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Commissioning for Nonresidential Mechanical and Lighting Systems

Updated April 28, 2006

Commissioning is a systematic process of verification and documentation to ensure that the building owner's design intent and operational requirements are delivered. Since 1997, the Seattle Energy Code has contained commissioning and completion requirements for building mechanical systems (Section 1416) and for lighting controls (Section 1513.7). For mechanical systems, the requirements include a commissioning plan, air and hydronic system balancing, functional performance testing, operational and maintenance materials, record drawings, systems operational training, and preliminary and final commissioning reports. For lighting, the commissioning requirements are limited to lighting controls. Drawing notes for both mechanical and lighting systems require commissioning and Final Commissioning Reports to be filed with the owner.

The code states that the construction documents shall require certain documentation or action. The owner receives commissioning documentation, not the building official. The building official checks to be sure that the construction documents include the appropriate requirements. The building official does not review the commissioning documents themselves, nor witness any tests. However, for complex mechanical systems, a preliminary commissioning report is to be completed prior to the building official issuing a final certificate of occupancy. Before the final inspection is signed off, the mechanical inspector will review the preliminary commissioning report to verify compliance with code requirements.

Benefits of Commissioning

While the Energy Code specifies that the installed equipment and systems must meet certain minimum requirements, the expected energy efficiency and energy savings have not always been achieved. The reasons vary: defective equipment, poor design, improperly installed systems, shoddy balancing, and a lack of information for owners and maintenance staff to operate and maintain the equipment and systems correctly. These are a few of the problems uncovered by commissioning. Typically, a multitude of these factors contribute to the problems and failures encountered on a project.

The benefits of the code requirement for commissioning and completion include a reduction in service callbacks, tenant complaints, energy costs, and equipment replacement to name a few. (See Appendix C for overviews and case studies.) While commissioning just makes good sense, placing these requirements in the code carries an additional set of benefits serving the interests of owners, contractors, utilities, architects and engineers. Commissioning raises the bar on efficient design, improves the quality of installation, and verifies that the systems operate effectively and as designed. Design professionals and contractors who perform high quality work appreciate the level playing field brought about by the code requirements for completion and commissioning. Contractors who rely on cutting corners to win low bid jobs learn they cannot make a profit when they are held accountable for their shortcuts. As a result, reputable contractors are more cost-competitive and are awarded more contracts. A higher overall standard of work is produced benefiting everyone involved.

Reports cited in the appendices document the energy saving benefits of commissioning. With improved efficiency, buildings consume less power and water. As a result, electric, gas, and water utilities are able to meet a greater portion of consumer demand from their own resources and eliminate the need for costly expansion of their operations. Efficiently operating buildings save money by reducing the cost of HVAC operations and lighting. A surprising amount of electricity can be saved with a well commissioned lighting system. Water use is also minimized when cooling towers are properly selected and adjusted, boiler blowdown is set effectively, and water purifica-

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tion systems backwash cycles are properly adjusted. All of these efficiency levels are a direct result of code requirements that ensure reduced energy usage and protection of the owner's interests through the commissioning process.

Architects benefit from knowing that their consultants have to consider operational issues more carefully. Those architects who already understand the benefits of commissioning have an ally in the code requirements that make sure commissioning is implemented. Their project designs gain the prestige of working effectively and producing high levels of customer satisfaction.

Engineers benefit from knowing that there will be fewer spurious claims about the errors and omissions of their designs. Many design professionals express frustration at not being able to persuade their clients to include commissioning early in the design and installation phase of their projects. When the design professional writes the narrative of system operation, they benefit from the clarification of their own design intent. As more of their projects undergo commissioning, they gain valuable feedback on how well their systems operate and how their designs can be improved in the future.

Building owners benefit from accepting a finished building that is functioning and ready for occupation. Commissioning eliminates start-up anxieties of wondering if all the systems work and if they don't work then who is responsible for the corrections. The cost of commissioning is usually off-set within several years of operation due to reduced down time, a reduction in operations staff overtime to trouble-shoot problems, tenants happy to be in their offices, and vastly reduced energy costs every year. With commissioning, the owner actually gets the results expected from the approved design.

The building's operations team benefits from having a building that works better from the first day of operation. This reduces tenant complaints, prevents breakdowns, and eliminates costly replacement of malfunctioning equipment. The frustration of trouble-shooting hidden problems is greatly reduced. Commissioning works the "bugs" out of the system.

Administrative Issues in the Commissioning Process

For the commissioning process to work well there must be an understanding of the goals of commissioning and the roles and responsibilities of the various participants. The Building Commissioning Association (BCA), an organization devoted to building commissioning, has attempted to address these issues. Its website indicates that "The BCA was originally formed by building commissioning professionals of the Pacific Northwest to promote building commissioning in the region. We believe it is necessary to develop within our industry a common understanding of what constitutes effective building commissioning. We recognize the need to establish essential practices that maintain high professional standards, and fulfill building owners' expectations."

As defined by BCA, "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."

The current consensus is that the commissioning process works best when a Commissioning Authority works directly for the owner and is involved early in the design process. BCA has developed a set of principles for effective building commissioning for the Commissioning Authority to abide by called the "Essential Attributes of Building Commissioning." These principles are contained on the BCA website (**www.bcxa.org/about/attributes.shtm**) and are reprinted with permission. While the scope of the "Essential Attributes of Building Commissioning" is much more comprehensive than the Seattle Energy Code requirements, the general principles are still applicable. The BCA also has a peer review process to ensure that BCA members follow the principles. (For details of this process, see **www.bcxa.org/about/peer_review.shtm** and for commissioning certification see **www.bcxa.org/certification/index.shtm**). In addition, the National Environmental Balancing Bureau (NEBB) has a certification program for Commissioning Authorities and firms (**www.nebb.org/bsccertif.htm**).

Commissioning should NOT be a process that starts after the building is constructed and systems are installed. For the most successful commissioning, the Commissioning Authority should be involved as early in the process as possible, ideally prior to design. In "Issues in Commissioning Administration, Process, and Technique – A Case Study Collage" in the Conference Proceedings of the 7th National Conference on Building Commissioning, Mike Kaplan reports finding that "15% to 33% of the deficiencies owed their existence to the designers. (This includes inadequate specifications, incompatibility among specified pieces of equipment, equipment design issues, equipment-building automa-

tion system [BAS] interface design issues, and specified equipment that does not meet the design intent, as well as errors and omissions in the design.)"

The commissioning process needs to include all of the important participants. The equipment control contractor is the key player for the Commissioning Authority to work with. Kaplan states that "it is important that the control contractor participate in all commissioning meetings. In every project I've ever seen, controls have been involved in at least half of the commissioning issues. These can not be resolved without participation of the control contractor." However, this does not need to be an adversarial relationship. Kaplan continues that "the control contractor can be an invaluable source of help in understanding program code, navigating BAS, achieving remote access via modem, and so forth. My experience is that they are usually happy to assist with these things since they gain so much from the commissioning agent's testing and troubleshooting."

For a smooth process, the Commissioning Authority's responsibilities should be clearly spelled out. Failing to do this can create difficulties. Kaplan indicates that there can sometimes be a "gray area in interpreting and assigning responsibility for correction of problems. Unless the commissioning agent is seen as unbiased by all parties involved, it is unlikely that they will accept his interpretation of problems." Recommendations for commissioning scope titled "Valuable Elements of Building Commissioning" are contained on the BCA website (**www.bcxa.org/about/attributes.shtm**) and are reprinted with permission in Appendix B.

Owners have an important role in the process. Owners should be aware that preparing a budget can be a challenge for a commissioning agent. Kaplan estimates that "at least 2/3 of the commissioning budget is highly dependent on factors beyond the commissioning agent's control. These factors include contractor performance, cooperation among the various commissioning team members, expanded construction schedules, design changes, expanded scope of testing, test repeats, and so forth …The discrepancy between expected and actual costs tends to be greatest when one or more members of the commissioning team are new or resistant to the commissioning process." Consequently, it is in the owner's best interest to set the tone and expectations for all participants from the start. Further, Kaplan emphasizes that "the owner must stay involved in the commissioning process no matter how long it takes to resolve all issues and deficiencies."

Finally, there is the question of the "price" of commissioning. Obviously, initial costs will vary depending on the extent to which the owner wants the commissioning agent involved in various aspects and phases of design, construction and completion. In terms of net costs, however, the title of an article by Carl Lawson in the January 1996 issue of the ASHRAE Journal answers this question succinctly: "The Price of Commissioning Equals Cost Savings." All owners and users want a building and systems that work. Commissioning helps ensure that they have this from the beginning of occupancy rather than after a period of three to five years of a piecemeal process trying to correct problems after designers and contractors are gone. It is much more efficient and much less costly for the original designers, manufacturers and installers to resolve the issues working with a competent commissioning agent, than it is for building occupants to suffer through an unhealthy or uncomfortable work environment with the associated disruptions and loss-of-productivity.

Seattle Energy Code Requirements for Completion and Commissioning

The Seattle Energy Code requirements for completion and commissioning are summarized below on a section-by-section basis with the actual energy code text following a summation. Complying with these code requirements may entail lengthy narrative text in the drawing notes which designers may wish to locate in the specifications. The drawings submitted with the permit application must, at a minimum, contain notes stating that the project will comply with the various Seattle Energy Code commissioning requirements in Sections 1416 and 1513.7. When necessary, the drawing notes may refer to specifications for further detail.

Appendix F contains sample text for acceptable notes and recommendations for note placement on drawings to be submitted with the permit applications.

1416.1 Mechanical Systems General Requirements

The general mechanical system requirements provide a list of items that must be addressed in a commissioning plan. Requirements are subdivided into "Simple Systems" and "Other Systems." Six elements are specified for "simple systems" (packaged equipment as listed in Section 1421 of the Energy Code, as well as systems in warehouses and semi-heated spaces). In addition to these requirements, "other systems" must also perform equipment functional performance testing and more-complete post construction documentation. Drawing notes must require commissioning and direct the creation of a project or systems manual.

1416.1 General. *Commissioning is a systematic process of verification and documentation that ensures that the selected building systems have been designed, installed, and function properly, efficiently, and can be maintained in accordance with the contract documents in order to satisfy the building owner's design intent and operational requirements. Drawing notes shall require commissioning and completion requirements in accordance with this section. Drawing notes may refer to specifications for further requirements.*

1416.1.1 Simple Mechanical Systems. *For simple mechanical systems, as defined in Section 1421, and for warehouses and semi-heated spaces, commissioning shall include, as a minimum:*

a. A Commissioning Plan,

b. System Testing and Balancing,

c. Controls Functional Performance Testing,

d. A Preliminary Commissioning Report,

e. Post Construction Documentation in the form of O&M and Record Drawing Review, and

f. A Final Commissioning Report.

1416.1.2 All Other Mechanical Systems. *For all other mechanical systems, commissioning shall include, as a minimum:*

a. A Commissioning Plan,

b. System Testing and Balancing,

c. Equipment Functional Performance Testing,

d. Controls Functional Performance Testing,

e. A Preliminary Commissioning Report,

f. Post Construction Documentation (all), and

g. A Final Commissioning Report.

1416.2 Commissioning Requirements

Contained within the Commissioning Requirements are the following categories: Commissioning Plan; Systems Balancing; Functional Performance Testing; Post-Construction Commissioning; and Commissioning Reports. Each of these is described below with the energy code text following the brief summation.

The general requirement is simply that the plan review drawings contain notes showing compliance with the commissioning requirements.

1416.2.1 General. *Drawing notes shall require commissioning in accordance with this section. Drawing notes may refer to specifications for further commissioning requirements.*

The next requirement is for a Commissioning Plan. The Commissioning Plan requires a narrative explanation of the design's goals, specific equipment and systems testing to be done, the environmental conditions that may impact the testing, and what constitutes acceptable performance. The plan further requires preparing preliminary and final reports to document the testing, conditions and results.

1416.2.2 Commissioning Plan. *The Plan shall require tests mandated by this section be performed and the results recorded. The Plan shall require preparation of preliminary and final reports of test procedures and results as described herein. At a minimum, the Plan shall identify the following for each test:*

a. A detailed explanation of the original design intent.

b. Equipment and systems to be tested, including the extent of tests,

c. Functions to be tested (for example calibration, economizer control, etc.),

d. Conditions under which the test shall be performed (for example winter and summer design conditions, full outside air, etc.), and

e. Measurable criteria for acceptable performance.

141.2.3 Systems Balancing

Systems Balancing requires that HVAC systems air and water flows are balanced to within 10% of the design intended rates, and it is the designer's responsibility to clearly state this requirement on the plans. The required balancing is to be done "in accordance with generally accepted engineering standards." Drawings should reference current standards of organizations such as the Associated Air Balance Council (AABC), National Environmental Balancing Bureau (NEBB), or ASHRAE. These organizations provide instrumentation, procedural and reporting guidelines. The owner must receive a written balance report.

1416.2.3.1 General. *Construction documents shall require that all HVAC systems be balanced in accordance with generally accepted engineering standards. Air and water flow rates shall be measured and adjusted to deliver final flow rates within 10% of design rates, except variable flow distribution systems need not be balanced upstream*

of the controlling device (for example, VAV box or control valve). Construction documents shall require a written balance report be provided to the owner. Drawing notes may refer to specifications for further systems balancing requirements.

1416.2.3.2 Air Systems Balancing. *Air systems shall be balanced in a manner to first minimize throttling losses then, for fans with system power of greater than 1 hp, fan speed shall be adjusted to meet design flow conditions.*

1416.2.3.3 Hydronic Systems Balancing: *Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions. Each hydronic system shall have either the ability to measure pressure across the pump, or test ports at each side of each pump.*

EXCEPTIONS:

1. *Pumps with pump motors of 10 hp or less.*
2. *When throttling results in no greater than 5% of the nameplate horsepower draw above that required if the impeller was trimmed.*

1416.2.4 Functional Performance Testing

Functional Performance Testing is to be done for equipment, for systems, and for controls. The testing ensures that each component is operating in a manner that achieves the designer's goals. The testing also ensures that maintenance access is protected and equipment is properly calibrated. The testing is required to address all modes of operation.

1416.2.4.1 General. *Drawing notes shall require commissioning in accordance with this section. Drawing notes may refer to specifications for further commissioning requirements.*

1416.2.4.2 Equipment/Systems Testing. *Functional Performance Testing shall demonstrate the correct installation and operation of each component, system, and system-to-system intertie relationship in accordance with approved plans and specifications. This demonstration is to prove the operation, function, and maintenance serviceability for each of the Commissioned systems. Testing shall include all modes of operation, including:*

a. *All modes as described in the Sequence of Operation,*
b. *Redundant or automatic back-up mode,*
c. *Performance of alarms, and*
d. *Mode of operation upon a loss of power and restored power.*

1416.2.4.3 Controls Testing: *HVAC control systems shall be tested to ensure that control devices, components, equipment and systems are calibrated, adjusted and operate in accordance with approved plans and specifications. Sequences of operation shall be functionally tested to ensure they operate in accordance with approved plans and specifications.*

1416.2.5 Post Construction Commissioning

Post construction commissioning covers the review and approval of the operation and maintenance manuals, the record drawings of actual installations, and the systems operational training for staff. Drawing notes should direct the creation of a project or systems manual. The manual contains a design intent narrative, an operating manual, a maintenance manual, contact information for local service organizations, and copies of approved submittal data and shop drawings. The design intent narrative, created by the design engineer and updated by the installing contractor, describes how each system is intended to operate, including suggested setpoints. The design intent narrative is an introduction to the operating manual. Organization of both the narrative and the manual should be parallel, and should be presented by logical system groupings instead of CSI (Construction Specification Institute) specification titles.

A general information section of the operating manual should describe the building and its function. The design intent narrative is an introduction to the operating manual. The operating manual lists design assumptions including indoor and outdoor design temperatures and internal loads. It contains general operating parameters such as air and water system setpoints and ventilation rates. The technical information section of the operating manual describes normal operating procedures, system interfaces with other equipment and systems, seasonal start-up and shut down of equipment and systems, change of operating modes, special and emergency procedures, and troubleshooting.

The maintenance manual addresses equipment inventory and maintenance program needs. The following should be included: descriptions of equipment; original purchase order number, date, vendor contact and warranty information; equipment function, capacity and performance data; recommended spare parts inventory; installation information; recommended

maintenance schedules and procedures; and contact information for local manufacturer-authorized service organizations. (The contact for services can be the same as the installer, but the information must be listed.) Copies of approved equipment submittals should also be included.

1416.2.5.2 Operation and Maintenance (O & M) Materials: *The O&M Materials shall be in accordance with industry accepted standards and shall include, at a minimum, the following:*

a. Submittal data stating equipment size and selected options for each piece of equipment requiring maintenance.

b. Operation and maintenance manuals for each piece of equipment requiring maintenance, except equipment not furnished as part of the project. Required routine maintenance actions shall be clearly identified.

c. Names and addresses of at least one service agency.

d. HVAC controls system maintenance and calibration information, including wiring diagrams, schematics, and control sequence descriptions. Desired or field determined set points shall be permanently recorded on control drawings at control devices, or, for digital control systems, in programming comments.

e. A complete written narrative of how each system and piece of equipment is intended to operate including:

i. A detailed explanation of the original design intent.

ii. The basis of design (how the design was selected to meet the design intent).

iii. A detailed explanation of how new equipment is to interface with existing equipment or systems (where applicable).

iv. Suggested control set points.

NOTE: Sequence of Operation is not acceptable as a narrative for this requirement.

Obtaining record drawings frustrates many owners. If completed at all, they often arrive too late to be useful as a learning and diagnostic tool for the O&M staff, and are frequently nothing more than re-stamped bid documents. The code requires timely delivery of these documents and defines minimum content. The intent of the code is to require drawing notes that call for the contractor to produce timely record drawings. Drawing notes also should direct the contractor to update equipment schedules to reflect make, model, performance data, and equipment nomenclature to match field labeling of actual installed equipment (in contrast to specified or basis of design equipment). Drawings should show accurate locations of equipment requiring maintenance, labeled with equipment nomenclature to match field labeling. This is particularly important for control system components such as sensors, valves, dampers, relays, and control boards and panels.

1416.2.5.3 Record Drawings: *Record drawings shall include, as a minimum, the location and performance data on each piece of equipment, general configuration of duct and pipe distribution system, including sizes, and the terminal air and water design flow rates of the actual installation.*

Maintenance staff training includes hands-on demonstrations of the installed equipment in addition to a review of the O&M materials and record drawings. An overview of the system, its equipment, and how it all interfaces together is important in order to continue to receive high quality output from the new system. The training reduces callbacks and tenant dissatisfaction by providing maintenance staff with the information needed to perform well.

1416.2.5.4 Systems Operational Training: *The training of the appropriate maintenance staff for each equipment type and or system shall include, as a minimum, the following:*

a. System/Equipment overview (what it is, what it does and which other systems and or equipment does it interface with).

b. Review of the available O&M materials.

c. Review of the Record Drawings on the subject system/equipment.

d. Hands-on demonstration of all normal maintenance procedures, normal operating modes, and all emergency shutdown and start-up procedures.

1416.2.6 Commissioning Reports

The preliminary and final commissioning reports are used to document the system and inform the owner of the results of the required commissioning tests. The preliminary report provides information on deficiencies found and the corrective measures that need to be made to bring the system up to the designer's intended performance. The preliminary report also

provides information on tests that could not be performed, the reasons for not testing, and the conditions necessary to perform the test at a future time. The final report provides information on the corrections made, testing results and a report of any tests deferred due to climate conditions not being suitable to test. The report should contain information about the climate conditions necessary for each deferred test.

1416.2.6.1 General. *Drawing notes shall require commissioning in accordance with this section. Drawing notes may refer to specifications for further commissioning requirements.*

1416.2.6.2 Preliminary Commissioning Report: *A preliminary report of commissioning test procedures and results shall be completed and provided to the Owner. The Preliminary Commissioning Report shall identify:*

a. Deficiencies found during testing required by this section which have not been corrected at the time of report preparation and the anticipated date of correction.

b. Deferred tests which cannot be performed at the time of report preparation due to climatic conditions.

c. Climatic conditions required for performance of the deferred tests, and the anticipated date of each deferred test.

1416.2.6.3 Final Commissioning Report: *A complete report of test procedures and results shall be prepared and filed with the Owner. The Final Commissioning Report shall identify:*

a. Results of all Functional Performance Tests.

b. Disposition of all deficiencies found during testing, including details of corrective measures used or proposed.

c. All Functional Performance Test procedures used during the commissioning process including measurable criteria for test acceptance, provided herein for repeatability.

EXCEPTION: Deferred tests which cannot be performed at the time of report preparation due to climatic conditions.

1416.3 Acceptance Requirements

The code contains acceptance requirements to ensure that the owner receives a building performing as it was designed. The commissioning report and the certificate of occupancy are related. At a minimum, the preliminary commissioning report must be completed prior to issuance of a certificate of occupancy.

1416.3.1 General. *Drawing notes shall require commissioning in accordance with this section. Drawing notes may refer to specifications for further commissioning requirements.*

1416.3.2 Acceptance: *Buildings or portions thereof, required by this Code to comply with this section, shall not be issued a final certificate of occupancy until such time that the building official determines that the preliminary commissioning report required by Section 1416.2.6.2 has been completed.*

Separate Seattle Fire Department Requirements: "Acceptance Testing" of Life Safety Systems

Seattle Fire Department requires “acceptance testing” of life safety systems. Proof of proper operation of the smoke control/exhaust system shall be subject to Seattle Fire Department approval before occupancy. To obtain Fire Department approval, a report prepared in accordance with Seattle Building Code section 909.18.8.3, shall be submitted to the Fire Department. Smoke control devices, equipment, components and sequences must be individually tested by an independent certificated third party. Information on certification can be found in Administrative Rule 9.01.04 on the Fire Department’s website at **www.seattle.gov/fire/FMO/firecode/adminRules.htm**. The report shall certify that the system has been fully tested and meets the requirements of this rule. Fire Department approval will be required before DPD will issue a certificate of occupancy.

1513.7 Lighting Control Commissioning

Lighting Commissioning requires that all lighting system controls be tested for functionality sequence of operation and for correct calibration of the equipment and sensors. Lighting control commissioning has a significant impact on energy consumption. Other aspects of lighting and motors addressed by this chapter of the code are less prone to functional deficiencies. Functions of the lighting control system to be functionally tested include: daylighting controls, occupant and daylight sensor calibration, adjustment and operation. A complete report of test procedures and results is to be filed with the owner.

1513.7 Commissioning Requirements: *For lighting controls which include daylight or occupant sensing automatic controls, automatic shut-off controls, occupancy sensors, or automatic time*

switches, the lighting controls shall be tested to ensure that control devices, components, equipment and systems are calibrated, adjusted and operate in accordance with approved plans and specifications. Sequences of operation shall be functionally tested to ensure they operate in accordance with approved plans and specifications. A complete report of test procedures and results shall be prepared and filed with the owner. Drawing notes shall require commissioning in accordance with this paragraph.

For Further Information

For projects within the Seattle city limits, further information on the Seattle Energy Code requirements is available online through DPD's Energy Code website at **www.seattle.gov/dpd/energy** and from the DPD Energy Code Technical Support Line at (206) 684-7846, available from 1:00-4:15 p.m., Monday-Friday.

Access to Information

Links to electronic versions of DPD **Client Assistance Memos (CAMs), codes**, and **forms** are available on the "Publications" and "Codes" pages of our website at **www.seattle.gov/dpd**. Paper copies of these documents are available from our Public Resource Center, located on the 20th floor of Seattle Municipal Tower at 700 Fifth Ave. in downtown Seattle, (206) 684-8467.

APPENDIX A

Essential Attributes of Building Commissioning

The 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) leads 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 who leads, plans, schedules and coordinates the commissioning team. 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. The CA shall develop and define the Owner's Project Requirements which includes information to properly plan, design, construct, operate and maintain the systems.
4. 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.
5. For each project, the commissioning purpose and scope are clearly defined in the CA contract.
6. The CA recommends the commissioning roles and scope for all members of the design and construction teams that are 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 that cover work to be commissioned, and
   e. The specifications for each system and component for which the suppliers' support is required.
7. Each project is commissioned in accordance with a written Commissioning Plan, which identifies the process and procedures for the Commissioning Process, and addresses the Owner's Project Requirements, the defined commissioning scope and budget. The commissioning plan:
   a. Provides a general description of the Commissioning Process activities including the systems to be commissioned,
   b. Is updated during the life of the project,
   c. Defines the scope of the commissioning process,
   d. Defines commissioning roles and responsibilities of the Commissioning Team,
   e. Documents the communication channels used throughout the project,
   f. Provides a schedule of activities including milestones,
   g. Provide verification procedures, and
   h. Provides quality based sampling procedures.
8. The CA reviews submittals, shop drawings, systems, assemblies and installation for commissioning-related

issues to achieve the Owner's Project Requirements throughout the project. The CA uses site visits to verify that the installed systems and procedures comply with the Owner's Project Requirements.

9. The CA will develop test verification procedures that define the means and methods for system and assembly verification to achieve the Owner's Project Requirements.
10. All commissioning activities and findings are documented as they occur. The Test Records shall indicate whether the observed results meet the expected results. These reports are distributed as they are generated, and are included in the final report.
11. The Test Procedure program objectively verifies that the building systems perform interactively in accordance with the Owner's Project Requirements. 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.
12. The commissioning authority provides constructive input for the resolution of system deficiencies or performance issues that are not in compliance with the Owner's Project Requirements.
13. Every commissioning project is documented with a Commissioning Process Progress Report that contains periodic status reports of the Commissioning Process and become a part of the Commissioning Process Record. The Commissioning Process Record includes:
    a. An evaluation of the operating condition of the systems at the time of test completion,
    b. Construction Checklist completion verification and summary results from the Issues Log (including the descriptions of issues and the measures that were taken to correct them and the uncorrected operational deficiencies that were accepted by the owner),
    c. Test Procedures and data,
    d. Commissioning Process Progress Reports,
    e. Deferred tests, the pre-requisite conditions and the estimated schedule for the tests,
    f. Lessons learned,
    g. Continuous Commissioning Process Plan, and
    h. Recommissioning Process Plan.

Source: Building Commissioning Association website ***www.bcxa.org/about/attributes.shtm***
Document Revision Date: April 2005, Page last modified: September 27, 2005

APPENDIX B

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 criteria. In order to accomplish this, the 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 & 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 systems' performance and addressing related issues.

Source Contact Information
Building Commissioning Association
1400 SW 5th Avenue, Suite 700
Portland, OR 97201
Phone: 877-666-BCXA (877-666-2292) Email: ***info@bcxa.org***

APPENDIX C

Commissioning Resources

There are many resources available to provide guidance on commissioning.

Portland Energy Conservation Inc. (PECI, 1400 SW Fifth Ave, Suite 700, Portland, OR 97201 phone: 503-248-4636; fax: 503-295-0820; e-mail: **peci@peci.org**; website: **www.peci.org**)

PECI has been the organizer for the National Conferences on Building Commissioning and is known as one of the leaders in the field. In addition to conference proceedings, the PECI website references many useful documents and provides links to documents that can be downloaded. The website resource library (**www.peci.org/library.htm**) has numerous documents available in the following categories:

- Commissioning Resources
- O&M Best Practices Series
- Overviews and Case Studies
- Procedural Guidelines
- Staff Papers
- Useful Engineering Links
- Organizations
- Links

Some of these materials have been reviewed and are listed in the sections below.

The Oregon Department of Energy (503-378-4040) at the Conservation Division's website **http://oregon.gov/ENERGY/CONS/constech.shtml** you can link to the commissioning section and find:

- Resources
- A large number of Oregon case studies and reports
- Links and Regional Contacts

Other resources include past issues of the ASHRAE Journal and ASHRAE Transactions (peer-reviewed papers) which have published numerous articles and papers on various aspects of commissioning. (Available from: **ASHRAE**, 1791 Tullie Circle NE, Atlanta, GA 30329 at 800-527-4723, **www.ashrae.org**).

Articles are also available from the **U.S. Department of Energy**, Energy Efficiency and Renewable Energy division online at **www.eere.energy.gov/EE/buildings.html**.

Overviews and Case Studies

Calibration & Commissioning: Tips for Daylighting, Building Technologies Program, Lawrence Berkeley National Laboratory, ©1997. Section 9 on page one, states that "Commissioning ensures that all lighting control systems function as close to design intent as possible after installation and before occupancy."
http://btech.lbl.gov/pub/designguide/copyright.html

Building Commission Association *Retrocommissioning Webcast*
"On December 13, 2005 the BCA, with support from BetterBricks and HPAC Engineering, sponsored a webcast titled Retrocommissioning: Is this the next "big thing" in the building industry? The goal of the webcast is to educate the buildings industry on what retrocommissioning is and who the stakeholders are, and to present both the costs and benefits. Use the link below to register and download the webcast."
www.bcxa.org/resources/index.shtm

The Building Commissioning Handbook, Second Edition, 404 pages, Authors: John A. Heinz and Rick Casault "This popular handbook has been revised by the original authors to include the most up-to-date information on all aspects of building commissioning. This is your guide to: Staying on Budget; Improving the Quality of your Buildings; Meeting your Schedule; Increasing Energy Efficiency. Chapters outline the commissioning process from pre-design to occupancy and explain the economics of commissioning and retrocommissioning."
www.bcxa.org/resources/index.shtm

White Paper: Commissioning for Great Buildings, Building Commissioning Association (BCA), February 2005
Page One: "Owners are exasperated and occupants are dissatisfied, budgets are constantly overrun and schedules are frequently severely compressed. For owners, O&M costs are high and, combined with high energy costs, represent a constant cash drain on the bottom line. What can we do to make buildings work better? Unfortunately, there is no one-size-fits-all solution. What's needed is a quality assurance process custom-made for each building and its unique problems. Commissioning does just that."
www.bcxa.org/resources/index.shtm

Functional Testing Guide: from the Fundamentals to the Field, Portland Energy Conservation, Inc. (PECI)
Page one: "As building systems grow increasingly complex and have tighter construction schedules, designers and commissioning providers need practical tools to help ensure efficiency and performance."
www.peci.org/ftguide/index.htm

Establishing Commissioning Costs, Portland Energy Conservation, Inc. (PECI) revised 02/14/2002.
Page one: The document summarizes "information on commissioning costs taking into account costing studies PECI has completed in-house reconciling our costing models and experience with Ron Wilkinson's ASHRAE Journal, February 2000 article."
www.peci.org/library/PECI_NewConCx1_1002.pdf

Commissioning of Smaller Green Buildings – Expectations vs. Reality, Portland Energy Conservation, Inc. (PECI) This paper contains graphs and charts.
Page one: "The paper reviews the authors' research on the costs, scope, and problems associated with commissioning LEED™ buildings under 60,000 square feet. The authors examine the most common conflicts and their causes. Topics discussed include the perceived and higher costs of commissioning small LEED™ buildings and the role of the commissioning agent in the LEED™ process. The paper also discusses various strategies for commissioning smaller LEED™ projects."
www.peci.org/library/PECI_SmallGreenCx1_1002.pdf

Retrocommissioning's Greatest Hits, Portland Energy Conservation, Inc. (PECI)
Page one: "This paper highlights key findings from several of PECI's retrocommissioning projects that have produces significant benefits for low costs. The RCX measures are described along with the estimated savings, simple paybacks, and related benefits." "The 15 individual energy-saving measures selected for discussion in this paper are based on their ease of implementation and simple payback of one year or less." This paper includes equations used in the calculation of energy savings.
www.peci.org/library/PECI_RCxHits1_1002.pdf

Investigation of the Persistence of New Buildings, California Energy Commission, Public Interest Energy Research Program, 2002.
Page twelve: "The success and cost-effectiveness of commissioning depends on how long the benefits persist. Without a good understanding of how to improve persistence, many benefits of commissioning will be lost. Bridging the gap between new building commissioning and day-to-day operations is a challenge that should continue to be addressed by the commissioning industry."
http://btech.lbl.gov/papers/51068.pdf

Evaluation of Persistence of Savings from SMUD Retrocommissioning Program – Final Report, California Energy Commission, Public Interest Energy Research Program, May 2004.
Excerpt from Executive Summary, page ii: "The Report is organized in five sections. The Introduction describes retrocommissioning background, persistence of savings issues and previous related work. The Methodology section provides an overview of the data analysis procedures. The Results and Discussion sections highlight and interpret key findings. The Summary Section provides conclusions and recommendations.
http://btech.lbl.gov/papers/54984.pdf

Building Commissioning Best Design Practices, Rebuild America Clearinghouse, U. S. Department of Energy, August 1, 2002
"This chapter of the National Best Practices Manual for High Performance Schools outlines the basics for building commissioning. Commissioning can optimize the energy efficient design features and improve overall school building performance. This chapter defines commissioning, outlines project responsibilities for commissioning,

defines the various phases of commissioning, and provides the benefits and costs of building commissioning."
www.rebuild.gov/lawson/newconstruction.asp

Building Commissioning: The Key to Quality Assurance, USDOE Rebuild America / PECI, 1998.
Pages 10 & 12: "The process of commissioning should not be confused with testing, adjusting, and balancing (TAB), the measurement of building air and water flows. The commissioning process, which is much broader in scope, involves functional testing and system diagnostics. Diagnostics and functional testing of equipment and systems helps determine how well building systems are working together. It also helps determine whether the equipment meets operational goals or needs to be adjusted to increase efficiency and effectiveness. A thorough commissioning effort results in fewer installation callbacks, long-term tenant satisfaction, lower energy bills, avoided equipment replacement costs, and an increased profit margin for building owners."
www.peci.org/library

Commissioning For Better Buildings in Oregon, Oregon Office of Energy, go to Conservation Division–Commissioning, prepared by PECI, 1997.
Page five: "Your building is an investment. Poor performance means you may be losing money … Building commissioning can restore an existing building to high productivity. It can ensure that a new building begins its life cycle at optimal productivity and improves the likelihood that the building will maintain this level of performance."
http://oregon.gov/ENERGY

What Commissioning Can Do For Your Building? PECI, 1997.
This colorful, informative brochure is designed to help commissioning providers sell their services to owners and is derived from a database of 175 case studies of commissioning of new construction, equipment replacements and upgrades in existing facilities, and "tune-up" work for existing facilities. This document presents the costs and benefits demonstrated by these case studies. 12 pp. Text not available on the web. (503) 248-4636.

Commissioning Four New Science Laboratory Buildings (U. of WA), Bonneville Power Admin./ Phoebe Caner Warren, 1997.
Commissioning case studies with detailed "lessons learned" information in all sections. ~70 pages. Text not available on the web. For print copies call (800) 622-4520.

Commissioning the Physics/Astronomy Building Control System (U. of WA), Bonneville Power/ Phoebe Caner Warren (currently with Seattle City Light), 1996.
Commissioning case study and report with lessons learned. ~110 pages. Text not available on the web. For print copies call (800) 622-4520.

APPENDIX D

Resource Library

PECI's Resource Library provides guides for commissioning. "The PECI Resource Library provides easy access to papers and helpful documents created by PECI staff. In addition, PECI offers selected links to other organizations, magazines, engineering links, and information. Please visit the California Commissioning Collaborative's *Online Commissioning Library* for a comprehensive library of resources."
www.peci.org/library.htm

Commissioning Resources

Proceedings of the National Conference on Building Commissioning
www.peci.org/ncbc/proceedings/index.htm

*Model Commissioning Plan and Guide Specifications (v2.05)**
www.peci.org/library/mcpgs.htm

Practical Guide for Commissioning Existing Buildings, Tudi Haasl and Terry Sharp, 1999
http://eber.ed.ornl.gov/commercialproducts/RetroCommissioningGuide-w-cover.pdf

Functional Testing Guide and Control Systems Design Guide (Updated June 2005)
www.peci.org/ftguide/index.htm

Building Commissioning: The Key to Quality Assurance (PDF 1.0MB)
US Department of Energy Rebuild America Guide Series: USDOE Rebuild America / PECI., 1998. Commissioning retrofits and existing buildings: overview, process and case studies. 68 pp.
www.peci.org/library/PECI_BldgCxQA1_0500.pdf

New Construction Commissioning Costs PECI 2002 (PDF 144KB)
www.peci.org/library/PECI_NewConCx1_1002.pdf

Establishing Cx Fees, Ronald J. Wilkinson, P.E. , ASHRAE Journal, February 2000 (available at ASHRAE online bookstore)
http://membership.ashrae.org/template/JournalLanding

Using the Commissioning Toolset, HPAC editorial, September 2003 (PDF 42KB)
www.peci.org/library/PECI_UsingCxToolset_0204.pdf

National Strategy for Building Commissioning (PDF 101KB)
www.peci.org/library/PECI_NatlStratBldgCx_2004.pdf

** Sample text from Model Commissioning Plan and Guide Specifications*

Overview
The Model Commissioning Plan and Guide Specifications details the commissioning process for new equipment during both the design and construction phases for larger projects. Going beyond commissioning guidelines, the document provides boilerplate language, content, format and forms for specifying and executing commissioning. The document generally builds upon The HVAC Commissioning Process, ASHRAE Guideline 1, 1996, with significant additional detail, clarification and interpretation added. The document contains four parts, totaling over 500 pages:

Part I. Commissioning Requirements - Design Phase
Commissioning requirements of the design team, including a full solicitation for commissioning services using either a negotiated or fixed-fee basis.

Part II. Model Commissioning Plan - Design Phase
Detailed commissioning boilerplate plan for commissioning during design, including design intent and basis of design format for 15 system types.

Part III. Commissioning Guide Specifications
Comprehensive guide specifications by specification section, covering protocols, procedures, and responsibilities of all parties. Includes complete specification language for Divisions 1, 15, 16 and 17. This part includes testing requirements for 15 system types. Also included are detailed prefunctional checklists for 20 types of equipment and example functional test procedures for 30 system types.

Part IV. Model Commissioning Plan - Construction Phase
Modular boilerplate commissioning plan with 30 representative forms to facilitate the commissioning process.

O&M Best Practices Series

Fifteen O&M Best Practices: For Energy-Efficient Buildings (pdf 1.1MB)
An overview of 15 O&M best practices that building owners and managers can employ to make their buildings more energy-efficient. These best practices are divided into four major categories: management, teamwork, resources, and energy-efficient.
www.peci.org/library/PECI_15BestOM_0302.pdf

Tuned Up for Success (pdf 1.6MB)
A brochure that summarizes the processes and results of the five commercial and retail facilities that participated in the Building Tune-Up Demonstration Project conducted by U.S. EPA and U.S. DOE. (8 pages)
www.peci.org/library/PECI_TunedUp1_0302.pdf

Operation and Maintenance Service Contracts: Guidelines for Obtaining Best-Practice Contracts for Commercial Buildings (pdf 2.4MB)
Frequently, building owners and managers outsource most if not all of the O&M services for their building systems. This publication provides an overview of current outsourcing trends and options, with guidelines for obtaining and managing good.
www.peci.org/library/PECI_Contracts_0302.pdf

Portable Dataloggers: Diagnostic Monitoring Tools for Energy-Efficient Building Operation (pdf 1.0MB)
A review of the benefits of using portable dataloggers and criteria for selecting data loggers.
www.peci.org/library/PECI_DxMonitoring1_0302.pdf

Operation and Maintenance Assessments: Best Practices for Energy-Efficient Building Operation (pdf 1.7MB)
Significant low-cost savings in energy and staff time as well as other non-energy benefits can be realized through operation assessments and building tune-ups. The guide provides information on how to plan and orchestrate the process, when out.
www.peci.org/library/PECI_EEOp1_0302.pdf

Energy Management Systems: A Practical Guide (pdf 4.4MB)
A guidebook covering the following topics: evaluating an existing EMS; specifying and selecting a new EMS; commissioning new EMS; service contracts for EMS; strategies for optimizations; using EMS for operational diagnostics; non-energy control applications; sample control specification language; and using spreadsheets for graphing and analyzing trend data.
www.peci.org/library/PECI_PracticalGuide1_0302.pdf

Putting the "O" Back in O&M Best Practices in Preventive Operations, Tracking, and Scheduling (pdf 644KB)
This document addresses continual schedule optimization and provides staff with methods to assess day-to-day operation of major plant equipment. The document will also emphasizes enhancing O&M plans to give equal weight to operational issues.
www.peci.org/library/PECI_OBackinOM.pdf

Source information: PECI website, ***www.peci.org***

APPENDIX E

Additional Commissioning Resources

Seattle City Light
"Seattle City Light supports commissioning through educational materials, links to qualified commissioning professionals, and financial incentives." Forms can be found in the Building Commissioning Assistance Handbook, Appendix A are posted for your information and use.
www.seattle.gov/light/conserve/business/BdgComA/cv6_bccs.htm

Building Commissioning Association
Professional association promotes building commissioning practices that maintain high professional standards, and fulfill building owners' expectations. Several documents are available.
www.bcxa.org

Commissioning Specialists Association of Great Britain
Information on the association's purpose and services
www.csa.org.uk

Florida Design Initiative
Ongoing articles & forum
http://sustainable.state.fl.us/fdi/edesign/resource/totalbcx

National Environmental Balancing Bureau
Cite information includes certification program and manuals. Use site map to find commissioning on NEBB site.
www.nebb.org

Oak Ridge National Laboratory: Building Technology Center
A Practical Guide for Commissioning Existing Buildings by PECI and ORNL
www.ornl.gov/~webworks/cppr/y2001/rpt/101847.pdf

Oregon Office of Energy
Benefits of Commissioning, case study, tool kit of new and existing commissioning application materials and the full text of Commissioning for Better Buildings in Oregon
http://oregon.gov/ENERGY/CONS/constech.shtml

Portland Energy Conservation, Inc. (PECI)
PECI produces the National Conference on Building Commissioning, and has a comprehensive online resource library.
www.peci.org

Texas A&M Energy Systems Lab
Retro-commissioning process information and software for sale
www.esl.tamu.edu

University of Washington
University commissioning guide specifications
www.depts.washington.edu/fsesweb/fdi/fdi.html

APPENDIX F

Required Drawing Text

Complying with the Seattle Energy Code completion and commissioning requirements of Sections 1416 and 1513.7 may entail a lengthy text insertion on the plans. Designers may wish to locate detailed text in the specifications. The drawings submitted with the permit application must, at a minimum, contain notes indicating that the project will comply with the various Seattle Energy Code requirements in Sections 1416 and 1513.7.

- If the application is for a combined building and mechanical permit, it is recommended that the following notes with the mechanical commissioning requirements be placed on sheet M-1 or the first available M sheet.
- If the application is for a mechanical permit only, it is recommended that the notes with the mechanical commissioning requirements be placed on the cover sheet or sheet M-1.
- If the application is for a building permit (with or without mechanical), it is recommended that the notes with the lighting control commissioning requirements be placed on sheet E-1 or, if no E sheet, then on the reflected ceiling plan of the A sheets.
- If the application is for an electrical permit, it is recommended that the notes with the lighting control commissioning requirements be placed on the first lighting sheet.

The following sample notes are considered adequate to comply with the completion and commissioning requirement for mechanical systems and for lighting controls when placed on the drawings by the designer. When further detail is placed in the specifications, please make reference in the plan notes that "additional detail may be found in the specifications."

Mechanical Commissioning and Completion Notation on Drawings

"Commissioning shall address all the features listed in Seattle Energy Code (SEC) Section 1416.1. The commissioning plan shall comply with SEC Section 1416.2.2."

"All HVAC systems shall be balanced and a written balance report shall be provided to the owner per SEC Section 1416.2.3."

"Functional performance testing for equipment, systems and controls shall be done in accordance with SEC Section 1416.2.4."

"An operating manual and maintenance manual and record drawings shall be provided to the building owner per SEC Section 1416.2.5."

"A preliminary commissioning report of test procedures and results shall be prepared prior to issuance of a final certificate of occupancy per SEC Section 1416.3.2; and a complete final commissioning report of test procedures and results shall be filed with the owner per SEC Section 1416.2.6.3."

For warehouses, semi-heated spaces, and simple systems (as defined in SEC Section 1420): "HVAC control systems shall be tested, calibrated and adjusted, sequences of operations shall be tested to ensure that they operate in accord with specifications and approved plans, and a complete report of test procedures and results shall be filed with the owner per SEC Section 1416.2.3."

For all other systems: "VAC control systems shall be tested, calibrated and adjusted, sequences of operation shall be tested to ensure that they operate in accordance with specifications and approved plans per SEC Section 1416.2.3. The necessary tests shall be identified per SEC Section 1416.2.4. A preliminary commissioning report of test procedures and results shall be prepared prior to issuance of a final certificate of occupancy per SEC Sections 1416.2.3 and 1416.3.2. A complete and final commissioning report of test procedures and results shall be filed with the owner per SEC Section 1416.2.6."

Lighting Controls Commissioning Notation on Drawings

"For lighting controls that include daylight or occupant sensing automatic controls, automatic shut-off controls, occupancy sensors, or automatic time switches: the lighting controls shall be tested, calibrated and adjusted, sequences of operation shall be tested to ensure that they operate in accord with specifications and approved plans, and a complete report of test procedures and results shall be filed with the owner in accordance with Seattle Energy Code Section 1513.7."