented, may be buried in meeting minutes or notes that are not readily accessible by the Project Team.

III. What are the success factors?

- Utilize a proven method to obtain and document OPR input: proven methods include: 1) questionnaires; 2) an OPR charrette or workshop.
- Assign a champion and utilize a good facilitator who can focus stakeholders and can ensure appropriate representation from all stakeholders.
- Update the OPR early and often. Begin early, before schematic design, and keep the OPR up to date throughout the project.
- Verify and measure success through the project by comparing the OPR to the BOD, to design documents and to system performance as verified by testing.



ISSUE 2

Industry Concern

CxA Design Reviews are being inconsistently performed.

CxA may be brought in late to project and intent and role of design review unclear.

Best Practice Solutions

- Ideally include three reviews and three review backchecks.
- Review level appropriate for the level of design completion.
- Reviewer should have appropriate level of expertise.
- Review comments and response to comments should be documented.

Issue 2: Commissioning related design reviews are being inconsistently performed and frequently miss the basic purpose and intent of a commissioning design review.

- I. What are the barriers?
 - CxAs are often involved late in the process after major decisions have been made.
 - The project team is unfamiliar with incorporating a Cx Authority in the design review process.
 - The CxA may lack understanding of the review intent. There may be confusion between peer reviews and the Cx review.
- II. Why is this important?
 - The design phase is the ideal time to incorporate maintainability, energy efficiency and equipment into the OPR.
 - This may assist in preventing design issues and change orders.
- III. What are the success factors?
 - Ideally there should be at least three reviews and three backchecks:
 1. At System Selection and Concept Phase.
A backcheck of these comments would be included in the subsequent design phase.
 2. Design Development (DD) Documents (includes back check of system selection and concepts comments)
 3. Mid-Construction Documents (CD) (includes back check of DD review comments)
A back check of these comments would be included in the subsequent design phase.
 - Commissioning reviewers should possess an appropriate level of expertise and experience such that they are qualified to provide critiques on the designs of a professional engineer.
 - The rigor of the review should be established in consultation with the owner, to meet the owner's needs and budget, preferably before the design reviews begin.
 - The Commissioning review comments should be written, specific and appropriate to the level of completeness of the design.



- The Designer should respond to each comment in writing and specify if and how the issue will be resolved prior to the development of the next design submission.
- At a minimum the review should include:
 1. Verification that that the design meets the Owner's Project Requirements.
 2. Evaluation of the Energy Efficiency aspects of the systems and that the systems and equipment specified meet the owner's energy efficiency goals.
 3. Ensure that appropriate O&M Documentation including the Systems Manual is detailed within the specification.
 4. Confirm that the training requirements included in the specifications are detailed and consistent with the training needs of the owner.
 5. Cx Specifications should be included that are consistent with the Project's Commissioning Plan.
 6. System specific design reviews for the systems included in the commissioning process are required. A special emphasis will likely be required for the Building Automation System which impacts multiple systems and is the key interface and control system for the O&M Staff.

Issue 3: Generic construction checklists or manufacturer's installation checklists are being utilized for the pre-functional verification process in lieu of checklists customized for the specific project requirements.

Industry Concern

Generic checklists are being utilized in lieu of project specific

Best Practice Solutions

- Supplement standard checklists with project specific information.
- Obtain input from the design, construction, and operation team.
- Complete checklist with aid of the construction team.

I. What are the barriers?

- Customized checklists take time to develop which can be an issue if the project has a limited commissioning budget, if inadequate time is allocated, or if the project has a compressed schedule
- If detailed project- specific information and sequences are lacking it can be difficult to develop a customized checklist.
- Projects may require the use of a "standard" Construction Checklist as a basis which is then passed through without customization.

II. Why is this important?

- Necessary to be sure that the specific requirements that are described in the OPR are addressed and verified.
- Helps to ensure that the unique project circumstances are not overlooked.
- Increases the "value" that the commissioning process and that the Commissioning Authority brings to the project.
- Improves the contractor's view and support of the construction checklist and commissioning process.
- Helps the contractor complete the project correctly the first time and improves efficiency of the construction and commissioning process.
- Helps the Commissioning Authority better understand the project requirements and to be prepared for the construction phase.

III. What are the success factors?

- Supplement standard checklists with specifics from the OPR, the manufacturer's installation requirements, and project-specific information and Contract Document requirements.
- Allocate adequate time and budget to prepare customized Construction Checklists.



- Solicit input or review from the design, construction and operations teams during Construction Checklist development.
- Strive to achieve buy in and acceptance of the use of Construction Checklists by the individuals actually performing the physical installation work.

Issue 4: Construction observations and field presence during construction by the Commissioning Authority are sometimes rare or non-existent.

- I. What are the barriers?
 - Lack of understanding of the construction phase commissioning process does not allow adequate scope of services to be defined and the appropriate costs to be budgeted.
 - Lack of notification/coordination among team members.
- II. Why are construction observation and field presence during construction important?
 - Assures that the OPR and BOD are being followed.
 - Assures that systems and equipment are maintainable, can be commissioned and are ready for functional testing.
 - Avoids deficiencies and associated cost implications and schedule delays.
- III. Success factors:
 - Be sure that the owner understands the benefits and supports the process and that sufficient field observations are included in the commissioning scope of work.
 - Proper understanding of the scope of services, benefits and schedule implications by the entire team.
 - Have regularly scheduled commissioning meetings that increase in frequency based upon construction process, the field observations can be coordinated with the commissioning meetings to improve efficiency.
 - Consider completing an abbreviated field report to document construction observations made during the periodic construction phase Cx visits.

ISSUE 4

Industry Concern

Construction observation by Commissioning Authority can be too infrequent.

Best Practice Solutions

- Owner should understand importance of field observations.
- Adequate field observations should be included in Cx Scope of Work.
- Couple field observations with regular project & Cx meetings.
- Consider abbreviated field report to document Cx visits.

Industry Concern

The functional testing process is sometimes inadequately performed

Best Practice Solutions

- The testing scope work should be well defined for all parties
- Follow the BCA Essential Attribute for functional testing
- Encourage O&M involvement in functional testing for training benefits
- Confirm all sequences details thru controls integration meetings.
- Utilize trend data as a supplement to functional testing.

Issue 5: The functional testing process is sometimes inadequately performed. Trend observation (sometimes called Passive Testing) is used without the use of physically testing each sequence of operation and documenting the expected response and the actual response.

- I. What are the barriers?
 - The project details needed for customized test development are not be adequately developed during the design process, and are difficult to obtain late in project construction.
 - Input is required from many project participants which may be difficult to obtain.
 - Adequate time and fee may not have been budgeted for quality customized test development.
- II. Why are customized tests important?
 - Necessary to verify all sequences, sustainable features and safeties that may not be included in a generic test.
 - Essential to verify important items detailed in the project specific Owner's Project Requirements (OPR).
- III. Key Factors to Success
 - Functional testing is identified as a BCA's Essential Attribute and is described and detailed as follows: *The functional testing program objectively verifies that the building systems perform interactively in accordance with the Project Documents. Written, repeatable test procedures, prepared specifically for each project, are used to functionally test components and systems in all modes of operating conditions specified for testing. These tests are documented to clearly describe the individual systematic test procedures, the expected systems response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion.*



- A well developed and detailed sequence of operations that can be verified is needed.
- Involve key project team members during testing, in particular the personnel responsible for Operations and Maintenance (O&M personnel).
- A controls integration meeting during the design phase is recommended to ensure that detailed sequences are provided, interoperability of controls is planned and that these requirements are fully detailed in the construction documents.
- A construction phase controls meeting is recommended during the submittal process to confirm system interoperability, the details of the sequence of operations and the control submittal and help plan for the testing process.
- Reviewing and analyzing trend data is an essential part of testing plan for many systems but should be not a substitute for testing.
- The testing scope of work should be well defined for both the commissioning authority and the contractors.

Issue 6: There is confusion and a lack of clarity surrounding the appropriate use of “sampling” during the design review and pre-functional and functional testing processes.

Industry Concern

There is a lack of clarity surrounding the appropriate use of “sampling”.

Best Practice Solutions

- I. What are the barriers?
 - Owner’s and Commissioning Authority’s lack of understanding of how to apply sampling in construction.
 - There is a lack of confidence in the statistical approach.
- II. Why is limited and selective use of sampling important?
 - Some tests or analyses are very costly to implement. Sampling costs less than 100% testing.
 - Sampling requires less time and may help scheduling concerns.
 - Sampling should be limited; extensive use of sampling may lead to results that are not meaningful.
 - Sampling is not a substitute for construction quality assurance/quality control. Ultimately, the goal is for the contractor to take responsibility for successfully completing and verifying all of the work.
- III. What are the success factors?
 - Sampling should not be used for high risk, complicated, life safety or mission critical design elements.
 - The sampling process should be spelled out in the commissioning plan and Cx specifications.
 - The sampling plan needs to address actions when failures occur in the initial sample, including what follow-up action will be taken and what part the subcontractor/GC play.
 - Sampling generally applies only to the testing or verifications required by the CxA as part of the commissioning process.

- CxA reviews with the Owner the resulting rigor, objectivity, cost, time and risk of potential sampling approaches.
- Sampling should not be done in high risk, life safety and complicated systems
- Define the sampling process in the commissioning plan and specifications

Industry Concern

The O&M personnel training can be ineffective at assuring efficient operation

Best Practice Solutions

- Define training needs early (in design)
- Include active participation from maintenance staff, CxA, designers, contractors and equipment vendors.
- Perform systems level training in addition to component level training.
- Include Systems Manual and Syllabus

Issue 7: The training program for the operations and maintenance personnel is sometimes just a site walkthrough or maybe some component training without a broader systems overview and training on the design concept, interactions between systems, failure modes, key O&M issues and optimization strategies.

- I. What are the barriers?
 - O&M Staff is not always available for the duration of quality training.
 - Design team is not tasked with participating in the training.
 - Traditionally, training just consists of a walkthrough and “show and tell”.
 - Compressed construction schedules don’t support adequate training.
 - Poor specification of training requirements.
- II. Why is it important?
 - It’s important for efficient system operation and understanding
 - Understanding necessary maintenance
 - Understanding new and improved operational standards
 - Reducing complaints from both occupants and the O&M staff
 - Understanding health and safety issues
- III. Success Factors
 - Define training needs and desires in the OPR during the design phase with input from the O&M staff.
 - Active participation from maintenance staff, CxA, designers, contractors and equipment vendors. Owner should ensure that the designers participate.
 - Utilize the Systems Manual as part of the training.
 - Clearly define training requirements in contract documents.
 - Require the trainer to develop the training syllabus prior to training.
 - Verify attendance through sign-in sheets.
 - Consider using a training evaluation or questionnaire at the conclusion of each training session



- Agenda must include not only component training but also systems overview and systems training.
- Incorporate training at a component level and a systems level, which may require an equipment vendor and a subcontractor sharing responsibility for the training.
- CxA should participate in and attend selected training sessions.
- Ensure that appropriate qualified personnel are providing the training.
- Professional videotaping is recommended.
- Testing of the O&M staff's knowledge after training may be appropriate for complex or mission critical facilities.

Issue 8: The Systems Manual and Final Commissioning Report left behind as a legacy of the commissioning process is sometimes not provided, or might be incomplete or inadequate.

- I. What are the barriers?
 - Owner doesn't understand the difference between the Systems Manual and the O&M manual.
 - Definition of the Systems Manual is not understood.
 - The Systems Manual and its components are not adequately specified in the contract documents.
 - Requires input from the designers during the construction phase as well as from other parties who may not have been identified.
- II. Why is it important?
 - The Systems Manual is a single source reference which documents design, construction, and operation and maintenance.
- III. What are the success factors?
 - Develop Systems Manual outline in the OPR early in the design phase with responsible parties identified.
 - Begin compiling the Systems Manual in the design phase and update it throughout the remainder of the project.
 - Include components required by the contractor in the project specifications and the contract documents.
 - At a minimum the Systems Manual should include:
 1. Owner's Project Requirements as adjusted through the design process
 2. Basis of Design as adjusted through the design process
 3. List of the original set points and an operational record of what changes throughout the course of commissioning
 4. Performance Metrics/Benchmarks
 5. One Line Flow Diagrams for major systems
 6. Seasonal Startup and Shutdown, Manual and Restart Operations

ISSUE 8

Industry Concern

The Systems Manual and Final Cx Report, if provided, are often inadequate and do not contain all necessary documentation.

Best Practice Solutions

- Develop the Systems Manual outline in the OPR.
- Include contractor requirements in contract documents
- Build the Systems Manual contents throughout the project



7. Complete As-Built Control Drawings
8. Description of and rationale for energy saving features and strategies
9. Recommendation for recalibration frequency of set points, sensors and actuators by type and use
10. Retesting schedules
11. Description of primary recommended trend logs
12. Plans for continuing commissioning or re-commissioning of the systems
13. List of user adjustable change points and schedules with description
14. List of occupancy time-of-day schedules and frequency for their review
15. Guidelines for establishing and tracking benchmarks
16. List of diagnostic tools to assist the staff
17. Fire alarm and emergency power matrices
18. Operator notes for ongoing achievement of the OPR

Industry Concern

The near-warranty-end review, if performed, often omits evaluation of key performance metrics

Best Practice Solutions

- Confirm that equipment setpoints are being met and are following schedules
- Utilize occupant satisfaction surveys
- Document warranty and operational issues and develop resolution plan
- Evaluate energy consumption trends, assist with energy tracking protocols

Issue 9: The near-warranty-end review is being inconsistently performed and frequently does not evaluate key system performance metrics, nor evaluate the success at meeting the OPR or the satisfaction of occupants and O&M staff.

- I. What are the barriers?
 - The project intensity is gone and much of the project team has moved on to other projects.
 - The Near Warranty End Review requirements are not clearly defined and are inconsistently used in the industry.
 - Standardized methods for obtaining occupant feedback and satisfaction are not well understood nor are they frequently utilized by the commissioning industry.
 - Permission to obtain access to occupants for feedback can be difficult to obtain.
- II. Why is it important?
 - Verify that the equipment is performing properly and identify any potential warranty items before the end of the warranty period so they can be addressed by the contractor.
 - The review substantiates /documents occupant and O&M staff satisfaction and develops a plan for corrective action of identified issues to maintain optimal building
- III. Success Factors
 - Utilize occupant survey to evaluate satisfaction and obtain feedback on any issues and opportunities for improvement.
 - Analyze occupant survey results and develop corrective action plan with the O&M Staff.
 - Document all outstanding construction and warranty issues, develop a plan for resolution and expedite completion.
 - CxA should assist with the establishment of energy training protocols.

Issue 10: The BCA's position on the qualifications of the CxA is not decisive

**Industry
Concern**

**What makes a
Commissioning Agent
qualified?**

Best Practice Solutions

- I. What are the barriers?
 - Optimal CxA qualifications vary, as they are a function of the project type, systems involved and desires of the owner for rigor and objectivity.
 - BCA's Essential Attributes #2 and #3 articulate the optimal CxA's qualifications, but stop short of stating in detail what constitutes "extensive and recent hands-on field experience."
- II. Why is it important to have decisive CxA qualifications?
 - Engaging a qualified CxA is the single most important factor in the success of the commissioning process.
 - Will make it easier for owners and others hiring CxAs to narrow the field for selecting a CxA.
- III. Success Factors
 - Experience as the Commissioning Authority (CxA) on similar projects.
 - The CxA should be an objective independent advocate of the Owner. If the CxA's firm has other project responsibilities, or is not under direct contract to the Owner, a conflict of interest exists. Wherever this occurs, the CxA discloses, in writing, the nature of the conflict and the means by which the conflict shall be managed.
 - CxA should have excellent written & verbal skills
 - The CxA should have good engineering knowledge of building systems and design and extensive and recent hands-on field experience regarding:
 - Building systems commissioning,
 - The physical principles of building systems performance and interaction,
 - Building systems start-up, balancing, testing and troubleshooting,
 - Operations and maintenance procedures, and
 - The building design and construction process.
 - An education in the architecture and engineering field, a certification in commissioning such as the Certified Commissioning Professional (CCP)

- Experience as the Commissioning Authority on similar projects.
- Independent Owner Advocate
- Excellent written & verbal skills
- Engineering knowledge of building systems and design.
- Extensive hands on field experience in construction, O&M, testing and troubleshooting.
- Related education, commissioning certification and/or professional license.



and/or a professional license in architecture/engineering are additional desirable qualifications.



Issue 11: Clarification should be provided on the role of the CxA in the design review process versus the role of the Designer of Record.

- I. What are the barriers?
 - Some CxA providers push for changes beyond the scope of their work.
 - Since there is a CxA, Owners may assume that there will be no design issues or errors and omissions issues

- II. Why is it important?
 - A misunderstanding of the CxA design review role can cause unnecessary conflict in a project.
 - Important Cx related issues such as operations and maintenance, verification that the OPR is being met and system performance issues can be missed without the correct understanding.

- III. Success Factors
 - The Engineer of Record is ultimately responsible for the project's design and therefore has final say on design issues and implements any design changes.
 - The Commissioning Authority can only make recommendations, suggestions and observations, but cannot direct the design team. CxA comments should be phrased accordingly.
 - The CxA should be clear as to the scope of the commissioning review and whether it is limited to commissioning facilitation or additionally includes peer review items.
 - Owners need to understand their role in arbitrating CxA suggestions that may increase project scope.

ISSUE 11

Industry Concern

Owners and the Building Industry as a whole do not always understand the Commissioning Authority's (CxA) role for the design review.

Best Practice Solutions

- The Engineer of Record is ultimately responsible for the project design and makes the final decision regarding the design.
- CxA comments should reflect a consulting, not a directing role.
- CxA limits their comments to their scope (Cx facilitation versus a peer review).
- Owner arbitrates designer / CxA issues.

Best Practice Solutions

- Owner desired control interfaces and functionality should be defined in the OPR and early in the design.
- A controls integration coordination meeting should occur in design and be fully detailed in the construction documents.
- Controls integration coordination needs to continue through the submittal process and construction.
- Controls integration needs to be verified through construction checklists and functional testing.
- Involve all relevant vendors/contractors to resolve integration issues.

Issue 12: The integration and functionality of control systems is problematic.

- I. What are the barriers?
 - Control integration is a technically complex issue with many variables.
 - Integration requirements are difficult to identify and detail early in the design and construction process.
 - Qualified technical experts on control integration may not be involved in the project or may have become involved too late in the process.
 - Responsibility resides with multiple vendors and contractors.
 - Adequate time and focus is not allocated nor devoted to debugging and verification of controls integration.
- II. Why is it important?
 - Creates delays in project completion and system testing
 - Inordinate quantities of deficiencies may result
 - Change orders to fix integration and functionality issue may occur
 - Issues may never be able to be satisfactorily resolved
- III. Success Factors
 - Owner desired control interfaces and the level of controls integration should be defined in the OPR.
 - A controls integration meeting during the design phase is recommended to ensure that detailed sequences are provided, interoperability of controls is planned and that these requirements are fully detailed in the construction documents.
 - A construction phase controls meeting is recommended during the submittal process to confirm system interoperability. The desired functionality and integration is confirmed to be reflected in the details of the sequence of operations and the control submittal.
 - Integration requirements should be identified in the construction checklist and verified by the contractor prior to system testing. It is recommended that the Commissioning Authority confirm control system integration testing readiness prior to the formal testing process.



- Involve all relevant vendors/contractors to diagnose and resolve any identified control integration issues.



Appendix C: Systems Manual

1. Systems Manual

The Systems Manual provides the information needed to understand and properly operate the building systems and assemblies. It should be understandable to people unfamiliar with the project. The Systems Manual is ideally delivered to the owner as in an electronic indexed (bookmarked) and hyper-linked format that can be updated throughout the life of the building. At minimum this should be provided in a scanned .pdf file format in small accessible files with a logical indexed folder structure. Ideally, the documents are provided in a format that is fully hyperlinked, starting from building schematics that offer graphic links that drill down to the O&M and Systems Manual elements of the systems, equipment and components.

The Systems Manual is organized by systems, then sub-systems, and then components.

Information is most effective when illustrated graphically and the index links to one-line flow diagrams for major systems, which link to sub-systems and components which link to related documentation.

The Systems Manual contains the following as appropriate for the building and its included systems:

A. Overview

- 1) Index – with notation to storage location if not in the actual manual.
- 2) Executive Summary
- 3) Facility Description

B. Basic Operation

- 1) Facility Contact Information
- 2) OPR
- 3) BOD
- 4) System schematic diagrams of major systems (control drawings may suffice for small packaged equipment).
- 5) Complete as-built control documents; Final sequences of operation, controls schematic drawings, points list and schedules (should include fire & stand-by power sequences).
- 6) Operators Notes
 - a) List of all user adjustable set points and reset schedules, their purpose and range of reasonable adjustments with energy implications.



- b) Description of and rationale for all major energy saving features with caveats about their function and maintenance.
 - c) Seasonal start-up and shutdown, manual and restart operation procedures.
 - d) Special useful notes to operators not found in the O&M manuals or control sequences coming out of the commissioning process. [By CxA.]
- 7) Training materials and any training video recording (for future staff).
- C. Ongoing Commissioning Plan
- 1) Commissioning process, procedures and schedules
 - 2) System optimization recommendations including recommendations for optimizing energy efficiency, comfort and control and maintenance.
 - 3) System persistence recommendations for including recommendations for recalibration frequency of sensors and actuators by type and use.
 - 4) Equipment monitoring, tracking, benchmarking and retesting plans with reference to completed construction tests and checklists. Include blank forms.
 - 5) Performance trending recommendations. Description of the primary recommended standard control system trend logs for diagnostics and energy efficiency.
- D. Additional Elements
- Each of the following elements should be provided as part of the overall project documentation, and are sometimes included as a subset of the Systems Manual, particularly when the System's Manual is electronic and hyperlinked.
- 1) Traditional O&M manuals
 - 2) Commissioning report, including original set points and performance benchmarks - Serves as system baseline and example of how to retest system.
 - 3) As-built drawings, specifications and approved submittals.
 - 4) Building Information Model (BIM)



Appendix D: BCA Essential Attributes



BUILDING COMMISSIONING ASSOCIATION

BUILDING COMMISSIONING ATTRIBUTES

(Revision Date: 4/14/99)

The Building Commissioning Association (BCA) promotes building commissioning practices that maintain high professional standards, and fulfill building owners' expectations. To help achieve this, BCA identifies two important categories of commissioning practices:

- *Essential Attributes of Building Commissioning* consists of characteristics that BCA considers fundamental to building commissioning. Written agreement to conduct all commissioning projects in accordance with these *Essential Attributes* is required for BCA membership.
- *Valuable Elements of the Building Commissioning Process* includes recommendations to optimize the effectiveness of the commissioning process. The *Valuable Elements* are not membership requirements but are strongly recommended as valuable practices.

Believing that diverse and creative approaches to commissioning benefit our profession and its clients, BCA focuses on identifying critical commissioning attributes and components, rather than attempting to dictate a rigid commissioning process. Because the scope of commissioning varies between projects, BCA defines the basic purpose of commissioning as follows, in order to clarify context for these *Essential Attributes* and *Valuable Elements*.

PURPOSE OF BUILDING COMMISSIONING

It is BCA's premise that, "*The basic purpose of building commissioning is to provide documented confirmation that building systems function in compliance with criteria set forth in the Project Documents to satisfy the owner's operational needs. Commissioning of existing systems may require the development of new functional criteria in order to address the owner's current systems performance requirements.*"



ESSENTIAL ATTRIBUTES OF BUILDING COMMISSIONING

BCA considers the following attributes to be so fundamental to effective building commissioning that all members agree in writing to adhere to them whenever they serve as a project's Commissioning Authority:

1. The Commissioning Authority (CA) is in charge of the commissioning process and makes the final recommendations to the owner regarding functional performance of the commissioned building systems.
2. The CA is an objective, independent advocate of the Owner. If the CA's firm has other project responsibilities, or is not under direct contract to the Owner, a conflict of interest exists. Wherever this occurs, the CA discloses, in writing, the nature of the conflict and the means by which the conflict shall be managed.
3. In addition to having good written and verbal communication skills, the CA has current engineering knowledge, and extensive and recent hands-on field experience regarding:
 - a. Building systems commissioning,
 - b. The physical principles of building systems performance and interaction,
 - c. Building systems start-up, balancing, testing and troubleshooting,
 - d. Operation and maintenance procedures, and
 - e. The building design and construction process.
4. For each project, the commissioning purpose and scope are clearly defined in the CA contract.
5. The CA recommends the commissioning roles and scope for all members of the design and construction teams be clearly defined in:
 - a. Each design consultant's contract,
 - b. The construction manager's contract,
 - c. General Conditions of the Specifications,
 - d. Each division of the specifications covering work to be commissioned, and
 - e. The specifications for each system and component for which the suppliers' support is required.
6. Each project is commissioned in accordance with a written commissioning plan that is updated as the project progresses. The commissioning plan:
 - a. Identifies the systems to be commissioned,
 - b. Defines the scope of the commissioning process,
 - c. Defines commissioning roles and lines of communications for each member of the project team, and



- d. Estimates the commissioning schedule.
7. On new building commissioning projects, the CA reviews systems installation for commissioning related issues throughout the construction period.
8. All commissioning activities and findings are documented as they occur. These reports are distributed as they are generated, and included in the final report.
9. The functional testing program objectively verifies that the building systems perform interactively in accordance with the Project Documents. Written, repeatable test procedures, prepared specifically for each project, are used to functionally test components and systems in all modes of operating conditions specified for testing. These tests are documented to clearly describe the individual systematic test procedures, the expected systems response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion.
10. The commissioning authority provides constructive input for the resolution of system deficiencies.
11. Every commissioning project is documented with a commissioning report that includes:
 - a. An evaluation of the operating condition of the systems at the time of functional test completion,
 - b. Deficiencies that were discovered and the measures taken to correct them,
 - c. Uncorrected operational deficiencies that were accepted by the owner,
 - d. Functional test procedures and results,
 - e. Reports that document all commissioning field activities as they progress, and
 - f. A description and estimated schedule of required deferred testing.

VALUABLE ELEMENTS OF BUILDING COMMISSIONING

Building commissioning is of greatest value to the owner when it provides, throughout the many phases of design and construction, a means of continuously communicating their building systems criteria and rigorously verifying compliance with these. In order to accomplish this BCA recommends that the building commissioning scope include the following elements.

1. Prior to design, assist the Owner in evaluating the facility's requirements regarding such issues as energy conservation, indoor environment, staff training, and operation and maintenance.
2. Review all phases of design and construction documents for:
 - a. Compliance with design criteria,
 - b. Commissioning requirements,
 - c. Bidding issues,
 - d. Construction coordination and installation concerns,



- e. Performance aspects, and
 - f. Facilitation of operations and maintenance, including training and documentation.
3. Review the equipment submittals for compliance with commissioning issues.
 4. Verify or manage the scheduling and procedures used for system start-up.
 5. Verify that the training for the owner's operating staff is conducted in accordance with the project documents.
 6. Verify that the operations & maintenance manuals comply with the contract documents.
 7. Prior to expiration of the construction contract warranty, assist the owner in assessing the systems' performance and addressing related issues.



Appendix E: Resources

1. Primary References

ASHRAE Guideline 0-2005

ASHRAE Guideline 1.1-2007

The USGBC LEED rating system

The BCA Essential Attributes and Valuable Elements of Commissioning

Other reference sources included

The BCA Commissioning Handbook

BCA training curriculum

The NEBB Procedural Standards for "Whole Building Systems Commissioning of New Construction"

National Institute of Building Science (NIBS) "Whole Building Design Guide"

2. Link to Resources on the BCA website

[Building Commissioning Association](http://www.bcxa.org/)

www.bcxa.org/

Select "Resources"