Retro-Commissioning Laboratories for Energy Efficiency

1 Introduction

Retro-Commissioning (Retro-Cx) has been extensively studied and a large amount of resources exist for understanding and implementing Retro-Cx projects and programs (see references at end of this Technical Bulletin). The purpose of this bulletin is to highlight unique process steps and energy- performance issues that relate to laboratories. When Retro-Cx laboratories to optimize their energy performance, three specialized areas need to be carefully evaluated:

1. Fume hoods or exhaust devices: the primary user-safety system.
2. Laboratory space or module: the secondary user-safety system.
3. Pressure or volume controlled HVAC systems: supporting user-safety systems.

Therefore, the primary issue for energy efficiency in laboratory modules is managing airflow volume and temperature in to, and out of, the lab space. Retro-Cx should first eliminate waste, and second, reduce use.

2 Basic Retro-Commission (Retro-Cx) Process Steps

A brief review of a basic Retro-Cx process is presented for reference in Figure 1. **Bold highlight** indicates area of focus in this Bulletin, and are described in more detail in the next section.

Figure 1: Retro-Cx Process

Planning
Initial Programming
Kick-off Meeting
Information Gathering
Developing a Retro-Cx Plan

Pre-Investigation
Interview Facility O&M
Verify monitoring systems
Drawing review
Site verification

Investigation
Benchmark Utility and Energy-use data
Trend data analyses
Site measurements
Develop Functional Tests
Perform tests
Log Findings
Compile Summary Report

Implementation
Prioritize and select improvements
Verify Improvement performance

Handoff

3 Unique Process Steps

3.1 Planning: Kickoff Meeting

Interviews are especially important when Retro-Commissioning laboratory spaces. The lab's client/user must be consulted, followed by discussion with facilities personnel, EH&S department staff, and in-house design engineers. Safety and preservation of research data must not be compromised during the Retro-Cx effort; therefore, a coordination "kickoff" meeting after individual meetings is essential. A probable result of the coordination meeting is that a dedicated Retro-Cx "test day" will need to be arranged.

3.2 Planning: Information Gathering

The design laboratory ventilation rate is a key component impacting energy used by the lab. First, obtain the ventilation rate for the lab as originally designed. Second, examine of the derivation and reasoning that resulted in the specified rate(s). This examination is warranted due to the ever-changing research mission of most laboratories. Third, confirm the current usage of the lab and reestablish ventilation design parameters. These usage data are critical since current lab safety needs will almost certainly be different than the original design. Reducing outdated, excessive ventilation rates, and related criteria such as fume hood airflow rates, will be the most advantageous starting point to maximize laboratory energy efficiency. Note that caution is advised during the evaluation of the original ventilation and airflow rates. Determining appropriate rates is an iterative process that must include all stakeholders. Lab safety must never be compromised to achieve a fixed energy-efficiency goal. Additional ventilation information resources are available through Labs21 to help evaluate and optimize the lab's ventilation rate and airflow requirements.

Generally, one of two types of HVAC systems will be used for conditioning lab spaces: 1) constant volume (CV) or 2) variable air volume (VAV). When installed, VAV systems have features and components that figure prominently in evaluating a lab's energy use, including:

- Variable speed drive (VSD) on supply and exhaust fans.
- Modulating valves and "VAV boxes."
- Presence of reheat coils.
- Sash position monitors.
- Occupancy sensors.
- Sensor locations.
- Control sequences.

Verify and catalog baseline readings and values for functional tests to be performed later.

3.3 Pre-Investigation: Verify monitoring systems

In addition to usual verification of Direct Digital Control or Building Automation Systems (DDC/BAS) efficacy, ensure that supplementary monitoring instrumentation specific to lab operation exists or can be installed, perhaps permanently. These additional monitoring points will address energy-use aspects of the lab space. These instruments and monitored points include:

- Supply air temperature sensors upstream and downstream of any reheat coil.
- Volumetric airflow meter/devices.
- Pressure differential monitor for lab space with reference to "cleaner" space.
- Stack exit velocity meter.
- Supply and exhaust duct static pressure.
- VSD readings.
- Laboratory equipment process load and lighting load.
- Energy recovery systems, when present.

Always check accuracy of sensors.

3.4 Investigation: Site Measurements

Gather historical energy-use data and trends and amass data streams from supplementary monitoring instrumentation prior to "test day." Of particular interest are the performance of fume hoods and other exhaust devices and the pressure and airflow characteristics of individual lab spaces. Responses by the HVAC system must be simultaneously recorded.

3.5 Investigation: Develop Functional Tests

Development of functional tests for each HVAC-type is similar, but VAV systems have many additional components that will affect performance with respect to both safety and energy efficiency. Specific and special tests, or challenges, for determining a lab's performance are presented below; others can be added depending on the lab's mission and the research performed. Accordingly, during actual testing, e.g., on a test day, coordination between a Retro-Cx agent, laboratory user, facilities technicians, BAS manager, and EH&S personnel is essential.

Challenges listed below for each level of practice are over-and-above usual building-data measurements that are recorded during a basic Retro-Cx program. Recorded measurements are compared to nominal values, usually provided in a design basis document. The goal is to identify when a measured value exceeds a tolerance of the nominal, reestablished design value, thus indicating a setting, or adjustment, that was either necessary to correct for a system deficiency or unscheduled due to a lack of ongoing commissioning. Both situations result in energy being wasted.

Functional Tests - Standard Practice

1. Measure and record face velocity for each fume hood.
2. Measure and record laboratory-space differential pressure.
3. Measure and record airflow offset between supply and exhaust flow rates.
4. ADDITIONAL for VAV: measure and record these values while operating hood sash full open to full close per ASHRAE 110-1995, Sash Movement Effect test.

Functional Tests - Good Practice

Advanced fume hood containment tests

In addition to Standard Practice tests, perform fume hood containment testing with tracer gas per ASHRAE 110-1995 to ANSI Z9.5-2003 thresholds. Although on the surface these tests seem to be solely for determining safety performance, energy use can be adjusted or applied in alternate ways that will support the safety aspects revealed during this level of testing practice.

System Operational Mode Test

A recommended procedure in ANSI Z9.5-2003, the System Operational Mode Test (SOMT), should be part of a "good practice" effort. This test procedure is a system-wide functional verification that examines how well all of the individual lab components and design features work together as a whole. Adequate and measured responses by the central HVAC system to normal lab operations are evaluated during a SOMT. Deliberate HVAC-responses must result from manipulations in a lab space, e.g., how precisely does the HVAC system airflow respond to operating a lab fume-hood's sash? Another consideration would be: how exactly is the lab-room pressure differential maintained during a door-opening sequence? In addition to possible safety breeches, the inability of an HVAC system to provide precise and exact responses directly translates into energy being wasted, often in excess of 20 percent.

Functional Tests - Better Practice

Innovative fume hood containment tests

In addition to Standard and Good Practices fume hood containment tests described above, perform innovative, non-standard tests including:

- Human-as-Mannequin Tests
- Walk-up and walk-by Tests
- Entry door operation during containment tests
- Vary supply air temperature during containment tests

Energy use can be adjusted or applied in alternate ways that will support the safety aspects revealed during this level of testing practice.

System Sensitivity Testing

In addition to the ANSI Z9.5-2003 SOMT procedure, noted above in the "good practice" effort, VAV system-sensitivity can be evaluated and optimized. More than coping with simultaneous actions in labs, this test determines how accurately changes-of-state are detected, reported, and processed by the BAS. Limiting factors for VAV responses include: repeatability and sensitivity of sensor inputs; coarseness of control sequences; precision of VAV devices; modularity of HVAC system components. As a matter of better practice, the central HVAC system should sense and accommodate changes of less than 15 percent in temperature and pressure of any lab's peak requirements. In combination with good practice efforts, energy-efficiency benefits from better practice sensitivity testing and subsequent fine-tuning can exceed 30 percent.

4 Energy-Performance Issues

4.1 Obvious Complaints

Objectionable odor(s) related by the laboratory user to the Retro-Cx team is an obvious indication that a lab space in not performing well, possibly due to hood spillage. This complaint directly relates to energy being wasted because, with objectionable odors present, the energy used is not effective in achieving the lab's primary goal of providing a safe work environment.

4.2 Hidden Issues

The primary hidden energy-use issue is simultaneous heating and cooling of the lab's supply airflow. Huge opportunities for saving energy are well covered in the literature. Secondary is the optimum operation of exhaust blowers, especially when installed in manifolded exhaust system. Carefully check blower VSD operation, leaking or non-functioning bypass dampers, control sequences. When safe, verify stack discharge velocity.

4.3 Typical Causes for Lab Energy Waste

- Underutilized fume hoods
- Inappropriate hoods or exhaust devices.
- Unnecessary reheat; either in the lab space or at the central heating/cooling plant.
- Positive pressure in hazardous containment labs.
- Pressure tracking for lab space isolation: offset is too great, or is not monitored or controlled. Consider a setback of differential pressure based on time or occupancy.
- Excessive duct static pressure.
- Over ventilated lab spaces
- Response time of flow tracking/modulating device for fume hood or supply and general exhaust system that leads to over- or under-shooting set points.
- Supply air temperature overshoot or undershoot: can upset fume hood containment. Can cause surges in airflow volume that sends system into an unstable, "hunting mode."
- Lack of load management within lab space. Determine profile of use by apparatus in lab space to determine potential to shift operations to more even loading.
- Poorly functioning energy recovery system.
- No unoccupied setback of temperature or airflow.
- Fans operating in override position, i.e., in "hand" rather than "auto" position.
- Dampers in fixed positions
- Fume hoods with large bypass openings.

5 Conclusion

Retro-Commissioning of laboratory spaces presents numerous design, personnel, and safety challenges. Carefully executed, potential energy-efficiency reductions have exceeded 30 percent of overall facility energy-use. Prudently evaluate airflow, pressure, and temperature requirements to accommodate current lab operations. Scrutinize simultaneous heating and cooling throughout lab spaces and try to eliminate this energy-intensive design approach. Retro-Cx payback periods are usually less than three years with additional advantages realized in reduced maintenance costs, increased system reliability, improved safety, and satisfied lab-users.

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Prepared at the Lawrence Berkeley National Laboratory
A DOE national laboratory