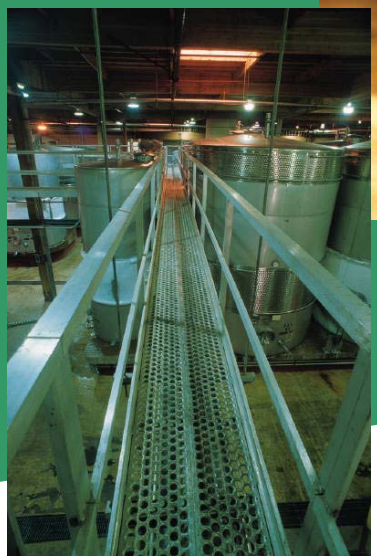

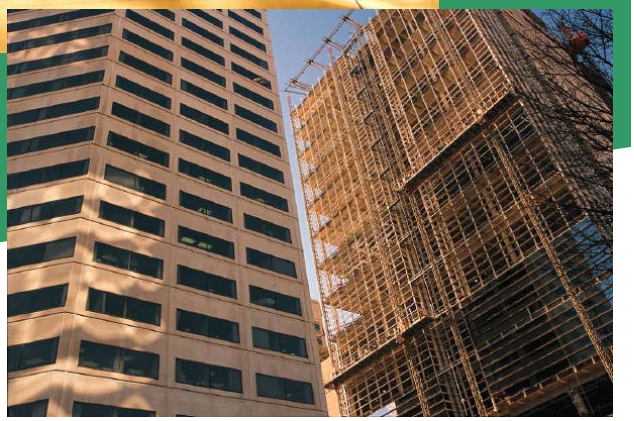

Building Commissioning

Recommended Guidelines

A Guideline for Building Better Buildings

Second Edition 2012

The National Association of State Facilities Administrators

Building Commissioning – Recommended Guidelines, 2nd edition

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About NASFA

The National Association of State Facilities Administrators (NASFA) is a professional organization whose mission is to provide leadership in the development and implementation of state facility administration practices. NASFA membership is composed of facilities professional from all 50 states, the District of Columbia and the U.S. territories. These professionals are responsible for the planning development, operations and maintenance of state facilities, including hospitals, prisons, parks, and colleges and universities. As a non-profit organization founded in 1987, NASFA has greatly expanded its activities and services to include a national conference and trade show, regular publications and several standing committees. NASFA is an affiliate organization of The Council of State Governments (CSG).

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Table of Contents

Page

A. Preface 1

B. Executive Summary 2

C. What is Commissioning? 4

D. Why Should I Commission My Building? 7

E. When to Commission? 9

F. Budgeting for Commissioning 11

G. Commissioning Delivery Methods 12

H. Selecting the Commissioning Authority 20

I. Defining the Scope of Work—The Owner's Commissioning Procedure 23

J. The Commissioning Process Step-by-Step 26

K. Commissioning Existing Buildings 31

L. Glossary of Terms 35

M. List of Acronyms 38

N. References 40

Appendix I Sample Procurement Documents for Cx Services
1. Commissioning Services Advertisement ..... I - 1
2. RFQ – Low Criticality Project ..... I - 2
3. RFQ – On-Call Commissioning Services ..... I - 6
4. RFQ – Building Enclosure Commissioning Services ..... I - 8
5. Scope of Work – Building Enclosure Commissioning Services ..... I - 13
6. Commissioning Authority Task List ..... I - 15

Appendix II Guidance for the Commissioning Process ..... II - 1

Appendix III Typical Building Systems and Components ..... III - 1

Appendix IV Owners' Project Requirements ..... IV - 1
1. Example Abbreviated OPR – Draft Template ..... IV - 3
2. Example OPR Template – Office, Condo & Retail Tower Project ..... IV - 5
3. Example OPR – University Laboratory Renovation & Addition ..... IV - 38

Appendix V Basis of Design Document ..... V - 1

Appendix VI Commissioning Process, Step by Step ..... VI – 1

A. Preface

This second edition of NASFA's Building Commissioning Recommended Guidelines recognizes the ongoing development of the commissioning (Cx) industry and incorporates best practices and enhancements since the 1st (2003) edition. These guidelines are intended to assist agencies during their development or implementation of the Cx process. It continues to be a "work in progress" by NASFA's Commissioning Subcommittee. This document is the product of several months of discussion and consideration by the parties listed below and is being made available to the membership. As technology advances and the Cx process matures, or as standards and guidelines are updated by professional and technical organizations, changes to the guidelines will be necessary. Any comments or suggestions on how to improve this document to make it easier to understand and use would be greatly appreciated.

Acknowledgements:

NASFA and the Commissioning Subcommittee wish to take this opportunity to express our sincere appreciation to our industry partners and those state employees who donated their time and effort to the development and production of the 2nd edition of these documents. Without their assistance, not only would the quality of this document have suffered, it would not have existed at all. We also thank those who worked on the 1st edition that set a path for this subcommittee to follow. We especially thank those states who shared their best practices and documents to be used in this 2nd edition… true to the values of NASFA.

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B. Executive Summary

Commissioning (Cx) is a planned, collaborative, and systematic process of review and testing conducted to confirm that a facility (building) and its subsystems perform as designed and as expected by the building occupant. In most cases this process occurs during the entire project, from planning and predesign through final acceptance and post occupancy of the building. Commissioning has been shown to improve building quality in thousands of major projects nationwide.

Commissioning has evolved from commissioning of new construction into other specialized applications:

- Re-Commissioning – Reapplication of the commissioning process to a facility that was previously commissioned.
- Retro-Commissioning – Commissioning of an existing facility that has been constructed, occupied and placed in operation.
- On-going Commissioning – Monitoring the building systems performance and implementing appropriate corrective actions for efficient operation of the building over time.
- Building Enclosure Commissioning – Application of the commissioning process to the building exterior enclosure systems and components.

Commissioning is not a “one-size fits-all” proposition. Thus, this document offers discussion, guidance and examples on the various approaches and applications. The appendices include a number of examples and templates from NASFA members. Each state will have statutes, rules and regulations that may further guide and/or complement the appropriate approach and application for your project. The references and resources include links to additional information and best practices for the commissioning process. This guideline is intended to assist you in selecting and implementing the best approach and process for your specific project.

An independently contracted consultant in private practice known as the Commissioning Authority (CxA) typically coordinates and oversees the Cx process. This firm is chosen using qualifications based selection process in a manner similar to selecting consulting engineers and architects. Other Cx delivery methods exist. Commissioning services can be provided by an in-house staff of Cx specialists, by the architectural and engineering design team, by the contractor, or by some combination of the above.

In awarding Cx projects to CxA firms, one should look for a staff including both professional engineers and experienced technicians. One should also expect Cx service providers to participate in the national Cx community through conferences and continuing education, and to be a part of national peer organizations.

The building systems selected and the level of rigor to be included in the commissioning process is a function of the building type, the Owner’s Project Requirements and the available budget for the project. In the majority of cases, Cx is recommended for at least the mechanical, life safety, and electrical systems of new buildings. Independent third party Cx should be performed on new building projects with a construction cost of approximately $2.5 million or more and for system retrofits costing approximately $800,000 or more. This appears to give the best value for the dollar considering climate and the types of buildings constructed. For smaller projects less objective parties like the contractor or the design team may be appropriate to coordinate and perform the commissioning tasks. In some regions of the country with harsher climates and/or in response to new codes and standards the building enclosure is often a part of the Cx process. Having flexibility in selection of systems, the level of rigor, and commissioning delivery method most appropriate for the specific building will provide the best value for the Cx dollar.

Traditional Factors Supporting the Need for Building Commissioning
► Unclear design intent
► Complex building systems
► Unclear standards and criteria for gauging systems
► Lack of functional performance testing
► Conflicts between drawings/specifications and applicable codes
► Inadequate system documentation
► Maintainability and equipment accessibility problems
► Inadequate provisions for maintenance
► Inadequate Operation & Maintenance (O&M) manuals
► Inadequate O&M training
► Numerous changes orders and cost overruns
Source: GSA Building Commissioning Guide, 1997

Agencies should anticipate fees of 1.25 percent to 2.25 percent of the new building construction cost as payment to the CxA for total building Cx. If agencies choose to commission only select systems, then the recommendation is to budget an average of 2.5 percent of the system component construction cost for Cx of that system. These fees are exclusive of travel, videotaping, testing-adjusting and balancing (TAB) work, and extra certifications beyond occupancy.

While cost of Cx constitutes only a very small part of the cost of the initial construction process, it has been shown to be a significant contributor to the economical construction, operations and maintenance of the facility for years to come.

C. What Is Commissioning?

It is generally agreed that commissioning (Cx) is a quality assurance process. However, there is not a "black and white" definition to describe or explain Cx. The following explanation and definitions are adapted from a report completed by the Lawrence Berkeley National Laboratory for the California Energy Commission and can be found on the California Commissioning Collaborative website (www.cacx.org).

The term Cx comes from shipbuilding. A commissioned ship is one deemed ready for service. Before being awarded this title, however, a ship must pass several milestones. Equipment is installed and tested, problems are identified and corrected, and the prospective crew is extensively trained. A commissioned ship is one whose material, systems, and staff have successfully completed a thorough quality assurance process.

> Commissioning – An intensive quality assurance process that begins ideally prior to design and continues through construction, occupancy, and operations. Cx ensures that the design meets the owner's project requirements and that the constructed building operates initially as the owner intended and that building staff are prepared to operate and maintain its systems and equipment.
>
> Re-commissioning – A type of Cx that occurs when an existing building that has already been commissioned undergoes another Cx process. The decision to re-commission may be triggered by a change in building use or ownership, the onset of operational problems, or some other need.
>
> Retro-commissioning – The application of the Cx process to existing buildings (also referred to as "Existing Building Commissioning or EBCx"). Retro-commissioning is a process that seeks to improve how building equipment and systems function together. Depending on the age of the building, retro-commissioning can often resolve problems that occurred during design or construction, or address problems that have developed throughout the building's life.
>
> On-going commissioning – An ongoing monitoring/adjusting process to ensure building systems remain operating optimally to provide the desired environmental control, occupant comfort, and energy efficiency over time. This process may be applied to a facility that may, or may not, have been commissioned previously.
>
> Building Enclosure Commissioning – The application of the Cx process to the exterior enclosure systems of the building to address the enclosure's performance to control air, vapor, heat, light, noise, as well as security, structural performance, constructability, durability, sustainability and maintainability.

Cx is *planned*. Benefits from Cx can be achieved no matter when the process starts, but the earlier one begins the process of Cx, the greater the potential benefit. Maximum benefit will be achieved when Cx is a part of the project from the very start, ideally the predesign phase of the project. Furthermore, Cx must be *integrated* into the project. This means that Cx, the integrated approach, takes place at every stage of the project: predesign, design, construction, acceptance, and post occupancy (warranty).

The factors of *planning* and *integration* are two key points that set Cx apart from traditional construction quality assurance processes. There are several entities providing Cx training and even certification. Two examples are the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)[1], a leader in HVAC issues who offers a course that is very

[1]ASHRAE can be contacted in Atlanta, GA at 404-636-8400. The ASHRAE web site can be accessed at www.ASHRAE.org.

helpful in getting acquainted with Cx for mechanical systems and the Building Commissioning Association (BC_xA)[2] which provides training and certification for Cx authorities.

Early approaches to Cx did not stress the integrated approach. Recently, the trend in Cx has become more of a Building or Total Systems Commissioning approach instead of the traditional HVAC or component Cx. The modern Cx process may include electrical systems, specialty systems such as IT, security and lighting controls, as well as Cx of building envelope systems.

Planned and Integrated Commissioning Is Vital

Using Cx during the design phase does not significantly change the way the design firm does business. What it does do is provide them additional information they need to do their job and requires that they document all assumptions, operational intent and submit quality design products.

Each design option developed by the design team must be linked back to the design intent which should be documented in an Owner's Project Requirements (OPR) document and/or the Basis of Design (BOD) document. When a specific design intent cannot be met, then this should be identified and the reason given to why it cannot be met. The project team then evaluates the design options on their ability to meet the design intent as a whole. Tradeoffs are made and the design intent is updated to reflect the decisions made. All decisions and reasoning behind design changes should be well documented.

The process of selecting each design option is iterative in that the designers are working as part of the project team to hone the shape, size and type of facility and components to meet the design intent. Sufficient time must be spent during this step to ensure all questions and concerns have been addressed and agreed to by the project team. Mistakes that are made but not caught during this step have repercussions throughout the life of the facility.

The implementation of Cx during the design phase is important for several reasons:

- The Commissioning Authority (CxA) can introduce all members of the design and construction teams to the process early. This avoids exposing team members to unexpected reviews and service requirements during the course of the project.
- The CxA should confirm that the design intent is complete during the predesign phase. The design intent document (formally referred to as the Owner's Project Requirements or OPR) is described in more detail later in this paper. If not complete, the CxA should assist in the development of the initial design intent document (e.g. OPR) that will be turned over to the A/E team so the BOD can be developed.
- The CxA checks the construction plans and specifications during the design phase to confirm that the documents include sufficient detail, such as sequences of operation, start-up and training requirements. They also check for sufficient equipment access to accommodate maintenance and repair operations.
- The CxA typically provides Cx specifications which include the requirements for Cx that ensures the contractor is aware of his responsibilities prior to submitting a bid.
- The CxA presence at pre-bid and pre-construction conferences further acquaints contractor personnel with the Cx process and draws the contractor(s) into the project team.
- CxA presence at any Value Engineering (VE) meetings is recommended, so they can address any operational affects resulting from VE items.
- While the designer is typically responsible for production of the BOD, the CxA contributes to its production in several ways. First, the CxA must be able to explain the OPR design intent. If the CxA is responsible for compiling the BOD, they must be able to explain its format and contents to the designers so that they understand what is needed from them.

[2] BCA can be contacted in Portland, OR at 877-666-229. The BCA web site can be accessed at www.bcxa.org

Once the designers begin submitting their BOD information, the CxA must review the information to verify that it follows the OPR, is a quality effort and to help reduce the occurrence of omissions. Next, as a part of the design review, the CxA must also compare the provided BOD information with the owner's design intent, as documented in the OPR, to verify that the design satisfies the owner's requirements.

- The CxA will document any OPR changes, and possibly BOD changes, and identify them to the design team so that the design team can insure coordination of drawings and specifications.
- The CxA can aid the designers by supplying a sample BOD format for guidance, which is likely to be very valuable to designers.

Commissioning Is *Collaborative, Systematic,* and *Documented*

Cx is *collaborative*. It is a team process from the very beginning and involves not only the CxA, but also the owner or end users and their representatives, the designers, and all contractors. *One of the most important responsibilities of the CxA is fostering cooperation and team formation and the development of a communications protocol.* The experienced Cx professional verifies that quality is included in the project from start to finish by creating a heightened respect for quality within the team. To be sure, there is a certain amount of error identification, both in design and construction. But in the main, quality is built in, not inspected in.

Cx is *systematic*. Cx includes testing all scope items in all modes of operation defined by the design documents. Equipment is first observed in a static condition to assure the correct components were installed per approved submittals, and can be maintained and operated as intended. Moving equipment is then started up by the installing contractors and equipment suppliers (and electrical equipment receives NETA$_{TM}$-type testing, and is then energized) for the first time under controlled conditions. After equipment is started up, systems of equipment are tested by the CxA, running together to demonstrate that the system as a whole will operate as required. Depending upon the project, the CxA may test the combined building systems for correct interaction (**integrated systems testing)**. For example, does the building automation system (BAS) respond correctly to loss and restoration of utility power and operation while on a generator? Does the BAS correctly manipulate mechanical and access control systems during a fire alarm?

Systematic refers to the Cx building blocks of inspection, start-up, and testing. It also refers to the “systems” nature of modern buildings. The Cx process is organized by system components (i.e., air handling units, pumps, boilers, chillers, water treatment, fire alarms, smoke evacuation, door locks, roofs, walls). Grouping the building into sub-systems makes it easier to understand how the building works and provides a framework for Cx.

Cx is *documented.* Confidence in the Cx outcome cannot be provided to the Owner without adequate documentation. The value of Cx remains long after the building is accepted and turned over to the Operations and Maintenance (O&M) staff. In the course of Cx, key parameters of the systems are documented, organized and preserved in the Cx report. Not the least of these items is the OPR. Based on the original scope of work the Cx report may record the intended use of the building and its various spaces so that if personnel change, O&M staff will be able to understand why things work the way they do. It also provides a baseline of system data and testing procedures which can be reused in the future, allowing ongoing evaluation of systems response.

The review and approval of the O&M manual and the organization of the training program are also frequently assigned to the CxA. This further insures that the tools required for future correct building operation are provided to the operational staff by the completion of the project.

D. Why Should I Commission My Building?

Commissioning (Cx) is both necessary and beneficial for the following reasons:

Why Is Commissioning Necessary?

- *Systems and equipment that are not installed and operating as intended will not perform satisfactorily.* Systems in today's complex buildings are highly interactive, with sophisticated and flexible controls that allow a wide range of options and strategies to provide comfort and save energy.
- *The Cx process ensures that your building will have systems that maintain proper comfort levels, minimize energy use, and are easily operated and maintained.* Effective building operations require subsystems and components that work effectively and reliably together, along with a building staff that has the training and resources to properly operate and maintain them.
- *Buildings turned over to owners with too many deficiencies, and with systems and equipment that are working sub-optimally.* As buildings, systems, and controls have become more complex and the specialization of labor has increased there has not been a commensurate increase in coordination and integration by technically qualified and objective parties.

What Are the Benefits of Commissioning?

- *The assurance of a completed building that operates correctly.* Cx should be integrated into the project in the planning process, design phase, and should continue throughout the construction and project turnover. The Cx authority reviews the plans and specifications throughout design to insure that they meet energy and comfort standards and maintenance and operation requirements. During the construction process, the Cx authority witnesses the control systems operation and reports any deficiencies.
- *Continued correct operation through training and documentation.* The Cx authority provides or facilitates in-depth operation and maintenance training to the maintenance staff, and is a resource for issues that arise after project completion.
- *Reduced energy usage.* Studies indicate that substantial energy savings are achieved with buildings that are properly commissioned, far outweighing the cost of Cx. Cx new buildings and re-commissioning existing buildings provides payback in energy savings and improved comfort levels within a short period of time.
- *An improved construction process.* Cx provides a systematic and inclusive approach to the verification of system operation. The Cx authority writes and submits functional test criteria to the owner, designer and contractor which detail how the systems will be tested to ensure system performance. This approach is designed to discover and correct deficiencies before the building is turned over to the owner.
- *Improved indoor environmental quality and employee productivity.* Cx ensures that systems operate as intended, including CO_2 sensors and outside air dampers that control outside air, temperature and humidity controls that monitor heating, cooling and humidity, and occupancy sensors and scheduling programs that determine when spaces are occupied.

Cx is the quality management process applied to building construction. It builds quality into each project and confirms correct system operation through testing. Quantitative and qualitative data supporting the benefits of Cx are available from numerous sources.

Top 10 Deficiencies Discovered by Commissioning New and Existing Buildings
► Incorrect scheduling of HVAC and lighting equipment ► Incorrect cooling and heating sequence of operations ► Incorrect calibration of sensors and instrumentation ► Lack of control strategies for optimum comfort and efficient operation ► Malfunctioning air and water-side economizers ► Under-utilized computer-based control systems ► Short cycling of HVAC equipment leading to premature failure ► Lack of design intent and building documentation ► Lack of training for building operators or service contractors on complex systems ► Missing specified and paid-for equipment
Source: Portland Energy Conservation, Inc.

E. When to Commission?

The decision whether or not to commission a facility should take into consideration more than square footage or construction cost alone. While these parameters serve as a general rule of thumb, other important factors should also be considered. Factors such as facility criticality, energy efficiency, building certification, facility age, availability of grants or incentives may influence the decision making process.

Facility criticality can be determined by answering a few basic questions. Does the facility perform a critical function or support critical functions occurring elsewhere? Would failure of this function result in unacceptable risk exposure? Risk exposure takes on many forms. Examples may include monetary, public safety, life safety, state or national security, etc. Typical high-risk facilities include 911 call centers, containment and research laboratories, cleanrooms, healthcare facilities, data centers, manufacturing, and research, etc. If the answer to any of these questions is yes, then as a minimum, applying commissioning (Cx) sufficient to verify performance of the critical function or functions is recommended.

Energy efficiency is taking on much greater importance in recent years, due to the sustainability movement, concerns over global warming, potential impact of cap and trade policy, and rapidly increasing energy costs. Efficiency goals are now mandated by the federal government and individual states may mandate even more stringent goals. It is not the intent of this document to describe these requirements, as they will likely change over time, and the reader is encouraged to research the current requirements. Building certification has also increased over the past several years. Some states now mandate building certification programs, such as USGBC's LEED certification. Certification may have direct bearing upon the Cx decision. For example, compliance with LEED certification, as a minimum, requires fundamental Cx, and may require enhanced Cx, depending upon the credits included in the LEED program. Fundamental and enhanced Cx are defined by the USGBC LEED Reference Guide for Green Building Design and Construction.

Building certifications and energy mandates aside, Cx buildings is generally a good investment with attractive payback periods and if implemented properly, can result in ongoing benefits throughout the facility's lifespan. In a report prepared by the California Energy Commission Public Interest Energy Research titled Building Commissioning, A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions (http://cx.lbl.gov/2009-assessment.html), Author Evan Mills, PhD notes that Cx is arguably the most cost effective method to reduce energy costs, and the benefits can continue for several years after initial Cx. In addition, the savings often offset or even exceed the cost of performing Cx. Depending upon the type and size of facility, payback periods of just over one year for existing buildings and approximately four and one half years for new construction can be expected. In addition, periodically repeating Cx (i.e. re-commissioning - See Section K) can help ensure energy savings continue. The report noted that the cost/benefit ratio seems to be independent of facility size, indicating that Cx smaller buildings are in general still cost effective. High tech buildings are especially good candidates for energy cost savings, due to their high power densities. The report noted that across the board, median whole building energy savings were in the range of 16% for existing facilities and 13% for new facilities and that Cx was cost effective in nearly all existing facilities.

The reader should note that the reported statistics above only take into account energy savings, while other non-energy benefits are also commonly realized. While it is more difficult to assign a dollar value to many of these collateral benefits, they do add real value to the project and further reduce payback periods noted. Examples include reduced change orders, better understanding of how Value Engineering decisions will affect facility operation, better trained Operations and Maintenance (O&M) staff, improved documentation, better use of warranties, reduced equipment wear and tear, and avoided premature equipment failure, etc. Any discussion of Cx benefits also

should include improved occupant comfort and wellbeing. It is a well established fact that when occupants are comfortable and feel safe within the work environment, they are more productive, use less sick time, and are generally healthier and happier. Cx can also mitigate liability due to indoor air quality issues and premature failure of equipment due to misoperation or lack of maintenance.

Whether a facility is new or undergoing major modifications due to upgrades or program changes also factors into the decision process. As noted above, the costs and benefits associated with Cx new versus existing facilities vary. The existing building inventory within the United States includes a tremendous number of buildings which have never received any Cx. These facilities represent a huge potential for energy savings because they include older less efficient equipment which is likely not operating at peak efficiency. This inefficient operation occurs due to the effects of time and service, lack of maintenance, drifting sensor calibration, etc. As such, existing facilities represent a greater potential savings than a comparable new facility which receives better maintenance, utilizes higher efficiency equipment with more precise digital controls that are not as prone to calibration drift.

While Cx is beneficial for all facilities, there is certainly a law of diminishing returns when considering nothing more than facility size or construction cost. If none of the considerations noted above warrant that a particular facility be commissioned, then the following rule of thumb may be applied. For this purpose, Cx should be performed on new building projects greater than ten thousand square feet or costing approximately $2,500,000 or more and for system retrofits costing approximately $800,000 or more. On projects smaller than this, the "using agency" should determine what level of Cx is appropriate, if any.

F. Budgeting for Commissioning

There are no set standards that can be applied to determine the proper cost of commissioning (Cx) for every building, since the extent of the Cx services, the complexity and size of the facility, and the delivery method employed will directly impact the Cx budget requirements for each project. For example, buildings containing complex systems (such as mission critical facilities) and/or systems with a large number of zones of control will have much higher Cx costs than less sophisticated packaged approaches. Buildings with complex systems may require a higher level of Cx effort during design, construction, and warranty periods. In the design phase, complex systems require more review and coordination to assure that they meet the Owners Project Requirements (OPR) and the Basis of Design (BOD). Complex systems may also require additional effort during construction to review submittals and develop detailed functional testing requirements for both functional and integrated system performance. Large buildings, by their nature, require more sophisticated and customized systems to achieve desired levels of performance and efficiency. Small, non-mission critical buildings often cannot justify complex system solutions and thus tend to be served by more standardized, packaged arrangements. As a result the rules of thumb when applied to Cx large buildings tend to reflect the costs more accurately than they do when applied to small buildings that employ complex systems.[1] Testing of sophisticated electrical systems such as emergency generators, uninterruptible power supply (UPS) systems, automatic transfer gear, etc., when included in the Cx contract will increase the cost of electrical system Cx. It is imperative for critical laboratory buildings and data centers that the electrical systems undergo extensive testing to ensure the proper operation of all emergency and backup systems. Additional factors such as operation and maintenance goals, training requirements, project duration, and travel requirements must also be considered in the budgeting process for Cx.

Various surveys on the cost of Cx have been conducted throughout the U.S. and Canada which provide a starting point for budgeting. The Lawrence Berkeley National Laboratory (LBNL) has developed a database of 643 buildings (all located in the United States, and spanning 26 states), representing 100 million square feet of floor space, $2.2 billion in total construction costs, and $43 million in Cx expenditures. In a 2009 report prepared for the California Energy Commission, Public Interest Energy Research (PIER), the median normalized cost to deliver Cx was $.30/square foot for existing buildings and $1.16/square foot for new construction. The Cx projects for which data is available revealed over 10,000 energy-related problems, resulting in 16% whole-building energy savings in existing buildings and 13% savings in new construction, with payback time of 1.1 years and 4.2 years, respectively.[2]

[1] Portland Energy Conservation, Inc., "Establishing Commissioning Costs", (PECI) 9/12/00; Revised 02/14/02; http://www.peci.org/sites/default/files/peci_newconcx1_1002.pdf
[2] Mills, E., "Building Commissioning: *A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions*", Lawrence Berkeley Laboratory Report prepared for California Energy Commission Public Interest Energy Research (PIER) 7/21/09; http://cx.lbl.gov/2009-assessment.html

G. Commissioning Delivery Methods

The "how-to" process of commissioning (Cx) begins with the decision-making requirement of, "Which delivery method should I use?" As important as it is to implement a Cx process, the method selected is critical to the success of a project. Relationships and trust established at the onset of the project are the significant drivers for success. Many factors and variables (procurement, purchasing, resources, budget, schedule) greatly influence which delivery method is chosen.

Variables in the Selection Process

Owners should review their individual state's statutes, rules, and regulations regarding the Cx delivery process. As a companion document to the individual state's requirements, this section provides only an overview of the basic variants and methods in the Cx delivery process. The variables are:

- Procurement method
- Risks
- Responsibilities
- Price/Value

The List of Commissioning Delivery Methods

The combination of these variables results in five primary Cx delivery methods shown below. These methods are driven primarily by who holds the Cx contract, and therefore has primary responsibility for completing the Cx work, and the organization and responsibility of the Cx team members. The methods are as follows, with a description of each method to follow;

The methods are:

- Independent "Third Party" Cx
- Owner-performed Cx
- Designer-performed Cx
- Contractor-performed Cx
- Hybrid Cx

Other Decisions: Procurement and Purchasing

Other decisions related to "delivery" include establishing the procurement and purchasing methods. "Procurement" in this context relates to how the selected delivery method will be obtained, advertised, and put in place. "Purchasing" refers to how the delivery method will be paid for and the terms and timing of the contract. (See "Selecting the Commissioning Authority" section for a detailed review of purchasing regulations, price, qualifications and value selection criteria weighting, and related factors.)

Further explanation of the procurement and purchasing process include the following:

Procurement: Procurement options and aspects include:

- Public advertisement
- Prequalified vendors list
- Invited contractors
- On-call/Indefinite delivery contract
- Master agreement

- Sole source
- Bid
- Proposal
- Interview
- Request for quotation (RFQ)
- Request for proposal (RFP)
- Other

Purchasing: Purchasing options and aspects include:

- Fixed-price/Fixed scope of work
- Hourly rates/Unit prices/Variable scope of work
- Time and Expense (sometimes with a Guaranteed Maximum Price)
- Best value/Set price (Tailor scope to fit budget)
- Qualifications-based selection (experience, firm, personnel, references, etc.)
- Value-based selection
- Other

As a state agency, the owner will have existing purchasing and procurement regulations, tools and procedures to support the Cx services contracting process so these processes are not detailed here. Rather, the focus is on explaining the delivery methods. Other sections of this document include development of the scope of work, scope of services, and other project specific aspects.

Understanding and Evaluating the Delivery Method Options: Pros and Cons

A brief description of each delivery method, with some of the advantages and disadvantages of each method is presented below. It is important that the delivery method chosen matches the level of rigor required for the building type, and that Cx is incorporated in the project as soon as possible once the decision to include it has been made, so a Cx authority can be brought on board early in the project, thereby maximizing their effectiveness.

Option 1: Independent "Third Party" Commissioning

In this option, an independent entity is responsible under subcontract directly to the owner. The owner may manage or subcontract the Cx management component. With an independent Commissioning Authority (CxA) there are several approaches that can be taken. The level of rigor is significantly different with each method, and care should be taken to carefully match the delivery method with the complexity and breadth of the building type, as well as the desired outcome from the Cx process.

1. Documentation: In this approach, the CxA limits their activities primarily to a reporting and observing role. Testing and field Cx activities are carried out by the contractors and independent third party testing providers hired by the contractors. The CxA simply documents findings and results provided to them by the contractors and third party testing providers. This method may be suitable where the primary goal of Cx is documentation. Cx documents, including testing procedures are typically boiler plate in nature and not tailored for specific systems and equipment installed. However, where the goal is to accomplish Cx with a great deal of rigor, such as for project types with more complexity, or greater risk to consequences of system failure, one of the other methods below may be more useful.

2a. Hands-On, Not Discipline specific: In this approach, the CxA makes heavy use of staff who is generalist in nature, rather than experts in all areas. For example, a mechanical engineer may serve as the project manager, but delegate the bulk of the activities and

tasks to a technician or to an engineer who is a generalist, lacking experience in some areas (such as electrical, mechanical, fire and life safety). This generalist approach, can apply to both design phase and construction phase Cx activities. However, this method would be most effective if during design, discipline specific engineers review the Basis of Design (BOD), Owner's Project Requirements (OPR), submittals, prepare test procedures, and review results of the testing, but this does not commonly occur. This method can provide a higher level of rigor than the documentation process described above, but not as much as the discipline specific process described below. In general, this method costs less than the method described below.

2b. Hands-On, Discipline Specific: In this approach, the CxA uses discipline specific engineers for critical activities. For example, the CxA would utilize discipline specific engineers (electrical, mechanical, fire and life safety etc.) to review the BOD, OPR, and submittals. Each engineer would also prepare equipment specific Cx documentation, such as test procedures, for their area of expertise (Building Automation System (BAS), emergency power, and smoke control, as examples). Finally, each discipline specific Cx engineer would be present during testing and direct and oversee the execution of those test procedures, and evaluate the results. While this method generally results in higher Cx fees, overall project costs can be lower. It is also the most rigorous and objective, provides the least conflict of interest by the CxA, and would be suitable for building types such as data centers, laboratories or central plants that have complex MEP systems.

Advantages

- This option utilizes an independent third party CxA, providing impartiality without a link to profitability or reverse incentives.
- Documentation is provided directly to the owner, saving time and facilitating communications.
- The CxA has no vested interest other than the owner's. The independent CxA is not responsible for design and installation and is more likely to ask questions, identify failure scenarios, and act as the owner's advocate.
- An experienced CxA may bring field testing experience to the design phase.
- Properly prepared Cx documentation can be utilized by the O&M staff to establish repeatable test procedures specific to their equipment.
- Cx testing results and data can provide a baseline for future retesting and system trending.
- Early involvement during planning and design allows familiarity with the OPR and BOD requirements and maximizes Cx benefits.

Disadvantages

- The third-party role can result in "reporting problems" without resolution. The independent CxA is not responsible for design or construction, and may not have the contract authority to resolve design or construction issues. If so, the CxA may not have a strong position from which to resolve design or construction issues.
- Who then takes the lead to resolve issues or affect change and action where needed? Does this fall back to the owner, the A/E or the contractor? Who is the decision-maker?
- Increased Cx process management and coordination by owner or their representative.
- The owner usually expects the CxA to participate in issue resolution by assisting the owner in identifying who is responsible for deficiency correction. This can contribute to an adversarial relationship between the CxA, the designer and the contractors.
- Conflicts can arise when there is disagreement between the CxA and the design team or construction team over system designs or installation details. If each party is under a separate direct contract with the Owner, the Owner will then need to resolve these conflicts quickly to keep the project on track. This can often lead to the losing party becoming disenchanted with the process and result in a less than desired outcome to the Cx process.

Option 2: Owner-performed Commissioning

In this option, the owner provides Cx with in-house staff. No third party CxA is retained. No contractor or designer is contractually responsible for Cx. To implement this method effectively, the owner must have staff on hand with Cx experience and skills that match the relative complexity of the building type and the systems contained within the project (mechanical, electrical, fire and life safety, etc), and with the available time needed to perform the Cx tasks.

Advantages

- Owner retains control and decision-making ability over all other parties, often resulting in quicker issue resolution.
- Quick and single-point action is possible.
- Can make transfer of information to O&M staff easier.
- May have lower initial cost than contracting with others for Cx services.
- Owner's team retains all the lessons learned during the Cx process.
- Provides the owner with another opportunity for designer and contractor performance evaluation.
- Owner is fully aware of all issues encountered during Cx.
- Owner's team retains all the lessons learned during the Cx process.

Disadvantages

- Owner may not have in-house Cx staff with the skills and experience necessary.
- Owner may not be able to maintain impartiality in decision-making ability when trying to resolve gray areas, particularly in the area of responsibility for corrections.
- Owner may not have a sufficiently assertive manager to run the process well or resolve conflicts in a timely manner. (For example, there may be a difference in opinion between the design engineer and the mechanical trade subcontractor on outside air requirements which needs to be effectively resolved quickly.)
- Owner's Cx leader may not be empowered to make decisions, take risks, resolve gray issues, and spend money.
- True completion of a commissioned facility may be less likely without the benefit of state-of-the-art industry professionals.
- True total cost, including callbacks, problems, and downtime may greatly exceed the apparent initial savings of contracting with others for Cx services.
- Owner may not have in-house specialist required for complex building types (laboratories, data centers, etc.) with multiple critical systems (BAS, mechanical, electrical, fire protection, for example).
- Owners may not have the required equipment, or have staff that is properly trained to use or calibrate the equipment.
- Owner retains all responsibility and liability.
- Owner must provide all documentation required. Typically this includes communication to the contractors and designers detailing their required participation, as well as final documentation of the Cx process.
- Owner's staff may not have the magnitude of time available at the needed times to perform the Cx tasks, resulting in construction delays with costly time extensions given to the contractor.

Option 3: Designer-performed Commissioning

In this option, the designer assumes responsibility for conducting or subcontracting for the Cx. The owner may still manage or subcontract management of the Cx process.

Advantages

- Design and Cx team has a high level of cooperation rather than an adversarial relationship.
- Designers may view this arrangement as a logical extension of their role as consultant or advisor.
- Designer/CxA has a strong understanding of the BOD and the OPR which are important to the Cx effort.

Disadvantages

- Cx/Design team may be hesitant to address, resolve, or accept responsibility for issues discovered that are related to design issues.
- Traditional adversarial relationship between design/testing entities versus contractors can remain.
- Designer may try to perform Cx with staff which do not have the proper experience or skill sets (particularly with field testing, interpreting testing results and troubleshooting) to effectively execute all aspects of the Cx process.

Option 4: Contractor-performed Commissioning

In this option, the contractor provides Cx under his contract via in-house staff, trade subcontractors, or an independent entity under contract to the contractor. Cx specifications are required in order to describe the contractor's responsibility for Cx, and preparation of these specifications is normally included in the designer's contractual responsibilities. The owner relies upon a hired, experienced, field Cx and management team rather than in-house staff. Cx of all necessary systems (mechanical, electrical, fire and life safety, envelope, etc.) should be specified and provided. Note: Owning agency may have to provide Cx management personnel if this is not provided under the agreement with the contractor.

Advantages

- Interdisciplinary problems may be resolved more quickly and with less pain if contractor is made contractually responsible for construction and Cx.
- Single contract may mean less coordination and communication by all team members.
- Cx costs are potentially lower due to competitive bidding.

Disadvantages

- Perception that contractor may not have incentive to find and resolve deficiencies, or if resolved, they may not get reported to owner.
- Not recommended if contractor is awarded via low-bid, hard-bid method from a non-selective pool of candidates.
- Generally, the contractor is not on board during the design phase; consequently, may not have participated in, nor have a great understanding of the BOD or the OPR.
- The owner may not know if the work was really completed and that all systems are performing as intended.
- Contractor may minimize the Cx effort. With every defect found, the contractor will need to spend more time and money, and may perceive that it would reflect poorly on their QA/QC process.

- Specifications must clearly call out contractor responsibilities, or change orders may result.
- Contractor approach is normally “punch list” or “check list” oriented, and may not include thorough testing and troubleshooting. The use of generic, off the shelf or generic manufacturer forms and test procedures is common, in place of formulating forms and specific test procedures based on the actual equipment installed.
- Contractors and subcontractors are not necessarily well suited to analyze interaction between various disciplines, as required during facility integrated systems testing.

Option 5: Hybrid Approaches

If the owner chooses, a combined approach of some or all of the above methods can be developed to meet the project's needs.

For example:

- An independent CxA may be used with a practical reporting relationship directly to the owner, but with a subcontract through the designer, contractor, or construction manager (CM) at risk for accounting or funding reasons.
- The owner may contract directly for and provide management staff for the Cx effort, but subcontract the hands-on field component to an external entity.
- Under a design-build contract, all responsibilities may be contracted under a single contract with a design-build-commissioning firm.
- Designers may subcontract for "total building assurance" as an additional service, with the independent CxA falling under their contract. (Similar to designer-performed Cx identified above.)
- An operating and maintenance entity may contract directly with a state procurement or ownership entity to provide Cx and ongoing maintenance services and write the Cx procedures, training requirements, and design criteria for some or all systems.
- An independent CxA may subcontract system testing, for example, mechanical testing, testing adjusting and balancing (TAB), automatic temperature control system testing, electrical gear and electrical controls testing, security systems testing, fire alarm systems testing, etc.
- An independent CxA may coordinate and oversee most commissioning activities, but have the contractor perform testing, coordination, execution and documentation for some systems after joint testing the first few pieces of equipment with the CxA. The CxA then reviews contractor test reports and spot checks results. This can offer increased efficiency and reduced cost while providing sufficient objectivity, rigor and confidence in the testing results, especially when there are large numbers of similar equipment (air terminal boxes, numerous air handlers, fans, unit heaters, etc.).

Which Delivery Method Is Best?

One approach is to have several different Cx delivery methods on hand so as to be able to choose the best one for any given project. In general, the first choice of delivery method nation-wide is the use of the independent, third-party service provider contracted directly to the owner. This appears to give the most objective service and provides the most accountability to the owner.

The delivery method will most often be determined by the project type. The complexity of the building type should be matched with the delivery method. For example, buildings with complex mechanical, electrical, and/or fire and life safety systems, such as laboratories and data centers, would normally be commissioned with expert, discipline specific Cx staff at a high level of rigor. This might require the use of the Hands-On, Discipline specific approach. Other building types,

such as low cost office buildings, may be a candidate for owner performed Cx if qualified, in-house staff is available.

The skill sets of the parties that will be involved in the construction project (low-bid versus CM versus negotiated) might play a role. If the contractor has the confidence of the owner and has a skilled qualified staff, he could be the Cx service provider with some owner oversight. If the contractor has specialized experience that none of the local CxA's posses, the contractor might be an appropriate choice.

Finally, the budget available to commission a facility will play a part in the delivery method. However, choosing the least expensive delivery method to meet the budget may not be the right approach. Hybrid approaches, or using the tactic of "Best Value" by having the Cx provider help the owner tailor the Cx scope to the project needs and budget, can be an effective way of dealing with insufficient budgets while still securing a minimum, but effective level of Cx.

When Should Cx Be Started?

Ideally, the Cx process should be started in the predesign phase. If that is not possible, begin in the design phase. The Cx delivery method should be selected in the early planning process to allow time for selection and contribution to the team. As defined previously, "*Commissioning is a quality-focused, systematic process for enhancing the delivery of a project. It is a collaborative process that begins at project inception . . . .*" At this point the design team can begin working with the CxA to develop the quality assurance procedures for the design; the building product that meets the design intent; and the drawings and specifications that will facilitate Cx during the construction phase.

In most cases, the earlier in the project the Cx activities can begin, the greater the effect they can have on the performance and final outcome of the design, construction, and Cx process. There are a variety of reasons for this, including the following:

- The need to develop a relationship of "trust" between the CxA and the design team and the owner's staff. When the CxA is brought in late in the design phase, the designers have a tendency to view the CxA in an adversarial role rather than as a member of the "team."
- The need to have a full understanding of the BOD and the OPR. This is communicated more effectively in face-to-face programming meetings with all parties involved rather than in just written form.
- The CxA can provide valuable insight during the Value Engineering process and let the design team know the operational affect that will result from equipment deletion or changes.
- Ideally, the team selected to perform Cx has extensive experience with start-up and troubleshooting of buildings. Having the CxA on board and fully mobilized for drawing, specification, and schedule review allows the CxA to identify design issues that will be much less costly to correct on the drawings than after the systems are constructed.
- It is important that the contractors have a clear understanding of their role in the Cx process. The CxA needs to have listed those requirements clearly in the specifications. This is especially true when using a CM to help with the construction budgeting process.
- The CxA will help to ensure that sufficient balancing devices, measuring devices, control items, and load banks, for example, are included in the bid documents, which is more cost-effective than adding these devices to the project through the "change-order" process.
- If the Cx entity is able to participate in the creation of the BOD and OPR, it is more likely to bring its knowledge from the field of "what works" and "what doesn't work" to the design stage.

Implementing the Commissioning Delivery Process

Once the decision has been made to include Cx, several other decisions are necessary in order to begin the process. For example, one must decide what level of Cx is appropriate for the building type, when it will begin, and how to select the appropriate party to perform the services. Following are the usual initial steps in the Cx process:

1. Establish a candidate list or roster of approved commissioning providers.
2. Decide the form of Cx delivery.
3. Identify the members of the design and construction team.
4. Select a CxA.
5. Conduct a Cx kick-off meeting (during planning or early design is best).

Determining the appropriate level of Cx is the owner's responsibility and should be performed prior to or during the planning or pre-design phase. Early Cx efforts were primarily directed to mechanical systems. Current concepts encompass "total building Cx," which includes mechanical, electrical, fire, life safety, security, and building enclosure systems as well as a variety of other ancillary systems. The choice of what to commission and the delivery method remain with the owner. In determining the extent of Cx, critical systems such as life safety systems, laboratory fume hoods, fire alarms, emergency generators, and security systems should have first priority.

H. Selecting the Commissioning Authority

When selecting a professional commissioning (Cx) services provider, the owner must consider the type of Cx delivery most appropriate for the project based on the size, use, and complexity of the building. The budget available for Cx should also be considered. After deciding on the type of Cx delivery the selection of the Commissioning Authority (CxA) can follow.

Selecting the Commissioning Authority for Owner-Performed Commissioning

Owner-performed Cx can be effective for small buildings if the owner's in-house Cx team is familiar with the building systems being implemented and has sufficient time to commission the building. The CxA should be a qualified individual with technical and communication skills who is capable of leading the Cx effort. After weighing the pros and cons and determining that the project can be commissioned by the owner's staff the leader should be chosen and integrated into the project team during the planning phase of a project. The owner CxA will need to provide Cx criteria and technical input to the design team for incorporation into the construction documents.

Selecting the Commissioning Authority for Designer-Performed Commissioning (Qualification Based Selection)

If the Cx process on a project is assigned to the consulting design team the CxA should be selected based on their qualifications as part of the overall team. The combined design and Cx team should be selected based on overall qualifications plus Cx qualifications as presented through written submittals and interviews. If the Cx is to be done by direct employees of the consulting design team, it is recommended that the CxA not be directly involved in the systems design. If the CxA is a sub consultant to the design team the Cx presentation should be part of the design consultant's presentation, and the team should be selected as a unit. If the design team is selected in part based on the qualifications of their CxA, they should not be allowed to switch CxAs after selection. The Cx team's qualifications should demonstrate sufficient skill sets and experience for the type and size facility being commissioned. The Request for Qualifications (RFQ) should include specific qualifications for the Cx team members (see "Selection Criteria" below).

After selection, the owner and design team will negotiate a fee. The CxA fee should be a line item in the overall fee and should be negotiated apart from conventional design fees.

Potential benefits of this contractual arrangement include quick resolution of design issues and reduced or no learning curve when becoming familiar with the owner's requirements and design philosophy. Potential shortcomings include possible conflicts of interest, because there may be a tendency for the Cx team to ignore Cx issues related to the design, because they are either employees of or controlled by the design firm.

Selecting the Commissioning Authority for Contractor-Performed Commissioning (Qualification Based Selection)

If the construction manager at-risk (CMAR) or best-value contractor (contractor selected on qualifications and price) employs the CxA, the CxA should be part of the contractor's team from the initial response to the Request for Proposal (RFP). The team should be selected as a unit with no substitutions allowed after selection.

When soliciting a RFP from a contractor for delivery methods such as CMAR or best-value, the owner should require the contactor to identify the qualifications of the proposed CxA. The RFQ

should include specific qualifications for the Cx team members (see “Selection Criteria” below). Prior to awarding the construction contract, the owner needs to approve the proposed CxA; including not only the company selected, but also the lead CxA, key CxA technical staff, and the planned Cx approach. As with designer-performed Cx (above), the contractor should not be allowed to switch CxA’s after the contract is awarded. The owner should consider this as an important area of negotiation prior to signing an actual construction contract and an item of importance when evaluating a best-value submittal.

Potential benefits of this contractual arrangement include quick resolution of Cx issues discovered during construction, reduced need for Cx coordination and lower Cx fees. Potential shortcomings include possible conflicts of interest, because there may be a tendency for the construction manager or their subcontractors to ignore construction issues because they are either employees of or are controlled by the construction manager.

Selecting an Independent Third-Party Commissioning Authority

The selection of an independent CxA for a public sector construction project should be comparable to the qualification-based process used to select consulting architects and engineers, and should not employ bidding. This will confirm that Cx is a professional service and not a commodity, and is not vulnerable to a “low bid” mentality. The RFQ should clearly state the required qualifications (see “Selection Criteria” below.)

The owner contracting for Cx services should issue an advertisement for services and make a selection in accordance with consultant selection procedures.

As the short list of qualified commissioning providers is assembled, it should be further reviewed with the project management representatives (architect and/or engineer) of the design team. Although the design team does not determine the qualified firms selected for the short list, they should be given an opportunity to provide input based on potential conflicts of interest and past experiences. These issues should then be researched by the owner, who makes the final decision as to whether the firm in question should remain on the shortlist. Care should be exercised when evaluating any designer’s negative opinions, to ensure they are not the result of the CxA simply doing their job of finding legitimate design and/or construction issues. The short listed firms should then be interviewed.

After a firm is selected, the owner negotiates a fee with that firm based on the project requirements. If a mutually acceptable fee cannot be negotiated, another firm on the original list is selected and negotiations repeated.

This method could also be used to select firms for indefinite delivery contracts where a standing contract would be in place with a few qualified firms and those firms would be used as projects are developed.

Potential benefits of this contractual arrangement include a Cx team dedicated to providing Cx services. They should have no conflicts of interest and will therefore be looking out for your best interests. Potential shortcomings include generally higher fees.

Sample RFQs are attached in Appendix I.

Hybrid Approaches

There is a variety of potential selection methods representing a combination of those described above, although the procurement process must continue to be qualifications-based, regardless of the method used to select and/or contract with the CxA.

Selection Criteria

Qualified Cx firms should have, at a minimum, access to personnel with the following capabilities:

- Registered professional engineer(s) on staff who will be directly involved in Cx activities.
- Experienced control and test and balance technicians available for mechanical systems Cx.
- Specialized personnel who are experienced in the types of systems being commissioned, whether that be controls, normal and emergency electrical systems, lighting controls, communication systems, audio/video, fire and life safety, etc.
- Experience in field engineering, such as remote monitoring, field troubleshooting of HVAC systems, and/or energy conservation retrofits.
- Involvement in professional Cx associations related to Cx, such as BCxA, NEBB, ACG, ASHRAE, PECI, etc., and a continuing education program as evidenced by staff attendance at seminars and other training sessions.
- Certification by a recognized professional Cx training institute or professional society such as BCxA, NEBB, ASHRAE, AABC, etc. Note that certifications differ considerably and a careful review of each certification is recommended.

Generally, firms should be selected based on the following criteria:

- They have the expertise and experience required for the level of complexity represented by the project.
- They are capable of providing onsite personnel within a reasonable time frame.
- They have enough staff to handle the size of the proposed project.

I. Defining the Scope of Work – The Owner's Commissioning Procedure

After a state agency decides to incorporate building commissioning (Cx) into a project, two critical decisions must be made:

- Which Cx "delivery method" to use? (Refer to Section G)
- Which "systems and specific components" will be commissioned (a critical part of the overall scope of work)?

Advantages and disadvantages of the common Cx delivery methods have already been discussed. Since no two state agencies are alike, each agency should select the Cx delivery method that best meets the needs of its particular project. This decision is largely influenced by the size, composition, workload, and technical skills of the agency staff, as well as the project's magnitude and level of technical difficulty, as reflected by the scope of work.

Deciding which specific systems and components to commission, as well as Cx activities to be included in the Cx process, is primarily a function of the facility's size and complexity, criticality of the planned systems, and funds specifically available for Cx. The owner's project manager must determine what portions of the building are most vital and tailor the scope of work accordingly, investing available resources to return the greatest benefits from Cx. The end result of this process is a "systems list" that becomes the heart of the Cx request for proposal (RFP). This document forms the basis of the scope of the Cx work and is the forerunner of the "preliminary Cx plan" included in the bid specifications and the "Cx plan," which is released during construction (see Appendix II, "Guiding Documents of the Commissioning Process"). Developing the systems list may actually be an iterative process with minor revisions based on the design engineer's input and clarifications to the Cx RFP during the procurement process.

The importance of this step cannot be over emphasized. Without a clearly defined scope of work (SOW), the Cx may not be able to produce a commission plan that meets all of the Owner's expectations. Additionally the Owner (author of the SOW) and his agents may not have sufficient guidance in the SOW to properly evaluate the deliverables received from the Cx. This can lead to an ineffective or incomplete Cx report which may not be recognized until after the commissioning process has been completed when corrections or adjustments become expensive or impractical. Owner's often work in collaboration with the selected Cx (or a potential Cx) to develop the statement of work. While it is very important to work with the selected Cx in the development of the final statement of work it is imperative that the author of the SOW have a strong grasp of the total Cx process and a realistic expectation of the final product to ensure that the Owner's expectations can be realized to the maximum extent possible. For Owner's without extensive training or experience with the Cx process or full comprehension of all of the systems to be commissioned, developing this statement alone or relying too heavily on a consultant often results in less than satisfactory results. For owner agencies tasked with the responsibility of writing a SOW it is recommended that the agency consult with other agencies in their area which have had Cx performed on similar facilities or systems to better understand what worked well, what did not, and why. If agencies in your area do not have sufficient experience with Cx, consult with the central government agency responsible for construction oversight in your state. Another good source is regional or national associations such as NASFA. Many members of these organizations have experiences and example documents that are available on request.

A graphic representation of the various systems and subordinate components found in modern buildings is presented in Appendix III. This graphic is certainly not all-inclusive but does capture the most common systems' components encountered today. No building has all of these components, but nearly every building has a majority of them. If an agency chooses to commission every system and subordinate component, the process is called "total building Cx." As a minimum, most Cx providers recommend Cx the major mechanical, electrical, and plumbing

components, life safety systems, plus any system or components deemed absolutely critical to the operation of the facility.

In developing the systems list, it is important to note that most modern building systems do not operate independently. The advent and use of building automation software has advanced systems interoperability to an exact science, requiring systems to operate in concert, demanding accurate exchange of information between systems. However, equipment manufacturers often use unique communication protocols, requiring special translation equipment. Careful integration is critical to ensure systems can effectively "communicate" with the Building Automation System (BAS), and testing this capability should be included in the Cx process. To demonstrate this point, consider the following example:

> *A fire breaks out on the upper floor of a multi-story building. The smoke detector in the return-air ductwork senses the smoke and sends an immediate message to the building fire protection system. Several actions are then simultaneously (automatically) initiated. The damper controls for the air-handling units for the affected floor go to a "closed" position for smoke control. The fire protection system auto dialer sends a message to the 911 dispatcher and broadcasts an FM radio signal to the supporting fire department. Stairwell pressurization system comes on, preventing smoke from entering the emergency stairwell exits. Elevators are recalled to the ground floor and parked for fire department and emergency use. Fire protection system broadcasts a building-wide warning over the public address system. The security system releases secure doors in paths of egress and the gate at the loading dock automatically opens to allow fire department and emergency vehicle access. If the fire continues to spread, sprinkler heads activate and jockey pumps automatically start to provide adequate water pressure.*

As this example illustrates, multiple building systems automatically interact in concert without human intervention. The problem with traditional quality control and quality assurance methods in building construction is that each system is tested separately, but rarely (if ever) are they tested as an integrated system. Proper building Cx will address both discrete operations (functional tests) and the interoperability of the systems and component in the systems list (integrated systems testing).

Another important factor in developing the Cx scope of work is deciding the desired level of involvement of the Commissioning Authority CxA in the operations and maintenance training. Operations and maintenance training will be discussed in more detail at the end of the chapter. Conversely, an excellent early learning opportunity exists in getting the Operations and Maintenance (O&M) staff involved in the Cx testing performed by the CxA. This allows them to observe the testing and ask questions.

As mentioned earlier, the availability of funds to specifically support Cx will also influence the development of the systems list and Cx process. Ideally, Cx costs are included in the predesign phases of project development, using preliminary cost estimating guidelines. (See "Budgeting for Commissioning" earlier in this document.) These costs can then be further refined during the Cx procurement process.

Commissioning Authority Proposal

When a delivery method other than "Owner Performed Commissioning" (refer to Section G.) is selected, outside services and a CxA proposal for providing those services, will be required.

The CxA proposal can be divided into two distinct components: the initial response to the Request for Qualifications (RFQ) and fee negotiations.

Response to the RFQ

It is imperative the respondents have a clear understanding of the needs of the project and the owner's vision of the Cx process. Providing more project-specific Cx information in the RFQ will result in better and more complete proposals from the CxA's. The sample RFQs in Appendix I include criteria for evaluating responses. The process for selecting a CxA is similar to the process for selecting a design firm, and so the same procedures apply.

An opportunity to meet the CxA team leader as well as the key technical CxA staff is important. In Cx, interpersonal and communication skills can be as important as technical skills as developing team synergy is critical to overall Cx process success. A good CxA team leader may help to bridge the gap between the construction team and the design team because of his extensive field experience.

Fee Negotiations

A well-prepared scope of service clearly defining the owner's vision for Cx will help in the fee negotiation process. At the completion of design, an experienced CxA will be able to develop detailed spreadsheets, identifying tasks involved in the Cx process and the respective time to complete those tasks. As those spreadsheets are reviewed, it will become clear if the CxA and the owner have the same vision for Cx.

However, when the CxA is brought into the project early, it will be impossible to identify tasks because systems and quantities of components have not yet been defined. In this instance it is more appropriate to work with the CxA to negotiate Scope of Work and fees by phase. Refer to Section J, "The Commissioning Process – Step-by-step" which outlines CxA activities by phase that could be included in the CxA Scope of Work for each of the phases below.

1. Predesign Phase Services: If the CxA is asked to help with formulating the project scope, it may be logical to negotiate either a time-and-expense contract or a fixed-fee contract for just this portion of the project.
2. Design Phase Services: After the scope of the project is developed, a fee can be negotiated for the design phase services of the CxA. After the project size and anticipated systems have been preliminarily selected, the CxA will be able to provide a fixed fee for design-related services.
3. Construction and Post Occupancy Phase Services: At the completion of the 65% construction documents (CD's), the CxA can develop his fee and detailed scope of services to be provided during the construction and Post Occupancy phases. These negotiations need to be finalized prior to completion of the 95% CD's to allow addition of contractors' Cx requirements to the construction specifications in order to get accurate construction contract bids.

J. The Commissioning Process – Step-by-step

The commissioning process will vary in response to the complexity, type, size, and delivery method for each individual project. A comprehensive Cx process will have nine distinct phases, although depending upon when the Cx authority is introduced into a project some phases may not be applicable. As noted previously, Cx is most effective when introduced during Pre-Design/Planning. In addition, the activities associated with each phase noted below will vary depending upon the building systems utilized. Project phases include:

1. Pre-Design/Planning
2. Design
3. Contractor Selection
4. Early Construction
5. Static Inspection (Field Verification)
6. Start-up (Contractor/Supplier Functional Verification)
7. Functional Performance Testing
8. O&M Staff Training and Documentation
9. Warranty Review and Seasonal Testing
10. Measurement and Verification

This section describes the first phase "Predesign/Planning", and in particular, defining the Cx scope. Phases 2 through 10 are discussed in Appendix 6.

Predesign/Planning

The Owner's "Commissioning Scope" is defined during the Pre-Design phase. Development of this document should be directed by a member of the owner's staff, or by a consultant contracted by the owner, and should include a description of all of the services and deliverable documents that the owner will require from the Cx process. This scope includes a detailed listing of all of the building systems (or portions of systems) that will be commissioned, and describes the activities and level of rigor to be used in the Cx process.

The following factors should be used to determine the systems to be commissioned and the level of Cx process rigor for each project:

- Project Type: In general, project types can be classified into one of three broad categories:
    - High Criticality Facilities: Facilities whose continuous, normal operation is critical to achieving primary project goals. Malfunction of building systems would result in unacceptable risk, such as impacting life safety, resulting in large loss of revenue, or compromising public or national security, etc. Refer to Table 1 for typical examples of facilities meeting these criteria.
    - Medium Criticality Facilities: Facilities whose continuous, normal operation is not critical to achieving primary end user goals. Malfunction of building systems operation results in undesirable impacts on important secondary end user goals. Systems failures would not adversely affect life safety, public or national security, or achieving aggressive energy goals through the use of complex systems. Refer to Table 1 for typical examples of facilities meeting these criteria.
    - Low Criticality Facilities: Facilities whose continuous, normal operation is not critical to primary or important secondary end user goals, and for which failure represents an acceptable temporary inconvenience. Refer to Table 1 for typical examples of facilities meeting these criteria.

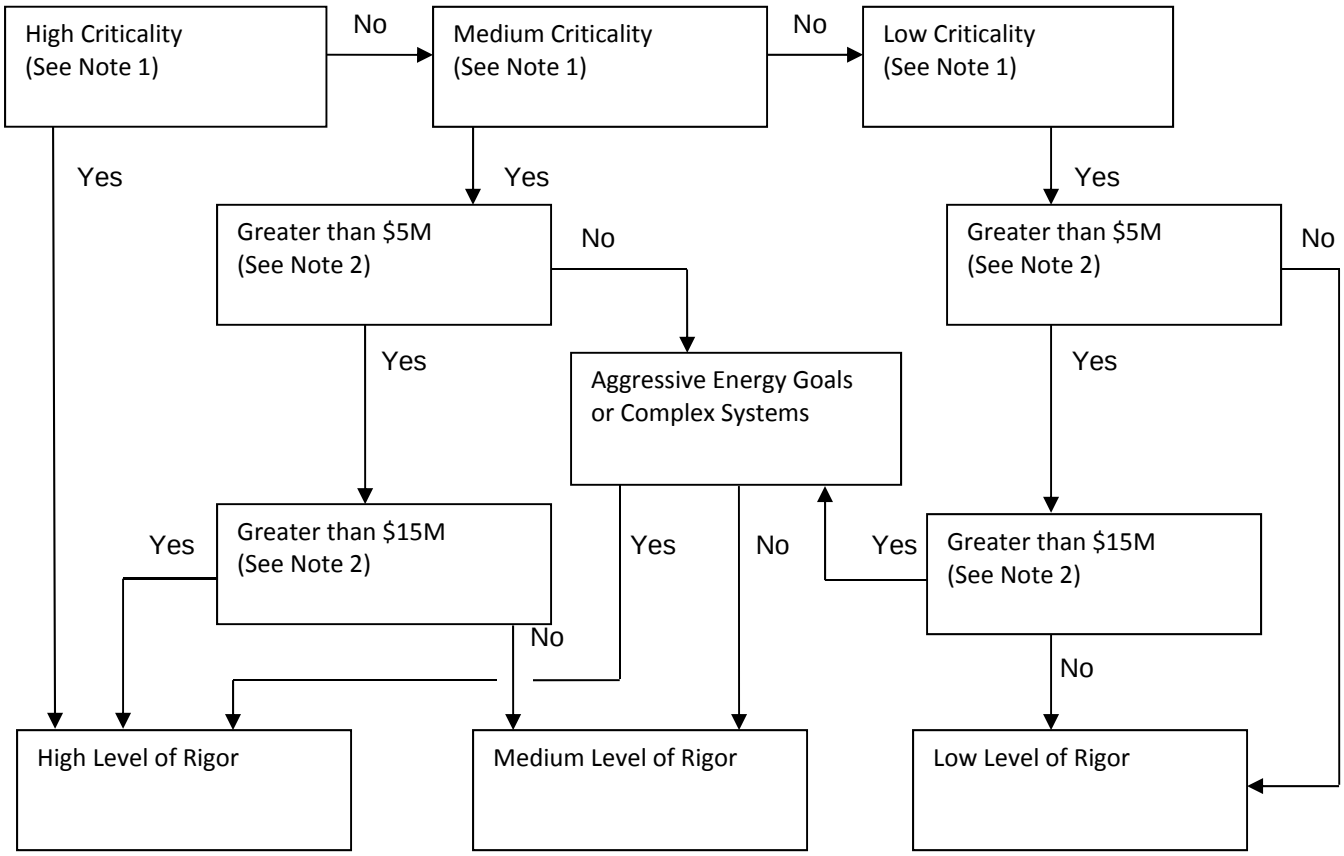
Table 1: High, Medium and Low Criticality Facilities

High Criticality	Medium Criticality	Low Criticality
Data Centers that are not backed up with fully redundant facilities	Data Centers that are partially or fully backed up with redundant facilities	Warehouses
Laboratories-R&D	Medical Office Buildings and Clinics	Office Buildings, under $15M in value
Hospitals-Medical	Kitchen/Dietary Facilities	Parking Structures
Central Utility Plants/Power Plants	Office Buildings, over $15M in value	Recreation Facilities
Emergency Operations Centers	Printing Plant	Stadiums and Grandstands
Communications Centers	Library	Park Shelters
Key governmental facilities important to public or national security		
	Fire and Police Stations	Maintenance and Shop Facilities
	Observatories	Natatorium
	Laundry	Marinas
	Detention/Correctional Facilities	Restroom and Shower Facilities
	Historical Facilities	Greenhouses
	Laboratory-Teaching	Gymnasiums
	Project types of Low Criticality, but where there are aggressive goals and equipment for achieving energy efficiency	Dormitories
	Hospitals-Mental	Armories
	Industrial Buildings	Apartments
	Hangers	Industrial Buildings
	Day Care Facilities	Visitors Interpretive Centers
	Dining Facilities	
	Project types of Low Criticality, but are located in High Rise Buildings	
	Museums	
	Schools	
	Class rooms	

- Project size: This can vary from owner to owner, but is usually based on construction cost. In general, High Criticality facilities require Cx of most building systems, while Cx fewer systems and/or components is acceptable for Medium Criticality facilities. Low Criticality Facilities require minimal Cx of systems and components. A list of typical building systems and components can be found in Appendix III.

Utilizing Table 1 will help the reader determine the level of criticality for their facility. Then utilizing the flow chart in Figure 1 (below), the reader can arrive at the desired level of rigor to include in the Cx process.

Figure 1: Decision Tree to Aid in Determining Level of Commissioning Rigor



Notes to Figure 1:

1. Refer to Table 1
2. Values shown may vary by state and should be verified

Commissioning Rigor Levels

High Level of Rigor: A high level of confidence in systems operation is necessary to avoid unacceptable risks, or facilities with aggressive energy usage goals, complex systems to achieve these goals, and the need to precisely verify and document baseline operations. The following might describe the Cx approach for this category;

- The "Hands On, Discipline Specific", Independent Third Party delivery method described in Section G might be utilized.
- The CxA would be expected to be intimately involved in a full Cx scope.
- Typically, all systems and components supporting critical functions are fully commissioned (no sampling is utilized).
- Typically, all systems and components supporting critical functions are tested at 100% capacity, including redundant equipment.
- Typically, all systems and components supporting critical functions are tested including normal and off-normal operating scenarios.
- Typically, the CxA would prepare the test scripts. Testing of all systems and components supporting critical functions is directed, witnessed and verified by the CxA.

Medium Level of Rigor: This might be employed on facilities where confidence in systems operations and good documentation of baseline operations is necessary. The following might describe the Cx approach for this category:

- "Full" Cx activities might be somewhat reduced by:
    - Utilizing sampling. Where numerous but similar system components are present (for example, HVAC units), it may be desired to have the CxA witness testing of only a representative sampling, typically 20%, to verify operations and document baseline operating parameters. In such cases, the contractor during their checkout and test-readiness effort tests a larger sample (possibly 100%) using the same test scripts as the CxA. Only near identical equipment like air terminal boxes see significant sampling by both the CxA and contractor. However, for those systems whose failure represents unacceptable risks, a full 100% Cx may still be applicable.
    - Review/Evaluation of results. Rather than directing, witnessing and evaluating all testing, the CxA might review and evaluate tests conducted by others, such as a contractor.

- Delivery methods other than "Hands On, Discipline Specific" might be considered. Refer to Section G.

Low Level of Rigor: This might be employed on project types that are not particularly complex, or where the primary goal of Cx is documentation.

- Typically, in this approach, the CxA would not formulate test procedures or direct and/or witness testing, but would evaluate the results of the documents completed by the contractors, and would assemble the documentation provided by others into a Cx report.
- Owner-performed or contractor-performed Cx might be used as the Cx delivery method. Refer to Section G.

Determining the level of rigor, as well as the initial list of Cx process activities will lay the framework for defining the Cx scope expected of the CxA. It will also assist in determining the desired Cx delivery method (See Section G), and in production of an effective Request for Qualifications (RFQ) document. This information is then used by the CxA to develop their fee proposal. After the CxA is under contract, they will develop a preliminary Cx plan which confirms the scope and extent of Cx services (drawing review, pre-functional checklists, functional performance testing, deliverables, etc. for the specific equipment identified in the RFQ).

During the Pre-Design process the owner or the architect develops the "Owner's Project Requirements" (OPR) document which defines the owners' *intention* and expectation of the *design and operation of the building*. These requirements must be achieved and documented by the project team in order for the project to be successful. It is the responsibility of the CxA to review the OPR and to confirm that all building systems operate in conformance with the OPR.

The OPR is conceptual in nature and should be developed during the planning phase by the owner, their consultant, or the project architect. The OPR should be written in non-technical performance-based terms and concentrate on major project goals. The design team then utilizes the OPR to develop the "Basis of Design," (BOD) the primary document that translates the owner's needs into building components such as occupancy type, room size, population, air quality, etc. The design team produces design documents based on the BOD. The CxA reviews the BOD and verifies that it conforms to the OPR.

The OPR and BOD should be available to the design and construction team, and updated during the construction process. At the pre-bid conference the design team should discuss both of these documents with the contractor. While it is true that many contractors will build according to

project plans and expect change orders for any work not shown; it is also true that some contractors will not suggest improvements prior to bidding. Some contractors, however, may make suggestions prior to bidding if they are informed of the actual intent of the structure. If given only the design and not the intent they cannot be expected to help improve the project without change orders.

The OPR and BOD should be presented again at the pre-construction conference, and there should be a discussion of the relationship between the two documents. The presentation of the OPR document at the pre-bid and pre-construction conferences should be used as a team building tool in defining a common goal, which is where the communication and team building skills of the CxA become very important.

The most basic inclusion in the OPR is the general description of the building type (prison, hospital, classroom, geriatric, office, etc.). Beyond the building type, details are stated such as the occupants' age groups, particular needs with regard to air quality, outside air volume, occupant load and pattern of occupancy. As an example, an OPR might describe an assembly area which will accommodate 100 persons for two hours and operate at maximum energy efficiency. The BOD could specify a variable air volume system integrated with occupancy sensors and special programming, and the actual design in the bid documents could specify components, air volumes, and the required control sequence. Cx would assure that the equipment has been supplied and installed correctly, the air volumes and control sequence are correct, and the overall system "works" at several occupancy levels.

Appendix IV begins with a summary of the elements that should be included in the OPR document followed by three OPR examples.

The remaining phases in the full Cx process are as outlined in Appendix 6.

K. Commissioning Existing Buildings

Up to this point, this manual has focused on the fundamental steps and concepts related to commissioning (Cx) of newly constructed facilities. Buildings are dynamic devices with many moving parts and external forces, such as wind, rain, sun, and people, acting upon them at all times. Occupancy activities and patterns change, utility costs fluctuate, machinery vibrates out of alignment and control devices drift out of set-point ranges over time. As with any finely tuned piece of equipment, a building must be checked and re-tuned from time to time.

Benefits of Cx existing buildings are similar to those for Cx new buildings: energy and operating cost savings, improved indoor environment and employee productivity, and increased building maintainability and reliability. The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) estimated that retro-commissioning (RCx) can result in energy savings of 5 to 15 percent, with a simple payback period of less than two years. In a report titled Building Commissioning, A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions (http://cx.lbl.gov/2009-assessment.html), Author Evan Mills, PhD notes that Cx is arguably the most cost effective method to reduce energy costs, and the benefits can continue for several years after initial Cx.

The following paragraphs describe the basic elements of three types of Cx activities that can be applied to existing buildings, on-going commissioning, re-commissioning and retro-commissioning.

On-Going Commissioning

All new buildings become existing buildings when the Owner takes possession and occupies the building or spaces. Just because you may have successfully completed the initial Cx of a new building does not mean that the building will remain in a highly tuned and efficient state of operation. A properly executed Cx plan should result in a final Cx report that allows the Owner's staff to not only understand the building systems and how they work, but also why they work the way they do and how to recognize when adjustments are required. A well developed Cx plan will contain checklists for equipment and systems and guidelines that may be used by the operations staff to monitor building performance over time.

Proper monitoring and implementation of appropriate corrective actions in a timely manner is the cornerstone of on-going Cx. Some components of a building's Cx plan should be monitored daily and corrective actions implemented as soon as possible. Typical daily monitoring requirements include critical set-points for building HVAC systems, start/stop schedules for equipment, building occupancy schedules and alarm systems. Typical weekly or monthly monitoring requirements include inspections of roofs, drainage systems, exterior envelope and windows, generator testing, preventative maintenance schedules, and utility consumption. Quarterly or seasonal monitoring requirements include outdoor reset control strategies, change-over valve functions, economizer functions, elevator functions, and fire alarm system tests.

With a proactive and documented on-going Cx plan in place, building operating personnel and facility managers remain aware of the operating characteristics of the building's systems and become more proficient with Cx concepts, which is essential to the efficient operation of the building over time.

One form of on-going Cx that is gaining in popularity is call "Continuous Commissioning®". The CC® process was developed by the Energy Systems Laboratory (ESL) which is a division of the Texas Engineering Experiment Station, The Engineering Research Agency of Texas. Continuous Commissioning® and CC® are registered trademarks of the Texas Engineering Experiment Station, a member of the Texas A&M University System, an agency of the State of Texas. The Continuous Commissioning® process is a specialized form of on-going Cx using standardized approaches to data gathering, monitoring, reporting, and implementation developed by the ESL

and custom adapted for each specific project application. The ESL licenses and supports independent providers under a licensing agreement to deliver this particular service. Agencies interested in pursuing this specialized form of on-going Cx should contract for this service through properly licensed providers only. You can contact the Texas Engineering Experiment Station for a listing of licensed providers by calling (979) 458-3434 or by visiting the Energy Systems Laboratory website at http://www.esl.tamu.edu. The reader may refer to the Continuous Commissioning® Guidebook for Federal Energy Managers for additional information on the CC® process and reference materials.

Another form of on-going Cx being developed is called "Monitoring-Based Commissioning (MBCx)". MBCx is similar to continuous Cx in that the process begins at any time after occupancy and may continue at an enhanced level throughout the life of the building. MBCx combines ongoing building energy system monitoring with standard retro-commissioning practices with the aim of providing substantial, persistent, energy savings [Brown et al. 2006 Brown and Anderson 2006]. MBCx incorporates three characteristics of Cx. The first is commonly associated with the measurement and verification (M&V) phase of a new project wherein metering of utility or energy systems is provided at the whole building level or the component system level for the purpose of monitoring the operations of a building for comparison with the projected performance based on a computer model of the building. The second characteristic is retro-commissioning of the building or systems based upon the analysis of the data provided in the M&V as opposed to an estimated performance. The third characteristic incorporates the long term process of continuous Cx as described above.

In a 2009 report entitled "Monitoring-Based Commissioning" by Lawrence Berkeley National Laboratory, Evan Mills, PhD and Paul Mathew, PhD benchmarked 24 buildings on the campuses of the University of California and California State University systems using the MBCx approach. Their in-depth analysis identified approximately 1100 deficiencies ranging from adjusting temperature set-points to mechanical system alterations. The report included buildings ranging from simple office buildings to complex laboratory buildings. The median Cx cost for these buildings was $1.00 per square foot with a median simple payback of 2.5 years. While impacts varied from project to project, on a portfolio basis, the study found MBCx to be a highly cost-effective means of obtaining program-level energy savings. Savings are expected to be more robust and persistent for MBCx projects that for conventional Cx alone [Monitoring-Based Commissioning et al, Mills and Mathew 2009].

Re-Commissioning

Re-commissioning is the process of verifying the performance of existing building systems that were commissioned previously. The intent of re-commissioning is to ensure that building systems continue to operate according to the design intent and the Owner's current operating needs, which can change over time. Unless on-going Cx has been established, this process is typically performed every 3-5 years, and is used to confirm that the building is performing as originally commissioned (barring major building program changes). When program changes occur, however, this process is useful in Cx minor alterations to an existing building, where the basic mechanical and electrical systems have been modified (but not replaced) for a new occupancy use or schedule. For major alterations or significant changes in building occupancy or use, reusing the existing Cx plan, process and test procedures may be impractical, and result in invalid results. If systems are reconfigured for significantly different duties, a new Cx plan and process should be developed. This should begin with the development of a new Owner's Project Requirements (OPR) document that includes all documentation from the original project (from the original planning phase through final operations and maintenance (O&M) training and closeout). Developing a new OPR minimizes the possibility of overlooking critical building information.

The re-commissioning process is essential to the persistence of a building's performance over time. The process begins with a re-evaluation of the OPR and Basis of Design (BOD) documents, and a review of the initial Cx plans and reports to ensure that the existing Cx plan

and processes are still applicable and complete. The Cx team should interview the building operations staff and selected occupants/tenants to identify problems that may have developed after the initial Cx process was completed. Detailed surveys of current operating conditions and parameters of the building's systems should be performed to establish current baselines. The original Cx plan should be updated, and re-commissioning of the building should be executed to the same level of detail as the first Cx process.

If the initial construction phase Cx plan included the building enclosure (envelope) it should be reviewed and verified during design and construction. Review of all existing enclosure (envelope) components may be difficult or costly, but attention should be given to accessible components during re-commissioning to confirm that the original report was accurate and to identify areas of potential deterioration due to age or damage by other activities.

Retro-Commissioning (Existing Building Commissioning)

Retro-commissioning (RCx) is the process of Cx an existing building (or its systems) that was not commissioned when the building was constructed, and is used to ensure that a building's systems perform interactively in conformance with the Owner's current operational requirements. This RCx process is also referred to as Existing Building Commissioning (EBCx). The retro-commissioning process measures existing building performance and identifies necessary modifications that will maximize the efficiencies of the building's existing equipment and systems. Improvements in equipment and systems performance are then verified through functional performance testing, existing O&M manuals are reviewed and updated, and where necessary, additional training is provided to operating personnel. The retro-commissioning process also results in a detailed RCx (EBCx) plan and report that include procedures for on-going RCx and periodic re-commissioning, as appropriate.

One of the biggest hurdles to the retro-commissioning process is the establishment of the building baseline, since the original OPR and BOD documentation often does not exist. If possible, it is useful to engage the original building's design team in the retro-commissioning process to get their comments on original design and program requirements. The original building contractor may also be able to provide information on how the building was constructed, and what issues or changes may have occurred during construction. The contractor may have a log of warranty or maintenance call backs during the initial warranty period that may shed light on current operating conditions.

Since many older existing buildings have little or no original construction or O&M documentation it may be necessary to have the Cx authority or a separate consultant prepare existing drawings of the building and its systems and to research and reconstitute the original O&M manuals. The costs for these activities will vary with the amount of existing information available and the age of the building components, but this information is essential for the successful completion of a retro-commissioning plan.

Retro-commissioning requires a greater amount of experience and analysis when compared with the Cx of new buildings, and is generally more difficult and expensive because the equipment is already installed and is not always easily accessible.

Typical candidates for retro-commissioning include buildings with complex systems, excessive operational or utility costs, significant environmental control problems, or buildings whose intended use has changed. Even the passing of time causes wear and tear and loss of calibration of devices, resulting in reduced efficiency and loss of normal control capacity. In extreme cases operators may spend all their time reacting to temperature and environmental control problems at the expense of routine preventative maintenance.

The RCx (EBCx) process for buildings that do not involve major renovation would include "Planning, Investigation, Implementation, Turnover and Persistence" phases. The reader may

refer to the Guidance for Retro-Commissioning[1,2] for additional retro-commissioning information and reference materials.

In more complex cases requiring a significant capital investment, the assistance of a design professional may be required to design a major renovation project in which the retro-commissioning process might occur in phases similar for new buildings. The initial "Planning" phase would include gathering and evaluating documentation, assessing installed equipment and testing systems to determine facility deficiencies. This would be followed by design and construction phases to implement the required renovations. During the design/construction phases it is recommended that the Cx authority perform reviews, make periodic site visits and complete equipment installation checklists, followed by functional testing of the renovated systems to ensure they perform as required.

[1] Energy Facility Contractors Group (EFCOG), Best Practice #42 "Retro-Commissioning Guide", Guidance for Retro-Commissioning, 4/21/2006; http://www.efcog.org/bp/p/42.htm.

[2] A Retrocommissioning Guide for Building Owners, PECI, January 1, 2007; http://www.peci.org/resources/library/retrocommissioning-guide-building-owners.

L. Glossary of Terms

Basis of Design: The Basis of Design is a narrative that explains how certain systems and space arrangements were chosen by the design team to satisfy the owner's project requirements. This document is typically prepared by the architect/engineer and is intended to be a living document.

Building Enclosure: The building enclosure includes all building systems that physically separate the outside or exterior environment from interior environments. The building enclosure systems include the below grade perimeter walls, slab on grade or crawl space; and the exterior above grade building envelope. The building enclosure manages, controls, and/or protects the interior environment from air (infiltration/exfiltration), water intrusion, vapor migration, thermal gains and losses, light, sound attenuation, as well as providing security and structure, .

Building Envelope: The building envelope is comprised of the above grade façade systems, fenestration, roofing systems, exterior walls and insulation, vapor retarders, air and water barriers.

Building Systems: Building systems are the architectural, structural, mechanical and electrical systems of a building along with their respective control systems, subsystems, equipment and components.

Commissioning (Cx): Commissioning is a quality-focused, systematic process for enhancing the delivery of a project. It is a collaborative process that ideally begins at project inception and continues for the life of the facility, in the form of new building commissioning, followed by periodic re-commissioning. A comprehensive commissioning process includes verifying and documenting the facility and all its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements.

Commissioning Authority (CxA): The qualified person, company, or agency that plans, coordinates, and oversees the entire commissioning process. The term is typically applied to the commissioning project manager, but is also commonly applied the entire team, company or agency performing commissioning, so it must be interpreted based upon context.

Commissioning Final Report: The document prepared during the acceptance phase of the commissioning process after all functional performance tests are completed. It includes an executive summary, building description, the completed commissioning plan, definition of commissioning scope, all completed forms and a description of all outstanding issues at the completion of commissioning.

Commissioning Plan: The document prepared for each project that describes all aspects of the commissioning process including schedules, responsibilities, documentation requirements, and functional performance test requirements. The level of detail in the document depends on the scope of the specified commissioning activities. The plan is often prepared in preliminary form during early design and is updated periodically throughout the project. As a result, it is sometimes referred to as a living document.

Commissioning Test Plan: The document prepared for each system, piece of equipment, or energy efficiency measure that details the pre-functional or functional performance test and describes the testing process. The test plans are included as an appendix to the final commissioning report.

Control Strategy: An approach to controlling equipment. Usually this term refers to automated programming implemented through a building automation system or energy management system that is designed to control equipment while providing safety, comfort, and energy efficiency.

Data logger: A stand-alone, electronic data-gathering device that utilizes sensors and a recording system to collect equipment information over time. Data collected could include temperature, pressure, current, humidity, or other operational information. May be installed temporarily or permanently, depending upon the intent.

Energy Management System (EMS): The automatic system used for controlling equipment in a building. Most likely, this will be a computer-based system, including either pneumatic or digital components, or both. The EMS may also be called an Energy Management Control System (EMCS) or a Building Automation System (BAS).

Existing Building Commissioning (EBCx): See Retro-Commissioning (RCx).

Functional Performance Test: Checks and tests carried out to determine whether components, subsystems, systems, and interfaces between systems function in accordance with the design intent in the installed condition. "Function" includes all modes and sequences of control operation, interlocks, conditional control responses, and specified responses during design day and emergency conditions.

Indoor Environmental Quality (IEQ): A term that refers to the artificial environment that exists in a building and includes the factors of thermal comfort, illumination, noise, ventilation, and level of indoor air pollutants.

Integrated Systems Test: Test designed to ensure that specified systems have been installed and coordinated to work as designed with other specified systems.

O&M Assessment: A systematic method for identifying ways to optimize the performance of an existing building. This assessment involves gathering, analyzing, and presenting information based on the building owner or manager's requirements.

Owner's Project Requirements (OPR): The OPR is a high level document developed during the conceptual or programming phase of a project either by the owner or a consultant. It typically defines fundamental project goals and provides broad functional requirements and design parameters. It is a living document, maintained throughout project design and construction phases, and serves as a guideline for subsequent design decisions, typically documented in the Basis of Design, defined previously.

Simple Payback (in years): The cost of an energy efficiency improvement divided by the net cost savings per year. In other terms, the length of time that an energy-efficiency improvement will take to pay back the cost of the initial investment, without discounting the savings for the time value of money.

Preventive Maintenance Program: A program that is implemented to proactively address equipment maintenance. The goal of such a program is to perform maintenance tasks on a regular schedule so as to maximize the operational efficiency and lifetime of the equipment.

Retro-commissioning (RCx): Retro-commissioning is the process of commissioning an existing facility that was not previously commissioned. It is the application of the commissioning process to a project that has been constructed and occupied.

Re-commissioning (ReCx): Re-commissioning is the periodic reapplication of commissioning to a facility which was previously commissioned.

Short-cycling: Equipment that goes through a complete on/off cycle too often is said to be short-cycling. Continued short-cycling operation can reduce equipment life, waste energy, and cause ineffective control.

Testing Adjusting and Balancing (TAB): TAB is the formal process of adjusting and balancing the building's HVAC system. The air and hydronic systems are measured for required flows; fans, pumps, dampers, valves, balancing and automatic control devices adjusted; and ductwork and piping distribution systems balanced to achieve the specified flow amount, retested for verification and documented.

M. List of Acronyms

AABC	Associated Air Balance Council
ACG	AABC Commissioning Group
A/E	Architect Engineer
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
BAS	Building Automation System
BC_xA	Building Commissioning Association
BECx	Building Enclosure Commissioning
BOD	Basis of Design
CC®	Continuous Commissioning®
CD	Construction Documents
CM	Construction Manager
CMAR	Construction Manager at Risk
CSI	Construction Specifications Institute
Cx	Commissioning
CxA	Commissioning Authority
DDC	Direct Digital Control
EBCx	Existing Building Commissioning (see Retro-commissioning)
EMCS	Energy Management Control System
EMS	Energy Management System
FPT	Functional Performance Test
HVAC	Heating Ventilating and Air Conditioning
IEQ	Indoor Environmental Quality
IST	Integrated Systems Test
LEED	Leadership in Energy and Environmental Design
MBCx	Monitoring-Based Commissioning
NEBB	National Environmental Balancing Bureau
$NETA_{TM}$	InterNational Electrical Testing Association

O&M	Operations and Maintenance (of a building)
OPR	Owner's Project Requirements
PECI	Portland Energy Conservation, Inc.
PM	Preventive Maintenance
R&D	Research and Development
RCx	Retro-commissioning
ReCx	Recommissioning
RFI	Request for Information
RFP	Request for Proposal
RFQ	Request for Qualifications
SOW	Scope of Work
TAB	Testing, Adjusting and Balancing
USGBC	U.S. Green Building Council

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Oregon Office of Energy. March, 1997, “Commissioning for Better Buildings in Oregon.” Prepared by PECI, Portland, Oregon. http://www.oregon.gov/ENERGY/CONS/BUS/comm/docs/commintr.pdf?ga=t.

Heinz, John A. and Casault, Rick. 1996. “The Building Commissioning Handbook” 2nd Edition, The Association of Higher Education Facilities Officers, Alexandria, VA. Order at www.appa.org/bookstore/index.cfm (choose "Planning, Design and Construction"); or call at 703-684-1446.

“The HVAC Commissioning Process”, ASHRAE Guideline 1-1996. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, Georgia. Order at www.ashrae.org.

US Army Corps of Engineers. July, 1995. “Engineering and Design-Systems Commissioning Procedures,” Publication Number ER 1110-345-723. http://publications.usace.army.mil/publications/eng-regs/er1110-345-723/toc.htm.

Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA). October, 1994. "HVAC Systems Commissioning Manual-First Edition." Order at www.smacna.org , or call 703-803-2980.

Kao, James Y. March, 1992. “HVAC Functional Inspection and Testing Guide” Paper No. NISTIR 4758, National Institute of Standards and Technology of the US Department of Commerce. http://www.ntis.gov/search/product.aspx?ABBR=PB92173012.

Other Information Resources:

The following organizations provide resource materials, webinars, training, certifications and links to other organizations:

American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE); www.ashrae.org
Associated Air Balance Council Commissioning Group (ACG); www.commissioning.org
Building Commissioning Association (BCA); www.bcxa.org
California Commissioning Collaborative (CCC); www.cacx.org
National Environmental Balancing Bureau (NEBB); www.nebb.org
National Institute of Building Sciences (NIBS); www.nibs.org
Portland Energy Conservation, Inc. (PECI); www.peci.org
University of Wisconsin-Madison, Dept. of Engineering Professional Development; http://cx.engr.wisc.edu/

The Annual National Conference on Building Commissioning is held each year in different locations throughout the US. The 20th national conference will be held in Nashville, TN on May 15th and 16th. The Building Commissioning Association (BCxA) and Portland Energy Conservation, Inc. (PECI) will be co-producing this event. Refer to their web sites at www.bcxa.org or www.peci.org for information about this year's conference.

The 8th Annual Conference on Total Building Commissioning will be held in Las Vegas, NV on April 25th thru 27th, 2012. The Associated Air Balance Council Commissioning Group (ACG) is organizing this event. Refer to their web site at www.commissioning.org for information on this year's conference.

California Commissioning Resources and Links

1. *Commissioning Toolkit for Small Buildings* - http://www.green.ca.gov/CxToolkit
    a. Includes instructions and templates for all aspects of fundamental commissioning for new buildings or major renovations. Templates are in Word or Excel format, and can be downloaded and edited.
    b. Developed by California's Department of General Services
2. *Existing Building Commissioning Toolkit* - http://www.cacx.org/resources/rcxtools
    a. Includes templates and sample documents for use in commissioning existing buildings. Templates and forms are in Word format for easy editing.
    b. Developed by the California Commissioning Collaborative, and including forms from PECI and PG&E.
3. *California Commissioning Guide for New Buildings* - http://www.documents.dgs.ca.gov/green/commissionguidenew.pdf
    a. Describes the building commissioning process.
    b. Intended for building owners, managers and operators.
    c. Developed by the California Commissioning Collaborative for the State of California.
4. *California Commissioning Guide for Existing Buildings* - http://www.documents.dgs.ca.gov/green/commissionguideexisting.pdf
    a. A guide for commissioning existing buildings (retrocommissioning) intended for building owners and managers. Provides a foundation for anyone considering a retrocommissioning project.
    b. Developed by the California Commissioning Collaborative for the State of California.
5. *CALGREEN Non-residential Commissioning Guide* - http://www.documents.dgs.ca.gov/bsc/CALGreen/Non-Res-Comm-Guide-10-10.pdf
    a. Guidance document clarifying commissioning requirements for the *2010 California Code of Regulations, Title 24, Part 11 (CALGREEN)*.

b. Includes intent and requirements code commissioning elements, as well as suggestions for compliance, templates and sample documents.
c. Developed by the California Building Standards Commission.
d. Building commissioning is required by code for all newly constructed non-residential buildings in California greater than 10,000 sq. ft.

Appendix I - 1
Sample Commissioning Services Advertisement (Courtesy of DGS, CA)

Provide professional engineering commissioning (Cx) services for the construction of a new _____located in _____. The _____ facility will include counter and drive test services to the public.

The DMV field office replacement project consists of a _____ SF, single story facility designed to accommodate public service operations for the community. The project will include demolition of an existing warehouse and field office structure currently located on the site in addition to earthwork, surface parking, underground utilities, concrete slab on grade, steel frame structure, with a concrete masonry unit & stucco exterior and standing seam metal roof elements of the new facility. The facility's HVAC system will include multiple packaged rooftop air conditioning units (electric cooling and natural gas heating) with integrated economizers, power exhaust, filter, supply fan with variable frequency drives (VFD) served by a Direct Digital Controls system.

The estimated cost of construction is $_____.

The firm will act as the independent third party Cx agent in an oversight capacity during the Cx process to verify that fundamental building elements and systems are designed, installed and calibrated as intended. In addition, the firm will verify that the State maintenance personnel are properly trained to operate the systems and have received a complete set of documentation of systems installed.

Interested firms may obtain a Request for Qualifications Package (RFQ) by downloading it from the _____ on the Internet at: _____. This is the preferred point of contact. The RFQ package may also be obtained by sending a request to one of the contact points listed below. Please include AD Number, contact person's name, firm name, firm's Federal Employer Identification Number (FEIN), mailing address and phone number. Request processing will be delayed if all information is not provided.

Submittal Deadline: _____
Duration: _____
City and County: _____
Department: _____
Internet Address: _____

Appendix I - 2
Sample RFQ - Low Criticality Project (Courtesy of DGS, CA)

Request for Qualifications
Department of General Services
Real Estate Services Division
Project Management Branch

The Department of General Services (DGS), Real Estate Services Division (RESD), Project Management Branch (PMB) is requesting Statements of Qualifications (SOQ) from Engineering Services consulting firms for the project(s) listed below.

_____
_____
_____
_____
_____
_____

Scope of Services

The Firm(s) shall provide professional engineering commissioning (Cx) services. The responsible party shall be an engineer licensed to practice in the State of _____ and all work shall be performed under and approved by a licensed design professional. Services may include review of design documents and Cx services during the preliminary plan, construction document, bid support and construction phases of the project.

Project Description

Provide professional engineering Cx services for the construction of a new _____ located in _____. The _____ facility will include counter and drive test services to the public.

The _____ project consists of a _____ sf, single story facility designed to accommodate public service operations for the Fresno community. The project will include demolition of an existing warehouse and field office structure currently located on the site in addition to earthwork, surface parking, underground utilities, concrete slab on grade, steel frame structure, with a concrete masonry unit & stucco exterior and standing seam metal roof elements of the new facility. The facility's HVAC system will include multiple packaged rooftop air conditioning units (electric cooling and natural gas heating) with integrated economizers, power exhaust, filter, supply fan with variable frequency drives (VFD) served by a Direct Digital Controls system. The field office is being designed to achieve LEED Silver certification. The firm shall have experience in Cx the construction of facilities of similar size and complexity.

The firm will provide services to assist the DGS, RESD in incorporating sustainable features included in the Leadership in Energy & Environmental Design (LEED) program to obtain a minimum of LEED Silver rating. A LEED accredited professional will be required for review, evaluation, and documentation.

The firm will provide fundamental and enhanced Cx services necessary to meet the requirements of Prerequisite 1 and Credit 3 of the Energy & Atmosphere category for LEED version 2.2. The firm will act as the independent third party Cx agent in an oversight capacity during the Cx process to verify that fundamental building elements and systems are designed, installed and calibrated to operate as intended. The firm will review the design intent and the basis of design

documentation; perform peer review as required to meet the requirements of Credit 3 of the Energy & Atmosphere category for LEED version 2.2, assure that the Cx goals have been incorporated into the construction documents; develop and utilize a Cx plan; verify installation, functional performance, training and operation and maintenance documentation; verify that State maintenance personnel are trained properly to operate systems and have the complete documentation; complete a Cx report; and perform other Cx duties as required by LEED and as deemed necessary by the State.

Project delivery method for this project will be "design-bid-build" using standard State procedures.

The Contractor's team selected for this work, including all sub-consultants, shall be precluded from participating in the bidding of any construction or other competitively bid contract work on the project.

The estimated cost of construction is $_____.

Minimum Requirements

Firms who are interested in providing professional services for this contracting opportunity shall submit the following information.

Submittals will be scored only upon receipt of the following minimum criteria, which are mandatory:

Submit <u>two (2) sets of the following</u>:

- Letter of Interest that includes the Federal Identification Number of the firm.
- Secretary of State Certification identifying _____ legal operating name. If operating under a fictitious business name, provide all supporting documentation. (i.e. Fictitious business name statement certified by the appropriate county clerk)
- Licensed Architect/Engineer - copy of _____ license.
- Written statement of the firm's qualifications that is responsive to the selection criteria. **Please respond to each and every numbered criteria listed in the "Selection Criteria" below with complete and organized responses.**
- Federal Form 330 Parts I & II for the firm and Federal Form 330 Part II for any proposed sub-contractors.
- **Disabled Veteran Business Enterprises (DVBE) compliance forms. IMPORTANT: Please see enclosure, "Disabled Veteran Business Enterprise Participation Requirements". Compliance will require immediate action on the part of the Contractor.**
- Provide Small Business Certification if certified as a small business.

The State encourages Small Business Enterprises to apply. If you feel your company or your subcontractor qualifies as a small business firm, you may visit _____ for more information or call the Office of Small Business and DVBE Services at (XXX) XXX-XXXX for further information. Please note no preference in the qualifications category can be given to Small Business firms under the contracting law set up for professional services (Architectural, Engineering, Environmental Services, etc.) contracts.

Documents shall be received no later than _____

Documents shall be submitted to:

_____

_____
_____
_____
_____

Facsimile (FAX) and e-mail submittals will not be considered.

Selection Criteria

1. Professional experience of the firm in relation to the work to be performed.

    a. List each person with their role and office location for all staff identified as a part of this proposal.

    b. Identify staff of sub-consultants similarly but separately.

2. Professional experience of the principals to be assigned to the project.

    a. List the Principals to be assigned to and involved with the project.

3. Professional experience and training of key personnel.

    a. List staff education, certification and training.

4. Demonstrated competence and specialized experience of firm.
5. Nature and quality of completed work.
6. Reliability of the firm and continuity of proposed firm's staff and sub-Contractors with firm.
7. Firm's workload and demonstrated ability to meet schedules.
8. Location of firm office(s) for project coordination and services.
9. Demonstrated effectiveness of Cx services and procedures being utilized by firm.

    Firm's team shall be comprised of all disciplines necessary to effectively perform the Cx services for the project including, but not limited to mechanical and electrical engineering. Consultant team shall be experienced with designs of similar size and complexity.

    Firms shall respond in writing indicating how they believe their qualifications fulfill the requirements of these criteria.

Contract Administrative Process

Firms will be selected on the basis of written responses to this Request for Qualifications (RFQ) and an oral interview.

Submittals will be evaluated and scored based upon the above selection criteria for those firms who have complied with the minimum qualification requirements.

At least three firms with the highest scores will be selected for the "short list". These firms will be invited for an interview and asked to make an oral presentation on their firm and its qualifications and experience.

Upon completion of all interviews, the firms will be rated in order of preference - 1, 2, 3, etc. The number one firm for each project will be asked to submit a fee proposal. The State reserves the right to select either one firm for each project or one firm for both projects. The PMB will attempt to negotiate a fee for services. In the event that a satisfactory agreement cannot be negotiated,

the PMB will terminate negotiations with the firm and begin negotiations with the next ranked firm and so on. After successful negotiations, a contract will be awarded and executed.

The State reserves the right to terminate the selection proceedings at any time.

Ten percent (10%) retention will be held for all progress payments made to Consultant. When the estimated amount to be retained exceeds ten thousand dollars ($10,000), and the retention continues for a period of 60 days beyond the completion of phased services, upon written request and at the expense of the Consultant, the State will pay the retentions earned directly to a state or federally chartered bank in this state, as the escrow agent. (Public Contract Code section XXX). See Public Contract Code section XXX for further requirements pertaining to sub-consultants.

The State encourages Small Business Enterprises to apply. If you believe your company or your sub-consultant qualifies as a small business firm, you may log onto _____ for more information. Please note that no preference in the qualifications category can be given to Small Business firms under the contracting law set up for Architectural and Engineering contracts.

QUESTIONS
All technical questions should be directed to _____.
Please reference the Ad Number when contacting our office. Questions related to this Request for Qualifications, the contents of the Statement of Qualifications, or related administrative matters should be faxed to _____.

Appendix I - 3
Sample RFQ - On-Call Commissioning Services (Courtesy of DES, WA)

March 1, 2011

NOTICE TO CONSULTANTS

Cx services are needed for Project No. _____, Cx Projects for Public Facilities, Statewide.

Scope of Work

The scope of work consists of Commissioning (Cx) services for _____. Chosen firms may assist in development and coordination of the Cx specifications (Divisions 01810, 15995, and 16995) and may participate in the design review process. The systems to be commissioned may include, but are not limited to Divisions 15 Mechanical (such as HVAC equipment, HVAC controls, ductwork, exhaust fans, smoke evacuation systems, carbon dioxide detectors, plumbing, fire/life safety, domestic hot water,); Division 16 Electrical (such as lighting controls, power monitoring systems, security, low voltage systems and emergency power); and building envelope. Chosen firms must meet LEED requirements. Chosen firms may be involved in reviewing the training materials and videotaping the training sessions. The Building Cx Guidelines for the State of _____, may be used as a guide for typical equipment to be commissioned in Divisions 15 and 16.

Chosen firms may be required to begin at the early design stages of the project and will stay with the project through completion. Chosen firms may also be required to check the systems periodically for one year after completion.

There is no implied guarantee of minimum number of projects.

Cx fees and services shall comply with the current Architectural/ Engineering Fee Schedule for _____ State Building Projects and the standard Division of Engineering and Architectural Services Agreement.

Firms will be considered for selection based upon the following criteria categories:

Qualifications of staff to be used on project

Professional background; membership or affiliation with building Cx associations; Cx certifications; years of hands-on experience performing Cx activities in mechanical, electrical, and building envelope systems; and other similar information.

Relevant Experience

Description of Cx projects in each of the following categories: new Cx, retro-commissioning, re-commissioning; LEED; maintaining Cx schedules; working with subconsultants; experience establishing Cx criteria; and other similar information.

Previous Performance

Letters of recommendation (owners, prime consultants); show how your firm has maintained

budget and schedule control and compliance; identify at least five Cx projects in the Northwest that your firm has been involved in within the past three (3) years and describe your firm's role; and other similar information.

Geographic Proximity

Identify company branch location(s) and dedicated staff at each.

The period of performance for these consultant services shall commence _____ and expire _____ unless altered or amended.

MWBE requirements for this project are 0% for Minority Business Enterprises and 0% for Women's Business Enterprises. However, MWBE participation is strongly encouraged.

Submit six (6) CDs of your qualifications

Do not submit fax or paper copies. Each CD should be formatted such that the information printed out includes: No more than fifteen (15) single sided pages (8½ X 11), up to three (3) letters of recommendation, and completed and signed Federal 330 form. (15 pages does not include cover letter, table of contents, nor the Form 330). Statements of qualifications and Federal 330 form should be saved as separate documents on the CD. **To qualify for consideration, submittals are required to be delivered to and date/time stamped prior to _____ PM, _____. Address submittals to:**
_____.
NO FAXED COPIES WILL BE ACCEPTED.

Anticipated dates for interviews are the week of _____. Firms will be notified of interview status no later than _____.

Following an evaluation of these submittals, the consultant selection board will interview firms deemed to be the most highly qualified for the required service.

Questions regarding this project should be directed to _____
Questions regarding the project selection process should be directed to
_____.

The state of _____ is an affirmative action employer. This is not a request for a proposal. All submittals become the property of the State.

Appendix I - 4
Sample RFQ - Building Enclosure Commissioning Services (Courtesy of DCAM, MA)

LAST DATE FOR FILING APPLICATION IS: _____

The Board requests applications to be submitted by any of the following firms:

(	)	Architect	(**X**)	Engineer (Structural)
(**X**)		Architect/Engineer (A/E)	( )	Other:

PROJECT NUMBER: _____

PROJECT TITLE: _____

PROJECT LOCATION: **Various State and County-Owned Facilities (Statewide)**

AWARDING AGENCY: _____

APPROPRIATION SOURCE: **Various (To Be Determined)**

AVAILABLE AMOUNT: **$**_____ **per contract**

ESTIMATED CONSTRUCTION COST: **N/A**

TOTAL FEE, excluding reimbursables, based on scopes of work and services authorized, shall not exceed:

(**X**) Lump sum established set fee per _____ _____Dollars

Immediate Services Authorized

( ) CERTIFIABLE BUILDING STUDY
( ) SCHEMATIC PLANS AND OUTLINE SPECIFICATIONS
( ) DESIGN DEVELOPMENT PLANS AND SPECIFICATIONS
( ) CONSTRUCTION PLANS AND SPECIFICATIONS
( ) ADMINISTRATION OF CONSTRUCTION CONTRACT
( ) OTHER (INDEPENDENT THIRD PARTY OVERSIGHT)

MBE/WBE Participation

Insert MBE/WBE participation guidelines here, if applicable.

Appropriation Language

N/A

General Scope of Work

This advertisement is for third-party Building Enclosure Commissioning services, a systematic process of ensuring that a building's exterior resists moisture intrusion and air infiltration and maintains a continuous thermal barrier. Building Enclosure Commissioning Agents (BECA) must

be qualified in organizing, scheduling, and coordination functional performance testing of building envelope systems for a wide variety of building types. Each BECA must have, as a minimum, extensive experience in building enclosure construction including (but not limited to):

- Opaque walls
- Windows
- Curtain walls
- Masonry
- Concrete
- Roofs
- Sub-grade and slab-on-grade construction

Each BECA must also be familiar with the characteristics and properties of commonly used building enclosure materials, and have an understanding of prevailing State building and energy code requirements. Each BECA must also have an excellent working knowledge of complex environmental separation construction, to include (but not limited to):

- Thermal protection
- Air barriers
- Vapor retarders/barriers
- Water management/drainage systems
- Waterproofing

Each BECA must be capable of resolving on-site construction problems, analyzing building code requirements and recommending appropriate modifications when necessary.

The BECA may be responsible for the following tasks as part of each assignment:

Design Phase

- *Commissioning Workshop* – The BECA will conduct a commissioning workshop with the Design Team to determine which envelope components are to be commissioned. The purpose of this workshop is to focus on specific key components within the building enclosure design or issues that occur during construction that may allow moisture and/or air infiltration.
- *Peer Reviews* – The BECA will conduct all peer reviews within the timeframe allocated for scheduled owner reviews, and will not impact the design process. The BECA will conduct reviews during the 50% and 100% Design Development Phases.
- *Constructability Reviews* – The BECA will perform a constructability review at the 60% Construction Documents submission. Individual details, components and materials are reviewed to assess compatibility within the confines of the system and to adjoining components or materials within the building envelope.

Construction Phase

- *Commissioning Workshop* – The BECA will conduct a commissioning workshop with the Construction Manager and subcontractors for the various components of the building enclosure. The BECA will explain the enclosure commissioning plan, and detail the various inspections and functional test procedures.
- *Review of Submittals, Substitutions, and Shop Drawings* – The BECA will review shop drawings during construction to determine whether the proposed details can be constructed according to the general design intent, and will issue related written/recommendations.

- *Onsite Inspections* – The BECA will review all documentation affecting the building envelope and its assemblies, and in collaboration with subcontractors and associated vendors will develop inspection and test procedures to verify the proper installation of each building envelope component. The BECA will provide a copy of the test procedures to the Construction Manager and/or subcontractor(s), who will review the tests for feasibility and warranty protection and issue related written comments/recommendations.
- *Performance Testing* – When included within the project scope, the BECA will review the construction and testing of a mock-up that is representative of both the skill level(s) of contractors working on the site as well as components of the system where failure is most likely to occur and will issue related written comments/recommendations.

Additional Supporting Documents

N/A

General Conditions for this Contract

Contract

If selected for study services, the applicant agrees to execute the _____ Contract or its successor, without revisions or modifications. _____ compensates the designer during the Study Phase for approved products in accordance with the approved work plan.

Financial Statement

Chapter XXX requires that on public design contracts where the total design fee is expected to exceed $_____ or for the design of a project for which the estimated construction cost is expected to exceed $_____ the designer shall:

1. File its latest CPA or PA audited financial statement with the _____, and continue to do so annually throughout the term of the contract;
2. Submit a statement from a CPA or PA that states that they have examined management's internal auditing controls, and expresses their opinion regarding those controls.

_____ Procedures

The designer will follow the procedures established in _____ Designer Procedures Manual dated _____. Applicants are urged to review and become familiar with the following supplemental material, which is available on the web at: _____.

Executive Order 484

Projects undertaken under this contract shall comply with all applicable requirements of Executive Order _____. All building studies shall include preliminary estimates of the project's energy use, water use, and greenhouse gas emissions using protocols established by _____ or as determined by _____. No building study shall be certified for final design unless all means, methods, and commitments required to mitigate the project's impact on the operating agency's plan for meeting _____'s goals are documented in the consensus solution, implementation plan and estimated construction cost.

Universal Design

In addition to complying with _____, the consultant will review ADA Title II, and the ADA Accessibility Guidelines, to ensure that the proposed design meets the civil right intent of this act. The requirements of these two laws may differ and the consultant must comply with the more stringent. Design solutions will meet the diverse and changing needs of users across age, ability, language, ethnicity and economic circumstance. _____ welcomes innovative design strategies that are simultaneously equitable, flexible and legible for all and extend beyond minimal compliance with accessibility regulations.

Construction Specifications

The designer shall utilize the _____ Standard Specification.

Cost Estimating

Cost estimates, cost models, and estimator participation in both the study and the design phases shall meet the requirements of the current _____ *Cost Estimating Manual* and will be submitted in Uniformat II in the study phase and in both Uniformat II to Level 3 and CSI Masterformat in the design phase. The *Cost Estimating Manual* can be found at _____, and Uniformat II can be found at _____.

Conditions for Application

The applicant's current or updated Master File Brochure must be on file with the Board prior to the date of application. As a condition of application, each applicant, if selected for the new project, agrees to carry professional liability insurance in an amount equal to the lesser of $_____ or __% of the Project's Fixed Limit Construction Cost, but in no event less than $_____ per claim in accordance with the Design Contract (i.e., minimum coverage of $_____ up to $_____ depending on the construction cost). The Agency may seek additional coverage for the selected designer, and if so will bear the cost of the additional coverage.

Application Evaluation - Personnel

Applications will be evaluated based on the following prime and sub consultant personnel and extent of compliance with MBE/WBE participation goals. Please see Section 6 on DSB Application Form: On the organizational chart, identify the team by listing them in the same order as below. Include resumes for all personnel.

1. Architect/Engineer, Structural Engineer (Prime)
2. Architect
3. Structural Engineer
4. Mechanical Engineer (M/P/FP)
5. Electrical Engineer
6. Civil Engineer
7. Cost Estimator
8. State Building Code Consultant

Where an "independent consultant" is required the Applicant may not provide the services "in house." If the Applicant plans to fulfill any of the other sub-consultant roles, so indicate on the

organizational chart. Project Managers for Study and Final Design should be listed separately on the organizational chart.

Application Evaluation - Project Experience

Applications will be evaluated based upon the requirements of _____ and the work listed on _____. Each firm responding to this solicitation must submit resumes outlining the experience of each of their in-house or consultant principals in the following areas identified in the Scope of Work for each project:

- Demonstrated experience with building enclosure construction, including but not limited to all types of roofs, opaque and concrete walls, curtain walls, masonry, all fenestrations, and all types of on-grade and sub-grade concrete construction.
- Demonstrated experience with complex environmental separation construction, including but not limited to thermal protection, air barriers, vapor retarders/barriers, waterproofing and water management/drainage systems.
- Ability to recommend modifications to solve problems during design and construction.
- Demonstrated experience with design and field administration of building enclosure systems, and working knowledge of project scheduling.
- Ability to provide examples of separate building enclosure commissioning projects previously completed by their firm.

Applicants Please Note

A copy of the most current Application Form and Instructions - _____ is included with this Notice, and is available for download at _____.

Appendix I - 5
Sample Scope of Work - Building Enclosure Commissioning Services (Courtesy of DCAM, MA)

Scope of Work

This advertisement is for up to six (6) firms that can provide third-party Building Enclosure Commissioning services, a systematic process of ensuring that a building's exterior resists moisture intrusion and air infiltration and maintains a continuous thermal barrier. Building Enclosure Commissioning Agents (BECA) must be qualified in organizing, scheduling, and coordinating functional performance testing of building envelope systems for a wide variety of building types. Each BECA must have, as a minimum, extensive experience in building enclosure construction including:

- Opaque walls
- Windows
- Curtain walls
- Masonry
- Roofs
- Sub-grade and slab-on-grade construction

Each BECA must also be familiar with the characteristics and properties of commonly used building enclosure materials, and have an understanding of prevailing State building and energy code requirements. Each BECA must also have an excellent working knowledge of complex environmental separation construction, to include (but not limited to):

- Thermal protection
- Air barriers
- Vapor retarders/barriers
- Water management/drainage systems

Each BECA must be capable of trouble-shooting on-site construction problems, analyzing building code requirements and recommending appropriate modifications when necessary.

The BECA may be responsible for the following tasks as part of each assignment:

Design Phase

- *Commissioning Workshop* – The BECA will conduct/attend a commissioning workshop with the Design Team to determine which envelope components are to be commissioned. The purpose of this workshop is to focus on specific key components within the building enclosure design or issues that occur during construction that may allow moisture and/or air infiltration.
- *Peer Reviews* - The BECA will conduct/attend all peer reviews within the timeframe allocated to scheduled owner reviews, and will not impact the design process. The BECA conducts reviews during the 50% and 100% Design Development Phases.
- *Constructability Reviews* – The BECA will perform a constructability review at the 60% Construction Documents submission. Individual details, components and materials are reviewed to assess compatibility within the confines of the system and to adjoining components or materials within the building envelope.

Construction Phase

- *Commissioning Workshop* – The BECA will conduct/attend a commissioning workshop with the Construction Manager and subcontractors for the various components of the building enclosure. The BECA will explain the enclosure commissioning plan, and detail the various inspections and functional test procedures.
- *Review of Submittals, Substitutions, and Shop Drawings* – The BECA reviews shop drawings during construction to determine whether the proposed details can be constructed according to the general design intent, and issues related written comments/recommendations.
- *Onsite Inspections* – The BECA reviews all documentation affecting the building envelope and its assemblies, and in collaboration with subcontractors and associated vendors develops inspection and test procedures to verify the proper installation of each building envelope component. The BECA also provides a copy of the test procedures to the Construction Manager and/or subcontractor(s), who review the tests for feasibility and warranty protection and issue related written comments/recommendations.
- *Performance Testing* – When included within the project scope, the BECA reviews the construction and testing of a mock-up that is representative of both the skill level(s) of contractors working on the site as well as components of the system where failure is most likely to occur and issues related written comments/recommendations.

Organization of the BECA's Team

Each firm responding to this solicitation must submit resumes outlining the experience of each of their in-house or consultant principals in the following areas identified in the Scope of Work for each project:

- Opaque walls
- Windows
- Curtain walls
- Masonry
- Roofs
- Sub-grade and slab construction

Any substitution of member(s) made by the BECA in their team organization during a project must have comparable experience and credentials and is subject to approval.

Appendix I - 6
Sample Commissioning Authority Task List
(Courtesy of Karl Stum, Summit Building Engineering)

1	Design Phase	Notes
1.1	Attend selected design team meetings	4 meetings
1.2	Review schematic design	30% design
1.3	Assist in developing owners requirements	OPR by Owner. CxA to provide OPR format/template and questions only. This will include some coordination of getting members to fill in the needed OPR elements.
1.4	Assist in developing basis of design	Narratives by A/E. CxA to review for completeness and clarity in Task 1.6.
1.5	Review owners requirements and basis of design	Review and comment on clarity and completeness.
1.6	Review Design Development documents	60% design
1.7	Provide controls checklist during DD phase.	This is a list of critical issues to be addressed specifically in the design, specifications or specific request to be included in Contractor submittals.
1.8	Review VE report	
1.9	Write draft const. phase Cx Plan	Write a draft scoping plan to inform the Cx Specs.
1.10	Write detailed and rigorous Cx Specifications specifically for this project	Submit table of contents for review, submit 01810 General Cx Reqr for review. Edit and resubmit with additional functional testing sections.
1.11	Review CD's at 50%	HVAC and controls. Limited other disciplines
1.12	Review CD's at 95%	Backcheck 50% CD comments only.
1.13	Prebid support	Attend pre-bid meeting to answer questions.
2	**Construction Phase**	
2.1	Project setup and interview with owner	Project controls, Cx notebook set up, accounting, etc. Interview owner to confirm objectives.
2.2	Planning meeting & kickoff prep and execution	Meeting and trip.
2.3	Misc. meetings (only for construction phase)	Most hours in 2.9.
2.4	Write Cx plan	Write plan and review project docs to become familiar with project.
2.5	Review contractor submittals.	Review to become familiar with equipment and comment on significant systems.
2.6	Issue Log management during Const Phase	Record issues, track, send out reports, update.
2.7	Request and gather special documentation	Request as needed to write tests, etc.
2.8	Write construction checklists and develop Cx notebooks for subs.	Gather vendor checklists and use if complete enough. Or augment with CxA checklists tailored for this project. Equip ID tags in checklists. Create Cx notebooks for major subs consisting of Checklists, functional tests (when done), Cx specs, Cx Plan.
2.9	General field observation and attendance at selected startup.	Misc. review to keep familiar with systems and progress.

2.10	Monitor balancing work	Review and comment on agenda, meet with TAB on site when they start, review TAB report.
2.11	Write functional test forms	Write detailed step by step repeatable test scripts. Subs use to pretest.
2.12	Formal progress reports	Periodically as needed.
2.13	Review RFI's and CO's	Contractor provides Cx-related RFI's and change orders to CxA for their information and use.
2.14	Confirm formal functional test readiness.	Work with subs as they begin to use the functional test scripts. Review their completed construction checklists and discuss their use of functional test scripts. Review BAS screens with controls contractor to confirm test readiness.
2.15	Review coordination drawing development	Check that they are being kept up, but CxA not required to validate.
2.16	Compile and manage Cx record documents	Notebooks of Issues Logs, construction checklists, functional tests, reviews, field visits, RFI's, etc.
2.17	Provide fire alarm and E-power matrices form partially filled in.	CxA provides format and first run at filling it in. Then it goes to subs to fill in the rest and questions go to design team. GC sees that it is completed.
3	**Acceptance Phase**	Acceptance begins after startup
3.1	Misc. meeting attendance	
3.2	Schedule, direct and document manual functional tests	Create and maintain test schedule, notify parties to be there, direct the full test (being performed with the Contractor). Document all results on test forms. Enter Issues in Log. Retest a small fraction on the fly during the test. Later retesting time due to failures is included in 3.10. Direct and document only first fraction of tests for equip with large numbers. Contractor tests the rest alone for which the CxA spot checks and reviews filled in forms.
3.3	Witness & review tests executed & documented by others.	This is for tests conducted and documented by the Contractor on their own. CxA spot witnesses and retests some tests and reviews all completed test reports that contractor documented themselves.
3.4	Review O&M manuals	CxA review specs and creates a matrix of equipment and requirements. Provide matrix to Subs who fill it in when submitting O&M's. CxA spot checks a statistical sample. It is assumed that 50% of this is done on site.
3.5	Coordinate and verify training completion	CxA reviews specs and pulls out requirements, creates agendas for all equipment and provides to contractor and tracks completion of training. CxA does not attend training. GC responsible to schedule and get trainers there.
3.6	Manage issues log and work to resolve issues and test schedule management	This is for the time that isn't included in above tasks. This doesn't include real troubleshooting time which is in 3.10.
3.7	Formal progress reports	NA
3.8	Maintain Cx Record documents	Meeting minutes and correspondence, construction checklists, test forms, RFI's, communications, schedules, progress tracking, etc.
3.9	Request, download, graph and analyze trend logs from BAS to	Develop trend plan. Transmit to contractor. Do trial run. Obtain download from Contractor. Convert data

	evaluate equipment performance.	as required, graph and analyze. Enter issues in the Issues Log and write a brief summary report.
3.10	Trouble shoot systems and retesting allowance	This task covers troubleshooting and retesting after the initial test failed. This task is within Summit's scope only if Summit has agreed that the system is ready for functional testing. Retesting is not included in the scope on equipment where schedule or other pressures resulted in Summit being required to functionally test equipment they deemed not ready or when required to test parts of equipment or systems when other elements of the system were not ready.
3.11	Formally compile functional testing record	Notebooks of Issues Logs, construction checklists, functional tests, reviews, field visits, RFI's, etc.
3.12	Formal Cx Summary report	Write a summary report giving the overall scope and process, the results with outstanding issues separately identified. Provide a draft and final version.
3.13	Submission to USGBC for LEED	
4	**Occupancy Phase**	
4.1	Compile and contribute to systems manual.	Sources of data given here. CxA to compile and format. Overall compilation by CxA, BoD (OPR optional) by A/E, 1-lines by AE, Ctrl dwgs & SOO's & setpoints by Contractor, Operating instructions by CxA, Maintenace schedule (in O&Ms), Recalibration & testing frequency and On-Going Cx Guidelines with forms by CxA.
4.2	Perform seasonal or deferred tests	This assumes the building will be finished in the summer, so peak cooling testing will occur during final testing. Thus, only off season testing confirming swing season system switchover will be needed. This will be done mostly by trend logs.
4.3	10 month warranty review	Return to the site for 1 day. Review with facility staff current building operation and condition of outstanding issues related to the original and seasonal commissioning. Assist facility staff in developing reports and documents and requests for services to remedy outstanding problems.
4.4	Occupancy period optimization	In addition to the on-call work (4.1), CxA will provide 3 days of on site support to fine tune and adjust setpoints and sequences of operation to improve control, comfort and energy efficiency.
4.5	Tenant Design & Construction Guidelines	Provide input to this document by Others. Attend 3 meetings (one on site, 2 by phone).
4.6	M&V plan assistance	Assist in developing the plan which is the prime responsibility of Others. Attend up to 1 site and 2 conf call meetings.

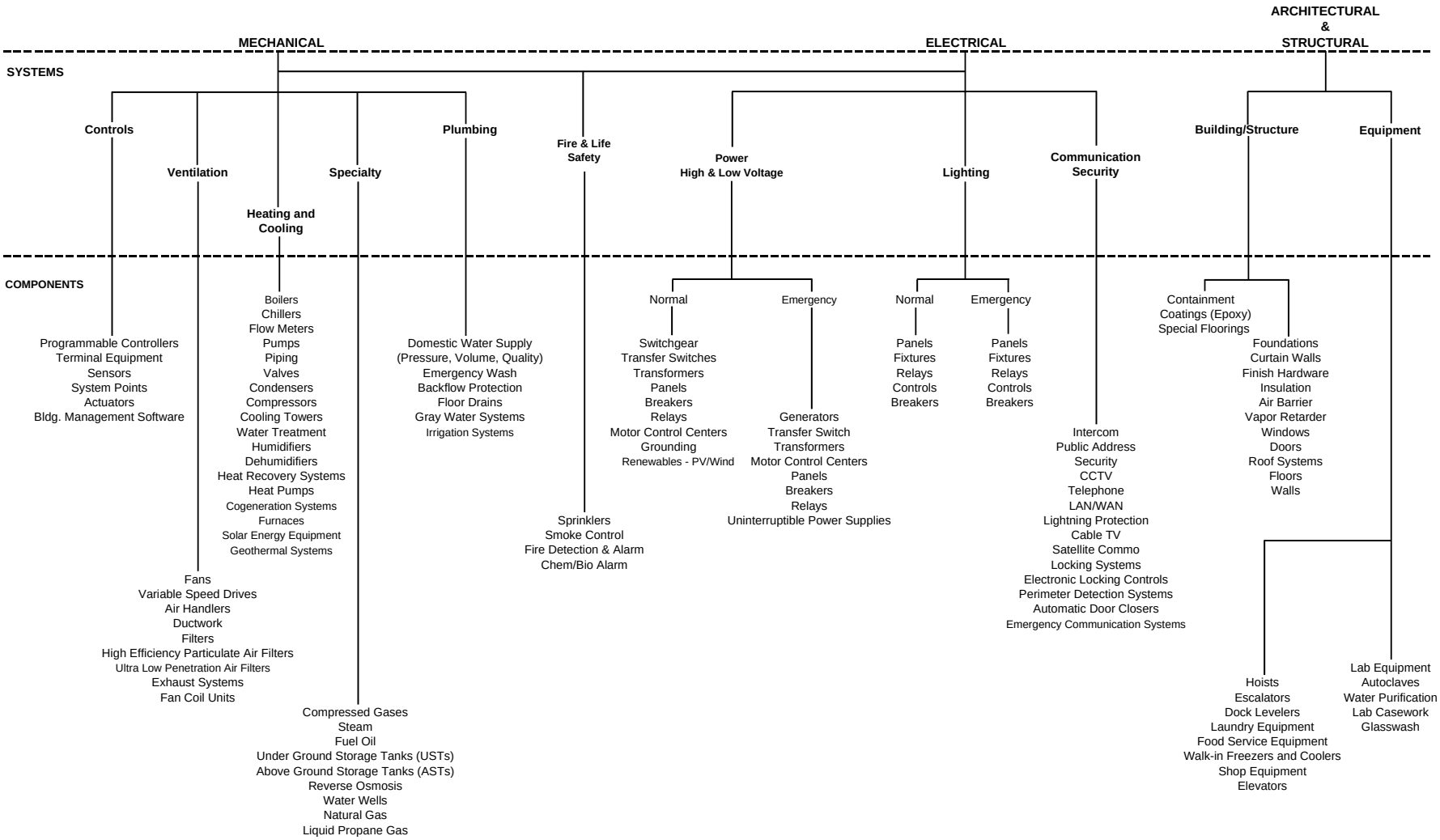
Appendix II - Guidance for the Commissioning Process

The following table provides guidance for the Commissioning (Cx) Process on a project.

- The term "contractor" is understood to refer to any of several entities that provide construction services. Depending on the project, this could include, among others, the owner's representative, construction manager, contractors and sub-contractors.
- Abbreviations: O&M: Operations and Maintenance Personnel; CxA: Commissioning Authority
- The term "owner's project requirement" is sometimes referred to as "design intent".
- Timing is based on traditional design-bid-build or design-build delivery method. Other methods such as BIM may alter the timing.

Commissioning Activity	**Timing (Project Phase)**	**Responsibility**	**Notes**
Owner's project requirements (OPR)	Pre-design or early in design	Owner or Project team, led by Project Manager, with CxA review	Describes Owner's goals and requirements for project including space, occupancy,
Cx Plan	Schematic design or Design Devel.	CxA	Identifies project information, Cx goals, systems to be commissioned, project team info, and Cx process including activities, schedule and responsibilities.
Basis of Design (BOD)	Schematic design or Design Devel.	Design Team, with CxA review	Describe systems and design assumptions and describe how they meet the OPR.
Cx Specifications	Working drawings	Design Team, with CxA review	Include the contractor's participation requirements in the specifications. Use Section 01810 (or equivalent). Include references to Section 01810 in mechanical and electrical divisions.
Develop pre-functional checklists	Working drawings	CxA (or Design Team)	The CxA develops checklists and provides to the Contractor.
Develop functional test procedures	Working drawings	CxA (or Design Team)	The CxA develops test procedures and forms for recording test results. Forms are provided to Contractor for review.
Cx Kick-off Meeting	Const.	Lead by CxA, attended by Contractor	Review the Cx requirements and the schedule with Contractor. Can be combined with pre-construction or other early construction phase meetings.
Complete construction checklists	Const.	Contractor, with CxA review	Completed and signed by Contractor indicating that installation is complete for each system being commissioned and that the system is ready for testing.
Perform functional performance testing	Const.	Contractor, with CxA guidance, witness and approval	Contractor executes tests under guidance of CxA. Deficiencies are noted by CxA. Retesting performed after Contractor corrects any deficiencies.
Integrated systems coordination plans	Const.		

Commissioning Activity	Timing (Project Phase)	Responsibility	Notes
Cx acceptance	Const.	CxA	CxA provides certification that Cx tasks have been completed successfully.
Cx Summary Report	Const.	CxA	Report includes executed construction checklists, completed functional test forms, and a record of deficiencies and resolutions. Also includes CxA certification of acceptance. Attach OPR and BOD. Include recommendations for End-of-Warranty Review activities.
Systems or Re-commissioning manual	Const.	Contractor, with CxA review	Contractor prepares manual for ongoing Cx and upkeep of commissioned systems including schedule and frequencies as well as forms. CxA verifies manual is complete.
Training	Occupancy	Contractor, with CxA witness and approval	Contractor trains operation and maintenance staff on operation of building systems, CxA verifies training is completed.
End of Warranty Review / Seasonal Testing	Occupancy	CxA, Contractor	Testing of building systems prior to warranty expiration (usually around 10 months into occupancy) so any deficiencies can be corrected while under warranty.



Appendix III Typical Building Systems and Components

Appendix IV – Owner's Project Requirements (OPR)

What is an Owner's Project Requirements (OPR) Document?

The OPR is a living document that defines the owner's expectations and requirements for how the facility will be used and operated, as it relates to the building systems being commissioned. The OPR document describes the facility's functional and physical characteristics and sets criteria for the building's performance and acceptance for evaluating the success of the project. The OPR is best developed as early in the building process as possible, preferably during programming or pre-design, so that the document can help guide the design process of the building systems. However, it can be developed later, with varying effects.

The Owner's Project Requirements (OPR) documents the functional requirements of a project and expectations of the building use and operation as it relates to systems being commissioned. The document describes the physical and functional building characteristics desired by the owner and establishes performance and acceptance criteria. The OPR is most effective when developed during pre-design and used to develop the Basis of Design (BOD) during the design process. The level of detail in the OPR will vary according to building size and complexity, the experience of the design team and owner preferences. Ideally, each building system addressed in the OPR will have defined performance and acceptance criteria.

This living document should be updated and revised throughout the design and construction process based upon owner-approved revisions to their goals and objectives. All changes to the OPR document during the project should be documented, reviewed, and approved by the owner or a representative designated by the owner.

The OPR should be written with non-technical language and should be understandable by everyone involved in the project, including the owner, maintenance staff, contractors, construction workers, architects, engineers, and equipment manufacturers.

Many different formats can be used to document an OPR. Due to the variation in owners' requirements for a successful building, the type of building being constructed, and the writing style of the person creating the OPR document, OPR documents will not always look the same; however, the information in the OPR is usually presented in a format from general to specific. Items such as the building's background, functional space uses, and general goals are usually presented first. More detailed information, such as measurable values to test or obtain during design, is then presented.

A building's architectural program usually provides a significant amount of information relative to the OPR. As a point of reference, the basis of design (BOD) document explains how specific systems and space arrangements were chosen by the design team to satisfy the requirements of the OPR.

OPR Format Example

1. Overview & Project Scope
2. Project's Goals and Objectives
3. Functional Requirements
4. Occupancy Requirements
5. Design and Performance Criteria

The above list is an example of one possible format for an OPR.

1. The document begins with an introduction that includes an overview of the project and the general reasons why the project is being accomplished. A brief description of the owner's commissioning process along with a list of the owner's key project requirements is typically contained in this section.

2. The description of the project's specific goals and objectives follows, to familiarize the reader with the size, scope, features, and other special requirements. The goals and objectives to be met during design and construction are then listed.

3. The expected functional requirements for the facility are detailed next. Examples include: cafeteria, closed office space, open office space (partitions), classrooms, computer, mechanical and electrical rooms. Each functional use area generally requires distinct building features, equipment, and systems in order to perform the intended tasks.

4. Occupancy requirement are listed next, including the intended number of people and the occupancy schedule for each functional use area.

5. Design and performance criteria for the various building equipment and systems are included next. Indoor Environmental Quality requirements, such as lighting levels, noise levels, temperature and humidity requirements, and ventilation requirements for each functional use area are also included. These criteria are used to select and specify the types of equipment systems for the building during the design stage and then are used in the turnover stage to develop the functional performance test procedures. Each performance criteria should be measurable and verifiable.

Please note that the OPR should be as specific as possible, providing clear direction to designers and constructors, thus eliminating the need to guess or interpret an owner's requirements. For example, rather than only stating that space comfort shall be maintained, the OPR document should define space comfort, giving specific temperatures, humidity, lighting, and noise levels that can be measured and verified.

In addition, budget considerations and limitations can be presented in the OPR along with general quality of materials and construction. While building owners would like to receive the best possible building, they are almost always bound by budget limitations.

Examples of OPR Documents & templates

1. Abbreviated OPR template developed by the State of California (other templates available at www.green.ca.gov/CxToolKit). (See Appendix IV-1)

2. Cx OPR template – questionnaire type (See Appendix IV-2)
   This questionnaire format example is very thorough, user friendly, and can be easily adapted for many building types. The example is for an office/condo/retail tower project and shows the completed OPR, but can be modified for other project types.

3. Cx OPR example document for a Montana State University laboratory building renovation and addition project in 2002 (See Appendix IV-3).
   Although a somewhat specialized facility, a primary chemistry and biochemistry testing and research facility versus a general use office building, the OPR provides specific in-depth examples of the documentation requirements. Some standard references in this 2002 example are outdated, but the example is still useful. As previously stated, there is no one specific format that must be used due to owner's requirement variations for the building type and specific style of the document's writer.

Appendix IV – 1
Abbreviated Owner's Project Requirements - Draft Template (Courtesy of DGS, CA)

(Documentation of Owner's Project Requirements (OPR) is one of the first steps required for Building Commissioning. This template is a guide to collecting the information recommended to guide the Cx process. The information should be developed by the project team in collaboration with and approved by the Owner.)

Owner and User Requirements

- *(Typically already covered in Project Scope as described in the building program. Includes primary purpose, program and use of project. May also describe future expansion needs, flexibility, quality of materials, construction and operation costs.)*

Environmental and Sustainability Goals

- Project shall meet performance requirements required by the owner.
- Other Owner requirements: *(e.g. Owner priorities among possible LEED points, etc.)*

Energy Efficiency Goals

- Project shall comply with ASHRAE 90.1-2007, California Title 24 2010 building energy efficiency standards, or achieve increased level of efficiency determined by owner.
- Lighting systems offer cost effective energy savings potential, and lighting fixtures and/or controls shall be selected to exceed Title 24 minimum efficiency requirements by level determined by owner.
- High efficiency HVAC equipment offers cost effective energy savings, and HVAC equipment shall be selected that exceeds Title 24 minimum efficiency requirements by level determined by owner.
- Additional energy efficiency measures that provide cost effective energy savings shall be included wherever feasible.
- Other Owner requirements: *(e.g. orientation, siting, daylighting, cool roof, natural ventilation, landscaping)*

Indoor Environmental Quality Requirements

- Indoor lighting requirements: *(List any specific non-standard requirements. E.g. pendant-mounted lighting, illumination requirements, special applications.)*
- Occupant lighting control requirements: (*List any non-standard requirements. E.g. multi-mode controls for assembly spaces)*
- Thermal comfort requirements: *(List any non-standard temperature or humidity requirements)*
- Ventilation and filtration requirements: (*List any non-standard requirements)*
- Occupancy HVAC control requirements: *(List any non-standard requirements. E.g. integration with existing control systems)*
- Acoustic environment requirements: (*List any non-standard requirements. E.g. local noise sources requiring mitigation, spaces such as classrooms that require low background noise and short reverberation times)*
- Other Owner requirements: *(E.g. natural ventilation, operable windows, daylight, views)*

Equipment and Systems Expectations

- Special HVAC equipment requirements: *(E.g. equipment type, quality, reliability, efficiency, control system type, preferred manufacturers, maintenance requirements)*
- Unacceptable HVAC system types or equipment: *(List if applicable)*
- Special lighting equipment requirements: (*E.g. list preferred lamp and ballast types that comply with Owner standards if applicable)*
- Other system requirements:

Building Occupant and O&M Personnel Expectations

- Day-to-day HVAC operation by: *(occupants, operating staff)*
- Periodic HVAC maintenance performed by: (*building occupants, operating staff, service company, Owner staff, other)*
- Lighting system maintenance will be performed by: (*building occupants, operating staff, service company, Owner staff, other)*
- Training required for building occupants: *(e.g. demonstration, instruction documents)*
- Training required for operating and maintenance staff: (*e.g. demonstration, classroom training, instruction documents)*
- Other Owner requirements:

Appendix IV - 2
Example OPR Template (Courtesy of DGS, CA)

Owner's Project Requirements

Office, Condo & Retail Tower

Any City, USA

Date of this version: _____

This version approved by: _____

Template Prepared by
Summit Building Engineering

Owner's Project Requirements

Office, Condo & Retail Tower

Any City, USA

Table of Contents

1. Overview and Scope 7
2. General Requirements 8
3. Design Process 11
4. Heating, Ventilating and Air Conditioning 12
5. Electrical Systems 22
6. Commissioning 25
7. Sustainability 27
8. Building Envelope 32
9. Plumbing Systems 34
10. Fire Alarm 35
11. Data and Communications Systems 35
12. Security and Access 36

1. Overview and Scope

1.1 Overview and Definition

The Owner's Project Requirements (OPR) provide an explanation of the ideas, concepts and criteria that are considered to be very important to the owner, coming out of the programming and conceptual design phases and which are desired to be tracked throughout design and construction. The OPR is developed by the owner, not the design team. The OPR provides the direction for the design team. The OPR document sets the functional goals that the design is judged against and establishes the basis of the criteria used during construction to verify actual performance. The OPR does not list items that are already required by code. The OPR is generally not a description of what specifically will be included in the project design, but is the more general feature and categorical performance criteria to be met by the design. Where practical and known, the OPR includes measurable indicators used to verify that the performance requirements were met.

The OPR will be followed by the basis of design or design narrative written by the design team and included with design package submissions. The basis of design documents the primary thought processes and assumptions behind the design decisions and describes the design elements being incorporated to meet the OPR.

1.2 Scope

This document includes requirements for the systems that are more likely to be included under the formal commissioning umbrella or be impacted by their interactions. For reference, systems not included in this project and OPR that are typically commissioned and should have an OPR developed for them include: process mechanical and plumbing, paging, automatic doors and gates, presentation screens, and other moving mechanical devices.

This document is not a comprehensive project OPR, and does not include all project requirements and directives to the design team which could include: Other disciplines such as fire protection, structural, landscaping, civil, geotechnical and other earth work, utilities, specification division 1 requirements, demolition, all the materials, furnishings and special construction disciplines, drawing, specification and calculation requirements, codes and references, etc.

This document focuses on the mechanical, energy and comfort related systems and on the sustainability requirements of the project. Other areas impacted by commissioning or commissioned systems are covered more broadly. The design areas included in this document are:

Covered More Thoroughly

- Heating, ventilating & air conditioning (HVAC)
- Electrical
- Sustainability
- Commissioning

Covered Peripherally

- General requirements
- Design process
- Building envelope
- Fire alarm
- Plumbing
- Data and communications
- Security and access

1.3 Format

Under each area or building system is a list of pertinent questions and data needed to be answered. Blue, indented italicized text indicates the answers to the questions and specific information about the project requirements for this project.

1. OPR Process and Tracking

The following table lists the design areas and the party assigned to fill in the OPR and its current status. Track changes should be used for all versions after the initial.

Design Area	Responsible Party for OPR Input	Status of Input
Overview and Scope		
General Requirements		
Design Process		
HVAC		
Electrical		
Commissioning		
Sustainability		
Building envelope		
Plumbing systems		
Fire alarm		
Data and communications		
Security and access		

Updating Required: The following articles are missing information. This document will be updated when this data is submitted. Sections 3.6.3.2, 7.4.1 and Section 9.

2. General Requirements

2.1.1.1 What are the general overall objectives of this project?

The Office Tower is designed to be a smart building with compelling retail spaces, high performance offices, and condominiums for intelligent living. Comprehensive energy efficiencies will be integrated in a whole building systems approach to significantly reduce carbon dioxide emissions and create an "intelligent building" that is both environmentally, and socially, responsible.

2.1.1.2 Describe the existing conditions of the site.

The site used to contain a 75 year old office building which was removed in 2008. The site takes up an entire city block and is now vacant in the fringes of northern downtown with adjacent low and high rise buildings on four sides.

2.1.1.3 What type of activities/functions will occur in this facility? (Provide a general overview. The space planning / utilization is included in another document by the Architect).

Office, Parking, Retail, Condominiums (no restaurant)

2.1.1.4 What type of facility culture does the owner want designed into the facility (corporate, office, formal, relaxed, business, leisure, academic, natural, etc.)? Explain for each type of occupancy.

Office- formal Class A, high-end office space.
Retail- premium, compelling tenants
Condos- highest-income, upper echelon.

2.1.1.5 How many square feet of floor area is planned for each of the use types (retail, office, condo, parking)? How flexible are the totals and the fraction of each?

See floor area summary table below.

Floor	Flr to Flr Hgt	Floor (GSF)	Floor (NSF) USABLE	Core (NSF)	Retail (NSF) USABLE	Usable (NSF)	# Res Units / efficincy
mech room-top of roof	29.00						
33	13.00	4,934					0
32	13.00	8,417					2
31	13.00	9,847					0
30	13.00	9,909					3
29	11.00	14,438					11
28	11.00	14,255					11
27	11.00	14,084					11
26	11.00	13,659					11
25	11.00	14,200					11
24	11.00	14,200					10
23	11.00	14,200					11
22	13.40	15,634	15,285	2,506		12,779	
21	13.40	15,634	15,285	2,506		12,779	
20	13.40	15,634	15,285	2,506		12,779	
19	13.40	15,634	15,285	2,506		12,779	
18	13.40	15,634	15,285	2,506		12,779	
17	13.40	15,634	15,285	2,506		12,779	
16	13.40	15,634	15,285	2,506		12,779	
15	13.40	15,634	15,285	2,506		12,779	
14	13.40	15,634	15,285	2,506		12,779	
13	13.40	15,634	15,285	2,506		12,779	
12	13.40	15,634	15,285	2,506		12,779	
11	13.40	15,634	15,285	2,506		12,779	
10	13.40	15,634	15,285	2,506		12,779	
9	13.40	15,634	15,285	2,506		12,779	
8	13.40	14,555	14,257	2,506		11,751	
7	13.40	16,317	15,969	2,506		13,463	
6	13.40	16,317	15,969	2,506		13,463	
5	13.40	16,317	15,969	2,506		13,463	
4	13.40	16,317	15,969	2,506		13,463	
3	13.40	16,317	15,969	2,506		13,463	
2	20.00	20,489	18,701	2,090	16,611		
1	20.00	19,339	18,901	2,332	10,240		
LL1	20.41	24,559	23,694	2,663	0		
LL2	10.95	24,074	23,338	2,529			
LL3		23,757	23,110	2,529			
LL4		23,757	23,110	2,529			
LL5		23,757	22,896	3,122			
LL6	10.95	20,517	19,683	3,340			
TOTALS							
33	466.00	486,987			26,851	257,972	81
Including u/g retail/parking/stor.		535,620					

*Not accounted for in GSF of floor 30 is 226 SF of deck space which counts towards FAR
*Not accounted for in GSF of floor 31 is 234 SF of deck space which counts towards FAR

2.1.1.6 What are the floor number and/or building height requirements, desires and limitations?

33 Floors, 515' height with spire, project design falls within designated limitations. 460' ht limitation in code modified to allow increased height.

2.1.1.7 What is the proposed facility's life expectancy?

100 years

2.1.1.8 What future flexibility in function/activities must this facility accommodate?

TBD.

2.1.1.9 The building houses retail, office and residential condominium occupancies. Are spaces anticipated to be converted from one use to another?

No

2.1.1.10 How long does the current owner intend to own this building?

ACE Development Inc., develops commercial properties for its own account with the intention of holding onto the investment indefinitely.

2.1.1.11 Will the Owner operate and maintain the building?

We operate and maintain all our commercial assets.

2.1.1.12 What frequency of change will the building undergo during its lifetime?

We would expect normal "roll-over" of tenants in line with a Class-A office buildings as lease terms expire in the fifth and tenth years.

2.1.1.13 What type of changes and tenant fit-up are envisioned?

High end finish levels typically associated with Class-A office buildings (can we insert our intention to educate new tenants on LEED CI)

2.1.1.14 What are the overall energy efficiency goals and objectives? (ASHRAE 90.1, State Code, Energy Star, other indices, this building's past performance, etc.)

Use of high efficiency HVAC systems with an energy efficiency goal of 30-50% better than code requirements.

2.1.1.15 What other environmental goals and requirements are there?

(Detailed LEED goals will be given later.)

A building that will provide environmental control utilizing sustainable design practices in the pursuit of achieving LEED Platinum. Incrementally work to achieve the 2030 Challenge to result in zero fossil fuel based energy.

2.1.1.16 What are the objectives relative to the local neighborhood?

The project will be inherently sustainable by virtue of its location, mixed-use "live/work" accommodations, and the higher-density development designated for this site, what is now commonly referred to as the "compact city." There is a direct correlation between urban density and energy consumption as density promotes walking, cycling, and mass transit as alternatives to driving.

Effectively, a dense development in this location leverages the City's significant investments in the adjacent LRT system on SW Markel and Yancey Streets, the Transit Mall on SW Fifth and Sixth Avenues, City Streetcar line on SW Tenth and Eleventh Avenues, and the required supporting infrastructure.

2.1.1.17 What are the challenges relative to the local neighborhood and adjacent buildings?

While the building will necessarily cast shadows to the immediately adjacent properties to the north, it will not shadow the new park located immediately to the south or nearby Pioneer Courthouse Square at any time. The use of a clear, highly transparent low-E glass will transmit abundant daylight to the interiors while minimizing the admittance of infrared solar heat. This high-performance glazing selection will purposefully mitigate unwanted reflections and solar loads on other building's, and along with computer simulations studies of seasonal solar shading, was reviewed and approved by the City Design Review Commission. A traffic study was conducted and concluded there would be no significant adverse traffic or parking impacts. This traffic analysis was both required and approved by the City Design Review Commission.

2.1.1.18 What direction is intended for the front of the building to face? How much latitude is in this?

Front: West (no latitude).

2.1.1.19 Describe the expected phasing of the project for construction, tenant fit out and occupancy? Include descriptions for each of the occupancy types.

Retail: Anticipated occupancy, 4th quarter 2010, all finished at once.
Office: Anticipated occupancy, 4th quarter 2010, all finished at once.
Condo: Anticipated occupancy, 2nd quarter 2011, all finished at once.

3. Design Process

3.1 Basis of Design Documentation

3.1.1.1 Describe the requirements for the design team to develop the basis of design (including design narratives and design rationale) for the various design packages.

With each design submission the design team will include a written basis of design. This will be updated and become more detailed with each successive submission. The basis of design includes two primary elements—a design narrative and the design rationale.

During the schematic design phase the design narrative is the written description and discussion of the concepts and features the designer intends to incorporate into the design. In subsequent design phases the design narrative is a description of what they have incorporated to meet the owner's project requirements and associated performance criteria.

The design rationale is the basis, rationale and assumptions for calculations, decisions, schemes and system and assemblies selected to meet the owner's

project requirements and to satisfy applicable regulatory requirements, standards and guidelines.

3.2 Design Reviews

3.2.1.1 Describe the expected design reviews and the expectations of the design team regarding responding to comments.

There will be owner review as well as third party commissioning review for commissioned systems for each design submission. The design team will respond in writing to each comment and will consult with the Owner on issues that may increase scope, project budget or timeline beyond what they feel the Owner may desire. Reviewer comments will be responded to and comments with questions or disagreements between reviewers and the design team will be adjudicated prior to proceeding with impacting portions of the next design phase, unless directed by the Owner.

4. Heating, Ventilating and Air Conditioning

4.1 Occupancy, Climatic, Temperature and Sizing Requirements

4.1.1.1 **Time of day schedules.** List tenant types with their time of day and days of week they occupy.

Office: 6am – 6pm M-F.
Data center: 24/7 continuous.
Retail: 8am – 8pm M-F, 8am – 6pm Sat
Residential Condos: 24 hrs/day, 7 days/week

4.1.1.2 List and describe any spaces that will require night time operation. Indicate how often and how long this after hours occupancy is likely to be.

All office areas shall have local override capabilities for the HVAC and lighting to allow after hours occupancy. Override should be accomplished from local override switches in the space. In general, this after hours operation is expected to be rare lasting from a few hours to all night. However, the there shall be 20,000 sf of office space, yet to be located, that will house an accounting firm that will require 2 months, twice a year of 24/7 operation.

4.1.1.3 **Climatic design criteria.** What climatic conditions shall the HVAC systems be designed to--ASHRAE 0.4%, 1% or 2% (the latter being more typical and assumes less extreme weather).

ASHRAE 2%.

4.1.1.4 **Temperature and humidity.** List the interior temperature and relative humidity conditions that must be maintained for each tenant or occupancy type. List any special conditions or spaces.

Relative humidity: All temperatures within a given space should be compliant with ASHRAE 55 standards of 5F in the occupied zone.
Retail spaces: 68F heating, 75F cooling, <55% RH.
Office areas: 68F heating, 75F cooling,, <55% RH.
Data center: 73-76F, 35%-45% RH
Condos: 68F heating, 75F cooling, <55% RH.
Stair towers: 64F heating, 79F cooling.

4.1.1.5 **Tolerances.** List the space temperature and humidity tolerances that each space type must stay within during occupied hours.

The HVAC system shall control the temperature in all spaces, including the data center to within +/-3F of the given heating and cooling set points.

4.1.1.6 **Air Drafts.** How tolerant are the occupants expected to be of noticeable HVAC air movement—none, little, some, moderate.

The occupants of this Class A office building and high end condo tenants will have little tolerance for drafts.

4.1.1.7 **Diversity.** Is it OK to plan for reasonable diversity—typically around 85%—that is, the assumption and likelihood that not all spaces will experience worst case load conditions at the same time?

Assume moderate diversity in both heating and cooling for interior spaces. For perimeter spaces, assume only a small diversity for heating. For perimeter spaces on a given orientation, assume only a small diversity for cooling.

4.1.1.8 **Redundancy.** What redundancies are desired for specific HVAC services (chilled water, hot water, space air temperature, humidity, air quality) and why?

Pumps, floor-by-floor delivery (eliminates 'top down' approach).

Provide redundant (backup) pumps for the condenser water loop system. Provide multiple boilers, cooling towers, and DHW boilers that will allow partial capacity to be met if one were to go down, but none are a full backup or fully redundant.

4.2 Air Quality and Ventilation

4.2.1.1 What are the goals and requirements for indoor air quality--standard, above average, exceptional? List any special requirements.

To maintain ventilation standards as stated by ASHRAE 62.1 2004 while maintaining thermal comfort. Air handlers will be required to be filtered to reduce dust buildup on system components. Building flush out is required to meet LEED requirements.

Generally the goal is to have above average air quality.

4.2.1.2 What are some of the methods considered valid for meeting these goals? (ASHRAE and codes, higher than code required minimum levels of natural ventilation (with associated higher energy costs), additional filtration (with associated higher fan energy and O&M costs), minimizing outdoor air ventilation rates with demand controlled (CO2) ventilation (to minimize energy use), reducing indoor contaminants).

Minimum ventilation requirements as stated in ASHRAE Standard 62.1 2004 and meet thermal comfort requirements as stated in ASHRAE Standard 55-2004. Use of demand control ventilation. CO2 monitors in high occupancy areas.

4.2.1.3 What guidelines should be referenced and applied as much as reasonable for this project?

Indoor Air Quality Guide, ASHRAE.

4.2.1.4 Will there be rooms that store bulk quantities of flammable, combustible, radioactive, or biological materials?

No.

4.2.1.5 Where are operable windows acceptable (office, retail, condominiums)? Where are operable windows desired? Are patio doors desired for the condominiums?

Acceptable in offices. Desired in condominiums. Patios are desired for the condos.

4.2.1.6 Where, if any, will smoking be permitted in the building?

No smoking.

4.2.1.7 What level of air flow separation is desired between condominiums to control odors (standard, above standard, exceptional)?

Exceptional. Makeup air supply and slight corridor pressurization will negate the need for additional odor control.

4.2.1.8 What level of air flow separation (from common mechanical system air and natural air leakage) is desired between restaurants and adjacent spaces to control odors (standard, above standard, exceptional)?

No restaurants.

4.2.1.9 Is the underground parking garage ventilation system desired to be controlled to the ventilation rate to meet code maximum carbon monoxide levels, or at a more liberal constant air change rate?

Keep ventilation to a minimum, using CO control.

4.3 General HVAC Systems Data

4.3.1.1 What system types and brands are not desired or are not acceptable?

No system types or brands have been identified as preferred or excluded.

4.3.1.2 What system types or brands are mandatory?

No system types or brands have been identified as preferred or excluded.

4.3.1.3 Is larger central equipment desired over smaller more numerous distributed equipment? (Central equipment typically is easier to maintain, but requires vendor support, lasts longer, is more energy efficient, but may cost more.)

Because of multiple commercial tenants, staged fit out and individual condominium ownership, smaller distributed equipment is preferred.

4.4 Design Calculation and Tools

4.4.1.1 List the requirements for engineering calculations and assumptions.

The A/E shall perform engineering calculations to support the mechanical design. Standard, recognized computation techniques shall be used; shortcut methods and rules of thumb are not acceptable. All assumptions shall be clearly stated with supporting documents referenced. The calculations shall be properly indexed and bound, signed, and dated by the designer and checker; approved and stamped by a registered professional engineer holding a valid license and presented as part of the design package.

4.4.1.2 List any special design guidelines or standards besides ASHRAE 62 Air Quality, ASHRAE 90.1 Energy, NFPA 101 and 110 Fire and Emergency Power and applicable state codes and standards that should be used in designing this building with appropriate elements incorporated.

ASHRAE Advanced Energy Design Guidelines

4.4.1.3 What design tools are desired to be used for this project (standard 2-D computer-aided design, 3-D modeling of the exterior building shape, 3-D modeling of the mechanical, electrical and plumbing, 3-D modeling of the interior spaces and lighting levels, 3-D visualization of light levels)?

eQuest, DOE-2, FlowVent (CFD), AutoCad

4.4.1.4 What methods are desired for informing the design relative to energy efficiency, ventilation and comfort (standard written guides and practices, bin analyses, hourly simulation tools, computational fluid dynamic tools for special situations)?

Design Simulation and Computational Fluid Dynamics

4.5 HVAC Budget Issues

4.5.1.1 What are the budget goals for the HVAC system (standard typical cost as % of entire design, OK to exceed the standard cost fraction if justified through life cycle cost analysis)?

Cost effectiveness is a general criteria for system selection but a percentage has not been specified.

4.6 HVAC Performance Requirements

4.6.1.1 Describe the general HVAC performance requirements.

All of the HVAC equipment should perform as described on the project plan and schedules with regards to capacities, pressure drops, efficiencies, etc. While the performance of every piece of equipment precisely to its rating may not be crucial to proper operation of the facility, there is specific equipment whose performance is more vital. Central heating and cooling equipment, for example must be able to meet their intended performance ratings so that building temperatures can be maintained. Sequences of operation which are critical for maintaining precise pressure relationships must perform properly.

The commissioning process will establish that critical equipment and systems perform properly when the building is turned over to the owner. Carefully planned and executed maintenance programs will help ensure that the systems and equipment continue to function as intended over time.

4.6.1.2 Capacity for the following systems shall be verified through a) certified factory testing of units shipped, b) field tests, or c) via ARI ratings only (specify). (e.g., Air handler or roof top DX unit cfm, cooling coil capacity or, heating coil capacity. Chiller, cooling tower or boiler heating or cooling capacity.) List.

ARI ratings are acceptable for all equipment.

4.6.1.3 Efficiency for the following systems shall be verified through a) certified factory testing of units shipped, b) field tests, or c) via ARI ratings only (specify). (e.g., DX unit EER, boiler efficiency, chiller kW/ton). List.

ARI ratings are acceptable for all equipment.

4.7 Energy Efficiency and Demand Reduction

4.7.1.1 The goals and targets of overall building energy efficiency are given in the Sustainability section under Energy Efficiency.

4.7.1.2 List any specific HVAC energy efficiency features or equipment desired or required for this project.

None specifically.

4.7.1.3 What level of HVAC equipment energy efficiency are desired (standard, above standard, exceptional)?

The current equipment energy efficiency target is 30-60% better than code requirements.

4.7.1.4 Are power demand reduction features important? These include, listed from moderate to rigorous: staggering of equipment startup, active automatic load limiting, thermal energy storage, etc. List those required or of interest.

Staggering of equipment startup is sufficient.

4.8 Renewable Energy

4.8.1.1 Describe any renewable energy goals.

Renewable energy goal is to provide 2.5% of total design energy cost with renewable energy such as wind or solar. Project seeks to incrementally meet the requirements of the 2030 Challenge, to achieve carbon neutrality by 2030.

4.9 New Concepts and Systems

4.9.1.1 Would incorporating new or relatively untried systems and equipment be seriously considered (no, possibly, likely)?

Yes.

4.10 HVAC Flexibility for Tenant Churn

4.10.1.1 What are the requirements for flexibility in the HVAC systems to accommodate changing floor layouts and occupancy needs (normal, above average flexibility, very flexible. List the areas that apply or any special needs)?

Zones will be able to be added as deemed necessary. HVAC design must be intentionally flexible.

We have two retail tenants on 20 year term leases, with 20 year renewals.

Retail HVAC flexibility is also very important.

4.11 Maintainability

4.11.1.1 What are the maintainability objectives for the HVAC equipment (standard level, above standard, exceptionally easy to maintain)?

Require all pumps, motors, terminal units and associated equipment to be easily accessible to maintenance staff. Goal is to be above standard.

4.11.1.2 Is it expected that there will be normal, above normal or exceptional accommodation for replacement of chillers, cooling towers, boilers and air handlers?

Normal.

4.11.1.3 How much desire is there for top of the line equipment features that simplify and make maintenance easier? (e.g., hinged access doors, filter pressure monitoring, direct expansion equipment with refrigerant hose access plugs and taps, hose bibs on roof, lights in cabinets, service outlets in units or nearby, etc.). Little, some, significant.

Significant.

4.12 Reliability and Durability

4.12.1.1 What are the reliability and durability objectives for the HVAC equipment (standard level, above standard, exceptionally reliable)? Would this include smaller components like dampers, actuators, valves, sensors, etc. and not just the larger equipment?

Provide equipment with at least 1 year warranty. Temperature, CO2, and airflow monitoring devices to be calibrated and factory tested before installation.

Above standard reliability and durability of major and smaller components are desired.

4.13 Operations and Maintenance Documentation

4.13.1.1 Are electronic O&M manuals desired?

Yes.

4.13.1.2 Are single-line system flow diagrams beyond the control diagrams desired to be provided for O&M staff of the primary systems? List--chilled water, process water, heating hot water, air handlers, cross section air riser diagrams of floors' supply, return and exhaust flows, etc.

Yes. All listed.

4.13.1.3 What comprehensiveness of Systems Manual is desired (minimum, moderate or very comprehensive)? The Systems Manual describes the operational (in contrast to maintenance) procedures for the systems and equipment and building as a whole—system flow diagrams, set points, strategies for seasonal control optimization, shutdown procedures, emergency procedures, energy optimization and tracking recommendations, restesting and calibration methods and frequencies, etc.

Very comprehensive.

4.14 Training

4.14.1.1 Who will be operating the building HVAC and electrical systems? (in-house staff, outsourced staff)

In-house staff.

4.14.1.2 How much equipment will be maintained by equipment vendors vs. in-house staff?

All equipment will be maintained by in-house staff except for significant issues with major equipment like chillers, boilers and built-up air handlers which will be handled by equipment vendors.

4.14.1.3 What level of training is desired for the in-house staff for operating and maintaining the systems and assemblies of the building?

All staff will be new to this building. A comprehensive level of training is desired.

4.14.1.4 How much of the training is desired to be video recorded? [All, most, some.]

Most systems will have their trainings recorded.

4.14.1.5 Is it desired to have the engineer and architects provide some orientation / training on the primary mechanical and electrical systems?

Yes.

4.15 Building Automation System (BAS) and Controls

4.15.1.1 Are there special owner control system standards that need to be followed?

No.

4.15.1.2 What sophistication is desired in the control system (standard, above standard, exceptional)?

Above standard

4.15.1.3 Are control schematic diagrams of all controlled equipment required to be in the design documents, or will the sequences of operation suffice?

Control schematics required for all equipment.

4.15.1.4 Is a specific controls points list required in the design documents that lists each point and whether it's a binary or analog input or output and the equipment it is

tied to, or is the contractor required to determine control points from the specified features and sequence of control?

Points list required.

4.15.1.5 What level of detail is desired for the control sequences of operation to be included in the design documents—moderate, above standard, very detailed? Detailed sequences are finely numbered and include: overview narrative, interactions, interlocks, delineation of control with packaged controllers, startup, warm up, cool down, occupied, unoccupied, optimal start/stop, capacity control, staging, set points, setbacks, setups, resets, demand limiting, loss of network, loss of power, alarms, delays, etc. and result in fewer questions of, and require only limited adjustment by the controls contractor.

Require detailed sequences.

4.15.1.6 For the operator's interface screens, how many summary tabular screens of conditions of grouped equipment are desired (e.g., air terminal unit zone: cfm design and actual, space temperature set and actual, discharge temperature. All air handlers, etc.). Few, some, many?

Many.

4.15.1.7 What control systems are not acceptable?

Wireless may not be desirable. Mechanical engineer to provide list of approved manufacturers.

4.15.1.8 What control systems are mandatory or highly desirable?

No control system types or brands have been identified as preferred or excluded.

4.15.1.9 List any control element type or brand that is not to be used.

Paddle type flow meters are not to be used in the open condenser loop system.

Paddle or blade type flow switches are not to be used anywhere.

4.15.1.10 Is a web-based accessible system desired?

Yes.

4.15.1.11 Will the control system need to tie into another existing building automation control system from another building? Explain.

No?

4.15.1.12 How much is desired to be included in one integrated work station monitor (HVAC, lighting, fire, security), vs. separate monitors and work stations?

There may be separate controllers or systems, but there should be some monitoring between them. See subsequent questions below.

4.15.1.13 Describe interlocks to the HVAC system from the Security System.

The HVAC OWS will not monitor any security elements other than three levels of general security alarms.

4.15.1.14 Describe interlocks to the HVAC system from the Fire Alarm System.

Fire alarm system is separate, except general alarms are passed to the BAS.

4.15.1.15 Describe interlocks to the HVAC system from the Lighting Control System.

The HVAC operator's work station (OWS) will control the HVAC and monitor the lighting schedules, but doesn't have to be able to change schedules, though that would be OK.

4.15.1.16 Describe interlocks to the HVAC system from the elevators.

An alarm in the elevator will be transmitted to the BAS and the security system for monitoring and the elevator sump pump alarm will be seen at the BAS.

4.15.1.17 How much interoperability communication between the central control system and the mechanical equipment is desired? (none, little, some, significant) Add details in the next article.

Some.

4.15.1.18 Interoperability Details. (edit the following)

For Primary equipment (chillers, boilers, main airhandlers) the BAS just monitors some? many? all? points.

For primary equipment, the BAS passes set points and other commands to the equipment.

For the following other equipment, the BAS sees through BACnet, Modbus or Lon most of the equipment's point values and status: _____

4.15.1.19 For the chiller, boiler and pumps are there any of these that will not require automatic changeover to the backup / lag piece without operator action should one piece of equipment fail?

No.

4.15.1.20 How fast should the refresh rate be on the operator's work station? (standard, above average, exceptional)

Standard.

4.15.1.21 What fraction of the BAS set points should be able to be adjusted from the OWS graphics screens? (none, few, some, most, all)

Most.

4.15.1.22 For non-measurement and verification (M&V) purposes, like energy optimization and troubleshooting, how many system monitoring points are desired, above that required to execute the sequences of control (none, some, many)?

Some.

4.15.1.23 Is there going to be a measurement and verification (M&V)--rigorous energy tracking, or significant ongoing commissioning program after occupancy, requiring numerous additional power and HVAC monitoring points? Mention it's part of LEED, if applicable.

Yes. The M&V credit will likely be included, but cost estimate for the points will determine if the measure remains in the project.

4.15.1.24 Is linking the sequences of operation and/or the O&M manual data to an icon in the graphic screen of each piece of equipment desired?

Yes, both.

4.15.1.25 How much expansion capacity is desired for adding control point inputs and outputs in each field control panel and primary controller? (none, 5%, 10%, 20%, etc.)

10%

4.15.1.26 Are there areas of the building that require essentially uninterrupted delivery of the HVAC (which would affect how the controls were designed)? List.

None.

4.15.1.27 Are there any critical areas that need their controllers to have redundancy in their power supplies?

No.

4.15.1.28 Upon a control system network failure should all equipment not being controlled by local controllers control to the last known value?

Yes.

4.15.1.29 Upon restoration of power after an outage, which equipment is allowed to require an operator to go to the equipment and reset it before it will start? Or require operator action at the workstation?

None to either.

4.15.1.30 Upon a general alarm that shuts down the equipment, upon the condition correcting itself, what equipment is allowed to or should require an operator to reset the unit at the equipment? Or require action at the workstation?

None to either.

4.15.1.31 What other desires for the control system are there?

TBD

4.16 Occupant HVAC Control

4.16.1.1 What level of control is desired for the occupants to have over the temperature and ventilation in their space—list for each occupancy type (temperature adjustable by occupants at a zone thermostat, ventilation control adjustable by

occupants for their specific area, temperature control adjustable only by facility staff, ventilation control adjustable only by facility staff)?

Office and Retail: Occupant accessible thermostats should all have timed override buttons in the office and retail areas for HVAC. Every 1,000 sf or so should have an override. The thermostat temperature should be adjustable by the occupant about +/-2F. No ventilation control by occupants, except if there are operable windows.

4.17 HVAC Acoustics --See Acoustics in the Sustainability section.

4.18 Entry Design

4.18.1.1 What level of minimizing drafts in and out of the main entrances are desired (standard, above standard, exceptional)?

Above standard. Desire revolving doors with signage. No vestibule.

4.18.1.2 What types of doorways that control drafts are desired or not acceptable?

Revolving doors desired. One sided lobby.

4.19 Building Pressurization

4.19.1.1 Are there any building pressurization control schemes that are not acceptable, or that are mandatory?

No, project should have standard active positive pressurization.

5. Electrical Systems

5.1 General

5.1.1.1 List general requirements for the electrical system.

All electrical equipment will bear the UL label and no rebuilt, refurbished or remanufactured or used equipment or material shall be specified or installed. Complete raceway routing from panels to the field devices shall be indicated on the drawings for power, fire alarm, security, PA, intercom and CCTV.

Complete 1-line power diagram(s) are required.

5.1.1.2 List any requirements for coordination studies (short circuit study, protective relays/breakers, voltage drop / transient study for large motors, etc.).

Short circuit study is required.

5.1.1.3 List requirements for connected and operating electrical load estimate, including future project loads, if applicable, lighting level calculations.

Both load calcs and lighting level calcs are required.

5.1.1.4 List any specific equipment brand or components that are to be included or not included in this project.

None.

5.2 Power Capacity

5.2.1.1 How much electrical capacity (W/sf) is desired for each type of space—standard for that type of space (typical), slightly above standard, moderately above standard, significantly above standard? List any specific capacity promised to office tenants.

All spaces should have a standard power density capacity provided.

5.3 Power Quality

5.3.1.1 What level of power quality are desired (standard, above standard, exceptional)?

Standard.

5.3.1.2 Are there any spaces that require special power quality requirements?

Unsure at this time and no special provisions. TBD in tenant improvement.

5.3.1.3 What level of safeguard is required to monitor and maintain the integrity (such as voltage or phase imbalance) of the incoming power (e.g. - protection of sensitive lab equipment)? What equipment or devices are included in the design to meet this requirement?

TBD

5.3.1.4 Are there special grounding and EMF mitigation requirements for these lab environments and equipment? What measures will be taken to mitigate?

TBD

5.4 Lighting and Visual Quality

5.4.1.1 What is the general level and description of the visual quality desired in the facility? (standard, above standard, exceptional)?

Exceptional for lobby and elevator lobby spaces; above standard for parking levels, with emphasis on minimizing glare while maintaining security and energy efficiency. Exceptional for condominium units, should we move forward with including lighting design in this Contract for interior design for these spaces.

5.4.1.2 Describe the level of aesthetic and artistic license for the lighting design for each of the occupancy types.

Aesthetic design will be made in close concert with the architectural and interior design for condominiums, lobby, elevator lobby and parking spaces.

5.5 Lighting Levels

5.5.1.1 Required average maintained light levels for this project are listed below. For spaces not listed, the current IESNA light level recommendations shall be followed.

Offices: 45 FC with dual level switching and occupancy sensor.
Lobbies: 20 FC

Corridors and means of egress: 15 FC.
Conference rooms: 30 FC to 50 FC with dimming controls as required.
Restrooms: 20 FC
Equipment rooms: 30 FC
Computer Rooms/Data Center: 50FC with dual level switching.
Laboratories (general): 750 to 100FC.
Exterior lighting at building entrances, walkways, streets, and parking lots: Not more than 2 FC.

5.5.1.2 Would task lighting be an acceptable design feature required to achieve desired light levels in office areas?

Task lighting at workstations will be plug-in at discretion of the end-user. Where casework allows for integrated approach, undercounter lighting will be added.

5.6 Light Fixtures and Lamps

5.6.1.1 What level of energy efficiency is desired in the lighting equipment for each occupancy type (standard, above standard, exceptional)?

Exceptional - Premium Super T8 lighting, 3rd generation.

5.7 Lighting Control

5.7.1.1 What control of lighting is required in the various types of spaces (open office, closed offices, common areas, conference rooms, retail spaces, condominiums, exterior, parking garage, etc.)? Examples are manual switches to on, occupancy sensors to turn on or off, scheduled lighting controls and lighting sweeps and daylight dimming.

Open office: manual switch on, occupancy sensor off.
Closed office, storage and copy rooms: manual switch on, occupancy sensor off.
Corridors and other service spaces: time clock schedule.
Perimeter office (open and closed), lobbies and corridors: same as above, but also include daylight dimming.
Conference rooms: manual switch on, occupancy sensor off.
Parking garage: scheduled.
Exterior: photocell and time clock.

5.7.1.2 Do any spaces have special glare requirements?

Exterior of building

5.8 Emergency Generator and UPS

5.8.1.1 In general, what equipment is desired to be on generator power?

Life/safety equipment (fire pumps, emergency lighting, fire alarm, smoke control system fans, etc.) and local area network, building phone system, security system, elevator, data center backup HVAC.

5.8.1.2 How much extra capacity is desired in the generator (for potential special needs by tenants, etc.)?

Provide additional capacity to allow enlarging and powering the data center load by 50%.

5.8.1.3 How many hours of full load operation are desired in sizing the fuel tank?

Meet minimum code requirement.

5.8.1.4 What equipment will require uninterruptible power supplied?

UPS to be addressed by TIs, including the data center.

5.9 Power Monitoring

5.9.1.1 Is submetering of utility power desired? (list for gas, steam, electricity, water) What is the purpose of the monitoring of each? (resource efficiency tracking, measurement and verification (M&V), occupant billing, demand reduction, etc.)

Submetering of electricity is desired for tenants as incentive to reduce energy use.

5.9.1.2 What is the intended level of metering and sub-metering? (Main switchgear only, or including metering of energy consuming sub-systems, such as HVAC central plant, AHUs, lighting panels, etc.)

TBD

5.9.1.3 How will the metered information be presented and reported for the occupants and staff? (Integrated with BAS, separate monitoring station, touch screen displays in lobby/common areas, etc.)

TBD

5.9.1.4 Are peak demand reduction strategies desired?

Yes

5.10 Power Metering and Billing for Tenants

5.10.1.1 What are the needs for submetering and billing of / for tenants?

a. Eight 225-amp, 480Y/277-volt meters for the retail space. If only two tenants appear in the retail spaces, they could each have four meters apiece. If we need to combine these into two large meters, please let us know.
b. Each condo unit has their own meter.
c. The office spaces are served through two electrical risers, each riser have their own meter. Billing for each tenant space will be on pro-rata basis, based on the area of the tenant space.

6. Commissioning

6.1 Scope

6.1.1.1 What systems are desired to come under the commissioning umbrella (HVAC and controls, electrical lighting controls, emergency generator, electrical equipment (switchboards, panel boards, transformers, motor control centers, etc. list), envelope, plumbing (domestic hot water system, circulation, sump and booster pumps, grey and rainwater reclamation, automatic valves and lavatories), irrigation, laboratory and clean room systems and supports, special

systems (list), security system, data, intercom, CCTV, fire, life safety, fire alarm, etc.)

Current commissioning scope includes HVAC and controls, lighting controls, domestic hot water system, circulation, sump and booster pumps and HVAC interfaces with fire alarm and emergency power.

6.2 Rigor

6.2.1.1 What level of rigor is desired for the commissioning process (typical, above average, very rigorous)? Discuss the rigor of design review, commissioning specifications, field observation and functional testing.

Current commissioning scope is for above average rigor.

Design Reviews. *During design this is characterized by a thorough independent design review of the commissioned systems and assemblies by qualified engineers focusing on commissioning, performance and O&M issues.*

Commissioning Specifications. *Commissioning specifications will be very thorough and fully describe all requirements of the Contractor, including specific testing requirements for each type of equipment. Roles of all parties and the sequence of the commissioning process will be clearly and completely described.*

Installation Verification. *During early and mid-construction the level of rigor is characterized by field observation by the Commissioning Authority or team, as necessary, to observe component and system installations for general progress and issues affecting performance and testing. Contractors are responsible for the installation, set up and startup of their equipment and filling out Commissioning Authority provided and all manufacturer provided checklists.*

Performance Verification/Testing. *Performance verification shall be accomplished through review of control code programming, documented field testing of each sequence of operation for all equipment and through monitoring performance over time with trend logs from the building automation system. Testing will be conducted from detailed, step-by-step, repeatable test scripts specifically applicable to this project approved by the Commissioning Authority.*

In general, testing shall include testing each sequence in the sequence of operations, and other significant modes, sequences and control strategies not mentioned in the written sequences; including, but not limited to startup, shutdown, unoccupied and manual modes, modulation up and down the unit's range of capacity, power failure, alarms, component staging and backup upon failure, interlocks with other equipment, and sensor and actuator calibrations. All interlocks and interactions between packaged on-board controls, central control systems and other equipment shall be tested.

All larger, more complex or life-safety equipment will be individually tested. Testing only a sample of some equipment may be allowed where such equipment is small in physical size or importance, is numerous and is not complex or critical for life-safety (many smaller rooftop packaged units, air terminal units, exhaust fans, windows, etc.), as approved by the Commissioning Authority. When sampling is conducted a random spot check is required with sufficient sample size to provide reasonable confidence that the sampled results represent the entire population of units.

Tests for a given system or assembly shall not be conducted until they are fully operational under normal and reliable control with construction checklists, control calibrations, programming and control system graphics complete.

See related information in the HVAC Performance Verification Requirements section.

6.3 Objectivity

6.3.1.1 What level of objectivity and independence are desired for the commissioning process (typical, above average, significant)? Describe the independence of the Commissioning Authority, the reporting path of issues, how much testing the Contractor may do on their own, etc.

Current commissioning scope is for a typical level of objectivity.

Commissioning Authority Access. *This is characterized by the commissioning authority having direct access to independently discuss issues with any party of the project team and by all issues identified by the commissioning team from initial identification being concurrently distributed directly to the Owner, Architect and Contractor.*

Issue Management. *Issues are legitimate for identification and distribution when, 1) Any requirements as delineated in the contract documents are not being met, or 2) When significant elements of the Owner's Project Requirements are not being met). Issues shall be reported regardless of potential cost impacts to any party or potential impacts to the project schedule.*

Testing*. All documented testing for complex equipment shall be directed and overseen by the Commissioning Authority or by another independent party, such as the fire marshal or a certified independent testing company (e.g., electrical equipment testing). Documented testing for less complex equipment and repetitive equipment (of large quantities, e.g., air terminal units) may be directed by the Contractor alone, as approved by the Commissioning Authority, with spot retests and test report review by the Commissioning Authority.*

7. Sustainability

7.1.1.1 What are the general sustainability goals for this project?

The project is required to comply with the CALGreen Green Building Standards Code.

The specific sustainability goals for the project are listed in the categories below. The project has applied for a Green Investment Fund (GIF) grant from the City in the amount of $_____. The grant application describes specific green building strategies that shall be evaluated for their feasibility to be included in the project. These strategies are based on early project strategizing, ideas put forth in the project's green building kickoff meeting and individual meetings with the owner and architect. Failure to evaluate these strategies to the extent necessary as described in the Office Tower GIF proposal jeopardizes the project's eligibility for funding and probability of integration into project design.

7.2 Certifications

7.2.1.1 Describe any LEED or other certification goals and objectives.

The project's LEED goal is to achieve a Platinum level of certification using the LEED for New Construction version 2.2 program. At this time, the project team has identified 47 points as "certain", 14 points as "possible" and 8 points as "not likely". The point range to achieve Gold and Platinum is 39-51 and 52+ respectively. The LEED scorecard must be continuously updated to both inform and reflect design decisions as the project progresses.

LEED certification will make the project eligible for the State Business Energy Tax Credits and Utility Incentives. The amount of incentive money available to the project is significantly impacted by certification level- Gold and Platinum earn approximate pass-through values of $500,000 and $1,000,000 respectively. Obviously, moving below or above the Gold level of certification will strongly influence the project's financial performance.

7.3 Sustainable Siting and Planning

7.3.1.1 Provide the list of LEED sustainable siting and/or CALGreen Planning and Design features desired or required to be incorporated. List the LEED scorecard, if applicable.

The project shall, at a minimum comply with the City management requirements. The owner has a strong interest in rainwater harvesting for irrigation and/or toilet flushing to support LEED performance, GIF grant eligibility and overall project performance.

Most Likely	Possible	Not Probable				Responsible Party	Status
					SUSTAINABLE SITES		
Y			SSp1	C	**Construction Activity Pollution Prevention**	KPFF	Open
1			SSc1	D	**Site Selection**	GBS	Open
1			SSc2	D	**Development Density & Community Connectivity**	GBS	Open
1			SSc3	D	**Brownfield Redevelopment**	GBS	Open
1			SSc4.1	D	**Alternative Transportation**, Public Transportation Access	GBS	Open
1			SSc4.2	D	**Alternative Transportation**, Bicycle Storage & Changing Rooms	GBS	Open
1			SSc4.3	D	**Alternative Transportation**, Low Emitting & Fuel Efficient Vehicles	GBS	Open
1			SSc4.4	D	**Alternative Transportation**, Parking Capacity	GBS	Open
		1	SSc5.1	C	**Reduced Site Disturbance**, Protect or Restore Habitat	--	Closed
	1		SSc5.2	D	**Reduced Site Disturbance**, Maximize Open Space	--	Closed
		1	SSc6.1	D	**Stormwater Management**, Quantity Control	--	Closed
1			SSc6.2	D	**Stormwater Management,** Quality Control	KPFF	Open
1			SSc7.1	C	**Heat Island Effect**, Non-roof	GBS	Open
1			SSc7.2	D	**Heat Island Effect**, Roof	TVA	Open
		1	SSc8	D	**Light Pollution Reduction**	--	Closed
10	1	3			Total Points for Sustainable Sites		

7.4 Water Efficiency and Conservation

7.4.1.1 Describe the water efficiency goals of the project.

Project goal is to achieve a minimum 50% potable water use reduction for fixtures and toilets as compared to fixture requirements of the Energy Policy Act of 1992.

7.4.1.2 Is grey water recovery a consideration for this project?

Yes.

7.4.1.3 Is rainwater harvesting and use a consideration for this project?

No.

7.4.1.4 What level of low-water use landscaping is desired or would be considered?

There is not that much landscaping area to result in much actual water saved from extremely low water landscaping, so we are not that interested in these designs if they don't meet our primary landscaping objectives.

7.4.1.5 To what level of sophistication will the irrigation controls be, beyond simple typical time clock functions and above ground sprinklers, to reduce water consumption?

Some. We desire climatic-compensating watering controls.

7.4.1.6 Provide the list of the LEED and/or CALGreen water efficiency features desired or required to be incorporated or those that are not to be considered.

The LEED scorecard is provided below. Refer to the Plumbing section for additional efficiency issues.

WATER EFFICIENCY								
1			WEc1.1	D	**Water Efficient Landscaping**, 50% Reduction	MR	Open
	1		WEc1.2	D	**Water Efficient Landscaping**, No Potable Water Use	MR	Open
		1	WEc2	D	**Innovative Wastewater Technologies**	--	Closed
1			WEc3.1	D	**Water Use Reduction**, 20% Reduction	GBS	Open
1			WEc3.2	D	**Water Use Reduction**, 30% Reduction	GBS	Open
3	1	1			Total Points for Water Efficiency		

7.5 Energy Efficiency

7.5.1.1 What level of overall building energy efficiency is required above code? (none, 10%, 20%, 30%, etc.).

The project goal is to reduce design energy cost for electricity by 30% as compared to a comparable baseline building meeting CA Title 24.

7.5.1.2 Describe the desires for incorporating or not, all applicable low-cost / no cost efficiency features beyond code, evaluating moderate-cost efficiency features and state-of-the-art concepts. Define cost effective in relation to simple payback and life cycle cost and requirements for performing these analyses.

The design team shall comply with local codes and shall incorporate all applicable low-cost / no cost energy efficiency features beyond code or not specifically covered by code. The team shall seriously evaluate moderate-cost efficiency features beyond code that could be cost effective. The design team shall iteratively evaluate state-of-the-art concepts that appear to offer cost effective potential with a rough evaluation advancing to more thorough evaluation when promising, after consultation with the Owner. The design team will provide to the Owner lists of considered features whether incorporated or not.

Cost effective is defined as a simple payback of less than 5 years or a life cycle cost less than the baseline. A life cycle cost analysis (first cost, energy, operations, maintenance, replacement, productivity), is not necessary for measures with simple paybacks less than 5 years.

7.5.1.3 Specifics of HVAC energy efficiency are found in the HVAC section, lighting efficiency under Electrical and water heating under Plumbing.

7.5.1.4 List the LEED Energy and Atmosphere or CALGreen elements desired or required for this project.

					ENERGY & ATMOSPHERE		
Y			EAp1	C	**Fundamental Commissioning of Building Energy Systems**	SBE	Open
Y			EAp2	D	**Minimum Energy Performance**	IEI	Open
Y			EAp3	D	**Fundamental Refrigerant Management**	IEI	Open
1			EAc1.1	D	**Optimize Energy Performance**, 10.5% New / 3.5% Existing	IEI	Open
1			EAc1.2	D	**Optimize Energy Performance**, 14% New / 7% Existing	IEI	Open
1			EAc1.3	D	**Optimize Energy Performance**, 17.5% New / 10.5% Existing	IEI	Open
1			EAc1.4	D	**Optimize Energy Performance**, 21% New / 14% Existing	IEI	Open
1			EAc1.5	D	**Optimize Energy Performance**, 24.5% New / 17.5% Existing	IEI	Open
1			EAc1.6	D	**Optimize Energy Performance**, 28% New / 21% Existing	IEI	Open
1			EAc1.7	D	**Optimize Energy Performance**, 31.5% New / 24.5% Existing	IEI	Open
1			EAc1.8	D	**Optimize Energy Performance**, 35% New / 28% Existing	IEI	Open
1			EAc1.9	D	**Optimize Energy Performance**, 38.5% New / 31.5% Existing	IEI	Open
		1	EAc1.10	D	**Optimize Energy Performance**, 42% New / 35% Existing	--	Open
		1	EAc2.1	D	**On Site Renewable Energy**, 2.5%	--	Closed
		1	EAc2.2	D	**On Site Renewable Energy**, 7.5%	--	Closed
		1	EAc2.3	D	**On Site Renewable Energy**, 12.5%	--	Closed
1			EAc3	C	**Enhanced Commissioning**	SBE	Open
1			EAc4	D	**Enhanced Refrigerant Management**	IEI	Open
1			EAc5	C	**Measurement & Verification**	IEI	Open
1			EAc6	C	**Green Power**	TMT	Open
13		4			Total Points for Energy & Atmosphere		

7.6 Materials and Resource Efficiency

7.6.1.1 Describe any sustainability material and resources goals. Provide the LEED Materials and Resources scorecard or list of CALGreen applicable elements.

Project shall integrate interior materials that support very healthy, productive and safe indoor air quality. Project will specify and install materials to meet or exceed the LEED Materials and Resources credits requirements shown in the project LEED checklist. Construction and demolition waste recycling shall strive to achieve a 95% landfill diversion rate.

Most Likely	Possible	Not Probable				Responsible Party	Status
			MATERIALS & RESOURCES				
Y			MRp1	D	**Storage & Collection of Recyclables**	GBS/TVA	Open
		1	MRc1.1	C	**Building Reuse,** Maintain 75% of Existing Walls, Floors and Roof	--	Closed
		1	MRc1.2	C	**Building Reuse,** Maintain 95% of Existing Walls, Floors and Roof	--	Closed
		1	MRc1.3	C	**Building Reuse,** Maintain 50% of Interior, Non-Structural Elements	--	Closed
1			MRc2.1	C	**Construction Waste Management**, Divert 50%	Hoffman	Open
1			MRc2.2	C	**Construction Waste Management**, Divert 75%	Hoffman	Open
		1	MRc3.1	C	**Materials Reuse**, Specify 5%	--	Closed
		1	MRc3.2	C	**Materials Reuse**, Specify 10%	--	Closed
1			MRc4.1	C	**Recycled Content**, Specify 10%	Hoffman/TVA	Open
	1		MRc4.2	C	**Recycled Content**, Specify 20%	Hoffman/TVA	Open
1			MRc5.1	C	**Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	Hoffman/TVA	Open
	1		MRc5.2	C	**Regional Materials**, 20% Extracted, Processed & Manufactured Regionally	Hoffman/TVA	Open
		1	MRc6	C	**Rapidly Renewable Materials**, Specify 2.5%	--	Closed
	1		MRc7	C	**Certified Wood**	Hoffman/TVA	Open
4	3	6			Total Points for Materials & Resources		

7.7 Indoor Environmental Quality

7.7.1.1 HVAC related IEQ goals and requirements are listed in the HVAC section.

7.7.1.2 List any indoor environmental quality goals or elements from LEED or CALGreen.

Some elements are listed below. The LEED scorecard is also provided.

7.7.2 Lighting and visual quality requirements.

These are listed under the Electrical section.

					INDOOR ENVIRONMENTAL QUALITY		
Y			EQp1	D	**Minimum IAQ Performance**	IEI	Open
Y			EQp2	D	**Environmental Tobacco Smoke (ETS) Control**	TMT	Open
		1	EQc1	D	**Outside Air Delivery Monitoring**	--	Closed
		1	EQc2	D	**Increased Ventilation**	--	Closed
1			EQc3.1:	C	**Construction IAQ Management Plan**, During Construction	Hoffman	Open
1			EQc3.2:	C	**Construction IAQ Management Plan**, After Constn./Before Occ.	Hoffman	Open
1			EQc4.1	C	**Low-Emitting Materials**, Adhesives and Sealants	Hoffman/TVA	Open
1			EQc4.2	C	**Low-Emitting Materials**, Paints and Coatings	Hoffman/TVA	Open
1			EQc4.3	C	**Low-Emitting Materials**, Carpet	Hoffman/TVA	Open
1			EQc4.4	C	**Low-Emitting Materials**, Composite Wood & Agri-fiber products	Hoffman/TVA	Open
1			EQc5	D	**Indoor Chemical & Pollutant Source Control**	IEI	Open
1			EQc6.1	D	**Controllability of Systems: Lighting**	TMT	Open
1			EQc6.2	D	**Controllability of Systems: Thermal comfort**	TVA	Open
1			EQc7.1	D	**Thermal Comfort**, Design	IEI	Open
1			EQc7.2	D	**Thermal Comfort Verification**, Verification	TMT	Open
1			EQc8.1	D	**Daylight and Views**, Daylight 75% of Spaces	GBS	Open
1			EQc8.2	D	**Daylight and Views**, View for 90% of Spaces	GBS	Open
13		2			Total Points for Indoor Environmental Quality		

7.7.3 Acoustics

7.7.3.1 What is the desired level of acoustical performance and control (background noise levels) of each of the occupancy types (standard, above standard, exceptional)? List any spaces with special acoustical requirements. Give NC targets for each.

General goal: Above standard. Meet local code requirements and industry standards at a minimum.
Office general: Standard, NC 35-40
Office executive: Above Standard, NC 30-35
Condominium: Above Standard, NC 30-33 in Master Bedrooms, NC 30-35 in other bedrooms, NC 30-35 in primary living areas rooms, dining rooms (not kitchens and bathrooms, or utility rooms), and NC 35-40 in corridors.
Public Areas: Standard, NC 35-45
Retail: Standard, 35-40
Fitness: Standard, 35-45

7.7.3.2 Are there any areas where a special level of acoustical separation is desired to adjacent rooms, spaces or from outdoors? (e.g., between condominiums, executive offices, strategic planning rooms, recreation rooms, rest areas, conference rooms, mechanical rooms, etc.) Minimally, indicate these special acoustical separations to be above standard or exceptional. Ideally, provide a target separation (wall, ceiling, floor) Sound Transmission Class (STC).

Between condominiums: Walls. Minimum Laboratory rated, Sound Transmission Class (STC) for walls of 55, and 55 for floors. Higher performance is expected with the designed systems. Floors. Minimum Laboratory rated, Impact Insulation Class (IIC) for floors of 58, 60+ preferable.

8. Building Envelope

8.1 Overall Envelope Criteria

8.1.1.1 Describe the overall envelop design criteria and any special concerns that exist. List any special features desired or required to be considered or a part of this project. (e.g., rain penetration, sun and dryness, stack effects, envelope air leakage, façade mockup requirements, insitu water or air leakage testing, etc.)

The building envelope shall be designed to meet the wet City climate without water leaks of any kind during normal and extreme rainfall and winds. The design shall include provisions to weep to the outside any moisture that penetrates the outer façade without causing degradation to the building elements. Rain screens are required behind outer surfaces that are moisture permeable, like masonry. Water leakage integrity of the outer surface shall not rely solely on caulking, without a proper weepage plane and path.

The design will result in a very low air leakage rate for this type of structure and will minimize and mitigate impacts of the stack effect of this tall structure.

All horizontal sills will slope down to the outside. Wall assembly, flashing and caulking details will be clearly shown in the drawings for each configuration, type of joint, attachment and connection.

The specifications will require a mock-up or insitu performance testing of each major glazing type and adjacent building elements for air and water penetration using ASTM standard field tests.

8.2 Additional Envelope Criteria

8.2.1.1 Are there any envelope (roofing, façade, fenestration) products or techniques that are not acceptable, including glazing tinting, etc.?

No reflective glass. Glass shall not appear too "green" from interior.

8.2.1.2 Describe the basic building envelope requirements and concerns (roof, exterior wall, fenestration, daylighting, subgrade elements) in broad terms. Include issues such as aesthetics, context, durability, maintainability, sustainability, energy efficiency.

Transparency is important to this owner. Promote daylighting while avoiding significant heat loads that will overburden cooling systems. Highly reflective roofing is desired to comply with LEED (SRI >78). Low maintenance materials should be specified. US-based materials shall be preferred.

8.2.1.3 What are the fenestration requirements (natural daylighting for perimeter or deeper spaces, elimination of daylight, access to daylight views, solar orientation, internal uses, entrance location requirements based on site specific considerations, functional needs, aesthetics, climate)?

Revolving doors to be included. Natural daylighting shall be promoted to reduce electrical lighting dependence. Natural ventilation is desired and operable windows shall be evaluated. In general, the fenestration should respond to the region's temperate climate.

8.2.1.4 What are the roof shape and material considerations (climatic, aesthetic, traffic bearing, equipment support, cost, local expertise in materials considerations, etc.)?

The roof shape should pronounce the building as an icon. The building will be strategically lit at night to have the appearance of a lantern. Energy Star rated, low maintenance roof membrane. Mechanical equipment will be screened to be invisible.

The lighting of the building top will be accomplished using low-energy LED lights which will uniformly light translucent glass internally from behind to achieve a glowing, lantern effect while minimizing night-time light pollution.

8.2.1.5 What are the thermal performance criteria for the building envelope (energy code minimums, super-insulated, energy payback, green building components, occupant comfort)?

Goal was 60% energy use reduction beyond Oregon Energy Code. Meet ASHRAE 55 at a minimum.

The building envelope thermal performance will exceed code minimums by utilizing thermally broken and insulated curtain wall support members, insulated low U-value glass, and insulated metal panel components that minimize both unwanted exterior solar heat gain and interior heat and cooling losses.

8.2.1.6 What are the durability requirements (first cost considerations vs. life cycle cost, long-term monument vs. short-term speculative building, sustainability, future additions and/or transformations, flexibility for reuse)?

The building will be held by the owner. Life cycle costs for the envelope elements and assemblies will be evaluated to inform material and design strategy decision making. The goal is long-term value.

8.2.1.7 What are the maintenance requirements (minimum maintenance, availability of well staffed maintenance department, most maintenance outsourced, sophistication of maintenance department, availability of sustainable products for maintenance tasks, costs)?

The Office Tower will be maintained by in house fully accredited and licensed engineering and maintenance staff.

8.2.1.8 What are, if any, constraints on building envelope performance from future/proposed development and/or changes to adjacent lots/properties?

None

9. Plumbing Systems

9.1 Water Efficiency

9.1.1.1 Refer to the Water Efficiency section under Sustainability for details of the water efficiency objectives of this project.

9.2 Fixture Controls

9.2.1.1 Are auto-flushing and on/off controls desired on urinals, lavatories, toilets?

Yes

9.2.1.2 Are waterless urinals a consideration? Where?

Not at this time, but 1 pint urinals are desired.

9.3 Energy Efficiency

9.3.1.1 The water heating system energy design is desired to be: standard code, somewhat more efficient that code, much more efficient than code?

Much more efficient than code requires.

9.3.1.2 Are there specific system types that shall be incorporated or that are not to be considered (e.g., point of use heaters, electric heaters, etc.)?

No. This is up to the design team.

10. Fire Alarm

10.1.1.1 List the specific brand and/or model of fire alarm system required, if any.

No specific type required.

10.1.1.2 List any special features desired or required of the fire alarm system.

Fully addressable system required. Code compliant minimum system with additional features mentioned below.

10.1.1.3 Describe where the fire alarm signal is to be sent to off site.

Alerts or troubles will remain in the fire alarm panel. Alarms will be sent to the BAS as a general alarm and to the municipal fire department.

10.1.1.4 Is the FA system to have addressable and monitored fire smoke dampers (ones that can be commanded open or closed from the fire alarm panel)?

Yes.

10.1.1.5 Are the fire smoke dampers to have end switches that positively confirm closed and open positions or is the commanded position notification acceptable?

End switches are required.

11. Data and Communications Systems

11.1.1.1 Describe the data requirements in the building.

Data requirements for building are currently under review by the electrical designer and owner. However, scope of work at this time includes horizontal cabling for condominium units (phone and CATV), backbone cabling to each office level and each of two major retail tenant spaces, and house cabling needs. This includes copper, cable TV and fiber optic for backbone, and copper UTP and CATV for horizontal cabling.

11.1.1.2 Describe the needs for future expansions.

TBD.

11.1.1.3 Will special backbone, conduit and cabling be required to unfinished areas so offer those tenants adequate data and communications?

Conduit shall be provided through closed-in in accessible spaces

11.1.1.4 Describe the wireless internet systems desired for the building.

TBD

11.1.1.5 Describe the communication systems desired for the building.

TBD

11.1.1.6 Will the property owner/manager be reselling phone and internet services or will those services be provided directly to the tenant/resident by a service provider?

TBD

11.1.1.7 Are both CATV and Satellite availability required?

TBD

11.1.1.8 Are there any requirements for A/V system (condo home theater) options or pathways in the residential units?

TBD

11.1.1.9 Will wireless access to the internet be provided for the residential areas, or will this be by the tenants? For the office areas? For the retail areas?

TBD

11.1.1.10 Describe any tie-in between the data and communication systems and the security system or building automation system.

TBD

12. Security and Access

12.1.1.1 What are the securities concerns for this facility?

Controlling access to office floors and condo floors during the day and after hours. 24/7 monitoring of CCTV system.

12.1.1.2 List the specific brand and/or model of security system required, if any.

No specific type required.

12.1.1.3 What access control must this facility accommodate?

Office floors and condo floors should be securable during the day and/or after hours, depending on needs of tenants. Entry into the elevator lobbies themselves should also be controlled, ideally by the use of a proximity card access controls system, similar to the systems in place in both the Liberty Tower and 1000 Tahoma St. Buildings.

12.1.1.4 What areas of the facility will require controlled access?

All above retail floors including office, condo, and mechanical areas. All areas housing critical building systems will also need to be secured. Mail rooms and delivery areas should also be securable. Freight elevator access to all floors should also be controlled. Loading dock area after hours should be securable. Locker rooms/workout facilities/other amenity areas should also be secured.

12.1.1.5 Describe the desired security system features (e.g., card reader, fingerprint, retina scanner types, length of image storage capacity, remote access capabilities and backup features, user programmability, reporting functions, battery backup duration, etc.).

HD CCTV DVR systems; programmable magnetic proximity card reader system for individual door/floor access; steel rolling door to secure loading dock and/or garage entry; two way communication "distress" devices strategically placed throughout with direct communication to 24/7 on duty Security officer; 24/7 manned Security console/desk; possibly biometric fingerprint or retina scanners for highly sensitive areas.

12.1.1.6 Describe any required interlocks between the security system and the building automation system and HVAC.

None.

End of Example OPR Template

Appendix IV – 3
Example OPR - University Laboratory Renovation & Addition (Courtesy of Montana Architecture and Engineering Division)[3]

Gaines Hall Addition and Renovation—A/E No. 21-02-02

Overview

The purpose of this Owner's Project Requirements (OPR) document is to record the owner's requirements for the operation of the mechanical and electrical systems in the completed Gaines Hall project. The design, installation, start-up and final operation of the building systems will be confirmed and documented by the Commissioning quality assurance process as defined by ASHRAE Guideline 1-1996.

This OPR document will serve as the benchmark for the Gaines Hall commissioning process. Further general requirements of the commissioning process are described below. A more detailed description of the commissioning procedure and requirements for Gaines Hall is included in the Commissioning Program (Montana A/E Division, June 28, 2002).

This project includes a renovation and addition to Gaines Hall, a primary chemistry and biochemistry teaching and research facility on the MSU campus. The history, purpose and scope is described in the Programming document by L'Heureux, Page and Werner, PC, dated February 19, 2002. This OPR document is a distillation of the information included in the Programming Document, plus additional information defined during the early stages of design. As such, it is a dynamic document and will be updated as required throughout the design process.

Goals of the Facility

A Quality Research Environment

In the words of the programming document, Gaines Hall is to provide MSU with "State of the art labs allowing first rate research" while "maximizing human comfort, health, safety and productivity." This means that the lab and classroom spaces will be safe, effective and energy efficient on a level with any such structure built today with similar budgetary constraints. Fume hood spaces are to be designed with every possible consideration in mind to allow the safe and complete evacuation of fumes from the occupied area. This includes:

- Design of fume extraction systems to the latest and best design standards
- Best placement of the fume hoods with respect to foot traffic, and
- Automatic control of hood airflow and room pressurization through the building automation system (BAS) in conjunction with the laboratory HVAC system control system.

In the words of the planning document, the facility "Shall consider lifecycle costs, long term durability and long term operational costs over first costs." This underscores the need for quality, which will be assured through the commissioning process and the documentation of life-cycle cost analyses for all major equipment with a reasonable potential for payback as determined by the design team in conjunction with the Owner (see below). As an institutional building, this structure will have a long life expectancy (30 to 50 years from this time).

[3] Example OPR Document (Courtesy of L'Heureux, Page, Werner, PC, Great Falls, Montana)

Excellent Indoor Environmental Quality (IEQ)

IEQ includes lighting, temperature, humidity, air cleanliness, noise, vibration and aesthetic surroundings. All possible measures within the available budgetary and physical constraints will be taken in designing and constructing this project to assure that the best possible IEQ is attained from the first day of occupancy. This will be assured through the commissioning process (see detailed required below).

Use of the Latest Technology

This facility is to make use of cutting-edge technology wherever possible to achieve excellence in performance. This includes the best available approaches to building HVAC control, and lab and teaching equipment of all kinds. The building shall incorporate a direct digital control (DDC) system capable of trending critical building performance parameters for the life of the building. The DDC system shall have the ability to:

- Accurately measure and store building performance data for 100 control points measured at two minute intervals continuously for one week
- To display this data in graphical form, and
- To transmit this data over the existing campus data infrastructure

In addition, the system shall allow users to access the system using a standard Web browser such as Internet Explorer or Netscape. Authorized personnel, with password identification, shall be able to access the system from any Web-enabled personal computer or wireless device.

Sustainability

The building is to be sustainable in its design and allow complete access to equipment, piping and wiring through the use of well organized machine rooms and lighted chases sized to allow inspection and repair. Sustainability requires maintainability and includes commissioning, O&M staff training and O&M manuals. O&M training will be done with completed O&M manuals in their final form. The building will not be occupied, nor will substantial completion be certified, until O&M manuals are complete and approved and training is completed. Sustainability will be further ensured through the DDC system monitoring and trending described above.

To assist the Owner in maintaining the building, the following items shall be included:

- Training and operation and maintenance manuals shall be completed at the end of each construction phase.
- All training will be video taped for future reference.
- Operation and maintenance manuals shall be organized by CSI specification section and shall be submitted by the 70% payment request of each phase.
- A minimum of 2 hours of monthly retraining on the building automation system shall be provided for the first year of occupancy.
- Operation and maintenance manuals shall include the Basis of Design and Engineer's Narrative. Training shall include a presentation of the Engineer's Narrative by a representative of the design team.
- One-line diagrams of the water and air sides of the building shall be plastic laminated and mounted in areas designated by the Owner to assist maintenance personnel.

Flexibility for Future Needs

Lab and class spaces shall be modular in nature to assure quality and consistency of operation while allowing efficiency in design and construction. All environment control systems and utilities

shall be designed to allow access for future re-configuration and shall be provided with the space required for future load increases. Specifically, this includes a 20% growth factor for electrical power, and a 10% growth factor for ventilation, heating, cooling and all other services without the need to expand machine rooms or central switch gear cabinets. The physical restraints (i.e. limited floor to floor heights) of the existing building will dictate how much future growth is possible in the HVAC system and will need to be continually evaluated as the design progresses.

Data Infrastructure

Gaines Hall will be connected to the campus data infrastructure via the fiber-optic backbone and Ethernet local area network (LAN). All data required to control and monitor the building environmental control systems and ancillary equipment will be available on the LAN.

Utilities

Steam for heating and building pneumatic HVAC control air will be supplied from the campus central plant. Plant steam is treated with chemicals and will not be used directly for humidification or any laboratory uses without specific approval from the campus Facility Office. The primary power for the building is 12.47 Kv, loop fed, direct buried underground system.

Discipline Requirements

Energy Efficiency

The building is to use the latest cost effective technology to achieve energy efficiency while maintaining a safe and effective research environment. In the words of the program document, “Energy and resource conservation shall be considered in the planning and design of the project.” This means that life-cycle cost analyses will be performed and documented for each major building environmental system selection and comparable alternates where the Owner and the design engineer agree on savings potential.

This includes (but is not limited to) the consideration of the following energy conserving options:

- Groundwater extraction/injection well cooling,
- Economizer cycles and night-time cooling on areas with recirculated air,
- Heat recovery for 100% OSA areas,
- Variable volume strategies and variable frequency drives for both air and water systems,
- Water conserving plumbing and lab fixtures where feasible.

Indoor Environmental Quality (IEQ)

IEQ includes lighting, temperature, humidity, air cleanliness, noise, vibration and aesthetic surroundings. The highest quality research demands the highest IEQ. This will be reflected in (see specific noise and vibration requirements below):

- Maximum daylighting
- Correct operation of fume hoods (see below)
- Cleanliness of all systems before start-up (assured through commissioning)
- Isolation and negative pressurization of all stored chemicals including office and janitorial chemicals
- Isolation of all labs from adjacent spaces (as a minimum requirement, the programming document states: “Noise and fumes from building systems shall not be allowed to intrude on adjacent interior or exterior public spaces)”
- Absence of liquid water in ducts, air handling units (AHUs) and utility spaces

- No smoking in the building during construction
- No use of any adhesives, finishes or solvents containing volatile organic compounds (VOCs) in the building during construction if such usage can be accomplished outside of the building (in other words, no in-situ refinishing or cleaning operations on existing or new equipment or fixtures that can be moved outside of the building)
- The programming document states: "Orientation shall keep energy conservation principles in mind such as shading and protecting entrances from wind." Entrances shall also be protected from wind-blown dust and debris as well as tracked-in soil
- Noise attenuation for all AHUs and ductwork leading to adjacent spaces
- Vibration absorbers on all equipment
- Equipment mounted close to vertical columns
- No insulation shall be installed in air handling units, humidifiers, or any other location where it could get wet or absorb moisture.

Specific fume hood requirements

- Fume hoods are to be located a minimum of 10' from doors and out of pedestrian circulation areas to prevent air turbulence from impacting fume capture
- Air velocity through hoods shall be 100 fpm (±10 fpm) at 18" sash opening, 60 fpm minimum and 110 fpm maximum at any opening
- Fume hood ductwork shall be under a negative pressure for as much of the exit path as possible
- Hoods designated by the Environmental Health and Safety Authority as handling "especially hazardous" materials shall have dedicated ductwork to a dedicated exhaust fan
- The maximum ambient air velocity (supply or exhaust) in the vicinity of hoods is 50 fpm, measured 6 ft above floor
- Exhaust canopies and snorkels shall have a minimum exhaust air volume of 75 cfm per exposed linear foot of collector perimeter
- All fume hoods shall be equipped with alarms to indicate insufficient airflow and to indicate hoods left open (all hoods to be closed to an 18" sash opening when unused or in normal operating mode and open during set-up only)
- If direction of airflow is critical between spaces, monitoring devices shall be used to signal pressure relationships

Rooms shall be included with fume hoods and other exhaust devices as follows:

LABORATORY EXHAUST REQUIREMENTS				
ID	FLOOR	SPACE NAME	**FUME HOODS**	**OTHER EXHAUST**
2.01	Ground	Physical Chemistry Teaching Lab	1 @ 6'-0" adjustable	----
2.02	Ground	Optics	----	1 vacuum pump vent
4.02	Ground	Electronics Shop	----	2 snorkels
4.04	Ground	Machine Shop	----	Recirc dust collector
11.01	Ground	NMR	----	----
11.02	Ground	NMR/X-Ray	----	----
12.01	Ground	Mass Spec	----	----
12.02	Ground	Prep	1 @ 4'-0"	----
13.01	Ground	Physical Chemistry	1 @ 6-0"	4 vacuum pump vents
16.01	Ground	Physical Chemistry	1 @ 6'-0"	3 vacuum pump vents
16.02	Ground	Physical Instrumentation	----	----
23.01	Ground	Physical Chemistry Analytical	1 @ 6'-0"	1 vacuum pump vent
24.01	Ground	Analytical Research	1 @ 6'-0"	4 vacuum pump vents
25.03	Ground	Lecture Prep	1 @ 4'-0"	----
31.01	Ground	Unassigned Lab	1 @ 6'-0"	----

LABORATORY EXHAUST REQUIREMENTS				
ID	FLOOR	SPACE NAME	**FUME HOODS**	**OTHER EXHAUST**
1.01	First	Existing Freshman Lab	1 @ 6'-0"	----
1.02	First	Existing Freshman Lab	1 @ 6'-0"	----
1.03	First	Existing Freshman Lab	1 @ 6'-0"	----
1.04	First	Existing Freshman Lab	1 @ 6'-0"	----
1.05	First	General Chemistry Lab	1 @ 6'-0"	----
1.06	First	General Chemistry/Analysis	1 @ 6'-0" 1 @ 6'-0" adjustable	----
3.01	First	Organic Teaching	9 @ 8'-0" 2 @ 4'-0"	----
3.02	First	Organic Teaching	9 @ 8'-0" 2 @ 4'-0"	----
3.03	First	Organic Instruments	----	3 snorkels
3.05	First	Freshman Organic Stockroom	1 @ 4'-0"	----
26.01	First	General Chemistry Support (Amend)	1 @ 4'-0"	----
6.01	Second	Biochemistry Instruments	1 @ 4'-0"	----
6.02	Second	Ramen/Spec Lab	----	----
6.03	Second	Biochemistry Research (Dooley)	2 @ 6'-0" 1 @ 6'-0" Radioactive Isotope	----
7.01	Second	Biochemistry Research	2 @ 6'-0"	----
7.02	Second	Microscopy	----	----
7.03	Second	Spectroscopy	----	----
8.01	Second	Biochemistry Research	1 @ 4'-0"	----
8.02	Second	SPR	----	----
9.01	Second	Biochemistry Research (Lawrence)	1 @ 4'-0"	----
10.02	Second	Biochemistry Prep	1 @ 4'-0" Laminar Flow Hood	----
10.03	Second	Tissue Culture	2 @ 4'-0" Bio Safety Cabinets	----
10.04	Second	Biochemistry Equipment	----	1 snorkel (300 cfm)
10.05	Second	MMC	----	----
10.06	Second	Proteomics	----	----
14.01	Second	Inorganic Research	2 @ 6'-0"	----
14.02	Second	Inorganic Instruments	1 @ 4'-0"	----
31.03	Second	Unassigned Lab	----	----
15.01	Third	Inorganic Research (Abbott)	8 @ 6'-0"	----
17.01	Third	Organic Research (Cloninger)	10 @ 6'-0"	1 snorkel
18.01	Third	Organic Research (McClure)	6 @ 6'-0"	1 snorkel
18.02	Third	Organic Research (McClure)	4 @ 6'-0"	1 snorkel
19.01	Third	Organic Research (Holmgren)	3 @ 6'-0"	1 snorkel
20.01	Third	Organic Research (Greico)	12 @ 6'-0"	1 snorkel
21.01	Third	Organic Research (Livinghouse)	10 @ 6'-0"	1 snorkel

Noise and Vibration

The limiting of the transmission of noise and vibration throughout the building is of primary importance. Much of the equipment in the building is sensitive to vibration and, as described above, the limitation of building noise levels is vital for occupant IEQ. This includes noise and vibration from the following sources:

- Air movement through ducts and/or duct vibration
- Fan exit turbulence and/or fan instability
- Air turbulence past balancing dampers
- Air turbulence past variable air volume (VAV) boxes and other terminal devices

- Water flow turbulence or vibration (usually transmitted through the structure)
- HVAC refrigeration compressors or air compressors
- General machinery sources and imbalanced machinery
- Electrical eddy current vibration from light ballasts and transformers.
- Elevator machinery
- Truck and general vehicle traffic close to the building
- Pedestrians and events/gatherings close to the building

The design should include, to the greatest extent possible, the following items:

- Conduits should not link noise sensitive spaces, use flex conduit to isolate noise sources when allowed by code
- Light ballasts shall be electronic and shall have an “A” sound level rating.
- Use duct-mounted noise attenuation equipment (silencers) when AHUs or fans are close to the spaces served by their connected ductwork
- Keep supply duct air velocities as low as possible (less than 2200 fpm in mains and 800 fpm in branches). Allow architectural space for larger ductwork above ceilings for each floor
- Use wide-sweep elbows on ductwork, provide architectural space for wide-sweep elbows
- Use correct fan exit geometries to avoid turbulence, inefficiency and noise
- Because of the limited available floor-to-floor spaces in the existing building, and the large volumes of airflow required, it is expected that compromises will need to be made in the duct system design. Terminal noise attenuation equipment might need to be installed, especially in the teaching laboratories.

The design should include, to the greatest extent possible, the following items:

- Isolate all equipment and piping with elastomeric vibration isolators
- Place equipment and travel paths close to structural columns as the space will allow
- Design floors for a minimum of a 100 psf live load, structural requirements per VC-A criterion
- Masonry walls for mechanical rooms (use noise absorptive coverings if required)
- Specify equipment vibration isolators and inertial foundations for heavy equipment
- Provide special isolators on sensitive equipment (if a part of construction)

Ductwork

Ductwork construction shall be per the requirements of the relevant SMACNA standard including HVAC Duct Construction Standards Metal and Flexible. The duct pressure classes shall be defined in the contract drawings and all ductwork shall be sealed, reinforced and supported as required for the duct pressure class.

Representative portions of the ductwork systems shall be tested for leakage. In general, the testing of an entire system is not anticipated because of the time, energy, and financial requirements of the testing. As the duct system is designed, the design engineer, in conjunction with other interested parties, shall determine representative duct sections for leakage testing.

Ductwork Insulation

Duct liner shall not be used on supply systems with final filtration requirements (see below).

Laboratory Utilities

A non-potable source of hot and cold water shall be piped to the laboratories. Central reduced pressure backflow assemblies shall be install to protect the building's potable water source from the non-potable water system.

Purified water shall be provided from the existing system modified to meet any additional load demands. Equipment for more stringent water purity requirements will the responsibility of the individual laboratory or researcher. The system will meet the following criteria:

Electrical Resistivity	≥18.0	MΩ-cm (referenced to 25°C)
Total Organic Carbon	≤100	μg/l
Endotoxin	≤0.010	Endotoxin Units/ml

Laboratory compressed air shall be dried to 2.1 grams of H2O/lb dry air or 37 dF dew point at 100 PSIG. Compressed air shall be distributed at 100 psig and reduced to 15 psig at each floor.

Local vacuum pumps shall provide laboratory vacuum to each laboratory. These pumps will be the responsibility of the individual laboratory or researcher.

Laboratory gas shall be from the campus natural gas system and shall be delivered to the laboratories at 7 inches w.c.

Specialty gases (CO_2, N_2, O_2, H_2, He, Ar) shall be provided by local gas cylinders in the laboratories or in closets adjacent to the laboratories.

Piping Distribution

The purified water distribution system shall be designed as a continuous loop without any dead legs to minimize stagnant water in the system.

Emergency Power

The building shall be equipped with an emergency power source in the form of an emergency generator fueled with diesel oil. This generator shall serve both emergency power and standby power loads. These loads include:

- Emergency power serves loads where a definite potential for catastrophe exists including explosion, violent ejection of life-threatening chemicals or overheating. It also includes egress lighting, exit signs, elevators, fire alarm system, monitoring equipment (including the building management system) and safety equipment. These loads are code required to be on an additional power source.
- Standby power serves loads that minimize research damage in the event of a power failure. This includes critical research equipment, refrigerators, freezers, vacuum pumps, monitoring equipment, a minimal number of receptacles in each laboratory, select room HVAC systems and select room lighting. These loads are Owner required to be on an additional power source.

The attached table indicates which spaces and equipment need emergency power and standby power.

EMERGENCY AND STANDBY POWER REQUIREMENTS				
ID	FLOOR	SPACE NAME	**EMERGENCY**	**STANDBY**
2.01	Ground	Physical Chemistry Teaching Lab	----	Selected receptacles and/or hoods

EMERGENCY AND STANDBY POWER REQUIREMENTS				
ID	FLOOR	SPACE NAME	**EMERGENCY**	**STANDBY**
2.02	Ground	Optics	----	Selected receptacles and/or hoods
4.02	Ground	Electronics Shop	----	Selected receptacles and/or hoods
4.04	Ground	Machine Shop	----	Selected receptacles and/or hoods
11.01	Ground	NMR	----	Selected receptacles and/or hoods
11.02	Ground	NMR/X-Ray	----	Selected receptacles and/or hoods
12.01	Ground	Mass Spec	----	Selected receptacles and/or hoods
12.02	Ground	Prep	----	Selected receptacles and/or hoods
13.01	Ground	Physical Chemistry	----	Selected receptacles and/or hoods
16.01	Ground	Physical Chemistry	----	Selected receptacles and/or hoods
16.02	Ground	Physical Instrumentation	----	Selected receptacles and/or hoods
23.01	Ground	Physical Chemistry Analytical	----	Selected receptacles and/or hoods
24.01	Ground	Analytical Research	----	Selected receptacles and/or hoods
25.03	Ground	Lecture Prep	----	Selected receptacles and/or hoods
31.01	Ground	Unassigned Lab	----	Selected receptacles and/or hoods
5.02	Ground	Chemical Storage	Egress lighting	----
5.03	Ground	Chemical Storage	Egress lighting	----
5.04	Ground	Chemical Storage	Egress lighting	----
5.06	Ground	Chemical Storage	Egress lighting	----
5.08	Ground	Chemical Storage	Egress lighting	----
5.09	Ground	Chemical Stores	Egress lighting; Exit signs	----
00.00	Ground	Mechanical New	Egress lighting	Selected mechanical equipment
00.00	Ground	Mechanical Existing	Egress lighting	Selected mechanical equipment
00.00	Ground	Electrical Vault Existing	Egress lighting	Selected receptacles and/or hoods
4.05	Ground	Gas	Egress lighting	Selected receptacles and/or hoods
4.07	Ground	Hazardous Materials	Egress lighting	Selected receptacles and/or hoods
30.01	Ground	Stair West	Egress lighting; Exit signs	----
30.01	Ground	Stair East	Egress lighting; Exit signs	----
4.01	Ground	Office (Reinholz)	----	----
4.03	Ground	Load/Unload	----	----
4.06	Ground	Instrument Storage	----	----
5.01	Ground	Office (Larson)	----	----
5.05	Ground	Department Archives	----	----
11.03	Ground	Office (Busse)	----	----
12.03	Ground	Office	----	----
16.03	Ground	Grad Office	----	----
24.02	Ground	Storage	----	----

EMERGENCY AND STANDBY POWER REQUIREMENTS				
ID	FLOOR	SPACE NAME	**EMERGENCY**	**STANDBY**
24.03	Ground	Office	----	----
28.02	Ground	Student/Faculty	----	----
28.08	Ground	Computer	----	----
29.02	Ground	Office (Minton)	----	----
29.03	Ground	Office (Spangler)	----	----
29.09	Ground	Office (Singel)	----	----
29.12	Ground	Office (Callis)	----	----
29.22	Ground	Office (Sunner)	----	----
29.23	Ground	Office	----	----
29.24	Ground	Office (Grimsrud)	----	----
30.01	Ground	Corridor	Egress lighting; Exit signs	----
30.01	Ground	Stair South	Egress lighting; Exit signs	----
30.03	Ground	Men's Toilet	----	----
30.03	Ground	Women's Toilet	----	----
30.03	Ground	Women's Restroom Existing	----	----
30.03	Ground	Men's Restroom Existing	----	----
30.04	Ground	Electrical	Egress lighting	Selected receptacles and/or hoods
30.05	Ground	ITC	Egress lighting; Telephone; Fire alarm; Life safety equipment	Selected receptacles and/or hoods
30.11	Ground	Janitor Existing	----	----
30.11	Ground	Janitor	----	----
30.12	Ground	Building Storage	----	----
1.01	First	Existing Freshman Lab	----	Selected receptacles and/or hoods
1.02	First	Existing Freshman Lab	----	Selected receptacles and/or hoods
1.03	First	Existing Freshman Lab	----	Selected receptacles and/or hoods
1.04	First	Existing Freshman Lab	----	Selected receptacles and/or hoods
1.05	First	General Chemistry Lab	----	Selected receptacles and/or hoods
1.06	First	General Chemistry/Analysis	----	Selected receptacles and/or hoods
3.01	First	Organic Teaching	----	Selected receptacles and/or hoods
3.02	First	Organic Teaching	----	Selected receptacles and/or hoods
3.03	First	Organic Instruments	----	Selected receptacles and/or hoods
3.05	First	Freshman Organic Stockroom	----	Selected receptacles and/or hoods
26.01	First	General Chemistry Support (Amend)	----	Selected receptacles and/or hoods
25.01	First	Lecture Hall	Egress lighting; Exit signs	----
30.01	First	Vestibule NE	Egress lighting; Exit signs	----
30.01	First	Vestibule South	Egress lighting; Exit signs	----
30.01	First	Stairs West	Egress lighting; Exit signs	----

EMERGENCY AND STANDBY POWER REQUIREMENTS				
ID	FLOOR	SPACE NAME	**EMERGENCY**	**STANDBY**
30.01	First	Stairs East	Egress lighting; Exit signs	----
3.04	First	Organic Computers	----	----
3.08	First	Grad Student Bullpen	----	----
25.04	First	Classroom	----	----
25.06	First	Classroom	----	----
25.07	First	Classroom	----	----
27.01	First	Department Head	----	----
27.04	First	Admin Office	----	----
27.05	First	Work Room	----	----
27.06	First	Copy	----	----
27.08	First	Op Tech Office	----	----
27.09	First	Accounting Office	----	----
27.10	First	IT Tech Office	----	----
27.12	First	Conference	Egress lighting	----
28.01	First	Vending	----	----
28.03	First	Help Center	----	----
29.01	First	Office (Johnson)	----	----
29.25	First	Office (Amend)	----	----
30.01	First	Corridors	----	----
30.01	First	Lobbies	Egress lighting; Exit signs	----
30.03	First	Men's Toilet	Egress lighting; Exit signs	----
30.03	First	Women's Toilet	----	----
30.03	First	Women's Restroom Existing	----	----
30.03	First	Men's Restroom Existing	----	----
30.04	First	Electrical	Egress lighting	Selected receptacles and/or hoods
30.05	First	ITC	Egress lighting; Telephone; Fire alarm; Life safety equipment	Selected receptacles and/or hoods
30.11	First	Janitor	----	----
30.11	First	Janitor Existing	----	----
10.02	Second	Biochemistry Prep	----	Selected receptacles and/or hoods
10.03	Second	Tissue Culture	----	Selected receptacles and/or hoods
10.04	Second	Biochemistry Equipment	----	Selected receptacles and/or hoods
10.06	Second	Proteomics	----	Selected receptacles and/or hoods
14.01	Second	Inorganic Research	----	Selected receptacles and/or hoods
14.02	Second	Inorganic Instruments	----	Selected receptacles and/or hoods
6.01	Second	Biochemistry Instruments	----	Selected receptacles and/or hoods
6.02	Second	Ramen/Spec Lab	----	Selected receptacles and/or hoods
6.03	Second	Biochemistry Research (Dooley)	----	Selected receptacles and/or hoods
31.03	Second	Unassigned Lab	----	Selected receptacles and/or hoods
7.01	Second	Biochemistry Research	----	Selected receptacles and/or hoods
7.02	Second	Microscopy	----	Selected receptacles and/or hoods

EMERGENCY AND STANDBY POWER REQUIREMENTS				
ID	FLOOR	SPACE NAME	**EMERGENCY**	**STANDBY**
7.03	Second	Spectroscopy	----	Selected receptacles and/or hoods
8.01	Second	Biochemistry Research	----	Selected receptacles and/or hoods
8.02	Second	SPR	----	Selected receptacles and/or hoods
9.01	Second	Biochemistry Research (Lawrence)	----	Selected receptacles and/or hoods
10.05	Second	MMC	----	Selected receptacles and/or hoods
30.01	Second	Stairs East	Egress lighting; Exit signs	----
30.01	Second	Stairs West	Egress lighting; Exit signs	----
6.04	Second	Cold Room	----	Cooling equipment
6.05	Second	Grad Students	----	----
7.04	Second	Grad Students	----	----
10.01	Second	Cold Room	----	Cooling equipment
25.02	Second	Classroom	----	----
28.02	Second	Student/Faculty	----	----
28.06	Second	Res Computers	----	----
28.09	Second	Conference	Egress lighting	----
29.04	Second	Office (Dooley)	----	----
29.06	Second	Office (Dratz)	----	----
29.07	Second	Office (Teintze)	----	----
29.08	Second	Office (Lawrence)	----	----
29.10	Second	Office (Douglas)	----	----
29.26	Second	Office (Jackson)	----	----
29.27	Second	Office (Hapner)	----	----
30.01	Second	Corridors	Egress lighting; Exit signs	----
30.01	Second	Lobby	Egress lighting; Exit signs	----
30.01	Second	Stairs North	Egress lighting; Exit signs	----
30.03	Second	Women's Toilet	----	----
30.03	Second	Men's Toilet	----	----
30.03	Second	Women's Restroom Existing	----	----
30.03	Second	Men's Restroom Existing	----	----
30.04	Second	Electrical	Egress lighting	Selected receptacles and/or hoods
30.05	Second	ITC	Egress lighting; Telephone; Fire alarm; Life safety equipment	Selected receptacles and/or hoods
30.11	Second	Janitor	----	----
30.11	Second	Janitor's Existing	----	----
31.05	Second	Storage	----	----
15.01	Third	Inorganic Research (Abbott)	----	Selected receptacles and/or hoods
17.01	Third	Organic Research (Cloninger)	----	Selected receptacles and/or hoods
18.01	Third	Organic Research (McClure)	----	Selected receptacles and/or hoods
18.02	Third	Organic Research (McClure)	----	Selected receptacles and/or hoods
19.01	Third	Organic Research (Holmgren)	----	Selected receptacles and/or hoods

EMERGENCY AND STANDBY POWER REQUIREMENTS				
ID	FLOOR	SPACE NAME	**EMERGENCY**	**STANDBY**
20.01	Third	Organic Research (Greico)	----	Selected receptacles and/or hoods
21.01	Third	Organic Research (Livinghouse)	----	Selected receptacles and/or hoods
30.01	Third	Stairs West	Egress lighting; Exit signs	----
30.01	Third	Stairs East	Egress lighting; Exit signs	----
30.01	Third	Stairs North	Egress lighting; Exit signs	----
15.02	Third	Grad Office	----	----
17.02	Third	Grad Office	----	----
18.03	Third	Grad Office	----	----
19.02	Third	Grad Office	----	----
19.11	Third	Office (Livinghouse)	----	----
20.02	Third	Grad Office	----	----
21.02	Third	Grad Office	----	----
27.02	Third	Faculty Seminar	----	----
27.03	Third	Department Conference	----	----
28.02	Third	Student/Faculty	----	----
28.07	Third	Computer	----	----
29.11	Third	Office (Abbott)	----	----
29.13	Third	Office (Cloninger)	----	----
29.14	Third	Office (McClure)	----	----
29.16	Third	Office	----	----
29.17	Third	Office (Holmgren)	----	----
29.18	Third	Office (Department Head)	----	----
29.19	Third	Office (Secretary)	----	----
29.20	Third	Library	----	----
30.01	Third	Corridor	Egress lighting; Exit signs	----
30.01	Third	Lobby	Egress lighting; Exit signs	----
30.03	Third	Women's Restroom Existing	----	----
30.03	Third	Men's Restroom Existing	----	----
30.05	Third	ITC	Egress lighting; Telephone; Fire alarm; Life safety equipment	----
30.11	Third	Janitor	----	----
30.11	Third	Janitor Existing	----	----
00-00	Penthse	Mechanical Room	Egress lighting	Selected mechanical equipment
00-00	Penthse	Electrical Room	Egress lighting	Selected receptacles and/or hoods
00-00	Penthse	Refrigeration Machine Room	Egress lighting	Selected mechanical equipment

Emergency and Standby Power shall be fully available 30 seconds after a loss of power to the building and shall be within ±5% of the normal building supply voltage.

Any uninterruptible power supplies (UPS) required by equipment shall be the responsibility of the individual laboratory or researcher.

Electrical Interference with Magnets

Electrical equipment and feeders shall be located to not interfere with the magnetic laboratory equipment in NMR room 52 and NMR/X-Ray room 52B as recommended by the manufacturer. Where required by the manufacturer, shielding shall be installed.

Occupancy

The following schedules are tentative, but can be used to design and commissioning the building. The schedule is the normal hours of usage by occupants while the hours per day are the required mechanical system operation. Note that the number of people shown for each space are the mechanical design occupancies and not necessarily the code occupancies required for calculation of egress:

OCCUPANCY SCHEDULES AND DENSITIES					
ID	FLOOR	SPACE NAME	**SCHEDULE**	**HRS/DAY**	**NO. PEOPLE**
2.01	Ground	Physical Chemistry Teaching Lab	6am-8pm	24 hrs/day	12
2.02	Ground	Optics	6am-8pm	24 hrs/day	6
4.02	Ground	Electronics Shop	6am-8pm	24 hrs/day	3
4.04	Ground	Machine Shop	6am-8pm	24 hrs/day	3
11.01	Ground	NMR	6am-8pm	24 hrs/day	3
11.02	Ground	NMR/X-Ray	6am-8pm	24 hrs/day	9
12.01	Ground	Mass Spec	6am-8pm	24 hrs/day	4
12.02	Ground	Prep	12pm-12pm	24 hrs/day	3
13.01	Ground	Physical Chemistry	12pm-12pm	24 hrs/day	8
16.01	Ground	Physical Chemistry	6am-8pm	24 hrs/day	8
16.02	Ground	Physical Instrumentation	6am-8pm	24 hrs/day	3
23.01	Ground	Physical Chemistry Analytical	6am-8pm	24 hrs/day	3
24.01	Ground	Analytical Research	6am-8pm	24 hrs/day	6
25.03	Ground	Lecture Prep	12pm-12pm	24 hrs/day	1
31.01	Ground	Unassigned Lab	12pm-12pm	24 hrs/day	4
5.02	Ground	Chemical Storage	Intermittent	14 hrs/day	0
5.03	Ground	Chemical Storage	Intermittent	14 hrs/day	0
5.04	Ground	Chemical Storage	Intermittent	14 hrs/day	0
5.06	Ground	Chemical Storage	Intermittent	14 hrs/day	0
5.08	Ground	Chemical Storage	Intermittent	14 hrs/day	0
5.09	Ground	Chemical Stores	6am-8pm	14 hrs/day	2
00.00	Ground	Mechanical New	Intermittent	24 hrs/day	0
00.00	Ground	Mechanical Existing	Intermittent	24 hrs/day	0
00.00	Ground	Electrical Vault Existing	Intermittent	24 hrs/day	0
4.05	Ground	Gas	Intermittent	24 hrs/day	0
4.07	Ground	Hazardous Materials	Intermittent	24 hrs/day	0
30.01	Ground	Stair West	Intermittent	24 hrs/day	0
30.01	Ground	Stair East	Intermittent	24 hrs/day	0
4.01	Ground	Office (Reinholz)	6am-8pm	14 hrs/day	1
4.03	Ground	Load/Unload	6am-8pm	14 hrs/day	0
4.06	Ground	Instrument Storage	6am-8pm	14 hrs/day	0
5.01	Ground	Office (Larson)	6am-8pm	14 hrs/day	1
5.05	Ground	Department Archives	6am-8pm	14 hrs/day	1
11.03	Ground	Office (Busse)	6am-8pm	14 hrs/day	1
12.03	Ground	Office	6am-8pm	14 hrs/day	1
16.03	Ground	Grad Office	6am-8pm	14 hrs/day	4
24.02	Ground	Storage	6am-8pm	14 hrs/day	0
24.03	Ground	Office	6am-8pm	14 hrs/day	1
28.02	Ground	Student/Faculty	6am-8pm	14 hrs/day	1
28.08	Ground	Computer	6am-8pm	14 hrs/day	8
29.02	Ground	Office (Minton)	6am-8pm	14 hrs/day	1

OCCUPANCY SCHEDULES AND DENSITIES					
ID	FLOOR	SPACE NAME	SCHEDULE	HRS/DAY	NO. PEOPLE
29.03	Ground	Office (Spangler)	6am-8pm	14 hrs/day	1
29.09	Ground	Office (Singel)	6am-8pm	14 hrs/day	1
29.12	Ground	Office (Callis)	6am-8pm	14 hrs/day	1
29.22	Ground	Office (Sunner)	6am-8pm	14 hrs/day	1
29.23	Ground	Office	6am-8pm	14 hrs/day	1
29.24	Ground	Office (Grimsrud)	6am-8pm	14 hrs/day	1
30.01	Ground	Corridor	6am-8pm	14 hrs/day	0
30.01	Ground	Stair South	6am-8pm	14 hrs/day	0
30.03	Ground	Men's Toilet	6am-8pm	14 hrs/day	1
30.03	Ground	Women's Toilet	6am-8pm	14 hrs/day	1
30.03	Ground	Women's Restroom Existing	6am-8pm	14 hrs/day	2
30.03	Ground	Men's Restroom Existing	6am-8pm	14 hrs/day	4
30.04	Ground	Electrical	Intermittent	14 hrs/day	0
30.05	Ground	ITC	Intermittent	14 hrs/day	0
30.11	Ground	Janitor Existing	Intermittent	14 hrs/day	0
30.11	Ground	Janitor	Intermittent	14 hrs/day	0
30.12	Ground	Building Storage	Intermittent	14 hrs/day	0
1.01	First	Existing Freshman Lab	6am-8pm	24 hrs/day	20
1.02	First	Existing Freshman Lab	6am-8pm	24 hrs/day	20
1.03	First	Existing Freshman Lab	6am-8pm	24 hrs/day	20
1.04	First	Existing Freshman Lab	6am-8pm	24 hrs/day	20
1.05	First	General Chemistry Lab	6am-8pm	24 hrs/day	20
1.06	First	General Chemistry/Analysis	6am-8pm	24 hrs/day	20
3.01	First	Organic Teaching	6am-8pm	24 hrs/day	18
3.02	First	Organic Teaching	6am-8pm	24 hrs/day	18
3.03	First	Organic Instruments	6am-8pm	24 hrs/day	6
3.05	First	Freshman Organic Stockroom	6am-8pm	24 hrs/day	3
26.01	First	General Chemistry Support (Amend)	6am-8pm	24 hrs/day	5
25.01	First	Lecture Hall	6am-8pm	14 hrs/day	358
30.01	First	Vestibule NE	12pm-12pm	24 hrs/day	0
30.01	First	Vestibule South	12pm-12pm	24 hrs/day	0
30.01	First	Stairs West	12pm-12pm	24 hrs/day	0
30.01	First	Stairs East	12pm-12pm	24 hrs/day	0
3.04	First	Organic Computers	6am-8pm	14 hrs/day	2
3.08	First	Grad Student Bullpen	6am-8pm	14 hrs/day	6
25.04	First	Classroom	6am-8pm	14 hrs/day	45
25.06	First	Classroom	6am-8pm	14 hrs/day	50
25.07	First	Classroom	6am-8pm	14 hrs/day	22
27.01	First	Department Head	6am-8pm	14 hrs/day	1
27.04	First	Admin Office	6am-8pm	14 hrs/day	6
27.05	First	Work Room	6am-8pm	14 hrs/day	0
27.06	First	Copy	6am-8pm	14 hrs/day	0
27.08	First	Op Tech Office	6am-8pm	14 hrs/day	1
27.09	First	Accounting Office	6am-8pm	14 hrs/day	1
27.10	First	IT Tech Office	6am-8pm	14 hrs/day	1
27.12	First	Conference	6am-8pm	14 hrs/day	7
28.01	First	Vending	6am-8pm	14 hrs/day	0
28.03	First	Help Center	6am-8pm	14 hrs/day	20
29.01	First	Office (Johnson)	6am-8pm	14 hrs/day	1
29.25	First	Office (Amend)	6am-8pm	14 hrs/day	1
30.01	First	Corridors	6am-8pm	14 hrs/day	0
30.01	First	Lobbies	6am-8pm	14 hrs/day	0
30.03	First	Men's Toilet	6am-8pm	14 hrs/day	1
30.03	First	Women's Toilet	6am-8pm	14 hrs/day	1
30.03	First	Women's Restroom Existing	6am-8pm	14 hrs/day	3
30.03	First	Men's Restroom Existing	6am-8pm	14 hrs/day	4

OCCUPANCY SCHEDULES AND DENSITIES					
ID	FLOOR	SPACE NAME	SCHEDULE	HRS/DAY	NO. PEOPLE
30.04	First	Electrical	Intermittent	14 hrs/day	0
30.05	First	ITC	Intermittent	14 hrs/day	0
30.11	First	Janitor	Intermittent	14 hrs/day	0
30.11	First	Janitor Existing	Intermittent	14 hrs/day	0
10.02	Second	Biochemistry Prep	12pm-12pm	24 hrs/day	2
10.03	Second	Tissue Culture	6am-8pm	24 hrs/day	3
10.04	Second	Biochemistry Equipment	6am-8pm	24 hrs/day	0
10.06	Second	Proteomics	12pm-12pm	24 hrs/day	3
14.01	Second	Inorganic Research	6am-8pm	24 hrs/day	10
14.02	Second	Inorganic Instruments	6am-8pm	24 hrs/day	3
6.01	Second	Biochemistry Instruments	6am-8pm	24 hrs/day	8
6.02	Second	Ramen/Spec Lab	6am-8pm	24 hrs/day	3
6.03	Second	Biochemistry Research (Dooley)	6am-8pm	24 hrs/day	10
31.03	Second	Unassigned Lab	12pm-12pm	24 hrs/day	9
7.01	Second	Biochemistry Research	6am-8pm	24 hrs/day	8
7.02	Second	Microscopy	6am-8pm	24 hrs/day	3
7.03	Second	Spectroscopy	6am-8pm	24 hrs/day	2
8.01	Second	Biochemistry Research	12pm-12pm	24 hrs/day	8
8.02	Second	SPR	6am-8pm	24 hrs/day	3
9.01	Second	Biochemistry Research (Lawrence)	6am-8pm	24 hrs/day	8
10.05	Second	MMC	6am-8pm	24 hrs/day	4
30.01	Second	Stairs East	Intermittent	24 hrs/day	0
30.01	Second	Stairs West	Intermittent	24 hrs/day	0
6.04	Second	Cold Room	12pm-12pm	24 hrs/day	0
6.05	Second	Grad Students	6am-8pm	14 hrs/day	10
7.04	Second	Grad Students	6am-8pm	14 hrs/day	10
10.01	Second	Cold Room	12pm-12pm	24 hrs/day	0
25.02	Second	Classroom	6am-8pm	14 hrs/day	50
28.02	Second	Student/Faculty	6am-8pm	14 hrs/day	1
28.06	Second	Res Computers	6am-8pm	14 hrs/day	10
28.09	Second	Conference	6am-8pm	14 hrs/day	19
29.04	Second	Office (Dooley)	6am-8pm	14 hrs/day	1
29.06	Second	Office (Dratz)	6am-8pm	14 hrs/day	1
29.07	Second	Office (Teintze)	6am-8pm	14 hrs/day	1
29.08	Second	Office (Lawrence)	6am-8pm	14 hrs/day	1
29.10	Second	Office (Douglas)	6am-8pm	14 hrs/day	1
29.26	Second	Office (Jackson)	6am-8pm	14 hrs/day	1
29.27	Second	Office (Hapner)	6am-8pm	14 hrs/day	1
30.01	Second	Corridors	6am-8pm	14 hrs/day	0
30.01	Second	Lobby	6am-8pm	14 hrs/day	0
30.01	Second	Stairs North	6am-8pm	14 hrs/day	0
30.03	Second	Women's Toilet	6am-8pm	14 hrs/day	1
30.03	Second	Men's Toilet	6am-8pm	14 hrs/day	1
30.03	Second	Women's Restroom Existing	6am-8pm	14 hrs/day	3
30.03	Second	Men's Restroom Existing	6am-8pm	14 hrs/day	4
30.04	Second	Electrical	Intermittent	14 hrs/day	0
30.05	Second	ITC	Intermittent	14 hrs/day	0
30.11	Second	Janitor	Intermittent	14 hrs/day	0
30.11	Second	Janitor's Existing	Intermittent	14 hrs/day	0
31.05	Second	Storage	Intermittent	14 hrs/day	0
15.01	Third	Inorganic Research (Abbott)	6am-8pm	24 hrs/day	12
17.01	Third	Organic Research (Cloninger)	12pm-12pm	24 hrs/day	20
18.01	Third	Organic Research (McClure)	12pm-12pm	24 hrs/day	12
18.02	Third	Organic Research (McClure)	12pm-12pm	24 hrs/day	8
19.01	Third	Organic Research (Holmgren)	12pm-12pm	24 hrs/day	7
20.01	Third	Organic Research (Greico)	12pm-12pm	24 hrs/day	24

OCCUPANCY SCHEDULES AND DENSITIES					
ID	FLOOR	SPACE NAME	**SCHEDULE**	**HRS/DAY**	**NO. PEOPLE**
21.01	Third	Organic Research (Livinghouse)	12pm-12pm	24 hrs/day	20
30.01	Third	Stairs West	12pm-12pm	24 hrs/day	0
30.01	Third	Stairs East	12pm-12pm	24 hrs/day	0
30.01	Third	Stairs North	12pm-12pm	24 hrs/day	0
15.02	Third	Grad Office	6am-8pm	14 hrs/day	8
17.02	Third	Grad Office	6am-8pm	14 hrs/day	10
18.03	Third	Grad Office	6am-8pm	14 hrs/day	10
19.02	Third	Grad Office	6am-8pm	14 hrs/day	5
19.11	Third	Office (Livinghouse)	6am-8pm	14 hrs/day	1
20.02	Third	Grad Office	6am-8pm	14 hrs/day	8
21.02	Third	Grad Office	6am-8pm	14 hrs/day	10
27.02	Third	Faculty Seminar	6am-8pm	14 hrs/day	19
27.03	Third	Department Conference	6am-8pm	14 hrs/day	19
28.02	Third	Student/Faculty	6am-8pm	14 hrs/day	1
28.07	Third	Computer	6am-8pm	14 hrs/day	10
29.11	Third	Office (Abbott)	6am-8pm	14 hrs/day	1
29.13	Third	Office (Cloninger)	6am-8pm	14 hrs/day	1
29.14	Third	Office (McClure)	6am-8pm	14 hrs/day	1
29.16	Third	Office	6am-8pm	14 hrs/day	1
29.17	Third	Office (Holmgren)	6am-8pm	14 hrs/day	1
29.18	Third	Office (Department Head)	6am-8pm	14 hrs/day	1
29.19	Third	Office (Secretary)	6am-8pm	14 hrs/day	1
29.20	Third	Library	6am-8pm	14 hrs/day	10
30.01	Third	Corridor	6am-8pm	14 hrs/day	0
30.01	Third	Lobby	6am-8pm	14 hrs/day	0
30.03	Third	Women's Restroom Existing	6am-8pm	14 hrs/day	2
30.03	Third	Men's Restroom Existing	6am-8pm	14 hrs/day	4
30.05	Third	ITC	Intermittent	14 hrs/day	0
30.11	Third	Janitor	Intermittent	14 hrs/day	0
30.11	Third	Janitor Existing	Intermittent	14 hrs/day	0
00-00	Penthse	Mechanical Room	Intermittent	24 hrs/day	0
00-00	Penthse	Electrical Room	Intermittent	24 hrs/day	0
00-00	Penthse	Refrigeration Machine Room	Intermittent	24 hrs/day	0

Location Specific HVAC Design Criteria

Project Location: Bozeman, Montana
Latitude: 45°78'
Elevation: 4850 feet

Outside Design Conditions:

Summer Design Data: 91.0°F dry bulb; 61.0°F wet bulb.
Winter Design Data: -20°F dry bulb.

Space HVAC Design Criteria

The following schedule defines the design criteria for each individual space:

SPACE DESIGN CRITERIA						
ID	FLOOR	SPACE NAME	**TEMP (clg/htg)**	**HUMIDITY (hi/low)**	**100% OSA?**	**PRESSURE RELATION**
2.01	Ground	Physical Chemistry Teaching Lab	73°F/70°F±2°F	Uncontrolled	Yes	Negative
2.02	Ground	Optics	73°F/70°F±2°F	Uncontrolled	Yes	Negative
4.02	Ground	Electronics Shop	73°F/70°F±2°F	Uncontrolled	Yes	Negative
4.04	Ground	Machine Shop	73°F/70°F±2°F	Uncontrolled	Yes	Negative
11.01	Ground	NMR	73°F/70°F±2°F	70%/30%±5%	Yes	Negative
11.02	Ground	NMR/X-Ray	73°F/70°F±1°F	70%/30%±5%	Yes	Negative
12.01	Ground	Mass Spec	73°F/70°F±2°F	Uncontrolled	Yes	Negative
12.02	Ground	Prep	73°F/70°F±2°F	Uncontrolled	Yes	Negative
13.01	Ground	Physical Chemistry	73°F/70°F±2°F	Uncontrolled	Yes	Negative
16.01	Ground	Physical Chemistry	73°F/70°F±2°F	Uncontrolled	Yes	Negative
16.02	Ground	Physical Instrumentation	73°F/70°F±2°F	Uncontrolled	Yes	Negative
23.01	Ground	Physical Chemistry Analytical	73°F/70°F±2°F	Uncontrolled	Yes	Negative
24.01	Ground	Analytical Research	73°F/70°F±2°F	Uncontrolled	Yes	Negative
25.03	Ground	Lecture Prep	73°F/70°F±2°F	Uncontrolled	Yes	Negative
31.01	Ground	Unassigned Lab	73°F/70°F±2°F	Uncontrolled	Yes	Negative
5.02	Ground	Chemical Storage	73°F/70°F±2°F	Uncontrolled	Yes	Negative
5.03	Ground	Chemical Storage	73°F/70°F±2°F	Uncontrolled	Yes	Negative
5.04	Ground	Chemical Storage	73°F/70°F±2°F	Uncontrolled	Yes	Negative
5.06	Ground	Chemical Storage	73°F/70°F±2°F	Uncontrolled	Yes	Negative
5.08	Ground	Chemical Storage	73°F/70°F±2°F	Uncontrolled	Yes	Negative
5.09	Ground	Chemical Stores	73°F/70°F±2°F	Uncontrolled	Yes	Negative
00.00	Ground	Mechanical New	85°F/65°F±5°F	Uncontrolled	No	-----
00.00	Ground	Mechanical Existing	85°F/65°F±5°F	Uncontrolled	No	-----
00.00	Ground	Electrical Vault Existing	85°F/65°F±5°F	Uncontrolled	No	-----
4.05	Ground	Gas	85°F/70°F±2°F	Uncontrolled	No	Negative
4.07	Ground	Hazardous Materials	85°F/70°F±2°F	Uncontrolled	No	Negative
30.01	Ground	Stair West	85°F/65°F±5°F	Uncontrolled	No	-----
30.01	Ground	Stair East	85°F/65°F±5°F	Uncontrolled	No	-----
4.01	Ground	Office (Reinholz)	72°F/70°F±2°F	Uncontrolled	No	-----
4.03	Ground	Load/Unload	85°F/70°F±5°F	Uncontrolled	No	-----
4.06	Ground	Instrument Storage	73°F/70°F±2°F	Uncontrolled	No	Positive
5.01	Ground	Office (Larson)	72°F/70°F±2°F	Uncontrolled	No	-----
5.05	Ground	Department Archives	72°F/70°F±2°F	Uncontrolled	No	-----
11.03	Ground	Office (Busse)	72°F/70°F±2°F	Uncontrolled	No	-----
12.03	Ground	Office	72°F/70°F±2°F	Uncontrolled	No	-----
16.03	Ground	Grad Office	72°F/70°F±2°F	Uncontrolled	No	-----
24.02	Ground	Storage	72°F/70°F±5°F	Uncontrolled	No	-----
24.03	Ground	Office	72°F/70°F±2°F	Uncontrolled	No	-----
28.02	Ground	Student/Faculty	72°F/70°F±2°F	Uncontrolled	No	-----
28.08	Ground	Computer	72°F/70°F±2°F	Uncontrolled	No	-----
29.02	Ground	Office (Minton)	72°F/70°F±2°F	Uncontrolled	No	-----
29.03	Ground	Office (Spangler)	72°F/70°F±2°F	Uncontrolled	No	-----
29.09	Ground	Office (Singel)	72°F/70°F±2°F	Uncontrolled	No	-----
29.12	Ground	Office (Callis)	72°F/70°F±2°F	Uncontrolled	No	-----
29.22	Ground	Office (Sunner)	72°F/70°F±2°F	Uncontrolled	No	-----
29.23	Ground	Office	72°F/70°F±2°F	Uncontrolled	No	-----
29.24	Ground	Office (Grimsrud)	72°F/70°F±2°F	Uncontrolled	No	-----
30.01	Ground	Corridor	72°F/70°F±2°F	Uncontrolled	No	-----
30.01	Ground	Stair South	85°F/65°F±5°F	Uncontrolled	No	-----
30.03	Ground	Men's Toilet	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	Ground	Women's Toilet	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	Ground	Women's Restroom Existing	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	Ground	Men's Restroom Existing	73°F/68°F±5°F	Uncontrolled	No	-----

SPACE DESIGN CRITERIA						
ID	FLOOR	SPACE NAME	**TEMP (clg/htg)**	**HUMIDITY (hi/low)**	**100% OSA?**	**PRESSURE RELATION**
30.04	Ground	Electrical	85°F/65°F±5°F	Uncontrolled	No	-----
30.05	Ground	ITC	73°F/68°F±5°F	Uncontrolled	No	-----
30.11	Ground	Janitor Existing	85°F/65°F±5°F	Uncontrolled	No	-----
30.11	Ground	Janitor	85°F/65°F±5°F	Uncontrolled	No	-----
30.12	Ground	Building Storage	85°F/65°F±5°F	Uncontrolled	No	-----
1.01	First	Existing Freshman Lab	73°F/70°F±2°F	Uncontrolled	Yes	Negative
1.02	First	Existing Freshman Lab	73°F/70°F±2°F	Uncontrolled	Yes	Negative
1.03	First	Existing Freshman Lab	73°F/70°F±2°F	Uncontrolled	Yes	Negative
1.04	First	Existing Freshman Lab	73°F/70°F±2°F	Uncontrolled	Yes	Negative
1.05	First	General Chemistry Lab	73°F/70°F±2°F	Uncontrolled	Yes	Negative
1.06	First	General Chemistry/Analysis	73°F/70°F±2°F	Uncontrolled	Yes	Negative
3.01	First	Organic Teaching	73°F/70°F±2°F	Uncontrolled	Yes	Negative
3.02	First	Organic Teaching	73°F/70°F±2°F	Uncontrolled	Yes	Negative
3.03	First	Organic Instruments	73°F/70°F±2°F	Uncontrolled	Yes	Negative
3.05	First	Freshman Organic Stockroom	73°F/70°F±2°F	Uncontrolled	Yes	Negative
26.01	First	General Chemistry Support (Amend)	73°F/70°F±2°F	Uncontrolled	Yes	Negative
25.01	First	Lecture Hall	72°F/70°F±2°F	Uncontrolled	No	-----
30.01	First	Vestibule NE	85°F/65°F±5°F	Uncontrolled	No	-----
30.01	First	Vestibule South	85°F/65°F±5°F	Uncontrolled	No	-----
30.01	First	Stairs West	85°F/65°F±5°F	Uncontrolled	No	-----
30.01	First	Stairs East	85°F/65°F±5°F	Uncontrolled	No	-----
3.04	First	Organic Computers	72°F/70°F±2°F	Uncontrolled	No	Positive
3.08	First	Grad Student Bullpen	72°F/70°F±2°F	Uncontrolled	No	-----
25.04	First	Classroom	72°F/70°F±2°F	Uncontrolled	No	-----
25.06	First	Classroom	72°F/70°F±2°F	Uncontrolled	No	-----
25.07	First	Classroom	72°F/70°F±2°F	Uncontrolled	No	-----
27.01	First	Department Head	72°F/70°F±2°F	Uncontrolled	No	-----
27.04	First	Admin Office	72°F/70°F±2°F	Uncontrolled	No	-----
27.05	First	Work Room	72°F/70°F±5°F	Uncontrolled	No	-----
27.06	First	Copy	72°F/70°F±5°F	Uncontrolled	No	-----
27.08	First	Op Tech Office	72°F/70°F±2°F	Uncontrolled	No	-----
27.09	First	Accounting Office	72°F/70°F±2°F	Uncontrolled	No	-----
27.10	First	IT Tech Office	72°F/70°F±2°F	Uncontrolled	No	-----
27.12	First	Conference	72°F/70°F±2°F	Uncontrolled	No	-----
28.01	First	Vending	72°F/70°F±5°F	Uncontrolled	No	-----
28.03	First	Help Center	72°F/70°F±2°F	Uncontrolled	No	-----
29.01	First	Office (Johnson)	72°F/70°F±2°F	Uncontrolled	No	-----
29.25	First	Office (Amend)	72°F/70°F±2°F	Uncontrolled	No	-----
30.01	First	Corridors	72°F/70°F±5°F	Uncontrolled	No	-----
30.01	First	Lobbies	72°F/70°F±5°F	Uncontrolled	No	-----
30.03	First	Men's Toilet	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	First	Women's Toilet	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	First	Women's Restroom Existing	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	First	Men's Restroom Existing	73°F/68°F±5°F	Uncontrolled	No	-----
30.04	First	Electrical	85°F/65°F±5°F	Uncontrolled	No	-----
30.05	First	ITC	73°F/68°F±5°F	Uncontrolled	No	-----
30.11	First	Janitor	85°F/65°F±5°F	Uncontrolled	No	-----
30.11	First	Janitor Existing	85°F/65°F±5°F	Uncontrolled	No	-----
6.01	Second	Biochemistry Instruments	73°F/70°F±2°F	<70%±5%	Yes	Negative
6.02	Second	Ramen/Spec Lab	73°F/70°F±2°F	Uncontrolled	Yes	Negative
6.03	Second	Biochemistry Research (Dooley)	73°F/70°F±2°F	Uncontrolled	Yes	Negative

SPACE DESIGN CRITERIA						
ID	FLOOR	SPACE NAME	**TEMP (clg/htg)**	**HUMIDITY (hi/low)**	**100% OSA?**	**PRESSURE RELATION**
7.01	Second	Biochemistry Research	73°F/70°F±2°F	Uncontrolled	Yes	Negative
7.02	Second	Microscopy	73°F/70°F±2°F	Uncontrolled	Yes	Negative
7.03	Second	Spectroscopy	73°F/70°F±2°F	Uncontrolled	Yes	Negative
8.01	Second	Biochemistry Research	73°F/70°F±2°F	Uncontrolled	Yes	Negative
8.02	Second	SPR	73°F/70°F±2°F	Uncontrolled	Yes	Negative
9.01	Second	Biochemistry Research (Lawrence)	73°F/70°F±2°F	Uncontrolled	Yes	Negative
10.02	Second	Biochemistry Prep	73°F/70°F±2°F	Uncontrolled	Yes	Negative
10.03	Second	Tissue Culture	73°F/70°F±2°F	Uncontrolled	Yes	Positive
10.04	Second	Biochemistry Equipment	73°F/70°F±2°F	Uncontrolled	Yes	Negative
10.05	Second	MMC	73°F/70°F±2°F	Uncontrolled	Yes	Negative
10.06	Second	Proteomics	73°F/70°F±2°F	Uncontrolled	Yes	Negative
14.01	Second	Inorganic Research	73°F/70°F±2°F	Uncontrolled	Yes	Negative
14.02	Second	Inorganic Instruments	73°F/70°F±2°F	Uncontrolled	Yes	Negative
31.03	Second	Unassigned Lab	73°F/70°F±2°F	Uncontrolled	Yes	Negative
30.01	Second	Stairs East	85°F/65°F±5°F	Uncontrolled	No	-----
30.01	Second	Stairs West	85°F/65°F±5°F	Uncontrolled	No	-----
6.04	Second	Cold Room	39.2°F	Uncontrolled	No	----
6.05	Second	Grad Students	72°F/70°F±2°F	Uncontrolled	No	-----
7.04	Second	Grad Students	72°F/70°F±2°F	Uncontrolled	No	-----
10.01	Second	Cold Room	39.2°F	Uncontrolled	No	-----
25.02	Second	Classroom	72°F/70°F±2°F	Uncontrolled	No	-----
28.02	Second	Student/Faculty	72°F/70°F±2°F	Uncontrolled	No	-----
28.06	Second	Res Computers	72°F/70°F±2°F	Uncontrolled	No	-----
28.09	Second	Conference	72°F/70°F±2°F	Uncontrolled	No	-----
29.04	Second	Office (Dooley)	72°F/70°F±2°F	Uncontrolled	No	-----
29.06	Second	Office (Dratz)	72°F/70°F±2°F	Uncontrolled	No	-----
29.07	Second	Office (Teintze)	72°F/70°F±2°F	Uncontrolled	No	-----
29.08	Second	Office (Lawrence)	72°F/70°F±2°F	Uncontrolled	No	-----
29.10	Second	Office (Douglas)	72°F/70°F±2°F	Uncontrolled	No	-----
29.26	Second	Office (Jackson)	72°F/70°F±2°F	Uncontrolled	No	-----
29.27	Second	Office (Hapner)	72°F/70°F±2°F	Uncontrolled	No	-----
30.01	Second	Corridors	72°F/70°F±5°F	Uncontrolled	No	-----
30.01	Second	Lobby	72°F/70°F±5°F	Uncontrolled	No	-----
30.01	Second	Stairs North	85°F/65°F±5°F	Uncontrolled	No	-----
30.03	Second	Women's Toilet	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	Second	Men's Toilet	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	Second	Women's Restroom Existing	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	Second	Men's Restroom Existing	73°F/68°F±5°F	Uncontrolled	No	-----
30.04	Second	Electrical	85°F/65°F±5°F	Uncontrolled	No	-----
30.05	Second	ITC	73°F/68°F±5°F	Uncontrolled	No	-----
30.11	Second	Janitor	85°F/65°F±5°F	Uncontrolled	No	-----
30.11	Second	Janitor's Existing	85°F/65°F±5°F	Uncontrolled	No	-----
31.05	Second	Storage	85°F/65°F±5°F	Uncontrolled	No	-----
15.01	Third	Inorganic Research (Abbott)	73°F/70°F±2°F	Uncontrolled	Yes	Negative
17.01	Third	Organic Research (Cloninger)	73°F/70°F±2°F	Uncontrolled	Yes	Negative
18.01	Third	Organic Research (McClure)	73°F/70°F±2°F	Uncontrolled	Yes	Negative
18.02	Third	Organic Research (McClure)	73°F/70°F±2°F	Uncontrolled	Yes	Negative
19.01	Third	Organic Research (Holmgren)	73°F/70°F±2°F	Uncontrolled	Yes	Negative
20.01	Third	Organic Research (Greico)	73°F/70°F±2°F	Uncontrolled	Yes	Negative
21.01	Third	Organic Research (Livinghouse)	73°F/70°F±2°F	Uncontrolled	Yes	Negative
30.01	Third	Stairs West	85°F/65°F±5°F	Uncontrolled	No	-----
30.01	Third	Stairs East	85°F/65°F±5°F	Uncontrolled	No	-----

SPACE DESIGN CRITERIA						
ID	FLOOR	SPACE NAME	**TEMP (clg/htg)**	**HUMIDITY (hi/low)**	**100% OSA?**	**PRESSURE RELATION**
30.01	Third	Stairs North	85°F/65°F±5°F	Uncontrolled	No	-----
15.02	Third	Grad Office	72°F/70°F±2°F	Uncontrolled	No	-----
17.02	Third	Grad Office	72°F/70°F±2°F	Uncontrolled	No	-----
18.03	Third	Grad Office	72°F/70°F±2°F	Uncontrolled	No	-----
19.02	Third	Grad Office	72°F/70°F±2°F	Uncontrolled	No	-----
19.11	Third	Office (Livinghouse)	72°F/70°F±2°F	Uncontrolled	No	-----
20.02	Third	Grad Office	72°F/70°F±2°F	Uncontrolled	No	-----
21.02	Third	Grad Office	72°F/70°F±2°F	Uncontrolled	No	-----
27.02	Third	Faculty Seminar	72°F/70°F±2°F	Uncontrolled	No	-----
27.03	Third	Department Conference	72°F/70°F±2°F	Uncontrolled	No	-----
28.02	Third	Student/Faculty	72°F/70°F±2°F	Uncontrolled	No	-----
28.07	Third	Computer	72°F/70°F±2°F	Uncontrolled	No	-----
29.11	Third	Office (Abbott)	72°F/70°F±2°F	Uncontrolled	No	-----
29.13	Third	Office (Cloninger)	72°F/70°F±2°F	Uncontrolled	No	-----
29.14	Third	Office (McClure)	72°F/70°F±2°F	Uncontrolled	No	-----
29.16	Third	Office	72°F/70°F±2°F	Uncontrolled	No	-----
29.17	Third	Office (Holmgren)	72°F/70°F±2°F	Uncontrolled	No	-----
29.18	Third	Office (Department Head)	72°F/70°F±2°F	Uncontrolled	No	-----
29.19	Third	Office (Secretary)	72°F/70°F±2°F	Uncontrolled	No	-----
29.20	Third	Library	72°F/70°F±2°F	Uncontrolled	No	-----
30.01	Third	Corridor	72°F/70°F±5°F	Uncontrolled	No	-----
30.01	Third	Lobby	72°F/70°F±5°F	Uncontrolled	No	-----
30.03	Third	Women's Restroom Existing	73°F/68°F±5°F	Uncontrolled	No	-----
30.03	Third	Men's Restroom Existing	73°F/68°F±5°F	Uncontrolled	No	-----
30.05	Third	ITC	73°F/68°F±5°F	Uncontrolled	No	-----
30.11	Third	Janitor	85°F/65°F±5°F	Uncontrolled	No	-----
30.11	Third	Janitor Existing	85°F/65°F±5°F	Uncontrolled	No	-----
00-00	Penthse	Mechanical Room	85°F/65°F±5°F	Uncontrolled	No	-----
00-00	Penthse	Electrical Room	85°F/65°F±5°F	Uncontrolled	No	-----
00-00	Penthse	Refrigeration Machine Room	85°F/65°F±5°F	Uncontrolled	No	-----

System Filtration Requirements

All conditioned spaces shall have a minimum air filtration of 25-30% efficiency and 90-92% average arrestance based on ASHRAE Test Standard 52.1-92. In addition, the following spaces shall have final air filtration of 80-85% efficiency and 98% average arrestance based on ASHRAE Test Standard 52.1-92:

SPACES REQUIRING FINAL FILTRATION		
ID	FLOOR	SPACE NAME
2.01	Ground	Physical Chemistry Teaching Lab
2.02	Ground	Optics
4.02	Ground	Electronics Shop
4.04	Ground	Machine Shop
11.01	Ground	NMR
11.02	Ground	NMR/X-Ray
12.01	Ground	Mass Spec
12.02	Ground	Prep
13.01	Ground	Physical Chemistry

SPACES REQUIRING FINAL FILTRATION		
ID	FLOOR	SPACE NAME
16.01	Ground	Physical Chemistry
16.02	Ground	Physical Instrumentation
23.01	Ground	Physical Chemistry Analytical
24.01	Ground	Analytical Research
25.03	Ground	Lecture Prep
31.01	Ground	Unassigned Lab
1.01	First	Existing Freshman Lab
1.02	First	Existing Freshman Lab
1.03	First	Existing Freshman Lab
1.04	First	Existing Freshman Lab
1.05	First	General Chemistry Lab
1.06	First	General Chemistry/Analysis
3.01	First	Organic Teaching
3.02	First	Organic Teaching
3.03	First	Organic Instruments
3.05	First	Freshman Organic Stockroom
26.01	First	General Chemistry Support (Amend)
6.01	Second	Biochemistry Instruments
6.02	Second	Ramen/Spec Lab
6.03	Second	Biochemistry Research (Dooley)
7.01	Second	Biochemistry Research
7.02	Second	Microscopy
7.03	Second	Spectroscopy
8.01	Second	Biochemistry Research
8.02	Second	SPR
9.01	Second	Biochemistry Research (Lawrence)
10.02	Second	Biochemistry Prep
10.03	Second	Tissue Culture
10.04	Second	Biochemistry Equipment
10.05	Second	MMC
10.06	Second	Proteomics
14.01	Second	Inorganic Research
14.02	Second	Inorganic Instruments
31.03	Second	Unassigned Lab
15.01	Third	Inorganic Research (Abbott)
15.03	Third	Inorganic Research
17.01	Third	Organic Research (Cloninger)
18.01	Third	Organic Research (McClure)
18.02	Third	Organic Research (McClure)
19.01	Third	Organic Research (Holmgren)
20.01	Third	Organic Research (Greico)
21.01	Third	Organic Research (Livinghouse)

Space Lighting Design Criteria

Lighting shall be provided according to the following table. This value is the average maintained foot-candle level within the space at the workplane. Average maintained foot-candle level to minimum maintained foot-candle level shall be a maximum of 1.5 to 1:

SPACE LIGHTING DESIGN CRITERIA			
ID	FLOOR	SPACE NAME	DESIGN LIGHTING LEVEL
2.01	Ground	Physical Chemistry Teaching Lab	70 fc ± 5 fc
2.02	Ground	Optics	70 fc ± 5 fc
4.02	Ground	Electronics Shop	70 fc ± 5 fc
4.04	Ground	Machine Shop	50 fc ± 5 fc
11.01	Ground	NMR	70 fc ± 5 fc
11.02	Ground	NMR/X-Ray	70 fc ± 5 fc
12.01	Ground	Mass Spec	70 fc ± 5 fc
12.02	Ground	Prep	70 fc ± 5 fc
13.01	Ground	Physical Chemistry	70 fc ± 5 fc
16.01	Ground	Physical Chemistry	70 fc ± 5 fc
16.02	Ground	Physical Instrumentation	70 fc ± 5 fc
23.01	Ground	Physical Chemistry Analytical	70 fc ± 5 fc
24.01	Ground	Analytical Research	70 fc ± 5 fc
25.03	Ground	Lecture Prep	70 fc ± 5 fc
31.01	Ground	Unassigned Lab	70 fc ± 5 fc
5.02	Ground	Chemical Storage	30 fc ± 5 fc
5.03	Ground	Chemical Storage	30 fc ± 5 fc
5.04	Ground	Chemical Storage	30 fc ± 5 fc
5.06	Ground	Chemical Storage	Existing
5.08	Ground	Chemical Storage	Existing
5.09	Ground	Chemical Stores	30 fc ± 5 fc
00.00	Ground	Mechanical New	30 fc ± 5 fc
00.00	Ground	Mechanical Existing	30 fc ± 5 fc
00.00	Ground	Electrical Vault Existing	30 fc ± 5 fc
4.05	Ground	Gas	Existing
4.07	Ground	Hazardous Materials	Existing
30.01	Ground	Stair West	20 fc ± 5 fc
30.01	Ground	Stair East	20 fc ± 5 fc
4.01	Ground	Office (Reinholz)	70 fc ± 5 fc
4.03	Ground	Load/Unload	20 fc ± 5 fc
4.06	Ground	Instrument Storage	30 fc ± 5 fc
5.01	Ground	Office (Larson)	70 fc ± 5 fc
5.05	Ground	Department Archives	70 fc ± 5 fc
11.03	Ground	Office (Busse)	70 fc ± 5 fc
12.03	Ground	Office	70 fc ± 5 fc
16.03	Ground	Grad Office	70 fc ± 5 fc
24.02	Ground	Storage	30 fc ± 5 fc
24.03	Ground	Office	70 fc ± 5 fc
28.02	Ground	Student/Faculty	70 fc ± 5 fc
28.08	Ground	Computer	70 fc ± 5 fc
29.02	Ground	Office (Minton)	70 fc ± 5 fc
29.03	Ground	Office (Spangler)	70 fc ± 5 fc
29.09	Ground	Office (Singel)	70 fc ± 5 fc
29.12	Ground	Office (Callis)	70 fc ± 5 fc
29.22	Ground	Office (Sunner)	70 fc ± 5 fc
29.23	Ground	Office	70 fc ± 5 fc
29.24	Ground	Office (Grimsrud)	70 fc ± 5 fc
30.01	Ground	Corridor	20 fc ± 5 fc
30.01	Ground	Stair South	20 fc ± 5 fc
30.03	Ground	Men's Toilet	30 fc ± 5 fc
30.03	Ground	Women's Toilet	30 fc ± 5 fc
30.03	Ground	Women's Restroom Existing	30 fc ± 5 fc
30.03	Ground	Men's Restroom Existing	30 fc ± 5 fc
30.04	Ground	Electrical	30 fc ± 5 fc

SPACE LIGHTING DESIGN CRITERIA			
ID	FLOOR	SPACE NAME	DESIGN LIGHTING LEVEL
30.05	Ground	ITC	30 fc ± 5 fc
30.11	Ground	Janitor Existing	30 fc ± 5 fc
30.11	Ground	Janitor	30 fc ± 5 fc
30.12	Ground	Building Storage	30 fc ± 5 fc
1.01	First	Existing Freshman Lab	Existing
1.02	First	Existing Freshman Lab	Existing
1.03	First	Existing Freshman Lab	Existing
1.04	First	Existing Freshman Lab	Existing
1.05	First	General Chemistry Lab	70 fc ± 5 fc
1.06	First	General Chemistry/Analysis	70 fc ± 5 fc
3.01	First	Organic Teaching	70 fc ± 5 fc
3.02	First	Organic Teaching	70 fc ± 5 fc
3.03	First	Organic Instruments	70 fc ± 5 fc
3.05	First	Freshman Organic Stockroom	50 fc ± 5 fc
26.01	First	General Chemistry Support (Amend)	70 fc ± 5 fc
25.01	First	Lecture Hall	50 fc ± 5 fc
30.01	First	Vestibule NE	20 fc ± 5 fc
30.01	First	Vestibule South	20 fc ± 5 fc
30.01	First	Stairs West	20 fc ± 5 fc
30.01	First	Stairs East	20 fc ± 5 fc
3.04	First	Organic Computers	70 fc ± 5 fc
3.08	First	Grad Student Bullpen	70 fc ± 5 fc
25.04	First	Classroom	70 fc ± 5 fc
25.06	First	Classroom	70 fc ± 5 fc
25.07	First	Classroom	70 fc ± 5 fc
27.01	First	Department Head	70 fc ± 5 fc
27.04	First	Admin Office	70 fc ± 5 fc
27.05	First	Work Room	70 fc ± 5 fc
27.06	First	Copy	70 fc ± 5 fc
27.08	First	Op Tech Office	70 fc ± 5 fc
27.09	First	Accounting Office	70 fc ± 5 fc
27.10	First	IT Tech Office	70 fc ± 5 fc
27.12	First	Conference	70 fc ± 5 fc
28.01	First	Vending	30 fc ± 5 fc
28.03	First	Help Center	70 fc ± 5 fc
29.01	First	Office (Johnson)	70 fc ± 5 fc
29.25	First	Office (Amend)	70 fc ± 5 fc
30.01	First	Corridors	20 fc ± 5 fc
30.01	First	Lobbies	20 fc ± 5 fc
30.03	First	Men's Toilet	30 fc ± 5 fc
30.03	First	Women's Toilet	30 fc ± 5 fc
30.03	First	Women's Restroom Existing	30 fc ± 5 fc
30.03	First	Men's Restroom Existing	30 fc ± 5 fc
30.04	First	Electrical	30 fc ± 5 fc
30.05	First	ITC	30 fc ± 5 fc
30.11	First	Janitor	30 fc ± 5 fc
30.11	First	Janitor Existing	30 fc ± 5 fc
10.02	Second	Biochemistry Prep	70 fc ± 5 fc
10.03	Second	Tissue Culture	70 fc ± 5 fc
10.04	Second	Biochemistry Equipment	50 fc ± 5 fc
10.06	Second	Proteomics	70 fc ± 5 fc
14.01	Second	Inorganic Research	70 fc ± 5 fc

SPACE LIGHTING DESIGN CRITERIA			
ID	FLOOR	SPACE NAME	DESIGN LIGHTING LEVEL
14.02	Second	Inorganic Instruments	70 fc ± 5 fc
6.01	Second	Biochemistry Instruments	70 fc ± 5 fc
6.02	Second	Ramen/Spec Lab	70 fc ± 5 fc
6.03	Second	Biochemistry Research (Dooley)	70 fc ± 5 fc
31.03	Second	Unassigned Lab	70 fc ± 5 fc
7.01	Second	Biochemistry Research	70 fc ± 5 fc
7.02	Second	Microscopy	70 fc ± 5 fc
7.03	Second	Spectroscopy	70 fc ± 5 fc
8.01	Second	Biochemistry Research	70 fc ± 5 fc
8.02	Second	SPR	70 fc ± 5 fc
9.01	Second	Biochemistry Research (Lawrence)	70 fc ± 5 fc
10.05	Second	MMC	70 fc ± 5 fc
30.01	Second	Stairs East	20 fc ± 5 fc
30.01	Second	Stairs West	20 fc ± 5 fc
6.04	Second	Cold Room	50 fc ± 5 fc
6.05	Second	Grad Students	70 fc ± 5 fc
7.04	Second	Grad Students	70 fc ± 5 fc
10.01	Second	Cold Room	50 fc ± 5 fc
25.02	Second	Classroom	70 fc ± 5 fc
28.02	Second	Student/Faculty	70 fc ± 5 fc
28.06	Second	Res Computers	70 fc ± 5 fc
28.09	Second	Conference	70 fc ± 5 fc
29.04	Second	Office (Dooley)	70 fc ± 5 fc
29.06	Second	Office (Dratz)	70 fc ± 5 fc
29.07	Second	Office (Teintze)	70 fc ± 5 fc
29.08	Second	Office (Lawrence)	70 fc ± 5 fc
29.10	Second	Office (Douglas)	70 fc ± 5 fc
29.26	Second	Office (Jackson)	70 fc ± 5 fc
29.27	Second	Office (Hapner)	70 fc ± 5 fc
30.01	Second	Corridors	20 fc ± 5 fc
30.01	Second	Lobby	20 fc ± 5 fc
30.01	Second	Stairs North	20 fc ± 5 fc
30.03	Second	Women's Toilet	30 fc ± 5 fc
30.03	Second	Men's Toilet	30 fc ± 5 fc
30.03	Second	Women's Restroom Existing	30 fc ± 5 fc
30.03	Second	Men's Restroom Existing	30 fc ± 5 fc
30.04	Second	Electrical	30 fc ± 5 fc
30.05	Second	ITC	30 fc ± 5 fc
30.11	Second	Janitor	30 fc ± 5 fc
30.11	Second	Janitor's Existing	30 fc ± 5 fc
31.05	Second	Storage	30 fc ± 5 fc
15.01	Third	Inorganic Research (Abbott)	70 fc ± 5 fc
17.01	Third	Organic Research (Cloninger)	70 fc ± 5 fc
18.01	Third	Organic Research (McClure)	70 fc ± 5 fc
18.02	Third	Organic Research (McClure)	70 fc ± 5 fc
19.01	Third	Organic Research (Holmgren)	70 fc ± 5 fc
20.01	Third	Organic Research (Greico)	70 fc ± 5 fc
21.01	Third	Organic Research (Livinghouse)	70 fc ± 5 fc
30.01	Third	Stairs West	20 fc ± 5 fc
30.01	Third	Stairs East	20 fc ± 5 fc
30.01	Third	Stairs North	20 fc ± 5 fc

SPACE LIGHTING DESIGN CRITERIA			
ID	FLOOR	SPACE NAME	DESIGN LIGHTING LEVEL
15.02	Third	Grad Office	70 fc ± 5 fc
17.02	Third	Grad Office	70 fc ± 5 fc
18.03	Third	Grad Office	70 fc ± 5 fc
19.02	Third	Grad Office	70 fc ± 5 fc
19.11	Third	Office (Livinghouse)	70 fc ± 5 fc
20.02	Third	Grad Office	70 fc ± 5 fc
21.02	Third	Grad Office	70 fc ± 5 fc
27.02	Third	Faculty Seminar	70 fc ± 5 fc
27.03	Third	Department Conference	70 fc ± 5 fc
28.02	Third	Student/Faculty	70 fc ± 5 fc
28.07	Third	Computer	70 fc ± 5 fc
29.11	Third	Office (Abbott)	70 fc ± 5 fc
29.13	Third	Office (Cloninger)	70 fc ± 5 fc
29.14	Third	Office (McClure)	70 fc ± 5 fc
29.16	Third	Office	70 fc ± 5 fc
29.17	Third	Office (Holmgren)	70 fc ± 5 fc
29.18	Third	Office (Department Head)	70 fc ± 5 fc
29.19	Third	Office (Secretary)	70 fc ± 5 fc
29.20	Third	Library	70 fc ± 5 fc
30.01	Third	Corridor	20 fc ± 5 fc
30.01	Third	Lobby	20 fc ± 5 fc
30.03	Third	Women's Restroom Existing	30 fc ± 5 fc
30.03	Third	Men's Restroom Existing	30 fc ± 5 fc
30.05	Third	ITC	30 fc ± 5 fc
30.11	Third	Janitor	30 fc ± 5 fc
30.11	Third	Janitor Existing	30 fc ± 5 fc
00-00	Penthse	Mechanical Room	30 fc ± 5 fc
00-00	Penthse	Electrical Room	30 fc ± 5 fc
00-00	Penthse	Refrigeration Machine Room	30 fc ± 5 fc

Commissioning

This building will be commissioned by an independent third party commissioning services provider (commissioning authority or CxA) selected by MSU and the A/E Division in consultation with the design team. The CxA will be contracted directly to the Montana A/E Division. Commissioning (Cx) will be conducted in accordance with ASHRAE Guideline 1-1996 and will be integrated into the entire project, from planning through design, construction and the first year of operation.

The design team will be required to develop a Basis of Design that incorporates the requirements of this OPR and includes an Engineer's Narrative describing, in detail, the operation of the building mechanical and electrical systems. The Basis of Design and Engineer's Narrative will be reviewed by the CxA and the design team shall incorporate those comments into the final documents. The CxA will review the design for consistency with the requirements of this OPR at the approximately the 50% design stage and the 95% design stage and those comments will be incorporated into the design as well. In addition to the review by the CxA, constructability and code compliance reviews may be conducted at the owner's option.

The CxA will develop a section of the specifications (nominally Division 17) describing the Cx process and will also provide parts of Divisions 1, 15 and 16 that the design team shall incorporate into the bid documents.

During construction, the CxA will be copied with all approved submittals and will inspect and test installed equipment. The design team should note that the Cx process does not diminish their contractual obligations during construction, or relieve the design team of any design responsibility at any stage in the project. The role of the CxA is to assure that the building systems operate in accordance with this OPR. If systems do not so-operate, the design team will be required to either show that the systems were not installed as designed, or redesign the systems as required for correct operation. It is expected that the design team will answer all questions posed by the CxA as if they were questions from the owner and that the design team will conduct their normal inspections and their normal punch list procedures as they would for a project without commissioning.

Commissioning Team

This commissioning includes the combined efforts of the following groups:

- MSU Bozeman Office of Facilities Services—Cecelia Vaniman, University Planner
  994-5449
- The Montana Architectural and Engineering Division:
  Russ Katherman, PE, Project Manager---444-3332, and
  Ron Wilkinson, PE, Commissioning Coordinator---444-3331
- L'Heureux, Page, Werner, PC--Design Consultants:
  Tim Peterson, AIA, Project Manager---771-0770
  Dane Willis, PE, Lead Mechanical Engineer---771-0770
  Henry Lindgren, PE, Lead Electrical Engineer---771-0770
- Facilities Improvement Corporation (FICO)—CxA—John Phillips, PE
  452-0009
- The general contractor and mechanical, electrical and controls sub-contractors (the Contractor).

Revisions:

Original	May 30, 2002	E-mailed to MSU, LPW for comment
1st Revision	August 28, 2002	E-mailed to State A/E for comment and review
2nd Revision	October 25, 2002	To be included in the Design Development Submittal
3rd Revision		

End of Gaines Hall OPR

Appendix V - Basis of Design Document

Overview

The Basis of Design (BOD) is the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the Owner's Project Requirements (OPR). The format below merges the salient parts of the OPR and BOD.

Under each area or building system is an outline of pertinent questions and data needed to establish the basis of design. Sequences of operation for all outlined dynamic systems and components should be clearly documented. Attaching equipment manufacturers' sequences may be acceptable, but will generally require additional narrative.

To the right of the heading for each section, the party responsible for providing the documentation is indicated, as is the phase of the design construction process during which documentation should be established.

The information following may be used as a template for the process of documenting the BOD. Representative building systems and issues are shown; the list is not intended be all inclusive but rather a starting point. Systems and issues should be added or deleted as necessary to meet the needs of the project.

Project: _____

Approved:

_____	_____	_____
Name	Owner's Representative	Date
_____	_____	_____
Name	Commissioning Authority	Date

The following abbreviations are used:

Item	Abbreviation	Refers To
Responsible Party	Arch	Architect
	Mech Engr	Mechanical Engineer
	Elec Engr	Electrical Engineer
	Ltg Des	Lighting Designer
	Ctrls Cont	Controls Contractor
Design Phase	Program	Programming Phase
	Concept Des	Conceptual or Schematic Design Phase
	Design Dev	Design Development Phase
	Const Doc	Construction Documents Phase
	Spec Dev	Specification Development (late Const. Documents Phase)

Contents

The following systems and issues are included in this document in this order:

1. General building design and function
   - Overview
   - Sustainable construction and environmental compatibility
   - Indoor environmental quality—thermal, air distribution, acoustics, air quality, visual quality
   - Landscaping
2. HVAC systems—General
   - Overview
   - Design conditions and load assumptions
3. Chiller system (chillers, cooling towers, pumps, piping)
4. Boiler and heating water system
5. Roof top packaged System, including all components
6. VAV terminal units (cooling only)
7. VAV terminal units (reheat)
8. Heat recovery unit
9. Computer room AC unit
10. Daylighting controls
11. Lighting sweep control
12. Building automation system
13. Split air conditioner or heat pump
14. Emergency power system

Heading Format Used at the Beginning of Each Section

X.X Issue to be Documented Responsible Party When To Do It

1. General Building Design, Function, and Landscaping

1.1 General Building Design and Function *Architect* *Design Dev*

What are the general design objectives regarding energy efficiency?

_____
_____
_____

Comfort and indoor environmental quality?

_____
_____
_____

Sustainability and environmental compatibility?

_____
_____
_____

Other:

_____
_____
_____

Sequences *Architect* *Spec Dev*

What are the main control sequences for the watering systems that ensure water conservation?

_____
_____

Maintenance *Architect* *Spec Dev*

Are there any special instructions as to the care of the landscape elements that will enhance or degrade their energy and comfort benefits? (Refer to Operations and Maintenance (O&M) manual sections, if applicable)

_____
_____
_____

1.2 Sustainable Construction and Environmental Compatibility

Basis of Design*-General Description and Function*

Architect *Design Dev*

How will the building/grounds systems meet the OPR?

_____
_____
_____
_____
_____
_____

1.3 Indoor Environmental Quality

Thermal Comfort*—General Description and Function*

Mech Engr *Design Dev*

Record the occupant activity and design temperatures for the various spaces in Table 1.

Air Distribution *Mech Engr* *Const Doc*

What issues were considered in choosing diffusers?

_____
_____

Is the return air (RA) ducted of open-plenum? Why?

_____

Are the RA grills in every room? Why?

_____

What special considerations are being given to spaces with high solar load regarding cooling, large glazed areas, cold-air convective drafts, etc.? What solutions were used?

_____
_____
_____

Acoustics *Mech Engr* *Const Doc*

What is the design NC (noise criteria) sound level? Provide this information in Table 1. Are there any special acoustical considerations for any areas (areas close to the AHU, private areas, open office areas, etc.)? How will these criteria be met? (flexible duct, duct lining, fan type, lead wrap, diffuser type, TU damper type, etc.)

Noise class (NC) 35-40 for closed offices and 41-43 for open offices, recommended by ASHRAE)

_____
_____
_____

Air Quality *Mech Engr* *Const Doc*

For the general building and individual spaces, what is the desired outside air fraction or cfm per person and the number of persons per square foot? (Provide this information in Table 1). Is the outside air (OSA) controlled by CO_2 monitors? Explain.

_____
_____
_____
_____
_____

Can occupants adjust ventilation? How and what limits apply to what areas?

_____
_____

Are there any special indoor pollutant source concentrations? How are they handled? List areas served by exhaust fans, the fan size, air changes per hour and operational control.

_____
_____
_____
_____

How will the fresh air rate be maintained at low supply air volumes of the VAV system? Are perimeter zones treated differently than interior zones (reheat box damper settings, etc.)?

_____
_____
_____

Where are the outside air intakes located? Are they near any potential sources of pollutants?

_____
_____

Are full-drain condensate pans used in the air handler units? ☐Yes / ☐No

What other special IAQ issues were considered?

_____
_____

Visual Quality *Arch, Ltg Des,* *Design Dev*

What are the design foot-candle levels for the various spaces? (Provide this information in Table 1). Why? Is additional task lighting assumed?

_____
_____
_____

Do any spaces have special glare requirements? ☐Yes / ☐No

How will they be met? (Special light fixtures and lenses, fixture layout, special CRT screens, etc.)

_____
_____

How will glare be controlled in daylight areas?

_____
_____

What are the parameters and sequences of operation for the day lighting controls and dimming lights? How will occupants interact with the system (overrides, education, etc.)?

_____
_____
_____
_____
_____

1.4 Landscaping *Architect* *Design Dev*

Basis of Design

Describe the objectives and the elements of the specific landscape design that contribute to energy efficiency, water conservation, and comfort?

_____
_____

_____
_____
_____

Number of sheets attached to this section: _____

1.5 Interior Conditions Basis of Design *Mech Engr* *Const Doc*

Table 1

Reception, records, conference room, closed offices, open offices, exercise room, lunchroom, inventory, stock, etc.

Space	Use / Activity	Occupant Type	Num of Occs	Operating Hours per Day	Design Cooling DB	Design Cooling WB or RH	Design Heating DB OSAT	OSA CFM / Person or CO_2	Design Noise Level (NC)	Design Light Level (FC)

2. HVAC Systems and Design Parameters

2.1 General *Mech Engr* *Design Dev*

General description of the main HVAC systems and areas served.

System	Areas Served

Why were the above particular systems chosen?

_____
_____
_____
_____
_____
_____

Describe the level of priority given to energy conservations for the system.

_____
_____
_____

2.2 Specific System Descriptions *Mech Engr* *Const Doc*

System	Heating / Cooling / Both	Areas Served

What is the rationale for the way the HVAC and lighting were zoned?

_____
_____
_____
_____
_____

2.3 Load Calculations *Mech Engr* *Const Doc*

What outdoor design conditions were assumed for load calculations?

Summer: DB_____ WB_____ Winter: DB_____

What indoor design conditions were assumed for load calculations?

Summer: DB_____ RH_____ Winter: DB_____ RH_____

Internal load assumptions: Lighting: _____W/sf. Misc: _____W/sf. Other: _____

People/100 sf: _____ Btu/hr/person: sensible _____, latent _____

Ventilation: _____cfm/person. Basis (code, etc.): _____

Infiltration: ☐ _____cfm/sf wall area, or ☐ _____ air changes per hour.

Glazing:

Orientation	% of Wall Area	Overall U	SC
N			
S			
E			
W			

What overall safety factor was used and how much diversity was assumed for the heating, cooling plant and fan size?

_____
_____
_____

For redundant equipment, what redundancy criteria were used?

_____
_____
_____

Number of sheets attached to this section: _____

3. **Chiller System** (Chillers, Cooling Towers, Pumps, Piping)

***Basis of Design**-Components Description and Methods for Meeting OPR*

Chillers *Mech Engr* *Const Doc*

Briefly describe the chiller system.

_____
_____
_____
_____
_____
_____
_____
_____

- ☐ Centrifugal ☐ Screw
- ☐ Hermetically sealed
- ☐ Heat recovery
- ☐ Refrigerant type:_____
- ☐ Air cooled ☐ Water cooled
- ☐ Evaporative cooled
- ☐ Capacity control type: _____
- ☐ Pre-rotation vanes
- ☐ Other:_____

- ☐ Reciprocating chiller
- ☐ Heat recovery
- ☐ Refrigerant type: _____
- ☐ Air cooled ☐ Water cooled
- ☐ Evaporative cooled
- ☐ Stages of unloading:_____
- ☐ Other:_____

How many chillers of each size are there? (Size and number of each size): _____
_____

Is there a standby / redundant chiller during design conditions? _____

Are there isolation valves for when only one chiller is running? _____

What method was used for determining the design cooling load? _____
_____

Attach load calculations and assumptions, if not given in a previous section. (Diversity, safety factor, outdoor DB, WB, indoor DB, lighting W/sf, plug loads W/sf, people/100 sf, ventilation cfm/person, infiltration rate, glazing % of wall, overall U; SC).

Describe any provisions in the chiller system for accommodating future building or load expansion.

_____
_____
_____

What evidence can be provided to show the chillers are not oversized? _____
_____
_____

Why were they chosen to be different or equal size? _____
_____
_____

Was variable compressor speed seriously considered? If not, why not? _____
_____
_____

Was heat recovery for the chiller analyzed?_____ Why or why not?_____
_____

What were the results of the analysis? _____
_____

What vibration and noise considerations are given to the model and features of the chosen chillers? _____
_____

What is the rated efficiency of each chiller at full load and the APLV, in kW/ton? _____
_____
_____

What rationale was used to select these efficiencies with the sizes? Were more efficient models analyzed?_____
_____
_____
_____

Attach engineering or energy simulation and economic calculations for the selections.

Are the chillers intended to be staged back and forth, depending on load, to minimize energy use?
_____

Will staging occur manually or automatically? _____

What special control strategies will be employed with the chiller system?_____
_____
_____
_____
_____
_____
_____

What controls will be in place to allow the lowest economical entering condenser water temperature to be realized? What other options were considered besides this strategy? _____
_____
_____

Fully describe the interface that the building automation system has with the chiller system: __
_____
_____
_____
_____

What control will the building automation system (BAS) have over the chiller system?

☐ BAS enables/disables the chiller, ☐ assigns the lead chiller, ☐ assigns the lead primary chilled water pump, ☐ assigns the lead secondary chilled water pump, ☐ assigns the lead condenser pump, ☐ assigns the lead cooling tower

The BAS monitors the following: ☐ LCHWT, ☐ RCHWT, ☐ ECDWT, ☐ LCDWT, ☐ CDW flow, ☐ CHW primary flow, ☐ Secondary CHW flow, ☐ Cooling tower bypass valve, ☐ Chiller alarms that report to BAS (list): _____
_____
_____

Other _____
_____
_____

The BAS can change the following: ☐ LCHWT set point, ☐ Reset parameters, ☐ ECDWT set point, ☐ Cooling tower fan staging parameters, ☐ Chilled water pumping pressure set points, ☐ Pressure reset parameters, ☐ Demand limits, ☐ Other _____

_____

_____

Cooling Tower *Mech Engr* *Const Doc*

Describe the cooling tower (cross flow, counter flow, etc.) _____

_____

What are the sizes of the cooling towers? _____

What is the approach temperature rating of the cooling tower?_____

_____

Why was a lower approach not chosen? _____

Attach energy and economic analyses.

Were oversized cooling towers analyzed to improve chiller efficiency?_____ Why or why not?

_____

Attach analysis.

How many motors are there per tower fan?_____ Describe. _____

_____

Are the motors premium efficiency?_____

How is the fan speed controlled?_____

_____

_____

How do the sizes of the chillers affect the sizes of the cooling towers selected? Are they paired? _____

_____

_____

Can two cooling towers serve one chiller?_____
How are the cooling towers staged? _____

_____

_____

Will condenser water flows be monitored?_____ If not, explain why. _____

_____

Will the cooling tower be used in winter?_____ Why?_____

_____

_____

Air or Evaporative Cooled Condenser *Mech Engr* *Const Doc*

☐ Air cooled ☐ Evaporative cooled

Why was an air-cooled condenser chosen over a cooling tower? _____

_____

Why was an air-cooled condenser chosen over an evaporative condenser? _____

_____

_____

Describe main features of the condensers and the chillers they serve._____
_____
_____
_____

Were more efficient models analyzed? (Attach analysis) _____
_____
_____
_____

Describe the staging features _____
_____
_____

Chilled and Condenser Water Pumps and Piping *Mech Engr* *Const Doc*

What pressure drop range was the piping system designed to?

☐ Very low pressure drop, ☐ Moderately low-pressure drop, ☐ Standard pressure drop. Was an analysis performed for using a lower pressure drop to reduce pump size and energy use?_____ Attach analysis. How were pipe losses determined? ___Rule of thumb, ___detailed take-off and calculation, ___other.

Are pipe circuits designed to be close to being self-balanced proportionally, to minimize the restriction (head loss) of balancing valves and circuit setters?

Describe the pumps chosen. Primary: _____
_____
Secondary:_____
_____
Condenser pumps _____
_____

Are they equipped with premium energy-efficient motors? _____

Why or why not? _____

How large of safety factor was used in the pump sizing? _____ What was the over-sizing rationale for the pumps? ☐ Potential system expansion, ☐ Safety factor, ☐ Both of above. _____
ASHRAE 90.1 doesn't allow flow throttling with a balancing valve more than 3 hp. Will this system comply?_____

Would a more detailed head loss calculation likely result in a smaller safety factor and pump?
_____

Describe any standby or redundant pumps and their operation. _____
_____
_____

Will the control sequences allow for automatic changeover to the lag or standby pump upon pump failure and similarly for cooling tower fan failure or will manual valving be required? Upon failure, does the lag pump or tower start or does the chiller go down and lag chiller start. Explain fully for each:

_____

Primary chilled water pumps:_____
_____

Secondary chilled water pumps: _____
_____

Condenser water pumps:_____
_____

Cooling tower fans: _____
_____

How is the secondary chilled water capacity controlled? ☐ Variable speed drives (VFD) on pumps, ☐ Bypass valve. If by bypass valve, explain the rationale for not using variable speed drives and attach the economic analysis. _____
_____

For VFD's, how will the pump speed be controlled? ☐ Constant water pressure set point, ☐ Reset water pressure set point. If the pressure is not reset, why not? _____
_____

For a VFD on pressure reset, how low of speed will the pump be allowed to go? Is this is as low as possible? Explain. _____
_____
_____

Will chilled water flows be monitored? ☐ Primary flow, ☐ Secondary flow. If not, explain. ____
_____

Chiller System Sequence of Operations and Operating Parameters

Mech Engr *Const Doc*

Attach a full and comprehensive sequence of operations, including but not limited to the following conditions and systems, including all interactions:

Chiller, Cooling Tower and Pumps

- List parameter conditions that initiate start-up.
- Provide a detailed narrative of the full sequence and status and action of EACH component during EACH stage of start-up: low load, medium load, high load, staging to next chiller, up to full load on all chillers, and then back down again to OFF condition. List all set points, delays, parameters, conditions, etc., that are required to pass through each stage. The components for which status will be given at each stage are: chiller stage and load, primary, secondary and condenser pump status, speed and flow, cooling tower stage, cooling tower bypass valve, cooling tower fans and speed, pipe pressures and set point resets.

Describe the sequences for the following:

- Chiller optimization staging.
- Temperature lockouts.
- Status and sequence at power outage and fire alarm.
- Effects of manual shutoff or failure of chiller, primary pump and secondary pump, condenser pump, cooling tower fan, vibration alarm.
- List all alarms.
- Include full sequences and set points for capacity and pressure control of the secondary chilled water system.
- Include full sequences and set points for condenser water temperature control and cooling tower fan control parameters.
- Cooling tower sump heater sequences, parameters and set points.
- List the full sequence of operation for all energy conserving strategies, including their set points and parameters.
- Weekend operation.
- Normal occupied and unoccupied modes.

Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Section 4 of the instructions.

For the chiller, cooling tower and pumps, the sequences are expected to be about five single-spaced, typewritten pages.

Number of sheets attached to this section: _____

4. Boilers and Heating Water System

4.1 Basis of Design-Components Description and Methods for Meeting the OPR

Boilers *Mech Engr* *Const Doc*

The boiler is a ☐ Condensing, ☐ Forced draft, ☐ Atmospheric burner, ☐ Packaged, ☐ Other:
_____

Briefly describe the boiler system.
_____
_____
_____

How many boilers of each size and type are there? (List number and size): _____
_____

Is there a standby / redundant boiler during design conditions?_____

What method was used for determining the design heating load? _____
_____

Attach load calculations and assumptions, if not given in a previous section. (Diversity, safety factor, outdoor DB, WB, indoor DB, lighting W/sf, plug loads W/sf, people/100 sf, ventilation cfm/person, infiltration rate, glazing % of wall, overall U; SC).

Describe any provisions in the boiler system for accommodating future building or load expansion.
_____
_____
_____

What evidence can be provided to show that the boilers are not oversized?_ _____
_____
_____

Why were they chosen to be different or equal size?_ _____
_____
_____

What vibration and noise considerations are given to the model and features of the chosen boilers? _____
_____

How many total stages of capacity does each boiler have? (Burner beds and stages of fire) __

What is the rated efficiency of each boiler? _____
_____
_____

What rationale was used to select these efficiencies with the sizes? Were more efficient models analyzed?_____
_____
_____
_____

Attach engineering or energy simulation and economic calculations for the selections.

Are the boilers intended to be staged back and forth, depending on load, to minimize energy use?

_____

Will this be done manually or automatically? _____

_____

_____

What special control strategies will be employed with the boiler system? _____

_____

_____

_____

_____

_____

_____

Fully describe the interface that the building automation system has with the boiler system: ___

_____

_____

_____

_____

What control will the building automation system (BAS) have over the boiler system?

☐ BAS enables/disables the boiler, ☐ assigns the lead boiler, ☐ assigns the lead primary boiler pump, ☐ assigns the lead secondary boiler water pump.

The BAS monitors the following: ☐ boiler alarm status, ☐ pump status, ☐ internal water temperature, ☐ steam pressure, ☐ HW primary flow, ☐ secondary HW flow, ☐ three-way mixing valve, ☐ boiler alarms that report to BAS (list): _____

_____

_____

Other _____

_____

_____

The BAS can change the following: ☐ LHWT set point, ☐ Reset parameters, ☐ Boiler water pumping pressure set points, ☐ Pressure reset parameters, ☐ Demand limits, ☐ Other _____

_____

_____

Will the boilers have low water cutout controls? _____

4.2 Heating Water Pumps and Piping *Mech Engr* *Const Doc*

What pressure drop range was the piping system designed to?

☐ Very low pressure drop, ☐ Moderately low pressure drop, ☐ Standard pressure drop.

Was an analysis performed for using a lower pressure drop to reduce pump size and energy use?_____ Attach analysis. How were pipe losses determined? ___Rule of thumb, ___detailed take-off and calculation, ___other.

Are pipe circuits designed to be close to being self-balanced proportionally, to minimize the restriction (head loss) of balancing valves and circuit setters?

Describe the pumps chosen. Primary: _____

_____

Secondary:_____

_____

Are they equipped with premium energy-efficient motors? _____

Why or why not? _____

How large of safety factor was used in the pump sizing? _____

What was the over-sizing rationale for the pumps? ☐ Potential system expansion, ☐ Safety factor, ☐ Both of above._____
ASHRAE 90.1 doesn't allow flow throttling with a balancing valve more than 3 hp. Will this system comply?_____

Would a more detailed head loss calculation likely result in a smaller safety factor and pump?
_____

Describe any standby or redundant pumps and their operation. _____
_____
_____

Will the control sequences allow for automatic changeover to the lag or standby pump upon pump failure or will manual valving be required? Explain fully.

_____

Primary heating water pumps: _____
_____

Secondary heating water pumps:_____
_____

How is the secondary heating water capacity controlled? ☐ Variable speed drives (VFD) on pumps, ☐ Bypass valve(s). If by bypass valves, explain the rationale for not using variable speed drives and attach the economic analysis. _____
_____

For VFD's, how will the pump speed be controlled? ☐ Constant water pressure set point, ☐ Reset water pressure set point. If the pressure is not reset, why not? _____
_____

For a VFD on pressure reset, how low of speed will the pump be allowed to go? Is this is as low as possible? Explain. _____
_____
_____

Will heating water flows be monitored? ☐ Primary flow, ☐ Secondary flow. If not, explain. ___
_____

How is supply water temperature controlled? ☐ 3-way mixing valve, ☐ Other _____
_____

4.3 Boiler System Sequence of Operations and Operating Parameters

Mech Engr *Spec Dev*

Attach a full and comprehensive sequence of operations, including but not limited to the following conditions and systems, including all interactions:

- List parameter conditions that initiate start-up.
- Provide a detailed narrative of the full sequence and status and action of EACH component during EACH stage of start-up: low load, medium load, high load, staging to next boiler, up to full load on all boilers, and then back down again to OFF condition. List all set points, delays, parameters, lockouts, conditions, etc., that are required to

pass through each stage. The components for which status will be given at each stage are: boiler stage and load, primary, secondary pump status, speed and flow, pipe pressures and set point resets.

Describe the sequences for the following:

- Boiler optimization staging.
- Temperature lockouts.
- Status and sequence at power outage and fire alarm.
- Effects of manual shutoff or failure of boiler, primary pump and secondary pump.
- List all alarms.
- Include full sequences and set points for capacity and pressure control of the secondary heating water system.
- List the full sequence of operation for all energy conserving strategies, including their set points and parameters.
- Weekend operation.
- Normal occupied and unoccupied modes.
- Warm-up mode

Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Section 4 of the instructions.

For the boiler and pumps, the sequences are expected to be about ____ single spaced, typewritten pages.

Number of sheets attached to this section: _____

5. Roof Top Packaged System(s) (RTU)

***5.1 Basis of Design**-Components Description and Methods for Meeting the OPR*

Mech Engr *Const Doc*

Give size, quantity, and other specific information and the areas served, and how it will meet the objectives.

Plant

Number of units of this type: _____ EER (cooling): _____ Tons cooling each unit:____

Accumulated capacity for all units of this type: Total tons cooling: _____

MBtu heating: _____ Heat Pump COP: _____ Gas efficiency: _____

Areas served: _____

Supply Fans and Capacity Control

Total CFM for packaged systems of this type:_____

☐ Inlet vanes ☐ VFD ☐ Vane axial ☐ Outlet damper ☐ Other: _____

Motor efficiency: ____Std. effic., ____Premium effic.

Return Fans / Exhaust Fans / Relief Dampers

Describe return fans, exhaust fans, or relief dampers, if any, and their function.

_____
_____
_____

Describe how building static pressure is controlled (set points, etc.). _____
_____
_____

VFD control:

Which fans does each VFD control? ☐Supply ☐ Return/Exhaust

Location of duct static-pressure sensor (distance from fan and proximity from branch takeoffs up and down stream): _____

Duct static pressure: ☐ Fixed set point / ☐ Reset or variable

Expected duct static pressure set point (or average if reset): _____

Total pressure across fan at design flow: _____[discharge pressure - suction pressure (negative)]

Minimum fan capacity (lower frequency limit setting in VFD, % of max.) _____

Are VFD settings ☐ monitored or ☐ controlled by the BAS system? (Check one)

Method used for sizing ducts _____equal friction _____static regain

> Note: Equal friction gives smaller ducts and higher pressure requirements. If equal friction was used, was a calculation made to make sure the increased pressure and subsequent increase in energy use by the fan is more than offset by the savings in duct materials?_____

Compressor(s)

Number of compressors per RTU: _____. Low ambient compressor package? ____

Number of condenser fans per RTU: _____. Locked out during morning warm up? _____

Compressor capacity control; general description:

_____
_____

Cooling coil

Provide general description and any special features (high efficiency, face velocity, low pressure drop, etc.). Was a low pressure drop coil analyzed? What were the results?

_____
_____
_____

Dampers

Describe the dampers and their function. _____
_____
_____
_____
_____

Smoke and Fire Dampers

Describe the smoke and fire damper system (location and operation). _____
_____
_____

Set point Temperatures

Supply air (SA): _____ SA reset (see strategy sequence): _____ Mixed air: _____

Filters

Provide general description and any special features (low pressure drop, etc.). Were low pressure drop filters analyzed? What were the results?_____

_____
_____

Heating System

Describe type, fuel, perimeter reheat, areas served, etc.

_____
_____
_____

Economizer and OSA Dampers

☐ Enthalpy ☐ Dry Bulb ☐ Integrated ☐ Economizer is first stage of cooling

Number of damper positions: ☐_____ or ☐ infinite.

Dampers closed during warm-up? ☐ Yes / ☐ No

If dry-bulb type: OSA changeover temperature: _____

If enthalpy: OSA enthalpy changeover: _____

Other special features of the RTU:

_____

_____

How will the fresh air rate be maintained at low supply air volumes of the VAV system? Are perimeter zones treated differently than interior zones (reheat box damper settings, etc.)?

_____

_____

_____

_____

How is the RTU controlled?

☐ Stand-alone controllers with thermostats in zones

☐ Above, but enabled/disabled by central building automation system (BAS)

☐ Integrated into BAS as below:

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
Mixed air temp.	_____	_____	Compressor stage		NA
RA temp.	_____	NA	Bldg. static pressure	_____	_____
SA temp.	_____	_____	Temp. Lock-out	_____	_____
SA reset parameters	_____	_____	CO_2 for OSA control	_____	_____
RA enthalpy	_____	NA	Htg. coil position	_____	NA
DA static pressure	_____	_____	Optimum start	NA	_____
Duct static pressure	_____	_____	Night purge	NA	_____
Supply fan status	_____	NA	Demand limit	NA	_____
Ret./Exh. Fan status	_____	NA	Alarms (list):	_____	_____
Supply fan speed	_____	NA	-Dirty filter	_____	_____
Ret./Exh. Fan speed	_____	NA	-Compressor fail	_____	_____
Supply fan cfm	_____	NA	-Fan loss of air	_____	_____
Ret./Exh. Fan cfm	_____	NA	-High DA pressure	_____	_____
Inlet vane position	_____	NA	-Fire/smoke	_____	_____
Filter Diff. pressure	_____	_____	-Emerg. Shutdown	_____	NA
Occup. schedule override	_____	_____	OSA compensation for VAV	_____	_____

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
Night low limits	_____	_____	OSA economizer	_____	_____
_____	_____	_____	_____	_____	_____

Describe other equipment tied to the ON/OFF status of the RTU (exhaust fans, etc.)

_____
_____
_____

5.2 RTU Sequence of Operations and Operating Parameters

Mech Engr *Spec Dev*

Provide a full and comprehensive sequence of operations, including but not limited to the following conditions and systems, including all interactions:

Systems

- supply fans
- exhaust fans
- return air and exhaust dampers
- supply air capacity control
- economizer and OSA dampers
- building static pressure control
- coil valve operation
- CO_2 sensor OSA control
- smoke dampers

Conditions or Modes

- start-up
- shut-down
- normal occupied & unoccupied periods
- warm-up
- temperature lock-out
- compressor and condenser staging
- override sequences
- winter/summer changeover
- weekend operation
- normal operation heating
- normal operation cooling
- through dead band ranges
- alarms: fire, smoke, shutdown, equip. failure, temp. and pressure limits, etc.
- all energy conserving strategies (optimum start/stop, resets, etc.)
- fire alarm

Include the position or status at which each component resides at start-up, what occurs at fire alarm, provide all set points and control parameters, including all time delays. In the sequences, describe what controls what. That is, what components must be ON or at certain conditions in order for others to operate? Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Section 4 of the instructions.

For this RTU system, these sequences are expected to be about _____ single spaced, typewritten pages.

Number of sheets attached to this section: _____

6. VAV Terminal Units—Air Conditioning Only (TU_AC)

6.1 System Description

Mech Engr *Design Dev*

Briefly describe the TU: _____
_____
_____

Number of TU_ACs: _____ Type of area served: _____

TU type: ☐ pressure independent / ☐ pressure dependent

Minimum air damper position: _____% open.

Are these fan powered?_____. ☐ Parallel, ☐Series. Why? _____
_____

TU measures air flow via total and static pressure sensors. Y/N ____.

☐ Cross, ☐ Linear flow station? Other flow method: _____

Describe TU controller type: _____

Damper actuator type: ☐ Electric, ☐ Pneumatic.

What noise considerations were used when specifying the TU's? _____
_____

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
TU air flow	_____	_____	TU air flow max.	_____	_____
TU air flow min.	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

6.2 TU_AC Sequence of Operations and Operating Parameters

Mech Engr *Spec Dev*

Provide a full and comprehensive sequence of operations (including all sequences, dead band, alarm actions, etc.) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

7. VAV Terminal Units—Reheat (TU_RH)

7.1 System Description *Mech Engr* *Design Dev*

Briefly describe the TU: _____
_____

Number of TU_RHs: _____ Type of area served: _____

TU type: ☐ pressure independent / ☐ pressure dependent, ☐ VAV, ☐ constant volume

Are these fan powered?_____. ☐ Parallel, ☐ Series. Number of fan speeds?_____
Why? _____
_____

What provisions will be made to minimize reheat? _____
_____

What provisions will be made to minimize system simultaneous heating and cooling?_____
_____

TU measures air flow via total and static pressure sensors. Y/N ____.

☐ Cross, ☐ Linear flow station? Other flow method: _____

Minimum air damper position: _____% open.

When the damper is at minimum in heating and space set point is not being maintained, will dampers open?_____ Why?_____

Describe TU controller type: _____

Damper actuator type: ☐ Electric, ☐ Pneumatic.

Heating coil type: ☐ hot water, ☐ electric resistance and stages _____.

Describe heating coil valve: ☐ Two position, ☐ Modulating. _____

Heating valve actuator type: ☐ Electric, ☐ Pneumatic.

Do some units have 3-way valves? Why? _____

Automatic flow control valve?___ Describe: _____

What noise considerations were used when specifying the TU's? _____
_____

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
TU air flow	_____	_____	TU air flow max.	_____	_____
TU air flow min.	_____	_____	Valve position	_____	_____
_____	_____	_____	_____	_____	_____

7.2 TU_RH Sequence of Operations and Operating Parameters

Mech Engr *Spec Dev*

Provide a full and comprehensive sequence of operations (including heat lockout parameters, heating valve sequences, dead bands, alarm actions, etc.) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

8. Heat Recovery Unit (HRU)

8.1 System Description

Mech Engr *Design Dev*

Briefly describe the system: _____
_____
_____
_____

On which air handlers does this system operate? _____

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

8.2 HRU Sequence of Operations and Operating Parameters

Mech Engr *Spec Dev*

Provide a full and comprehensive sequence of operations (including seasonal variations) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

9. Computer Room Conditioning Unit (ACU)

***9.1 Basis of Design**-Component Description and Methods for Meeting OPR*

Mech Engr *Design Dev*

Areas served:_____

Number of ACUs: _____ Sizes (tons) _____ EER: _____

Location of ACU: _____

☐ Ducted system or ☐ discharge only?_____

How is heat rejected? ☐ Cooling tower / ☐ DX air-cooled condenser / ☐ Other

Location of condenser:_____

Humidifier description: _____

Reheat description: _____

Is there a 3-way valve in the unit? _____ Will this defeat the purpose of any variable speed drives on the chilled water system? _____

How is the ACU controlled?

☐ Stand-alone controllers with thermostats in zones
☐ Same, but enabled/disabled by central building automation system
☐ "Fully" controlled by BAS

Does supply air enter this space from the main HVAC system? ☐ Yes / ☐ No

If Yes, when? _____
_____

How is fresh air brought into and controlled in the space?_____
_____

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

9.2 ACU Sequence of Operations and Operating Parameters

Mech Engr *Spec Dev*

Provide a full and comprehensive sequence of operations (including set points, unoccupied, occupied, fire alarm periods, etc.) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

10. Day Lighting Controls

10.1 Basis of Design *Elec Engr* *Design Dev*

System type: ☐ continuous dimming / ☐ stepped dimming in ____ steps

Describe related architectural features such as light shelves, sloped ceilings, skylights, special interior finishes, etc. _____
_____
_____
_____

How low are the lights allowed to dim? _____%.

The system is controlled by: ☐ main BAS / ☐ stand alone controllers

What is the light level set point(s) at the work plane?

Area	Design Foot Candles
_____	_____
_____	_____
_____	_____
_____	_____

How deep into the building do the lights dim? _____ft.

Are the dimming rates the same across this distance? ☐ Yes / ☐ No

Explain: _____
_____

What areas of the building have dimming control?

_____
_____
_____

How many zones and controllers (light sensors) are there? _____

How do occupants override the dimming? _____
_____

Who has access for adjusting light levels? _____

Where are these adjustments made? _____

Where are the sensors located? _____

10.2 Sequence of Operations and Operating Parameters

Elec Engr *Spec Dev*

Provide a full and comprehensive sequence of operations (including set points and occupied and unoccupied conditions, etc.) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

11. Lighting Sweep Control

11.1 System Description *Elec Engr, Ctrls Cont, Design Dev*

Briefly describe the system: _____
_____
_____

11.2 Operating Parameters Elec Engr, Ctrls Cont, *Spec Dev*

The system is controlled by: ☐ Main BAS / ☐ Stand-alone controller

How many zones will there be? _____ Describe the zones. _____

_____

What is the floor area of the largest zone? _____

How many sweeps will there be? _____

At what times?
Weekdays: _____
Saturday: _____
Sunday: _____

Describe the type of switching system that occupants will use to turn the lights back on in their zone. _____
_____

What is the maximum override duration? _____hours

Who will be able to globally override the sweeps or change the schedule?

_____

How will the sweeps work with housekeeping schedules? _____

_____

Number of sheets attached to this section: _____

12. Building Automation System (BAS)

12.1 Basis of Design–Component Description and Methods for Meeting the OPR

Mech Engr, Ctrls Cont, Const Doc

Central system is: ☐ DDC, ☐ pneumatic

Valve actuators: ☐ electric, ☐ pneumatic. AHU damper actuators: ☐ electric, ☐ pneumatic

VAV terminal box damper actuators: ☐ electric, ☐ pneumatic

Fire / smoke damper actuators: ☐ electric, ☐ pneumatic

User interface: ☐ graphical display of components

Limitations of the modules or features specified, compared to the highest model line system:

_____

_____

_____

Check the systems that the BAS will control (vs. local equipment. packaged controllers). Refer to the individual system section for a complete description of the points and their control by the BAS

	Virtually Full Control	Partial Control	Enable/Disable Only	Monitor Only
Rooftop packaged unit	☐	☐	☐	☐
Air handler unit	☐	☐	☐	☐
Terminal units	☐	☐	☐	☐
Economizer functions	☐	☐	☐	☐
Boiler plant	☐	☐	☐	☐
Heating water pumping system	☐	☐	☐	☐
Chiller plant	☐	☐	☐	☐
Chilled water pumping system	☐	☐	☐	☐
Cooling tower	☐	☐	☐	☐
Condenser water pumping	☐	☐	☐	☐
Terminal unit settings	☐	☐	☐	☐
Heat recovery unit	☐	☐	☐	☐
Day lighting set points	☐	☐	☐	☐
Lighting sweep control	☐	☐	☐	☐
Exterior lighting	☐	☐	☐	☐
Computer room HVAC unit	☐	☐	☐	☐
Fan coil unit and condenser	☐	☐	☐	☐
Unit heaters	☐	☐	☐	☐
Smoke and fire control	☐	☐	☐	☐
Emergency power system	☐	☐	☐	☐
UPS power system	☐	☐	☐	☐
Service water heating pump	☐	☐	☐	☐
_____	☐	☐	☐	☐
_____	☐	☐	☐	☐
_____	☐	☐	☐	☐

Location of user interface: _____

Type of user interface:

☐ Permanent on-site computer terminal
☐ Plug-in portable computer
☐ Remote terminal of _____
☐ Keypad only

Describe parties who will be able to change schedules only: _____
_____

Describe parties who will have full access to system: _____
_____

Check the energy conserving control strategies that will be operational in this building through the BAS.

- ☐ Holiday scheduling
- ☐ Zonal scheduling
- ☐ Sequential startup of equipment
- ☐ Lighting sweep
- ☐ Night setup/setback
- ☐ Optimum start
- ☐ Optimum stop
- ☐ Hot & cold deck reset (supply air)
- ☐ Chilled water reset
- ☐ Chiller staging and optimization
- ☐ Cooling tower component staging
- ☐ Air-side economizer control
- ☐ Night ventilation purge / pre-cooling
- ☐ CO2 outside air rate control
- ☐ VAV control-pressure independent
- ☐ VAV control-pressure dependent
- ☐ Duct static pressure reset
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ Occupancy-based outside air control
- ☐ DX compressor optimization
- ☐ Mixed air temperature control
- ☐ Boiler staging and optimization
- ☐ Heat element (coil) staging
- ☐ Hot water reset
- ☐ Heat recovery option control
- ☐ Water-side economizer control
- ☐ Variable speed pump control
- ☐ Occupancy based HVAC control
- ☐ Terminal regulated air volume (TRAV)
- ☐ Thermal storage control
- ☐ Demand limiting or load shedding
- ☐ Duty cycling of equipment
- ☐ DHW recirculation pump control
- ☐ DHW temperature control
- ☐ Full trending capabilities
- ☐ _____
- ☐ _____
- ☐ _____

List all special monitoring points installed for diagnostic, performance verification and trouble shooting purposes, which are not needed to execute the control sequences and strategies?

_____
_____
_____

12.2 BAS Sequence of Operations and Operating Parameters

Mech Engr *Spec Dev*

Provide a full and comprehensive sequence of operations, including set points, dead bands, etc. List full control sequences for all control strategies. Refer to sequences already provided in other component sections, if applicable. List on a separate sheet(s) and attach to this section of the form.

Include the position or status at which each component resides at start-up, provide all set points and control parameters, including all time delays. In the sequences, describe what controls what. That is, what components must be ON or at certain conditions in order for others to operate? Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Section 4 of the instructions.

Note: Complete BAS description, points list with all details, program listing, etc. are not part of the BOD or OPR, but will be required as part of the O&M documentation.

12.3 Points List *Mech Engr, Ctrls Cont* *Spec Dev*

For the OPR, list all points in a table that includes at ***least*** the information shown in the following example table.

Controlled System	Point Abbr.	Point Description	Display Units	Control or Set point Y/N	Monitoring Point Y/N	Intermediate Point Y/N	Calculated Point Y/N

Key:

Point Description: DB temp., air flow, etc.

Control or Set point: Point that controls equipment and can have its set point changed (OSA, SAT, etc.)

Intermediate Point: Point whose value is used to make a calculation which then controls equipment (space temperatures that are averaged to a virtual point to control reset).

Monitoring Point: Point that does not control or contribute to the control of equipment, but is used for operation, maintenance, or performance verification.

Calculated Point: "Virtual" point generated from calculations of other point values.

Number of sheets attached to this section: _____

13. Split System Air Conditioning; Heat Pump System

***13.1 Basis of Design**-Component Description and Methods for Meeting the OPR*

Mech Eng *Const Doc*

Give size, quantity, and other specific information and the areas served, and how it will meet the objectives.

Plant

Number of units of this type: _____ EER (cooling): _____ Tons cooling each: _____

Accumulated capacity for all units of this type: Total tons cooling: _____

MBtu heating: _____ Heat Pump COP: _____ Gas efficiency: _____

Areas served: _____

Compressor(s) and Condenser(s)

Number of compressors per condenser unit: _____. Low ambient compressor package? ____

Number of condenser fans condenser unit: _____

Compressor capacity control; general description: _____
_____

Evaporator / Cooling Coil

Provide general description and any special features (high efficiency, face velocity, low pressure drop, etc.). Was a low pressure drop coil analyzed? What were the results?

_____
_____
_____

Supply Fans and Capacity Control

Total CFM for inside fan coil or air handler of this type:_____

☐ Constant volume ☐ Inlet vanes ☐ VFD ☐ Vane axial ☐ Outlet damper ☐ Other: ____

☐ Evaporator fan cycles ON and OFF with compressor. Motor efficiency: ____Std. effic., ____Premium effic.

Dampers

Describe any dampers and their function._____
_____
_____
_____

Smoke and Fire Dampers

Describe the smoke and fire damper system (location and operation)._____
_____
_____

Set point Temperatures

Supply air (SA): _____ SA reset (see strategy sequence): _____

Filters

Provide general description and any special features (low pressure drop, etc.). Were low pressure drop filters analyzed? What were the results?_____

_____

_____

Heating System

Describe type, fuel, perimeter reheat, areas served, etc.

_____

_____

_____

Economizer and OSA Dampers

☐ No OSA via this unit ☐ Enthalpy ☐ Dry Bulb ☐ Integrated ☐ Economizer is first stage of cooling

Number of damper positions: ☐_____ or ☐ infinite.

Dampers closed during warm-up? ☐ Yes / ☐ No

If dry-bulb type: OSA changeover temperature: _____

Other special features of the split system:

_____

_____

_____

How will the fresh air rate be maintained at low supply air volumes of the VAV system? Are perimeter zones treated differently than interior zones (reheat box damper settings, etc.)?

_____

_____

_____

_____

How is the split system controlled? _____

☐ Stand-alone controllers with thermostats in zones. Number of zones: _____

☐ Above, but enabled/disabled by central building automation system (BAS)

☐ Integrated into BAS as below:

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
RA temp.	_____	NA	Compressor stage	_____	NA
SA temp.	_____	_____	Temp. lock-out	_____	_____
SA reset parameters	_____	_____	CO_2 for OSA control	_____	_____
RA enthalpy	_____	NA	Htg. valve position	_____	NA
DA static pressure	_____	_____	Optimum start	NA	_____
Duct static pressure	_____	_____	Night purge	NA	_____

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
Supply fan status	_____	NA		NA	_____
Ret./Exh. Fan status	_____	NA	Alarms (list):	_____	_____
Occup. schedule override	_____	_____	Night low limits	_____	_____
OSA economizer	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Describe other equipment tied to the ON/OFF status of the split system unit (exhaust fans, etc.)
_____

13.2 Split System Sequence of Operations and Operating Parameters

Mech Engr *Spec Dev*

Provide a full and comprehensive sequence of operations, including but not limited to the following conditions and systems, including all interactions:

Systems

- supply fans
- supply air capacity control
- economizer and OSA dampers
- building static pressure control
- coil valve operation
- CO_2 sensor OSA control
- smoke dampers

Conditions or Modes

- start-up
- shut-down
- normal occupied & unoccupied periods
- warm-up
- temperature lock-out
- compressor and condenser staging
- override sequences
- winter/summer changeover
- weekend operation
- normal operation heating
- normal operation cooling
- through dead band ranges
- alarms: fire, smoke, shutdown, equip. failure, temp. and pressure limits, etc.
- all energy conserving strategies (optimum start/stop, resets, etc.)
- fire alarm

Include the position or status at which each component resides at start-up, what occurs at fire alarm, provide all set points and control parameters, including all time delays. In the sequences, describe what controls what. That is, what components must be ON or at certain conditions in order for others to operate? Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Sections 4 of the instructions.

For this system, these sequences are expected to be about _____ single spaced, typewritten pages.

Number of sheets attached to this section: _____

14. Emergency Power System

Basis of Design*-Component Description and Methods for Meeting the OPR*

Elec Engr *Spec Dev*

Generator

Is the generator sized to be able to handle additional loads?_____ How many? _____

_____

What is the maximum time it should take the generator to be providing power from the time street power is lost (seconds)? _____

Is there an automatic generator exerciser?_____

For how long should the generator be able to provide power without refueling? _____

Describe any special frequency and voltage regulation output requirements for the generator.__

_____

Power Quality *Elec Engr* *Spec Dev*

Describe any special power quality concerns or considerations (sensitive equipment, etc.). ____

_____

_____

UPS

How many UPS systems are there? List all, including integral batteries in equipment. _____

_____

What kind of UPS bypass will be used on the stand-alone UPS?_____

_____

Emergency Power and UPS Schedule *Elec Engr* *Spec Dev*

In the following table, list each load on emergency power and/or on a UPS. List the UPS discharge time. List all the loads first that are only on emergency power.

Equipment / Loads	**On Emerg. Power** (Y/N)	**UPS**		
		On UPS (give UPS ID)	**Stand Alone UPS** (SA) **or Integral** (I)	**Full Load Discharge Time** (min.)

Number of sheets attached to this section: _____

15. Other Systems Needing Sample Formats

Fire Alarm and Protection Systems	
Service Water Heating	
Air Handler Units	Capacity control Supply fan Return/exhaust fan and dampers Heating and cooling coil valves Economizer and OSA and return air dampers Mixed air control
Exhaust Fans	

Appendix VI - Commissioning Process, Step by Step

Section J lists the phases of the full commissioning (Cx) process, and discusses the first phase of the full Cx process, "Predesign/Planning", including establishing the Cx Scope. The remaining phases in the Cx process, as well as Phase 1 from Section J (which is repeated so that all steps are discussed together), are as follows;

The Cx process will vary in response to the complexity, type, size, and delivery method for each individual project. A comprehensive Cx process will have nine distinct phases, although depending upon when the Cx authority is introduced into a project some phases may not be applicable. As noted previously, Cx is most effective when introduced during Pre-Design/Planning. In addition, the activities associated with each phase noted below will vary depending upon the building systems utilized. Project phases include:

1. Pre-Design/Planning
2. Design
3. Contractor Selection
4. Early Construction
5. Static Inspection (Field Verification)
6. Start-up (Contractor/Supplier Functional Verification)
7. Functional Performance Testing
8. O&M Staff Training and Documentation
9. Warranty Review and Seasonal Testing
10. Measurement and Verification

This section describes the first phase "Predesign/Planning", and in particular, defining the Cx scope. Phases 2 through 10 are discussed in Appendix 6.

1. Predesign/Planning

The Owner's "Commissioning Scope" is defined during the Pre-Design phase. Development of this document should be directed by a member of the owner's staff, or by a consultant contracted by the owner, and should include a description of all of the services and deliverable documents that the owner will require from the Cx process. This scope includes a detailed listing of all of the building systems (or portions of systems) that will be commissioned, and describes the activities and level of rigor to be used in the Cx process.

The following factors should be used to determine the systems to be commissioned and the level of Cx process rigor for each project:

- Project Type: In general, project types can be classified into one of three broad categories:
    - High Criticality Facilities: Facilities whose continuous, normal operation is critical to achieving primary project goals. Malfunction of building systems would result in unacceptable risk, such as impacting life safety, resulting in large loss of revenue, or compromising public or national security, etc. Refer to Table 1 for typical examples of facilities meeting this criteria.
    - Medium Criticality Facilities: Facilities whose continuous, normal operation is not critical to achieving primary end user goals. Malfunction of building systems operation results in undesirable impacts on important secondary end user goals. Systems failures would not adversely affect life safety, public or national security, or achieving aggressive energy goals through the use of complex systems. Refer to Table 1 for typical examples of facilities meeting this criteria.

- Low Criticality Facilities: Facilities whose continuous, normal operation is not critical to primary or important secondary end user goals, and for which failure represents an acceptable temporary inconvenience. Refer to Table 1 for typical examples of facilities meeting this criteria.

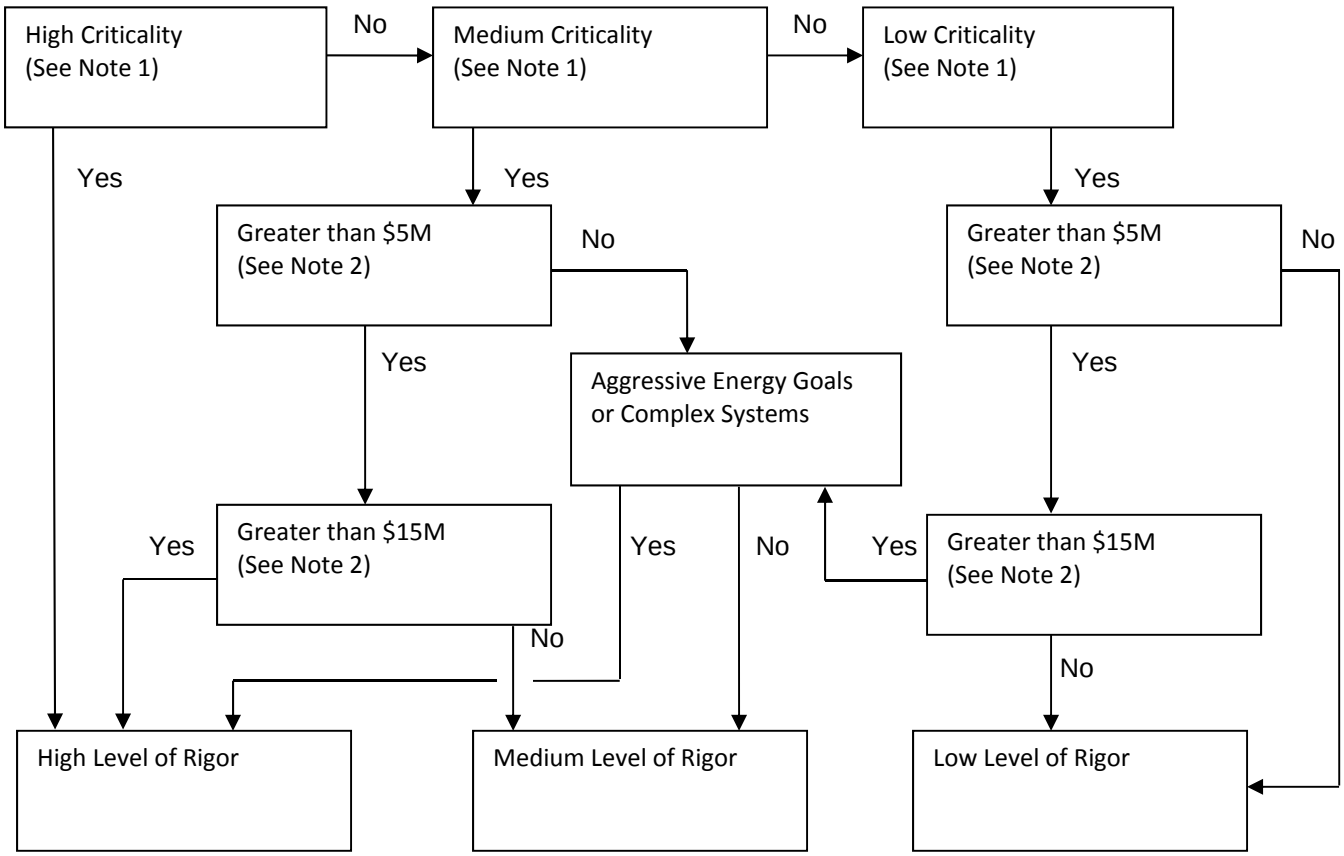
Table 1: High, Medium and Low Criticality Facilities

High Criticality	Medium Criticality	Low Criticality
Data Centers that are not backed up with fully redundant facilities	Data Centers that are partially or fully backed up with redundant facilities	Warehouses
Laboratories-R&D	Medical Office Buildings and Clinics	Office Buildings, under $15M in value
Hospitals-Medical	Kitchen/Dietary Facilities	Parking Structures
Central Utility Plants/Power Plants	Office Buildings, over $15M in value	Recreation Facilities
Emergency Operations Centers	Printing Plant	Stadiums and Grandstands
Communications Centers	Library	Park Shelters
Key governmental facilities important to public or national security		
	Fire and Police Stations	Maintenance and Shop Facilities
	Observatories	Natatorium
	Laundry	Marinas
	Detention/Correctional Facilities	Restroom and Shower Facilities
	Historical Facilities	Greenhouses
	Laboratory-Teaching	Gymnasiums
	Project types of Low Criticality, but where there are aggressive goals and equipment for achieving energy efficiency	Dormitories
	Hospitals-Mental	Armories
	Industrial Buildings	Apartments
	Hangers	Industrial Buildings
	Day Care Facilities	Visitors Interpretive Centers
	Dining Facilities	
	Project types of Low Criticality, but are located in High Rise Buildings	
	Museums	
	Schools	
	Class rooms	

- Project size: This can vary from owner to owner, but is usually based on construction cost. In general, High Criticality facilities require Cx of most building systems, while Cx fewer systems and/or components is acceptable for Medium Criticality facilities. Low Criticality Facilities require minimal Cx of systems and components. A list of typical building systems and components can be found in Appendix III.

Utilizing Table 1 will help the reader determine the level of criticality for their facility. Then utilizing the flow chart in Figure 1 (below), the reader can arrive at the desired level of rigor to include in the Cx process.

Figure 1: Decision Tree to Aid in Determining Level of Commissioning Rigor



Notes to Figure 1:

1. Refer to Table 1
2. Values shown may vary by state and should be verified

Commissioning Rigor Levels

High Level of Rigor: A high level of confidence in systems operation is necessary to avoid unacceptable risks, or facilities with aggressive energy usage goals, complex systems to achieve these goals, and the need to precisely verify and document baseline operations. The following might describe the Cx approach for this category;

- The “Hands On, Discipline Specific”, Independent Third Party delivery method described in Section G might be utilized.
- The Commissioning Authority (CxA) would be expected to be intimately involved in a full Cx scope.
- Typically, all systems and components supporting critical functions are fully commissioned (no sampling is utilized).
- Typically, all systems and components supporting critical functions are tested at 100% capacity, including redundant equipment.

- Typically, all systems and components supporting critical functions are tested including normal and off-normal operating scenarios.
- Typically, the CxA would prepare the test scripts. Testing of all systems and components supporting critical functions is directed, witnessed and verified by the CxA.

Medium Level of Rigor: This might be employed on facilities where confidence in systems operations and good documentation of baseline operations is necessary. The following might describe the Cx approach for this category:

- "Full" Cx activities might be somewhat reduced by:
    - Utilizing sampling. Where numerous but similar system components are present (for example, HVAC units), it may be desired to have the CxA witness testing of only a representative sampling, typically 20%, to verify operations and document baseline operating parameters. In such cases, the contractor during their checkout and test-readiness effort tests a larger sample (possibly 100%) using the same test scripts as the CxA. Only near identical equipment like air terminal boxes see significant sampling by both the CxA and contractor. However, for those systems whose failure represents unacceptable risks, a full 100% Cx may still be applicable.
    - Review/Evaluation of results. Rather than directing, witnessing and evaluating all testing, the CxA might review and evaluate tests conducted by others, such as a contractor.
- Delivery methods other than "Hands On, Discipline Specific" might be considered. Refer to Section G.

Low Level of Rigor: This might be employed on project types that are not particularly complex, or where the primary goal of Cx is documentation.

- Typically, in this approach, the CxA would not formulate test procedures or direct and/or witness testing, but would evaluate the results of the documents completed by the contractors, and would assemble the documentation provided by others into a Cx report.
- Owner-performed or contractor-performed Cx might be used as the Cx delivery method. Refer to Section G.

Determining the level of rigor, as well as the initial list of Cx process activities will lay the framework for defining the Cx scope expected of the CxA. It will also assist in determining the desired Cx delivery method (See Section G), and in production of an effective Request for Qualifications (RFQ) document. This information is then used by the CxA to develop their fee proposal. After the CxA is under contract, they will develop a preliminary Cx plan which confirms the scope and extent of Cx services (drawing review, pre-functional checklists, functional performance testing, deliverables, etc. for the specific equipment identified in the RFQ).

During the Pre-Design process the owner or the architect develops the "Owner's Project Requirements" (OPR) document which defines the owners' *intention* and expectation of the *design and operation of the building*. These requirements must be achieved and documented by the project team in order for the project to be successful. It is the responsibility of the CxA to review the OPR and to confirm that all building systems operate in conformance with the OPR.

The OPR is conceptual in nature and should be developed during the planning phase by the owner, their consultant, or the project architect. The OPR should be written in non-technical performance- based terms and concentrate on major project goals. The design team then utilizes the OPR to develop the "Basis of Design," (BOD) the primary document that translates the owner's needs into building components such as occupancy type, room size, population, air

quality, etc. The design team produces design documents based on the BOD. The CxA reviews the BOD and verifies that it conforms to the OPR.

The OPR and BOD should be available to the design and construction team, and updated during the construction process. At the pre-bid conference the design team should discuss both of these documents with the contractor. While it is true that many contractors will build according to project plans and expect change orders for any work not shown it is also true that some contractors will not suggest improvements prior to bidding. Some contractors, however, may make suggestions prior to bidding if they are informed of the actual intent of the structure. If given only the design and not the intent they cannot be expected to help improve the project without change orders.

The OPR and BOD should be presented again at the pre-construction conference, and there should be a discussion of the relationship between the two documents. The presentation of the OPR document at the pre-bid and pre-construction conferences should be used as a team building tool in defining a common goal, which is where the communication and team building skills of the CxA become very important.

The most basic inclusion in the OPR is the general description of the building type (prison, hospital, classroom, geriatric, office, etc.). Beyond the building type, details are stated such as the occupants' age groups, particular needs with regard to air quality, outside air volume, occupant load and pattern of occupancy. As an example, an OPR might describe an assembly area which will accommodate 100 persons for two hours and operate at maximum energy efficiency. The BOD could specify a variable air volume system integrated with occupancy sensors and special programming, and the actual design in the bid documents could specify components, air volumes, and the required control sequence. Cx would assure that the equipment has been supplied and installed correctly, the air volumes and control sequence are correct, and the overall system "works" at several occupancy levels.

Appendix IV begins with a summary of the elements that should be included in the OPR document followed by three OPR examples.

2. Design

The only new document created for the Cx process during design is the BOD, an example of which is included in Appendix V. The BOD describes the actual technical approach planned for the project as well as the actual design parameters to be used. It follows the OPR and must include all of the items defined in the OPR. The BOD is typically developed by the design engineer and is done in technical terms, whereas the OPR is done by the owner or project architect and is expressed in layman’s terms. See Section 1 - Pre-Design and Planning, above, for a description of the BOD as compared to the OPR.

The CxA can enhance quality during the design stage by reviewing the design documents, and this review should be coordinated with any review performed by the owner. Generally, reviews performed by the owner's design review group are limited to programmatic, code compliance and constructability issues. The Cx review performed by the CxA should determine, at a minimum, that the documents:

- Are consistent with the OPR and BOD
- Specify commissionable systems
- Include inspection and testing details
- Include verifiable equipment parameters
- Incorporate a format that supports testing and maintenance
- Fully describe the Cx process for bidders.

The CxA will review the contract documents during development and will generally offer comments and/or recommendations.

The review process does not transfer responsibility for the design, nor is it intended that the CxA "check" or "warrant" the design. Responsibility for design rests fully with the design professional. Design reviews should be used to provide an additional quality control feature that supports the design process.

The owner should monitor design reviews by the CxA and insure that the design team is made aware of any issues raised by the CxA. The owner should also insure that those issues are reviewed by the design team, and that a team consensus is reached. If a consensus cannot be reached on an issue, the owner should provide a decision/direction on the issue in consultation with the appropriate design professional.

The CxA will also review the contract documents to confirm that each piece of equipment or system is capable of being tested and has objective performance parameters that can be confirmed. For example, the CxA will confirm that pumps and other hydronic devices have test ports specified to allow flow measurement, maintenance access at air handling units or straight duct lengths where air flow measurements need to be taken.

Writing the Specifications

The CxA should develop the Cx specifications during the design stage. These specifications should be included in the appropriate division as determined by the Construction Specification Institute (CSI).

Sections of Division 1 that would be modified to include information about Cx include the following (actual numerical designations may vary slightly):

01011 – Summary of the Project
01030 – Alternates
01310 – Construction Progress Schedules
01330 – Submittal Procedures
01400 – Quality Requirements
01730 – Operation and Maintenance Data
01770 – Closeout Procedures

Division 15 sections include:

15000 – General Provisions/Testing and Balancing
15990 – Testing, Adjusting and Balancing

Division 16 sections include:

16000 – General Provisions

The Commissioning Plan

As the CxA is writing the specifications for Cx, the owner's original Cx procedure is developed into a semi-final Cx plan. This Cx plan extends the owner's original system-by-system Cx procedure and the CxA's preliminary Cx plan into a scope of work naming actual components, systems and procedures. Procedures are developed by the CxA for each of the systems to be commissioned. This interim plan is incorporated into the specifications to clearly define the

contractor's role in the process. After the bid is awarded and submittals are approved the CxA writes a final Cx plan that fully describes the Cx work (see step 4 below, "Early Construction."

The "Preliminary Commissioning Plan" is one of six documents that define the Cx process, starting with the OPR and ending with the Commissioning Report. Appendix II lists these guiding documents and their individual roles in the overall process.

3. Contractor Selection

Contractor selection is an important part of the Cx process, since the contractor must be a cooperative member of the project team if the team is to reach the goal of a quality building. The inspection and testing required by the CxA is either performed or assisted by contractor personnel, consuming time and money. These requirements also save contractor time and money, however, through reduced callbacks and early resolution of problems.

As the contractors bids/proposals are prepared, there will be questions about their role in Cx. These questions should be answered by the CxA either in writing or at a pre-bid conference, or both. Contractors may accept the process more readily if the CxA exhibits a positive, helpful, cooperative approach right from the start. This is a key aspect of independent third-party Cx as opposed to contractor or design team Cx. The CxA team leader should have above-average leadership and team building skills.

In addition to answering contractor questions, the CxA may need to answer questions for the design team. This is especially true if the project bids come in over the cost estimate. The CxA may be called upon to evaluate the operational ramifications from removal of equipment and systems from the project, as well as associated savings in Cx costs. Indeed, the CxA may be required to help defend the Cx process itself from elimination in view of a budget problem.

Most projects of a significant size ($5,000,000 or larger) follow a bid/proposal process similar to the following:

1. Distribution of the construction documents (plans and specifications),
2. Advertising for bids/proposals on state websites,
3. Conducting the prebid/preproposal conference/walk-through,
4. Issuing the first addendum - answers to questions from the prebid/preproposal conference,
5. Issuing subsequent addenda for questions submitted after the prebid/preproposal conference,
6. Collecting the sealed bids/proposals,
7. Opening the sealed bids/proposals,
8. Evaluating the bids/proposals with regard to budget,
9. Selecting deductive alternates according to the budget,
10. Reselecting if required by budget,
11. Awarding the project,
12. The contractor's submission of insurance and bond certificates, and
13. Issuing the notice to proceed.

Of these steps, the CxA will have some involvement in the following:

3. Conducting the prebid/preproposal conference/walk-through,
4. Issuing the first addendum - answers to questions from the prebid/preproposal conference,
5. Issuing subsequent addenda for questions submitted after the prebid/preproposal conference,
8. Evaluating the bids/proposals with regard to budget, and

9. Selecting deductive alternates according to the budget.

When the prebid/preproposal conference is organized, the CxA should be there to present a brief overview of the Cx process and answer specific questions posed by the contractors. The questions and answers that come out of this conference, including those related to Cx, should be recorded in the minutes and issued in writing to all bidders/proposers as an addendum. Answers to Cx questions should be provided by the CxA to the owner's PM, to be incorporated into an Addendum.

Subsequent addenda will answer questions posed to the owner and design team after the prebid/preproposal conference. They may or may not include Cx questions. All Cx questions posed by the contractor should be routed through the owner and then to the CxA to assure that each response is sent in an identical form to all contractors and all members of the design team. The CxA should review any addendum to confirm that revised drawings and/or specifications do not reduce the Cx requirements or capabilities. The CxA should stay aware of any changes in construction time as related to addenda. If there are significant changes in the project that will affect the time for CxA services, make sure there is adequate time added to the contractor's construction time in the addenda to allow for Cx.

Proposals to cut Cx because of cost should be met with resistance. It is wrong to compromise quality as a result of budget concerns. No matter what stays or goes, quality is mandatory.

4. Early Construction

The beginning of the construction process includes the following Cx-related activities:

- Preconstruction meeting
- Development of the construction schedule and schedule of values
- Submittal of equipment and materials
- Completion of the final Cx plan

During the early stages of construction, the CxA continues to answer questions for the contractor and verify that Cx is being integrated into the construction process. The best venue for this is the preconstruction meeting.

The first item of discussion is the schedule. Developing the schedule is actually two tasks: (1) getting Cx milestones placed on the construction schedule and (2) including contractor Cx activities in the schedule of values. The construction schedule and schedule of values are key documents that allow the owner to track the construction process. Having Cx included in these is a good way to confirm that the contractor is an active part of the Cx team.

The CxA works with the contractor, and if necessary the subcontractors, to discuss phasing and timing of Cx. This schedule gives the contractor an idea as to what Cx information has to be included in the contractor's overall schedule. The contractor is required to integrate the information into the overall schedule of the project. In this way all subcontractors are further notified as to the requirement for Cx.

When the schedules are submitted, copies are routed to the CxA for his review with regard to Cx milestones. The Cx milestones shown on the tentative schedule of Cx activities should be integrated into the overall schedule by the time the schedule is submitted for approval. Although it is true that this schedule may be revised many times before the bulk of the Cx activities are accomplished, these activities should be a part of the schedule from the start. As other milestones are revised, the Cx gets revised accordingly.

On some projects, state agencies may contract with a professional to manage the owner's daily on-site construction responsibilities. This work includes accepting and processing requests for information, change orders, evaluating weather conditions, and conducting construction meetings. As the project progresses, the CxA and the owner's manager need to coordinate their activities.

As the contractor makes equipment submittals to the design engineer, the manager routes copies of the approved submittals to the CxA for information only. The CxA doesn't approve submittals (that's the engineer's job) but the CxA does comment to the owner if there is anything in the submittals that appears seriously wrong. The CxA should make sure that any submittal requirements for items key to Cx are not left off contractor submittals.

Cx procedures include field verification and start-up and functional test descriptions. The CxA writes and assembles these procedures as part of the "commissioning plan" as equipment information is available from submittals. As the documents are completed, they should be submitted to the owner's manager and the designer for approval and to the contractor for scheduling. Meetings between the CxA and the contractor serve to further clarify the intent of the process and keep the contractor involved.

The final draft of the Cx plan is completed during the early stages of construction, after all equipment submittals have been approved, and before equipment has arrived on the site. It starts with the requirements on a system-by-system basis and provides more detail based on the actual design and the actual equipment ordered. The final Cx plan includes a description of how the different building systems are to interact and how they will be tested.

The Cx plan developed at this point should have detailed information on the support required from contractor personnel. Specifically, each field verification and test should be annotated to show the responsible sub-contractor. This document will be used by the general contractor's superintendent to schedule personnel to assist the CxA in testing and inspection (see Appendix II).

The ASHRAE Commissioning Guideline 0-1996 and the USDOE Model Commissioning Plan and Guide Specifications (Section II)[4] provide further information on the development of the Cx plan and how it fits into the planning and design process.

5. Field Verification

As the Cx plan is completed, equipment is ordered, and the building foundation and framing is beginning, the field verification phase of Cx begins. This phase lays the foundation for equipment start-up by confirming the equipment is installed to function in a safe and effective manner. In general, this includes verifying items such as:

- Equipment location according to plans and practical requirements (such as air handling units positioned to allow full access door openings for maintenance),
- Installation of instrumentation according to manufacturer's requirements (such as laminar flow for flow sensing devices) and according to engineering requirements (such as duct pressure sensors located 3/4 of the distance to the furthest point in a variable air volume duct system),
- Sloping of drain piping and pressure testing of piping systems as specified,
- Connections to power and other utilities, sheave and shaft alignments, and pipe and duct supports.

[4] "The HVAC Commissioning Process", Guideline 1-1996 (supersedes Guideline 1-1989), Approved June, 1996. American Society of Heating, Refrigerating and Air Conditions Engineers, Inc., Atlanta, Georgia.

The CxA provides Construction Checklists to construction personnel to carry out these inspections. These checklists incorporate manufacturer's requirements and basic items that would normally be done even without the Cx process and, therefore, should not take a great deal more time than the normal checkout procedure. As the contractor submits completed checklists, the CxA spot-checks the forms. If the checklists have not been completed accurately, shortcomings will come to light as the group attempts to begin functional performance tests (FPT's). If FPT's are cancelled and rescheduled, the contractor should be contractually held responsible for the cost of repeat testing (an important notice to be included in the specifications).

Examples of inspection activities are as follows:

Piping and HVAC Ductwork

- During construction, piping and ductwork should be inspected for correct installation and pressure tested.
- Items affecting maintenance, such as valve locations, damper access panels, plumbing cleanout access, sloped piping for drainage, should be verified during construction inspections.
- Domestic water and sanitary sewer piping testing is typically a code requirement and witnessed by the local "authority having jurisdiction." Pipe pressure testing is a contractor "quality assurance" requirement and should be witnessed by the owner's representative, the designer, or the CxA.
- Low-pressure (less than 3" static pressure water gage) ductwork need not be pressure tested. All ductwork should be inspected before insulation for correct joining and supports.
- Testing, adjusting, and balancing (TAB) of air and water systems have been preliminarily performed and ready for actual startup of the HVAC equipment. CxA to verify.

Air Handling Units and Other Major HVAC Equipment

- AHUs, make-up air units, rooftop heating/cooling units and similar equipment should be inspected for mechanical items such as case drains, filter sealing, maintenance access, general air tightness and vibration isolator supports.
- Control devices such as sensors and actuators are complete per the building automation system (BAS) points list and control diagrams, correctly located, and completely and soundly installed.
- All electrical wiring should be inspected for proper installation (in conduit), termination, grounding, and tested to confirm power and correct polarity (for motor rotation).
- HVAC piping should also be inspected for proper coil connections, drain pans and traps, control valve locations, balance valves, test ports, bypasses and maintenance isolation valves.
- Lubrication points for fan and motor bearings and movable supports should also be checked and mounting fasteners confirmed.

BAS Controls System

- The controls contractor should perform a complete point-to-point checkout of all control devices throughout the building. Checkout is used to confirm the Engineer's point list is installed as designed. CxA to verify. For laboratory and/or other critical environments as defined by the Owner, all input and output devices in the critical zones shall be calibrated to NIST traceable standard at the job site. Critical devices are defined in the contract documents in the I/O summaries or I/O list. Factory calibrations are not acceptable. This activity should be certified to have taken place prior to functional performance testing.

Electrical Systems

- During construction, nearly all major electrical components should have their basic electrical properties tested to ensure they are ready to be placed into service and energized. This testing is often specified to be performed in accordance with IEEE, NETA, or similar industry standards. Owner representative or CxA may monitor tests, but at a minimum the test results provided by the contractor or testing agency should be reviewed for accuracy and completeness.
- Generators, UPS, Switchgear, panel boards, etc., are to be inspected for proper connection and grounding.
- Authorized testing companies should certify building grounding and lightning protection systems.

Fire Protection and Life Safety Systems

- Fire Service water line piping is to be flushed and tested; NFPA certificate is required.
- Above ground fire protection piping is to be flushed and hydrostatically tested (preferably per floor). Witness is normally by local fire officials; NFPA certificate is required.
- Smoke and heat detector sensors installation at air moving equipment is to be verified and checked for proper installation.

6. Start-up (Functional Verification)

Equipment is started up for the first time with required factory representatives in attendance. The equipment is tested at all required speeds and preliminary programming is completed as required to allow subsequent safe and easy starting. On most projects, the main issues that arise during equipment start-up are related to control software for the temperature control system. It is recommended that the contractor be required to provide a detailed start-up plan to the project team for review. The plan should outline what equipment will be started up and when, as well as how the equipment will be protected from damage during start-up.

7. Functional Performance Testing

After equipment has been proven at start-up, functional performance tests (FPTs) are conducted to confirm that the components work together to function correctly as a system and that the various building systems function together as intended. The latter is sometimes called "Integrated Systems Testing" (IST) and is accomplished after the individual system tests have been satisfactorily completed. Examples of FPTs include;

- Tests to confirm that duct smoke detection causes AHUs to shut down and dampers to go into smoke control modes. Other tests assure that valves open on calls for heating and cooling and close when the set point is satisfied.
- IST testing to confirm that a smoke control system functions per design by confirming that fire alarm and detection properly interfaces with HVAC and BAS systems to initiate the intended smoke control functions (AHU and damper operation, smoke door closure, and occupant notification, for example) under manual (fireman's smoke control station operation) and automatic operation, even under emergency power situations.
- Tests to assure that AHU economizer cycles respond to outdoor air temperatures and indoor calls for cooling and that freeze protection actually shuts down the required equipment. AHU discharge temperature control is checked at the unit and also at the central energy management and control (BAS) control station.
- Dampers should be cycled and checked for leakage, especially face and bypass dampers on steam coils. All actuators should be stroked full open and full closed to check for binding, calibration and correct BAS addressing.

Functional tests include verifying BAS parameters such as programmed addresses, sensor calibration factors, occupied/unoccupied programming and trend logging. Programming charts, sequences of operation, block wiring diagrams and wiring termination diagrams should be included in the report. All BAS tuning variables such as response times, damping variables, delays and interlocks should be included in the report.

Laboratory and other critical facilities as defined by the owner will have the control input and output points loop calibrated. Inputs will be simulated with signal generators (4-20mA, 0-10vDC, etc.) and values reported on the central station console and checked against published loop calibration tolerances of the manufacturer. Outputs will be loop calibrated so that when the system calls for an output device to be at the 50% open position, the device is physically checked to be in that position. 10% open and 90% open are also checked in addition to full open and full closed. Variable speed drives will also be checked in this manner.

A sample of items included in the subcontractor's TAB report should be checked for accuracy. If a substantial failure rate is encountered, all should be corrected and a different sample chosen for a repeat test at the contractor's expense. Good practice suggests starting with checking 20% of air distribution terminal devices such as grilles and registers. Check all TAB parameters on AHUs and associated return/exhaust fans. On critical facilities such as laboratories, clean rooms and data centers, the owner may want to check 100% of the TAB readings. If the CxA has the capacity to perform the TAB with his own forces, the owner may elect to have the TAB performed by the CxA.

Electrical systems should also be included in the functional testing process. Depending upon the level of criticality of the facility, this may include all major pieces of equipment for both the normal distribution and emergency systems, as well as communication, lighting control, security/access control and surveillance systems. As a minimum, it is recommended that service entrance equipment, as well as emergency and standby systems be commissioned, as they are very important to the day to day operation of the facility, or back up critical loads and may affect operation of life safety systems. Frequently, testing of electrical equipment (transformers, panel and switch boards, etc.) is managed, executed and documented by a certified testing company hired by either the contractor or the CxA. The CxA spot witnesses testing and reviews completed test reports.

The functional performance tests are the heart of the Cx process and they are also the most difficult and time-consuming. This is when the team-building skills of the CxA pay off. If the CxA has succeeded in gaining the trust of the contractors by this time, the chances of completing the FPTs in a timely manner will be markedly increased. The best method of earning and keeping a good working relationship with contractors is constant communication. As the FPTs proceed, the CxA should constantly keep the contractors informed as to upcoming testing.

As field verification and testing proceed, the CxA will find a number of items that do not appear to work as intended. In some instances the intended operation is unclear. If the intended operation is unclear, the CxA should submit a "Request for Information" (RFI) to the design team through the owner's manager in the same manner that a contractor would submit an RFI. After confirming the intended mode of operation, the CxA can proceed with testing.

If equipment or systems are found to be malfunctioning, these problems should be listed on a deficiency form or listing. This form indicates the test and item involved and also tracks the status of the problem as it is corrected. System troubleshooting is a critical function of the CxA. The cost of troubleshooting is difficult to define depending on the quality and experience of the installing tradesmen, the subcontractors and the vendors. There will be a certain amount of retesting that will be performed by the CxA because of system and equipment failures during the initial testing. It is good practice to allow some time for retesting in the budgeting process because some equipment will always fail. The amount of retesting paid for by the owner and the

amount passed back to the contractor should be very clearly spelled out in the construction contract.

8. O&M Staff Training and Documentation

A properly designed and constructed building cannot function properly without an adequately trained operations and maintenance (O&M) staff. Unfortunately, O&M training is a traditional shortcoming on most construction projects. Problems with O&M training include unqualified trainers, insufficient training time, incomplete O&M manuals and record drawings, or even no O&M staff to train on new facilities. Training is often conducted before systems are fully functional (before the completion of performance verification testing), or focuses on discrete systems but fails to address the interoperability of modern building systems. Building users also tend to send the wrong personnel to training sessions, or miss scheduled training sessions entirely. The end result of these errors is an ill-prepared, overwhelmed O&M staff, and building problems from "day one."

The CxA's in-depth knowledge of the design intent and building systems makes him an ideal candidate to assist in O&M training. The following is a list of areas where the CxA can make a significant impact on O&M training:

- *Recommend the necessary O&M staffing (total personnel, qualifications, and required shifts) to satisfy the owner's operational intent*. Early identification of the O&M staffing requirements is absolutely necessary for new buildings, since customers often need a long lead time to hire additional in-house maintenance personnel, or to out-source their O&M staffing to a private service provider. Unfortunately, building users are often ill-prepared to develop their own O&M staffing requirements. A popular misperception is that modern building automation systems and equipment reduce O&M staffing requirements. Nothing could be further from the truth. Properly functioning building systems are more energy efficient, and provide greater user comfort, but they are also complex systems that require greater operator skills and involvement than similar buildings from even 10 years ago. The CxA is well suited to provide a recommended O&M staffing plan as early as the design phase of the project.
- *Develop a facility preventative maintenance plan.* This task is directly tied to the development of the O&M staffing. The CxA can develop a facility preventative maintenance plan that best utilizes the O&M staffing and ensures systems are properly maintained and are running at peak efficiency.
- *Review facility record drawings.* The accuracy of facility records can be verified during functional and performance verification testing.
- *Prepare framed instructions showing the sequence of operations and interoperability for major systems/components.* Framed instructions displayed beside major equipment items (chillers, boilers, air handling units, HV units, emergency generators, etc.) can be a major aid for training, routine preventative maintenance, and equipment trouble-shooting.
- *Develop master equipment lists for the transfer of real property to the customer.*
- *Document warranty coverage and warranty procedures (both standard warranties and any extended manufacturer's warranties).* Most standard warranties provide one-year of coverage for major equipment items from the date of installation. This warranty date may be weeks or months before building turnover to the customer. In some instances, manufacturers will offer equipment warranties beyond the standard one-year period, while others may include limited services during the warranty period. This type of information is usually found in either the equipment documentation or in the O&M manuals. The CxA can research the appropriate documentation and prepare a consolidated warranty list for the customer.
- *Prepare a recommended list of spare parts, bench stock, overbuy, and special tools/equipment required for the first year of building operation.*

- *Review O&M manuals.* O&M training should never be performed without the benefit of completed O&M manuals. Regrettably, O&M manuals are often incomplete or are completed after the scheduled O&M training. The CxA can provide quality assurance by reviewing the O&M manuals for completeness, accuracy, and timeliness.
- *Coordinate and supervise contractor and subcontractor O&M training (using the system's O&M manuals and framed instructions).* The contractor should generally schedule all O&M training, but the CxA can coordinate and supervise the training to ensure the training meets the user's needs.

O&M training is not a traditional task for CxA's, but it is one for which they are well suited. The contractor (with oversight by customer) traditionally provides the services shown above, or the customer performs these tasks himself. Unfortunately, many customers are not staffed to manage these activities. Customers desiring the CxA's assistance with O&M training will have to include specific O&M training tasks in their Cx Request for Proposal (RFP).

Digital recording (if used) should be performed by the CxA, or a professional working under the direction of the CxA. Many larger colleges and universities have communications courses dealing with video production and can provide an acceptable level of expertise at less cost than professionals. If the campus wants to provide these services, they need to provide a cost to the CxA for inclusion in the proposal. Agencies should know, however, that General Obligation Bond funds cannot be used to reimburse the agency of salary costs of its personnel. As a general rule, it pays to use professional camera operators when recording. Good sound is as important as a good picture. Remember to turn off air compressors and other devices which can render instructions inaudible. Professional digital recording costs about $400 to $600/day. Organize recordings by system and/or building.

The Engineer's System Operation Narrative

A brief presentation by the design engineer to the operations staff that includes a description of the intended overall operation of the system should be scheduled. This is a time for the staff to ask the questions that remain after the construction. This team process often acquaints the design team with facets of the system operation that they were not aware of as well.

The result is a comprehensive "as-built" description of the system. This should be recorded and transcribed to hard copy for inclusion in the O&M manual, the Cx report, or both.

The Commissioning Report

By the completion of training or shortly thereafter, the CxA should have completed the "Commissioning Report." The report is a collection of all that has gone on before. As such it contains copies of the following:

1. Owners Project Requirements (OPR)
2. Basis of design (BOD)
3. Construction checklists complete
4. Functional Performance Tests
5. TAB reports
6. System schematics
7. Control strategies and set points
8. Deficiency log
9. Guidelines for energy accounting.
10. Electrical systems acceptance testing reports

The Cx report, the TAB report, the O&M manuals and the record drawings and specifications form the bulk of the documentation that will be left with the O&M staff at the new building.

Additional information on building controls that includes block wiring diagrams, as-built control diagrams, and sequences of operation will also be included in either the Cx report or the O&M manual. All documentation should be provided in electronic format and hard copy.

9. Warranty Review and Seasonal Testing

The First Year of Building Operation

At the completion of training and all other work required in the contract documents, the building is occupied. There should be a specific notice in the specifications indicating to the contractor that the successful completion of Cx is a requirement for the issuance of the architect's final certificate.

Additional outstanding items are usually identified during the early months of occupancy, before final completion. Other items may come up during the one-year warranty period. But if the CxA process has been followed, they are minor and can be readily handled by the O&M staff armed with documentation and training.

Overall, the commissioned building will provide the optimal working environment required for the occupants, allowing the O&M staff to concentrate on establishing an effective preventative maintenance program that should work for the life of the building.

- Seasonal Testing

  Given weather extremes, it is likely that certain parts of the building mechanical system cannot be adequately tested due to the season of the completion. For instance, testing of a boiler system might be difficult in the summer, and testing of a chiller and cooling tower might be difficult in the winter. Checking an outside air percentage is much easier when there is a substantial difference in temperature between the outside air and the return air.

  For this reason, Cx plans should include off-season testing to allow testing certain equipment under the best possible conditions. This requirement must be clearly spelled out in the specifications as it will require some contractor personnel to return to the site after the project is completed. It is also necessary to withhold money for this activity in addition to that usually withheld for warranty items.

  It is also recommended to have the systems tested during the shoulder seasons (spring/fall). Items to look for include proper dehumidification sequences and part load performance of mechanical systems.

- EMCS Trend-logging

  During the completion of functional performance testing, the CxA is also asked to assist in the programming of the EMCS to include the trend-logging of a selected group of key performance indicators. These indicators usually include temperatures and pressures for boiler and chiller operations, duct pressures, air flows, variable air volume (VAV) boxes operating parameters and unitary equipment performance parameters. Trend-logging is also a valuable part of the training program, allowing the operating staff to start on the right foot and thus insuring that various systems' performance is maintained over the building's life. Some designers may require that temporary flow monitoring equipment be installed to verify system operation. The owner agency should consider making the flow monitoring equipment a permanent part of the project so the O&M staff can continue to use the instrumentation.

- Continuing the CxA Contact

  As noted in previous sections, the CxA is involved throughout the project and has gained valuable systems design, construction, and operations knowledge. At project completion, the CxA will have a better understanding of the building's systems and their interaction than even the installing contractors. The CxA's contract should provide the agency with the ability to contact the CxA for occasional, informal consultations throughout the warranty period or approximately the first year of building operation. This type of contact should normally amount to phone conversations. If complicated problems are encountered that involve conflicting opinions between the owner, designer, and contractor, or that relate to specific issues identified during Cx, an additional services contract with the CxA may be appropriate. Expecting the CxA to provide extensive services that were not identified in the original contract without compensation is not reasonable.

  If the Owner is concerned about the O&M staff's ability to operate the building during the first year of occupancy, periodic training sessions could be attended by the CxA who at this time consults with the staff about trend-log results and other emerging issues. The off-season testing would also be coordinated with one of these site visits.

10. Measurement and Verification (M&V)

When a primary goal of the project has been to meet aggressive energy goals, the owner may elect to have the CxA include M&V in their scope of work. Lawrence Berkeley National Laboratories defines M&V as “the process of using measurement to reliably determine actual savings created within an individual facility by an energy management, energy conservation or energy efficiency project or program. As savings cannot be directly measured, the savings can be determined by comparing measured use before and after implementation of a project, making appropriate adjustments for changes in conditions.”

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