Incorporating a Method of Verifying Performance into California's Nonresidential Energy Standards

Tav Commins, California Energy Commission
Jeff Johnson, New Buildings Institute
Amanda Potter, Portland Energy Conservation, Inc.

ABSTRACT

California has one of the most stringent energy codes for commercial buildings in the United States. Yet studies have shown that equipment required by code is sometimes not installed and often installed but not functioning properly to deliver projected energy savings. To address this issue, the California Energy Commission proposed to incorporate acceptance requirements for the most problematic pieces of equipment into the 2005 revision of the California Energy Efficiency Standards for Nonresidential Buildings (the Standards). "Acceptance requirements" refers to a set of inspection checks, functional tests and performance tests applied to specific building components (pieces of equipment, systems, and interfaces between systems) for the purpose of assessing how well or if the components conform to the criteria set forth in the building's construction contract documents (its plans or specifications) or the Standards. The selected equipment includes ductwork, packaged HVAC units, lighting controls, economizers, and the outdoor air portion of variable air volume systems.

This paper details the research and conclusions of the project on how acceptance requirements will be incorporated into the Standards. Other topics include how acceptance requirements differ from commissioning, how the requirements will be incorporated into the existing code compliance process, and the organizations who will have the authority to conduct the acceptance requirements testing.. The paper concludes by looking toward next steps in the drafting and implementation of the revised Standards.

Introduction

California has one of the most stringent energy codes for commercial buildings in the United States. Yet more often than not, equipment required by the code does not function properly. A study of 60 commercial buildings in Oregon found that more than half suffered from control problems, 40% had problems with HVAC equipment and one-third had malfunctioning sensors. Fifteen percent of the buildings were missing specified equipment and 25% had malfunctioning energy management control systems (EMCS), economizers, and/or variable speed drives (PECI 1997).

To bridge this gap between design intent and actual building performance, the California Energy Commission (CEC) decided to incorporate "acceptance requirements" into the 2005 Standards. California is not the first state to incorporate acceptance requirements into its energy code. Massachusetts and Washington have language in their energy codes that allows for "acceptance requirements" or "commissioning." However, California's Standards are the first to specifically state testing requirements for specific equipment and require the owners agent to certify the test results, differences expected to give the Standards more enforcement strength.

The CEC has taken on this project with two goals in mind: 1) Identifying specific approaches within the Standards to provide building owners with reliable building performance; and 2) Developing alternative implementation approaches to ensure that the method of verifying acceptance requirements is compatible with the scope of the regulatory process.

Acceptance Requirements Defined

The term "acceptance requirements," as used in the Standards and in this paper, refers to a set of inspection checks during both the design and construction phases of a project and performance tests applied to specific building components (pieces of equipment, systems, and interfaces between systems) for the purpose of assessing if the components conform to the criteria set forth in the building's construction contract documents (i.e. plans and specifications) or the Standards.

It is important to note that the presence of acceptance requirements in a state's building code does not take the place of building commissioning. The reason for this confusion is simple enough. Acceptance requirements are in fact one aspect of commissioning. They are a necessary part of the commissioning process but certainly not sufficient in and of themselves. Commissioning refers to a much broader practice that, ideally, touches every stage of a new building, from conception to occupancy. At a minimum, commissioning includes: verifying design intent during the design development phase of a project; verifying the performance of equipment through inspection checks and performance testing; and documenting the building's systems and O&M training for building operators and managers.

Project History: Phase I

The project has two phases due to funding requirements from the U.S. Department of Energy. Phase I began in the summer of 2000 and was completed in the spring of 2001. Phase II began in the summer of 2001 and is still under way.

In the first task of Phase I, a feasibility study (CEC 2000) established initial recommendations on which systems should have acceptance requirements and suggested which testing protocols should be followed. Various studies (PECI 1996 and 1997, RLW Analytics 1999 and 2000, Pacific Consulting 2000, and Yoder and Kaplan 1994) provided an understanding of the energy characteristics of new buildings and helped prioritize compliance measures. Twenty-two of the most common equipment types and energy features in new buildings were evaluated according to their opportunity for energy savings, cost (of testing and correcting common deficiencies), impact on comfort, and persistence.

The next step was to determine the field protocols required of each system or piece of equipment. Finally, a survey of verification methods yielded a short list of nine essential testing requirements deemed to capture the majority of deficiencies in system performance. They include:

- Verification of thermostat/sensor/actuator calibration

- Verification of sequence of operation, interlocks, setpoints and schedule
- Verification of setpoint hold, no simultaneous heating/cooling, cycling or hunting by monitoring
- Verification that installed capacity is within 20% of design
- Verification that installed efficiency is within 20% of design
- Verification of low-load modulation and part-load performance
- Verification of connected load
- Verification of min/max air or water flow and leakage rate
- Verification of refrigerant system charge and operation

The project team determined which requirements applied to each of the twenty-two systems. As a result of the evaluations performed in Phase I, the following systems were given high priority as candidates for acceptance requirements:

- Building Automation System
- Variable Air Volume System/Variable Frequency Drive Fan
- Chiller and Cooling Tower System
- Ductwork
- Packaged units
- Lighting Controls
- Economizers

Deciding how to incorporate acceptance requirements into the Standards was perhaps the most difficult and controversial part of the project. In the second task of Phase I, interviews with 29 industry stakeholders including building officials, contractors, engineers, and owners led to important conclusions that are part of the final recommendations to the CEC. They include:

- A preference for specifying system performance requirements but not testing procedures;
- The inclusion of physical testing as part of acceptance requirements;
- An emphasis on building automation systems, variable air volume systems/variable frequency drive fans, ductwork, and economizers as the most important systems to test;
- The ability to adapt requirements to the size and complexity of the building;
- The use of a third party to verify results;
- The requirement that design intent, design assumptions and control sequences be documented in order to obtain a building permit; and
- Tying successful fulfillment of acceptance requirements to the building permit and/or final occupancy permit.

The third task in Phase I included research on the existing code enforcement process in California and in other parts of the country, along with the results of tasks 1 and 2, were used to finalize recommendations to the CEC. The final report includes: summaries of California's building and occupancy permit processes; final recommendations and their key reasons for support, concerns, ideas for implementation and remaining questions; and two models for certifying a third party verification specialist. At the culmination of Phase I, a public review workshop was held where the conclusions were presented to the attendees for feedback. The workshop was successful and set the stage for future collaboration in developing acceptance requirements.

Project History: Phase II

Phase II has been underway since the summer of 2001. The project will conclude in the fall of 2002 when a final draft of the code language and a process for implementing the acceptance requirements are delivered to the CEC. The following sections will discuss these topics in greater detail.

Acceptance Requirements

Acceptance requirements were developed for the following systems:

- Outside air ventilation for variable air volume systems;
- Economizers;
- Lighting controls;
- Packaged HVAC systems; and
- Duct leakage.

The acceptance requirements are based on verifying specific requirements within the Standards and do not necessarily reflect a "best practice" for system design and operation

The owners agent (as defined by the California Business and Professions Code) will perform and certify the acceptance requirements on each piece of the above listed systems during three phases in the construction process. These phases are:

- Design phase;
- After equipment installation; and
- Equipment start-up.

Design phase. The acceptance requirements for each piece of equipment will include requirements for the type of information that must be included in the design documents. The owners agent will be looking over the design documents and making sure that all the design requirements are properly documented.

After equipment installation. The owners agent makes sure that the equipment is properly installed.

Equipment start-up. The owners agent performs the required tests once the building is completed. The owners agent documents the satisfactory completion of each test, the adequacy of operations and maintenance materials, and signs a "Certificate of Acceptance" prior to the issuance of a final occupancy permit.

Daylighting Controls Example

Several lighting controls strategies are identified in the Standards, some that are mandatory and others that are available for compliance credits. Acceptance requirements were developed for the following control strategies: manual daylighting controls; automatic daylighting controls; occupancy sensors; and automatic time-switch control. Daylighting controls are receiving increasing attention as the benefits of daylighting are being documented (HMG 2002).

Approximately 12% of recently constructed nonresidential buildings incorporate some kind of automatic daylighting controls, with step switching controls (as opposed to continuous dimming) accounting for 90%–95% of daylighting control installations (RLW 2000). Studies report persistent problems with daylighting controls operation and reliability, especially for small, side lit spaces with windows. Figure 1 shows how these controls can get out of calibration, become disabled or malfunction.

Figure 1. The Operating Problems for Daylighting Controls, as Reported by Different Professions that were Interviewed

Question	3. Operating Problems								
Profession	don't maint proper light	don't achieve opt'm savings	cause lamp or ballast failure	switch too frequently	callibr'n or maint difficult	irritate occup'ts	occup'ts disabled	reason for failure unknown	other
Architects	33%	33%	33%	0%	33%	67%	67%	0%	67%
Contractors	50%	0%	50%	0%	0%	0%	0%	0%	50%
Controls manuf	50%	38%	25%	0%	50%	75%	86%	25%	50%
Engineers	60%	67%	0%	0%	40%	20%	17%	17%	17%
Facility manager	33%	33%	33%	17%	33%	33%	17%	17%	33%
Lighting Rep	57%	14%	29%	43%	33%	33%	33%	0%	71%
Lighting designer	0%	20%	20%	0%	80%	40%	60%	0%	80%
Researcher	50%	50%	25%	25%	75%	75%	67%	25%	50%
Utility	43%	86%	0%	14%	29%	57%	14%	14%	43%
	42%	38%	24%	11%	42%	44%	40%	11%	51%

(HMG 2000)

Since these controls receive a credit in the Standards (you can increase your lighting power or reduce system efficiency), it is important that these controls deliver savings. The cost of assuring these devices perform must be included in the overall cost of the measure before an owner decides to pursue daylighting controls for credit.
The automatic daylighting control requirements listed below are an example of the style and rigor being proposed in the Standards.

Design Documentation

When automatic daylight controls are used as a compliance credit in lieu of the manual controls the following design issues should be checked for compliance prior to issuing a building permit. Check to see that the circuiting and switching of all light fixtures within the daylit area are correctly designed to achieve the desired control; and all automatic control devices (photosensors) are located on the drawings according to manufacturers specifications to achieve the desired control.

Construction Practices

Prior to testing, the acceptance requirements include verifying and documenting the following: all dimming ballasts meet power reduction and operating requirements as stipulated in the Standards, including "reduced flicker operation"; a time delay or switching dead band value of 3 minutes, per the Standards, is programmed into the stepped dimming and stepped switching daylight control system, respectively, to prevent short cycling; all daylight control systems provide a visual or audible signal to indicate device failure; and all control devices (photocells) have been calibrated for appropriate set points and threshold light levels, per manufacturer's recommendations.

Equipment Start-Up

During testing, the system is assessed under various operating conditions and system response is verified and documented. For example bright and dark ambient conditions will be simulated and the system responses that we are verifying in order to demonstrate compliance for each system type are outlined below.

- **Automatic dimming – bright conditions.** Lighting power reduction is at least 50% under fully dimmed conditions; amount of light delivered to the space decreases uniformly; and the dimming ballasts provide reduced flicker operation over the entire operating range, defined as "the operation of a light, in which the light has a visual flicker less than 30% for frequency and modulation" per the Standards.
- **Automatic dimming – dark conditions.** The amount of light delivered to the space increases uniformly to meet desired light level setpoint; and the dimming ballasts provide reduced flicker operation over the entire operating range, defined as "the operation of a light, in which the light has a visual flicker less than 30% for frequency and modulation" per the Standards.
- **Stepped dimming – bright conditions.** Lighting power reduction is at least 50% under fully dimmed conditions; amount of light delivered to the space decreases per manufacturer's specifications for power level verses light level; the dimming ballasts provide reduced flicker operation over the entire operating range, defined as "the operation of a light, in which the light has a visual flicker less than 30% for frequency and modulation" per the Standards; and the minimum time delay between step changes is 3 minutes to prevent short cycling.
- **Stepped dimming – dark conditions.** The amount of light delivered to the space increases per manufacturer's specifications for power level verses light level to meet desired light level setpoint; the dimming ballasts provide reduced flicker operation over the entire operating range, defined as "the operation of a light, in which the light has a visual flicker less than 30% for frequency and modulation" per the Standards; and the minimum time delay between step changes is 3 minutes to prevent short cycling.
- **Stepped switching – bright conditions.** Lighting power reduction is at least 50% under fully dimmed conditions; amount of light delivered to the space decreases per manufacturer's specifications for power level verses light level; and adequate dead band between switching thresholds to prevent short cycling.

- **Stepped switching – dark conditions.** The amount of light delivered to the space increases per manufacturer's specifications for power level verses light level; and adequate dead band between switching thresholds to prevent short cycling.
- **All systems – failure condition.** visual or audible device indicates system problem.

Certificate of Acceptance

The owners agent is responsible for documenting the results of the acceptance requirement procedures including paper and electronic copies of all measurement and monitoring results. They are also responsible for performing data analysis, calculation of performance indices and crosschecking results with the requirements of the Standard. Once the testing process is complete, the owners agent is responsible for issuing a Certificate of Acceptance. Building departments will only release a final Certificate of Occupancy when a Certificate of Acceptance is submitted that demonstrates that the specified systems and equipment have been shown to be performing in accordance with the Standards.

Potential Owners Agents to Provide Acceptance Testing

Groups or individuals that are involved in the building construction industry and that potentially have the skills and experience to complete the Certificate of Acceptance include:

- Commissioning Agents
- Mechanical and electrical engineers
- Mechanical and electrical contractors
- Test and balance contractors

Organizations within each of these four groups likely have individuals knowledgeable of the fundamentals of acceptance testing at least in some categories of systems and equipment. Combinations of these four organizations are also likely to be a part of every construction project.

The potential roles, responsibilities and qualifications of each of the four groups are discussed below.

Of all four groups, the experienced *commissioning agent* may be the most qualified to undertake the acceptance testing duties. The commissioning agent is likely an engineer with in depth knowledge of building systems and equipment. They also likely have access to high quality measurement and monitoring instruments and are adept at data analysis and calculation of performance indices.

The drawback with this group is that there are a limited number of qualified commissioning agents available in California. It would not be possible to provide adequate acceptance testing coverage to the new construction marketplace by using only commissioning service providers.

Mechanical and electrical engineers have the in depth knowledge in their respective fields of the systems and equipment that require acceptance testing. They have the ability to undertake data analysis and calculate performance indices. They may not have the hands-on field experience to undertake measurement and monitoring. They also may not have access to high quality measurement and monitoring instruments.

As a stand-alone business, acceptance testing would likely underutilize the mechanical or electrical engineer's skills and experience. It could be an adjunct to their engineering practice.

Mechanical and electrical contractors including sub-categories of piping, sheet metal, controls, lighting contractors and so forth are typically responsible for system and equipment fabrication, installation and start-up. They may be responsible for test and balance work on smaller projects. They could have engineers on staff with similar qualifications to mechanical and electrical consultant firms. The mechanical and electrical contractors are less likely to have experience with measurement, monitoring, data analysis and calculation of performance indices.

Test and balance (TAB) contractors are usually present on larger and more sophisticated construction projects. They may not be present on the smaller projects where the mechanical and electrical contractors are more likely to provide TAB services. Their responsibilities are to test, adjust and balance air and water delivery systems to assure that the design intent is being met. They may do acceptance testing where it is required on projects. Data analysis and the calculation of performance indices are not necessarily a part of the regular services that they provide.

Test and balance contractors have national certification organizations. These are the Associated Air Balance Council (AABC) and the National Environmental Balancing Bureau (NEBB). These two organizations put forth qualification criteria for certification and test individuals to assure that they are qualified. Membership in organizations such as these or certification is not necessarily a requirement for test and balance contractors in California.

Next Steps

Several project goals remain on the drawing board. Acceptance requirements for building automation systems, variable air volume systems/variable frequency drive fans, and chiller and cooling tower systems should be incorporated into later code revisions. Administrative procedures need to be established to ease the process of verifying acceptance requirements. On the agenda are training programs, educational workshops for the building industry, and a written manual on testing requirements and recommended procedures, including official submission forms. A program to provide incentive funding for building owners who adopt the acceptance requirements before they become code will be investigated further.

Conclusions

The project to revise California's nonresidential energy standards raises important issues with relevance to any effort to incorporate acceptance requirements into code. First, the difference between acceptance requirements and building commissioning must be made clear to the building industry. Acceptance requirements should support the development of a commissioning industry that understands and advocates for a thorough, holistic commissioning process. Second, the needs of building owners must be carefully considered. Requirements must be kept manageable for owners, contractors, designers and building officials, while still delivering energy savings and guaranteeing building performance. The requirements should also provide demonstrable non-energy benefits to owners, and owners should be made aware of these benefits. Finally, this approach to demonstrating compliance with the Standards must overcome political obstacles in order to be incorporated into the Standards. In the mean time, it is a well-researched approach to demonstrating compliance with voluntary programs such as utility new construction programs and could gain valuable experience if used in conjunction with those programs.

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