Empowering Operations: Training and Training Lab Facilities as a Building Performance Tool

Michael Bobker, Technology Strategy
Asit Patel, Lead Trainer
Daniel Harris, Manager, Controls RD&D
Association for Energy Affordability, New York, New York

ABSTRACT

A case study is provided of how lab-based training in New York City has developed through energy efficiency programs for the multifamily housing sector. Training focuses on areas where heating system performance can be optimized by enhanced knowledge and skills of energy auditors, service contractors, and building operators, especially of controls and control logics and sequences. The lab also incorporates a digital data acquisition system and web interface for training exercises anticipating the next generation of heating system controls and requirements for operator capabilities.

INTRODUCTION

Training building operators is certainly a key element in optimizing the performance of buildings. Exactly how training interfaces with a local market determines how new skills can be introduced and made effective. This paper examines a particular case, that of the low-income multifamily housing sector in New York City, to explore how various organizations, programs, and initiatives interact to develop a training agenda for a local area.

AEA BACKGROUND

The Association for Energy Affordability (AEA) has been providing technical assistance to community-based weatherization agencies in New York City for fifteen years. Low-Income Weatherization Assistance is a federally funded program with a history going back to the first oil crises, 1973-77 and the country's first National Energy Plan, under President Jimmy Carter.

Weatherization Program funding flows from the federal Department of Energy to the state level, where administrative mechanisms may differ but generally share the common characteristic of implementation at the local level by community-based agencies. Typically these local agencies have developed and managed their own crews for much of the energy audit and installation work. Over the years weatherization has become a fertile ground for skills training in areas such as blower-door testing and evaluation, air-sealing, blown-in insulation, and hot air system improvements.[1] In most weatherization programs, as in most of the US, single family homes are the normal market. For income-qualified, resident home owners the weatherization work is provided at no cost (ie – 100% grant).

In NYC with its high concentration of larger multifamily (apartment) buildings, the program works a bit differently. The predominance of *rental* housing posed an early policy issue. Since a building that houses a low-income population is often not owned by a low-income person, access to funding for multifamily buildings was initially a problem for the NYC market. This was resolved by program rules that require the building owner to share in the costs of the weatherization work, which can be significant. Recommended weatherization packages typically run $6-8,000 per apartment with a median building size of 35 apartments. The cost-sharing is negotiated by the local agency's weatherization director, with a target of 50% owner-contribution.

NYC program also follows somewhat distinct technical procedures, responding to the systems, energy dynamics, and construction requirements of larger buildings. With central plant equipment, in particular for heating, a different set of skills is required. The locally based agencies joined together to establish AEA as a shared resource for deeper engineering expertise than any one of them alone could maintain. AEA performs energy audits and supports the agencies in bidding and supervising the work,. Much of the work is done by outside contractors, working under sub-contracts with the local weatherization agency.

EVOLUTION OF TRAINING AT AEA

This structure of the NYC program determined the first two target audiences for AEA's training activities:

- Community-based agency staff, responsible for initial assessments, owner negotiation, and installation oversight;

- Contractors bidding for work , who needed to be familiarized with the requirements and expectations of the program.

Agency staff, hired largely from their respective communities, generally lack background in energy work and so need grounding in fundamentals. Program management topics are regularly treated, covering topics such as contract budgeting and coordination of the cycle of intake-audit-owner negotiation-installation. The "Clean Boilers" module provides more technical knowledge about boiler plants, as their upgrading or replacement is a common feature of packages and training covers topics specifically related to specifications that are part of the upgrading packages. AEA has delivered this kind of training for over five years as part of its DHCR contract, with topics developing over each summer training season.

Training for both of these target audiences was geared to support *program performance*. Making the program work better in terms of service delivery, getting the right equipment installed and set-up in the right way, was the dominant theme. The program is structured for production, in terms of installations completed. The program has had minimal emphasis on *building performance* over time, lacking contract mechanism to maintain on-going engagement with client properties. Little post-installation performance monitoring is conducted. Nevertheless building performance research has been influential at key points in shaping program policies. In the early 1980's performance research found that combining shell and mechanical measures yielded significantly better results than either alone.[2] In the mid-1990's AEA research employing detailed building system monitoring suggested that impacting a building's operating economy really required extended information equivalent to that obtained by a multi-point energy management system.

This research proved influential in the local market, especially as it came at a time when the state's System Benefit programs were developing under the administration of the New York State Energy Research and Development Authority (NYSERDA). Their buildings sector programming specifically took a "performance" based approach with the phrase used prominently in several program names. The idea of including an energy management system was incorporated into the rules of their main multifamily housing program. The Building Performance Institute was established to create certifications for what was seen as a new industry emerging from market transformation efforts. AEA was one of several technical organizations selected (competitively) to develop curriculum and pilot training for BPI certifications for the multifamily housing market. Focus on building performance added a third and critical target to the training market:

- Building managers, superintendents, and maintenance staff.

This addition greatly enlarges the potential market for training. Moreover, building staff remain with their building over time. So their inclusion marks a shift from one-time service delivery to a longer-term concern with achievement (and maintenance) of energy performance goals. Local weatherization directors have developed enduring relationships with local property owners around treating a series of properties within a portfolio but are only now beginning to see the potential role of community-based energy services provider and energy manager.

Seeing this emergent series of developments around training activities, AEA expanded its facilities to a new training center in the South Bronx that incorporated operating heating equipment in a teaching-lab setting. AEA instructors had long relied on field demonstrations for hands-on elements of training but these are inherently limited logistically. As will be discussed further below, the teaching lab environment has opened new avenues in addition to facilitating demonstration of equipment operation. One such important avenue has been attention to **advanced digital controls and data acquisition** as a next generation of performance-enhancement.[3]

But just how to bring this new target sector into training programs poses a challenge. The comprehensive "Energy Efficiency in Building Operations" curriculum developed for NYSERDA, is a 35-hour program with a price tag of at least $1,500 per student with a minimum class size of 10. Time away from work seems to be as much of a barrier as the price tag for this market segment that is not at all used to formal training. Unlike commercial office building operators, there are no operating licenses or certifications required by law or used as a criteria for employment and advancement.[4] Various Program-based approaches are being tried or considered:

- For participants in NYSERDA's Assisted Multifamily Program (AMP), tuition is currently waived and absorbed by the program. However, the program has thus far stopped short of *requiring* off-site formal training[5].

- For Weatherization clients, rules are being considered to require superintendent training with the cost allowable as part of owner matching funding.

- The Local 32 Service Employees International Union (SEIU) has periodically offered training classes for its members and is exploring a more regular program possibly bearing credit through the City University of New York.

- Presentations to the major multifamily housing industry associations, to promote enrollment, of course, but more importantly to discuss adoption of certifications into personnel management practices.

While AEA has perhaps been disabused of the idea that "if you build it, they will come", a strong programmatic faith persists that the quality of learning opportunity available through advanced lab training will gradually and steadily prove its value in the market. Moreover, that as new skills and capabilities with new technologies are provided to the market, that new forms of work and working relationships will emerge incorporating focus on building performance enhancements.

LAB-BASED TRAINING

The idea that classroom concepts need to be specifically connected to the real, physical world has long been recognized by trainers of working people. Homework exercises can require observation of equipment at the student's home workplace with some form of reporting back in class. The class demonstration is another form of this, bringing samples of hardware into the classroom or taking the class to look at sample systems. The lab environment deepens this experience and, especially from the instructor's perspective, adds a significant element of controllability to demonstrations and exercises. Students are able to actually work with equipment – turning things on and off, changing setpoints, adjusting cycles, testing and tuning up. For more advanced students, such as mechanics, being able to take equipment apart and put it back together or to program a control set-up and watch the resulting operating pattern, is worth a thousand pictures.

The AEA heating lab is built around two steam boilers, shown in Figures 1, that could be found in a typical NYC apartment building.

Figure 1 Boiler Lab equipment

The boilers are connected to a hydronic loop with a rooftop air-cooled condenser for heat rejection. Multi-speed pump and condenser fan control allows the "load" to be varied. The arrangement is shown schematically in Figure 2. Both burners are dual fuel (gas/oil) with modulating burners.

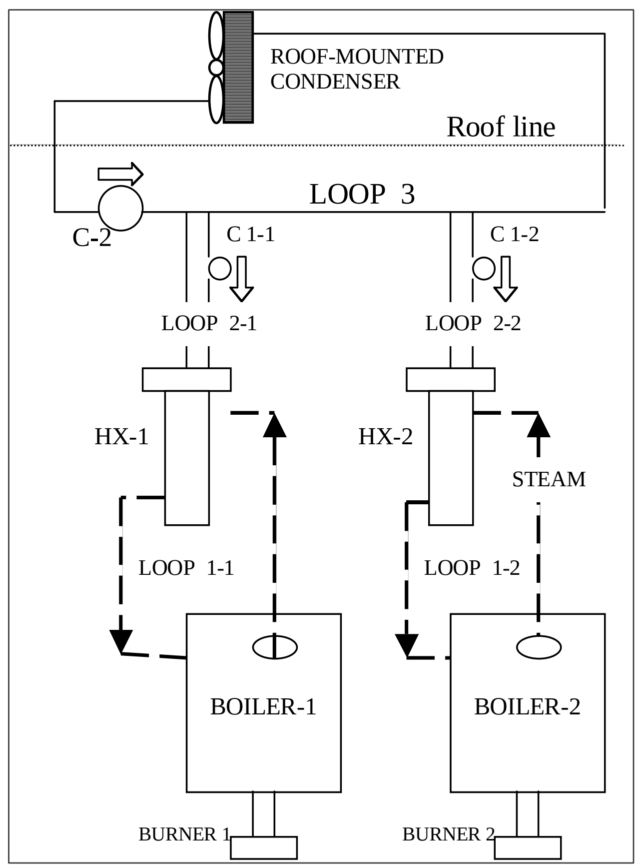

Figure 2 Schematic of Heating Simulation Equipment

A LabView digital data acquisition set-up connects the system to an adjoining room set up with work-stations to simulate a remote, digital monitoring location. In addition to the boiler lab data, this location has limited access to selected locations through the HeatTimer web site and to web sites for buildings piloted in AEA's on-going work with wireless web-based building control systems.[6]

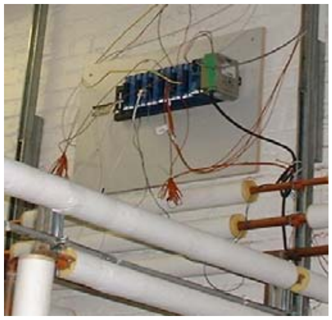

Figure 3 LabView Data Collection Point

Exercises are being developed to show a variety of boiler operating principles, practices, and sequences, that coordinate with classroom lecture topics, as suggested in Table 1.

1	Normal boiler start-up and burner firing sequence
2	Opening boilers for inspection, cleaning, leak identification, and re-closing with proper gasketing
3	Low-water cut-off blow-down and switch testing and full boiler blow-down
4	Flame failure safety shutdown, response, and troubleshooting
5	Identification of surging and priming and corrective steps such as water level adjustment, firing rate adjustment, and skimming blow-down
6	Domestic hot water production and mixing valve control at various boiler temperatures and load conditions
7	Combustion efficiency testing and adjustment at various firing rates
8	Pressure control settings and burner firing rate modulation
9	Boiler lead-lag control and cycling in relation to varying load conditions
10	Outdoor temperature reset sequences and adjustments for steam and hot water

Table 1 Boiler Operation Lab Exercise Topics

Figure 4 Boiler no.2 clean-out access for exercise

Firing rate modulation is one particularly good example of how the lab provides functional features for teaching opportunities that can contribute directly to improved energy performance. Easy to observe physically, it is often poorly understood and neglected or by-passed in the field, as it is not essential for provision of heating. Yet it is an important efficiency element, allowing burner cycling to be minimized by matching firing rate to load requirements.

Figure 5 Burner Modulation, showing mechanism of motor, jackshaft, and linkages controlling air damper and oil metering pump

Its set-point is highly subject to drift and malfunction. In the lab environment, students can observe the difference in operating pattern with and without modulation through repeated cycles. Proper setting and adjustment can be practiced. Moreover, the critical relation can be explored to combustion (air/oil ratio settings) efficiency adjustment at various firing rate positions (unless the system is equipped with oxygen trim control), making clear the need for special care in set-up. The positioning of linkages for optimized combustion across the firing range can be quite complex and tedious (requiring procedural repetitions) and therefore something that mechanics can usefully practice in the lab setting.

Higher level control functions, such as lead-lag sequencing and outdoor temperature reset, are also worthy of special attention in the lab's controlled environment. Once again, proper set-up, let alone optimization, of these control sequences are not critical in order to provide heat, so their tuning is commonly neglected. In fact, these controls are commonly left so that *excess heat* is provided to the building with residents trimming the control function by opening windows! [7]

In the lab, control set-ups and operating results can be demonstrated and experienced under controlled conditions with a constant load and response to varying load. Use of hydronic loop pump speed control and rooftop condenser fan speed control allows exercises to specify load conditions. BTU metering in the loop allows confirmation of the simulated load. A structured series of exercises can give operators a logical view of what they are seeing in their own plant operations as conditions vary.

Burner firing mode	Load Condition	Observations
On/Off	Fixed	Cycling pattern, timing
Modulating	Fixed	less cycling, overshoot and anticipation (PID)
On/Off	Varying	Increased cycling as load reduces
Modulating	Varying	more modulation action as load reduces

Table 2 Lab Exercise Set for Plant Dynamics

Cycling imposes an efficiency penalty on the plant's performance, due in large part to the pre- and post-purge segments of the firing cycle that are mandatory, for safety reasons, for equipment in this commercial size range.

Lab Impacts on Target Audiences

In light of the opportunities for building control optimizations, it is worthwhile to re-examine the three separate target audience segments previously identified, to see how the lab can best function to serve and enhance their specific needs and roles.

Weatherization (and other energy program) Staff

- Improve diagnosis of existing boiler operations and overall (seasonal) efficiency by better understanding of operating sequences, control settings, adjustments and field observable patterns
- Improve installation inspections and results with respect to equipment and controls set-up and adjustments, including better ability to interact with contractor mechanics
- Provide a framework for testing and commissioning of weatherization work
- Provide basis for more productive on-going working relationships with building managers and superintendents as part of a community energy services vision

Contractor and Service Personnel

- Practice set-up procedures for optimized combustion and equipment cycling so that improved results can be more easily and readily achieved in the field;
- Learn new or advanced equipment options such as Oxygen trim, Low NOx, variable speed fan control [8]
- Understand and be better able to implement new generations of controls and capabilities for advanced functions, such as optimized set-back/set-up, reset ratios, firing-rate and lead-lag sequences;

Building Managers and Superintendents

- Understand and recognize various operating patterns and their relationship to building energy performance
- Improve maintenance of efficiency adjustments through better recognition, information, and communication with service firms and mechanics.
- Realize how new sensor technology and GUI-web interfacing can provide data for monitoring building conditions and tracking gradual improvement efforts.

Table 3 Lab Impacts by Target Audience

EMPOWERING DIGITAL BUILDING CONTROL

Thus far we have limited lab learning to the more or less familiar area of physical equipment function, with the somewhat less well understood overlay of control function. Crossing the frontier into a world of fully digital control, data acquisition, and equipment access is the next level of new empowerment for building technicians. Automobile technicians have already been forced to make such a transition.[9] It is no longer possible to provide even the most basic service to a car without access to computerized diagnostics and digital tools. Buildings, being longer-lived and less mass-produced, lag behind but nevertheless are surely moving in this direction.

Building automation systems (BAS), the more comprehensive successor to energy management systems, are taking buildings down this path and are part of the lives of most office building operators, if not yet so of housing. Various equipment components have been chip-based for awhile now -- burner management controls from Honeywell and Fireye were solid-state with LED displays by the 1990's as was HeatTimer, the dominant heating system (outdoor reset type) control in the New York market since the 1950's when automatic control was introduced as coal-firing of boilers was replaced by oil. With chip-based component controls widespread, integration will not be far behind.[10] It is noteworthy that just this year, HeatTimer has introduced a new generation of controls featuring data acquisition from numerous external sensors and web-based graphical interface. As integration proceeds, there is little question but that data-intensive capabilities will enhance building operations if building operators understand how to use them.

Advanced BAS functionalities include energy performance indicators for upper level alarming; open-ended data acquisition and graphical interface with automated trending, alarming for deviations from normal operations and diagnostics; capture and utilization of interval metered data; peak electrical demand limitation and demand-responsiveness.[11] Building operators are almost certainly not equipped to work with these functions.

The pedagogical challenge, then, is to educate operators so that they can relate digital data records to the physical building and boiler events to which they are accustomed. The LabView system allows full graphing and charting of selectable types of data For a series of boiler operating events sets of parameters – pressures, temperature points, on/off states – can be viewed, discussed, interpreted. The pedagogical process involves structuring experiences that require the student(s) to perform a series of operations and observations with the equipment and then to observe the digital record of that set of events.

Without going into a lot of cognitive theory, the idea being pursued in the "digital data" section of AEA;s lab is that students will learn the new digital information environment best when they move back and forth between the physical and the digital worlds. This is especially true for non-academic students, people whose main experience is working with their hands, directly with equipment. Interestingly and conversely, people who work purely with digital systems may find the opportunity to connect directly from digital to physical a refreshing challenge too. This seemed to be the experience of the engineering-trained programmer who developed the Labview application for AEA.

Exercises can be performed first in real-time, connecting the physical events with the digital traces. Then as students develop their digital facilities, longer term histories would be presented for interpretation. Views in one parameter set would raise issues for investigation by viewing of the same history through other parameter sets to develop a full interpretation of events. This framework provides measurable progress for student evaluation. It also has moved students from observation of the near-present of direct equipment events, in which mechanical work generally resides, to the much more powerful viewing of historical data and their patterns, in which mechanics can begin to address building performance issues.

CONCLUSION

If we wish to optimize building performance with results that persist, the knowledge and capabilities of operators really matter. Their training and education must provide well-designed hands-on experience in controlled settings that allow for demonstration of concepts and repetition of practical exercises using familiar equipment. The teaching lab setting is ideal for this and should be an integral part of any sustained building performance program.

While the initial optimization focus is on typically existing conditions, the same lab platform provides an excellent opportunity for the introduction of next-generation emerging technology. We identify data-intensive systems as one of these that is closely upon us. The lab provides a setting in which practicing operators can learn to see in the graphing of data traces the familiar physical sequences of equipment functions. Combining such recognition with energy-use data empowers building operators to operate their buildings for performance. Creating teaching labs that can do this is, then, an empowering operation

NOTES AND REFERENCES.

[1] The non-profit organization Affordable Comfort supports this market with a long-running series of educational conferences.

[2] Optimal Weatherization: Proceedings of the National Conference on Optimal Weatherization, December 1980 Information Dynamics, Silver Spring MD

[3] Initial funding support for this work, as well as other work in the AEA lab is gratefully acknowledged from the Bronx Overall Economic Development Corporation (BOEDC).

[4] Another significant example of operator training in NYC is provided by the Local 94 of the International Union of Operating Engineers. Their training of stationary engineers for larger office buildings is supported by local law requirements for certain kinds of licensing and real estate industry acceptance of various certifications as the basis for career ladder advance.

[5] The AMP program does require measure-specific training to be delivered on-site, addressing the specific maintenance of newly installed equipment.

[6] See Lempereur, Bobker and Harris in ICEBO Proceedings 2004 and Harris and Bobker in Capehart Information Technology for Energy Managers, v.2, forthcoming

[7] This is one of the fundamental inefficiencies of heating practice in NYC multifamily housing. It can be traced to an interconnected set of thorny operating issues, some technical and some social,

- Fully detailed knowledge of control functions and set-ups
- Responsibility for avoiding overheating in apartments
- Severe penalties (fines) for under-heating if discovered by city inspectors in response to phoned-in resident complaint (see below);
- Difficulty of balancing heating distribution, a topic requiring its own treatment
- Tradition and culture (beliefs about ventilation, tropical-country origins, etc).

NYC local laws establish heating requirements for multifamily properties based on time of day and outside temperature and are enforced by the city's Dept of Environmental Protection.

[8] Several of these functions are included in the German-made Weishaupt burner, one of the two lab units. Retrofit kits are being explored for the more familiar US-made Industrial Combustion burner.

[9] "What If Buildings Were Built More Like Cars" Energy Engineering winter 2005

[10] The Weishaupt burner system pushes such integration furthest, through joint product development with Siemens, resulting in on-board full compatibility with Siemens BAS.

[11] Reference is made to the work of Mary Anne Piette , LBNL Commercial Technologies Division. Her colleague Evan Mills led a team considering the associated learning needs of technicians at the community college level, "Developing a Next-Generation Community College Curriculum for Energy-Efficient High-Performance Building Operations" Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings