Training for Retrocommissioning: How Do You Teach Experience?

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ABSTRACT

The commissioning of existing buildings—retrocommissioning—is a systematic investigation of the current performance of a building's systems, and their ability to meet the owner's operating requirements. There are several guidelines that describe the process, including detailed descriptions of the tasks undertaken in the investigation, implementation, and hand-off phases, as well as outlines of the typical deliverables. At the heart of retrocommissioning is a systematic search for indicators of improvement opportunities, trending of equipment performance to identify potential problem areas, and rigorous functional testing of equipment to identify root causes of performance deficiencies. This requires a significant amount of judgment, usually based on previous experience with designing, operating, and troubleshooting buildings.

In California, all the major utilities are planning to undertake sizable retrocommissioning programs, and currently there are too few qualified providers to staff these activities. Training programs must be defined—quickly—to meet the demand of these upcoming programs. Given that retrocommissioning requires significant experience and field judgment, how will this training be provided?

This paper discusses the results of a survey of commissioning providers, owners, and contractors, to determine gaps in available training topics. It goes on to describe the need for training also in terms of audience, learning mode, scope and business model. These factors are used to describe several training activities that are currently underway and proposed. The plans of a state-wide commissioning industry collaborative to fill the gaps in available training are also presented.

Introduction

When a new building is commissioned, it undergoes an intensive quality assurance process that begins during design and continues through construction, occupancy, and operations. Commissioning ensures that the new building operates as the owner intended and that building staff are prepared to operate and maintain its systems and equipment. Commissioning can also be performed on existing buildings. This type of commissioning, known as retrocommissioning,[1] identifies operations and maintenance (O&M) measures that improve the building's operations, comfort and overall performance. Retrocommissioning is an excellent way

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[1] Retrocommissioning can also involve the commissioning of retrofits that are made to an existing building. It is quite similar to new construction commissioning, in that it includes the steps of identifying retrofit intent, reviewing design and specifications, observing installation, testing performance, and ensuring training and documentation are provided.

to improve the performance of an existing building—it should always be considered alongside any other whole-building energy efficiency measure.

Retrocommissioning is a different type of energy efficiency measure, however. When auditing a building, it is easy to identify the need for a lighting retrofit. And, when a light fixture is replaced, it is fairly easy to project what the impact will be, and then to estimate what the impact was. Retrocommissioning is a much broader collection of interventions and is much more difficult to define, scope, prepare for, conduct, and measure. In California, there have been many programs to support retrofits, and utilities and policymakers are becoming increasingly aware of the untapped resource available through retrocommissioning. Between 2006 and 2008, all of the investor-owned utilities are supporting large retrocommissioning programs. The State of California has issued a "Green Building Action Plan," which requires larger state buildings to be retrocommissioned initially, and then to be *re*commissioned every five years. It also requires large state buildings to achieve a LEED®-EB rating, which requires retrocommissioning. The California Commissioning Collaborative (CCC), a non-profit organization convened by a collection of stakeholders in the commissioning industry, has undertaken the task of further defining the processes of retrocommissioning and filling the gaps in the retrocommissioning infrastructure (Duhon and Welker, 2004).

Retrocommissioning requires a solid knowledge of HVAC fundamentals and control system operations, as well as field experience, a "forensic personality," an eye for detail and organization, a willingness to document everything, and well-developed people skills. In today's market, trained retrocommissioning providers (CxPs) are scarce. This is partly because it is a relatively new domain. But it is also because it is a difficult skill to train. The essential attributes of CxPs are the intuition to hone in on the most significant improvement opportunities and the judgment to identify the underlying causes of what is observed. These attributes are really only developed by having experience working in buildings. However, even those who have a depth of in-building experience do not always have the fundamental knowledge, the people skills, or the interest in documentation. While it is conceptually attractive for in-house personnel to lead retrocommissioning projects, the in-house providers will have to be well-qualified initially, and will have to obtain the specific skills needed for retrocommissioning (in addition to having time available to focus on the task—something rare among building operators). Does this mean that there is no way to train new people for this industry, or to prepare more experienced people to switch to this industry? We hope not. The authors have been involved in a number of different types of training activities, and have developed some insight into what is working and what is not. They have also been involved in CCC activities to develop strategies for improving training opportunities in California.

This paper describes some the insights of the authors from their experiences and from the findings in PECI's *Commissioning Training Strategy Report* (PECI 2005). It begins by outlining some of the most important issues to be addressed by training, and then describes a number of past, current, and in-development trainings in context of these issues.

Identifying the Need for Training

The CCC has made training one of its highest priorities, and engaged one of the authors to conduct a study to develop a strategy for approaching training needs. The CCC and the U.S.

Department of Energy's Federal Energy Management Program (DOE/FEMP) sponsored the drafting of two Training Strategy Reports (PECI 2004, 2005). The first phase of the project involved surveying building owners, commissioning providers, and building contractors, and asking them to prioritize their training needs. The report provides training recommendations based upon the survey results. The second phase of the project built upon that work by reviewing existing training offerings in California, assessing how the previously-identified training needs are currently being met, and recommending opportunities to enhance training offerings for commissioning providers in the California market.

These studies resulted in a set of priorities for training of different actors (only commissioning providers are the focus of this paper). The conclusion was that there will always be practitioners new to the field as well as those who want ongoing, specific commissioning training opportunities. Therefore, the recommendations were both to expand basic commissioning training and to develop advanced commissioning trainings. Potential topics identified for such trainings are summarized in Table 1 (PECI 2005):

Table 1: Potential Training Topics for Commissioning Providers

Basic Cx Training	Advanced Cx Training
Overview of Cx and RCx	System-level commissioning techniques
Top 10 Cx and RCx issues	RCx tools and techniques
Writing Cx specifications	Diagnostic testing using dataloggers, BAS, and manual tests
Design phase Cx	
Construction observation	Design review
Diagnostic testing overview and techniques	Warranty review
Developing functional tests	Developing systems manuals
Developing Cx-grade sequences of operation	Controls integration
Tools for managing the Cx process	Specifying control & monitoring points
Roles/responsibilities of *all* team members	Managing commissioning team relationships
Cx resources	

Table 2 presents the results of the investigation of trainings currently available and which of the needs identified in the *Training Needs Survey* are addressed by each (much more information is provided on each of these training opportunities in the *Commissioning Training Strategy Report,* PECI 2005). This snapshot of the existing training programs highlights the significant number of training courses and events for commissioning providers around the country. However, in many cases, the existing trainings provide only a cursory overview of the topic. The matrix also provides a good sense of which trainings address the various identified needs. The highest priority gaps in the available trainings were:

- introductory orientations for practitioners new to the field
- hands-on technical training programs for practitioners, especially in the area of controls
- training for public sector facilities managers and staff

Table 2: Topics Emphasized in Currently-Available Trainings

Existing Training Programs	Basic Training Topics	Overview of RCx	Top 10 RCx issues	Writing Cx specifications	Dx testing overview and techniques	Developing functional tests	Developing Cx-grade sequences of operation	Tools for managing the Cx process	Roles of Cx team members	Cx Resources	Advanced Training Topics	System-level commissioning techniques	RCx tools and techniques	Dx testing using data-loggers, BAS, manual tests	Controls integration	Specifying control & monitoring points	Managing Cx team relationships
ASHRAE																	
An Integrated Approach to Building Cx		√		√					√								
Design/Specification of DDC Systems							√									√	
AABC Commissioning Group																	
CxA Workshop				√					√								
AEE																	
Fundamentals of Building Cx		√		√	√				√			√					
BCA																	
Building Cx 101									√								
Building Cx for Cx Service Providers					√												
NCBC																	
Top Ten RCx Issues																	
NEBB																	
Building Systems Cx Seminar					√		√	√				√				√	√
Marketing Retrocommissioning Services																	
Conducting Retrocommissioning Interviews													√				
NYSERDA																	
Hands-on RCx Training		√			√	√				√		√	√				
PG&E, Pacific Energy Center																	
Retrocommissioning, Parts 1-3		√	√		√	√						√	√	√		√	
Energy Management Systems & Controls																√	
Identifying and Assessing Common RCx Opportunities		√			√							√	√	√		√	
Exploring the New and Improved FT Guide					√	√				√							
HVAC System Air Flow and Static Pressure Diagnostics					√							√				√	
Packaged HVAC: Economizers, Compressors, Analysis												√					
Using the Cx+ Tool: A Web-based Resource for Cx Projects							√	√		√							

Table 2: Topics Emphasized in Currently-Available Trainings (cont.)

Existing Training Programs	Basic Training Topics	Overview of RCx	Top 10 RCx issues	Writing Cx specifications	Dx testing overview and techniques	Developing functional tests	Developing Cx-grade sequences of operation	Tools for managing the Cx process	Roles of Cx team members	Cx Resources	Advanced Training Topics	System-level commissioning techniques	RCx tools and techniques	Dx testing using data-loggers, BAS, manual tests	Controls integration	Specifying control & monitoring points	Managing Cx team relationships
PG&E, Pacific Energy Center (cont.)																	
DDC Sequences for Demand Reduction and Energy Savings							√									√	
Cx with Dataloggers					√									√			
Cx Persistence																	
Design Review																	√
Practical Introduction to Cx		√															
University of Wisconsin - Madison																	
Cx Process for Delivering Quality Constructed Projects								√									
Cx Process for RCx Projects		√	√										√				
Cx Process for LEED Projects																	
Cx Process for Building Assemblies and Systems												√					
Certification Training for Accredited CCP																	

PECI, 2005.

- seminar for commissioning providers about effectively presenting the business case for commissioning to building owners and managers
- "beyond the basics" training for building owners and managers that provides a foundation on building assessment tools and techniques.

The California Commissioning Collaborative Advisory Council also convened a training committee to identify ways in which the CCC can impact the availability of trained CxPs. The Advisory Council went through an extensive discussion and prioritization process. Several insights surfaced from these discussions, including the need to make a distinction between near-term training and longer-term education: both are important at this point. Through the prioritization process, the following training and educational priorities were identified (in order of priority):

- Toolkits and training for in-house CxPs
- Publicizing career opportunities
- Analysis of educational opportunities (distinct from training)
- Support for community college programs
- Controls training
- Mentorship for new CxPs, and scholarships to attend commissioning conferences for students.

Identification of Issues and Analysis of Selected Trainings

Issues in Training

There are many different types of trainings, and they all reach different audiences in different ways. They can be categorized by audience, learning mode, scope and business model.

Audience. One of the most important and often overlooked issues for any kind of training is to clearly define the audience, and to focus the training appropriately, without trying to be all things to all people. This begins with getting a better understanding of who really does retrocommissioning work. People who enter this field can range from someone fresh out of a four-year engineering program, to someone who has been doing facilities management for forty years, after maintaining boilers in the Navy, to someone experienced in facility quality control, but in the pharmaceutical industry. All will require different types of training. Many people entering the field are technicians and not engineers, and yet many trainings are geared toward engineers. There may also be differences between third-party and in-house providers. They typically have different backgrounds, and different needs for understanding the process (retrocommissioning as a career vs. one project or job assignment among many). In-house providers also have different needs for process-related information. They need to know how retrocommissioning fits with other responsibilities and how to determine whether or not to do the work in-house. There is also a difference between those who need a technical understanding of retrocommissioning and those who need a process or business understanding.

Scope. Having identified the audience, the scope of the training must be well-targeted. The students may or may not need to be taught fundamentals of building and HVAC design, control, and operation. A building operator, for example, may be quite familiar with what it takes to keep a pump up and running, but not understand the relationship between head and flow, and not be aware of how much its performance could improve if the head were reduced. A licensed engineer, on the other hand, may be familiar with these principles, but may not be aware of problems encountered in the field and how to detect their obvious indicators of improvement opportunities. Courses may focus on retrocommissioning techniques, such as measurement, trend analysis, conducting functional performance tests. They can also focus on conveying a way of looking at buildings with a troubleshooting perspective. For pump performance evaluation, for example, the provider will need to know the techniques for safely turning on and off the pump, using the control system to force the building into a wide-open maximum load

condition; measuring flow rate, differential pressure, temperatures, and power; evaluating trends of power use; and documenting the results. Still other trainings must focus on process-related topics, such as retrocommissioning team structure, roles and responsibilities; how to keep a master findings log; how to write and conduct a test; and what training and documentation should be provided. Other important issues might be covered as well, such as non-energy benefits, persistence of impacts, and measurement and verification of savings.

Learning mode. After deciding what the audience needs to know, the next step is to decide how to teach it. Training can range from a classroom lecture format, to a hands-on experience in a test-bed or real building. Classroom training has several advantages. It is inexpensive and easy to find a location. Classroom training can be delivered to a sizable number of people, make use of materials such as workbooks and projected materials, and can be delivered by a number of qualified instructors. Webcasts expand these capabilities by reaching a vastly larger number of people very conveniently. However, both of these are less effective than hands-on training in actually giving students an opportunity to practice the techniques that are taught. Many trainings should have a combination of both. There is a spectrum of ways to learn something: hearing it, seeing it used, mimicking how someone else is doing it, and applying the information and techniques to a new situation. Wherever possible, training should include some combination of these. Format is also important: information provided in a one-time half-day course will not be retained as long as information provided in an intensive 5-day course. Training that is composed of a series of courses provided over time will provide the best opportunity to reinforce information provided earlier and to allow participants to apply it in their own jobs before coming back to share experiences. The most effective and intensive training would be on-the-job training, where participants learn by actually doing retrocommissioning in their own jobs.

Business model. The best designed training in the world will not be effective if it can't be delivered to enough people cost effectively. For example, very expensive trainings may only be provided on a small scale. Training possibilities have to be evaluated according to these criteria:

- How many people will be trained?
- What kind of special facilities will be required to provide the training?
- How far will participants have to travel?
- Will participants be traveling to a convenient and desirable destination[2]?
- Will participants have to be away from their important jobs for a long period of time?
- Can instructors be found who are good teachers as well as experienced CxPs?
- Do curriculum materials have to be developed for the course?
- Are the materials of high enough quality?
- And most importantly, who is paying for the course development, course delivery, and participant fees?

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[2]Instructors from the University of Wisconsin's Engineering Professional Development program have commented that courses provided in Las Vegas are always well attended.

There are a range of innovative business models for providing training. A large percentage of trainings are sponsored by utilities, and provided in their customer training centers. Some entities are in the business of providing training, and they are funded either by participant fees or by program implementers. The CCC has plans to develop curriculum materials that can be used by others. These might be provided as a "train-the-trainer" offering. Some of the most relevant trainings are provided by trade groups. Some of these are tied to a certification. The Building Operator Certification (BOC) program involves many of these concepts. The BOC program offers a menu of courses that a participant can complete to gain credits to obtain a certification. It also includes project assignments for participants to complete in their own facilities. The training and certification are packaged as a turnkey program and licensed to interested organizations (Putnam 2004).

Description and Evaluation of Select Trainings

How are all these issues addressed in available trainings? There are a large number of trainings available, a good portion of which were cataloged in PECI, 2005. We describe here a number of trainings with which the authors have been involved in some way. This list represents a range of trainings types. Some are well established, and others are somewhat experimental, or in the development stage. Together these offerings provide a good cross-section of the ways that training can be provided.

On-the-job-training. A large resort hotel in San Diego is a pilot participant in a utility-funded retrocommissioning program. While an experienced third-party retrocommissioning provider has been engaged, the operations staff of the hotel is providing much of the labor. Over the course of the project, the third-party provider is gradually becoming more of a consultant or coach for the staff, which is becoming more experienced, confident, and capable. Because of the success of this activity, the authors are considering ways to provide more experiences like this, through a more deliberate program of on-the-job training. This is an effective way for people to learn retrocommissioning techniques and processes, although it is still important to find an effective way to teach fundamentals. The costs of such training will be an issue, as will be the scale at which it can be provided. It requires a well-qualified CxP who is also an effective trainer or coach. It is conceivable that one outcome of this activity will be development of a specification of training scope that others can include in a retrocommissioning scope of services, to ensure that training that is included in most retrocommissioning projects is effective in getting staff up to speed for subsequent projects.

Retrocommissioning workshop series. This utility-funded workshop series meets with the same set of 12 students one day a month for a year, at the utility's training center (some of the participants can be seen in Figure 1). The theme of the course is instruction in retrocommissioning through actual retrocommissioning of the training facility. It includes a focused combination of hands-on techniques, fundamentals, process, and discussion of typical problems. It is offered by a California utility at its customer learning center. This is a good example of an extensive course, aiming to teach a range of required material. It is a relatively expensive way to provide training (as it requires an extremely qualified instructor, a specific

facility, and it only reaches 12 students per year), but it is one of the most innovative trainings available.

Figure 1. Participants in Retrocommissioning Workshop Series

Mentorship program. Many people have learned the commissioning trade from formal or informal mentors. The CCC is about to begin development of a mentorship program that matches participants with experienced retrocommissioning providers who commit to meeting with the participant periodically to answer questions and provide feedback, either in an informal setting, on one of the mentor's jobsites, or at one of the participant's jobsites. This program is a good example of a non-traditional training mode, based on the way most people actually learn about retrocommissioning. It will probably not be able to provide more than a sense of what the retrocommissioning process and techniques are, but it is expected to have a place on the training spectrum. It remains to be seen whether or not experienced CxPs will be willing to make this time commitment, (especially if the participant is from another firm).

National Conference on Building Commissioning. The National Conference on Building Commissioning (NCBC) is the premier venue for networking and learning with commissioning providers in the U.S. The annual conference brings together commissioning researchers, program implementers, vendors of related tools, policy-makers, as well as commissioning providers—both experienced and new. Topics covered at the conference include innovative techniques, program lessons learned, state of the art tools, research findings, and related issues such as liability and marketing. This forum is a good way for those new to the field to learn about commissioning, as well as a way for more experienced individuals to obtain continuing education, and to learn about advanced or innovative techniques, and what works and what doesn't. It also is a good forum for networking and learning from others. With such a large industry presence, it is often the anchor around which other trainings are given. The conference environment is not the best place to provide hands-on training, although the conference sometimes includes a workshop at which participants actually look for improvement opportunities in the conference hotel.[3]

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[3] Parenthetically, participants of one such workshop identified about $90,000 of savings potential for the host hotel, and implemented about $18-20K of documented savings in the course of the conference. That workshop also led to the facility getting into the local RCx program and led almost directly to the development of the host hotel's on-the-job training referred above. It pays to host a commissioning conference!

Retrocommissioning tools and techniques. This is an intensive four-day hands-on course sponsored by a state research and development authority through a Department of Energy State Technologies Advancement Collaborative. This course has been offered on a limited number of occasions at different buildings.   Its goal is not only to provide some background on the retrocommissioning process, but also provide exposure to how it's done.   The course presentation materials were developed to facilitate delivery of the course by a number of qualified instructors. While most of the course takes place in a classroom, actual inspections and tests are conducted on the mechanical systems of the training location. This requires a very interested host and several days of preparation at the site.   This course demonstrates the possibility of providing hands-on training without a specialized HVAC training facility. Although it was sponsored by a public organization, it could easily be adapted to take place at an owner's facility to train the owner's staff.

Analog lessons in a digital world. This is a new utility-sponsored class covering pneumatic control basics as well as similarities and differences between pneumatic and direct digital controls. Although pneumatic controls are considered obsolete in the modern building construction, there are many more existing buildings with some form of pneumatic control than not. The course will address control and pneumatic fundamentals, with hands-on exercises on a demonstration pneumatic system. This is a good combination of fundamental information and hands-on practice, addressing a topic that is completely overlooked in traditional trainings, and has real-world relevance to participants. Development of the demonstration equipment was a required investment, although it will be used for a number of trainings and other activities at the utility training center. It is a portable demonstration unit, that can be shipped to different training sites—a good way to include hands-on experiences without constraining where the training can be held.

Monitoring-Based Commissioning training for campus staff. The public university systems in California and the California investor-owned-utilities have partnered to implement a "Monitoring-Based Commissioning" (MBCx) program for campus facilities. This program is essentially a retrocommissioning program, with emphasis on using building monitoring to identify improvement opportunities, assist in the retrocommissioning process, collect data to verify savings, and allow the building operators to conduct ongoing trending and diagnostics. A two-day training is offered for campus personnel to educate them on the program, following the principle that if owners understand the program, they will be able to make the most of it. This is particularly true for retrocommissioning projects, where the role of the owner is always essential, and the persistence of savings is almost entirely in the owner's hands. The course covers the commissioning process, fundamentals of monitoring and HVAC systems, problems that are often encountered in HVAC systems, the preparation and evaluation charts of trend data, and the use of alarming to detect problems. This is a good example of an intensive mix of fundamentals, process, techniques, and typical problems.

Identifying RCx opportunities.   This utility-funded class is a basic introduction to retrocommissioning. It focuses on practical tools and techniques that can be used to identify and assess retrocommissioning opportunities in existing buildings.   The class techniques are

discussed and illustrated with examples from actual projects. Topics include HVAC fundamentals, utility consumption analysis and benchmarking, building documentation review, and site inspection and observation techniques. The class also includes a mock scoping exercise that applies techniques to systems and data at the utility's customer training center. Examples illustrate how the information from an initial assessment can be used to guide the commissioning process through implementation. Part of this course is also provided online.

Top ten commissioning issues. This one-day workshop introduces both new and experienced individuals to the specific types of problems that they are most likely to encounter in existing buildings. (This type of information was also presented in Haasl, et al., 2004). The highlighted issues include control systems, economizers, loop tuning, minimum outdoor air control, scheduling, air-side systems, variable-speed drives, throttled pumps, fire and smoke dampers, and filtration. The workshop includes some information on the HVAC fundamentals required to understand each of these issues. It presents examples of the most important problems found in buildings. This course is a good example of a focused topic that is geared towards specific information CxPs need to know. It attempts to balance the need to keep things interactive against the need to teach some very dry fundamentals in order for participants to understand the examples. Attendees come from a wide range of professions, from providers to policy-makers.

Summary and Implications for Future Training Programs

There is no single solution to training for retrocommissioning. Retrocommissioning requires knowledge in a combination of areas including HVAC fundamentals, the retrocommissioning process, testing, measurement, and analysis techniques, and problems typically found in buildings. Professional Engineers may be well grounded in fundamentals, and yet weak on knowledge of problems in real buildings. Facilities personnel know building problems intimately, yet may be lacking knowledge of fundamentals. All may need to pick up the retrocommissioning perspective, and learn the techniques of retrocommissioning by actually doing it in either controlled laboratory settings or on the job. A range of different trainings are needed to fulfill distinct training needs, and training planners need to clearly define the most appropriate audience, scope, learning mode, and business model.

With so many ground-breaking retrocommissioning programs on the horizon in California, there is a pressing need for training: the success of these programs will depend upon it. Training will need to prepare the retrocommissioning workers of the future to conduct retrocommissioning effectively. At the same time, training must be as cost-effective as possible to satisfy the requirements of publicly-funded programs. The CCC is pursuing a number of different training strategies, including developing toolkits and training for in-house CxPs, publicizing career opportunities in commissioning, analyzing educational opportunities (distinct from training), supporting community college programs, developing controls training, and providing structured opportunities for mentorship for new CxPs. Other states are also starting to include retrocommissioning in their portfolio of energy efficiency efforts, and will need to address similar issues.

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