**(This annex is not a mandatory part of the referring ASHRAE SSPC 300 standard or guideline. It is merely informative and does not contain requirements necessary for conformance to the standard or guideline.)**

**(The following informative annex is provided to illustrate, explain, or support the ASHRAE SSPC 300 commissioning process. The information presented herein represents consensus good practice but does not contain mandatory commissioning process provisions. This informative annex supports more than one ASHRAE SSPC 300 commissioning standard or guideline and is not intended to serve as a standalone document. See the referring ASHRAE SSPC 300 standard or guideline for mandatory commissioning process requirements and guidance.)**

# ASHRAE SSPC 300 INFORMATIVE ANNEX 10—TESTING AND REPORTING

## 10.1 Overview

The initial review steps for the Cx Provider (CxP) include OPR and BOD review, followed by design and submittal reviews. Once these steps are completed and approved designs and submittals are in hand, the next steps to ensuring a successful project are:

- Creation of project specific test protocols
- Field observation to ensure that building systems are being installed as designed and submitted
- Testing to ensure that building systems perform as designed and in compliance with OPR goals and acceptance criteria
- Reporting of test results and verification of test completion submitted to the Owner by the CxP

All of the tasks listed above are project specific. While general templates may exist, the Owner and CxP should agree what specifically will be done for the project in question, and how extensive each of the activities should be.

A standard office Tenant Improvement (TI) retrofit will require less effort than a data center for all four tasks, and to remain competitive, a CxP will typically adjust their scope to this end, but possibly without clarifying methods and expectations to the Owner. A clear description from the CxP as to how each activity will be conducted, and how many site walks for observation and days of testing are expected is a good idea. To make this discussion possible, a description of planned observation and testing is required which non-technical staff at the executive level can follow. This allows them to make decisions related to the cost of testing while retaining an understanding of what levels of quality assurance are provided.

- Detailed checklists used in the actual execution of tests are typically too complex for this task and remain largely unintelligible for those not immediately involved in executing or supervising tests.
- The description of which systems are to be commissioned (e.g., electrical, security, etc.) are too global and contain too little to be useful in a discussion about the scope of testing.
- A test scope matrix should be created as part of the Cx Plan to provide the following elements:
  - A summary of tests that will be executed, along with the level of sampling employed in each test.
  - For the benefit of the project scheduler, adding clear short task descriptions and expected durations for both contractor testing and witness testing is also advisable.
  - Many test types require the involvement of third-party subcontractors. These involve activities (e.g., window spray testing) where neither the contractor nor the CxP typically provide the actual test apparatus or operation. Such activities should be clearly defined in the test scope matrix so that subcontractors can be brought on board and scheduled in a timely manner.

Different trades may require different test approaches, regardless of the criticality of the project. The following examples illustrate this:

- Mechanical systems can typically only be tested once all major equipment is installed, powered, and started; this will naturally occur toward the end of construction. All related ductwork and piping will be installed at this point as well, so earlier construction observations are required to ensure that these systems are installed according to approved plans. The testing phase thus occurs toward the end of the construction phase. Where seasonal testing is desired, test may last well into the warranty phase.

- Building enclosure systems are installed much earlier. Before all windows or curtainwall elements are installed, testing should ensure that they meet their respective goals of preventing water entry and complying with air leakage criteria. This testing has to occur before all elements are installed; it may even occur on a mockup on the job site, but before regular installation of even the first element is scheduled. This then presents the exact reverse of the mechanical observation and testing schedule; in this trade, testing occurs first and is followed by observation of the subsequent installation, although additional testing may occur again on the final completed enclosure.

SSPC 300 Informative Annex 02, "Quality Based Sampling Process" describes procedures for sampling, which are important to read in conjunction with this definition of tasks. A test protocol will look different if every single element of a mechanical, electrical, or enclosure system is tested compared to a test protocol which employs sampling on a subset of elements. This may also affect the overall building schedule next to pricing for just the CxP's efforts. The Owner makes decisions about how much sampling should be used, but the CxP plays an active role in helping the Owner make this decision by using their experience on other projects to recommend an approach that meets the Owner's budget and still provides the desired level of quality.

The protocol for observation and testing should be established as the OPR is created, and an experienced CxP should be able to illustrate various scenarios using existing documentation from other projects. This allows the Owner to participate in the level of quality control that they wish to apply for their project, weighed against the different price levels that different approaches and sampling rates will incur.

To clarify what tests will be conducted and how site observations will be reported, the CxP may develop example observation and test procedures from past projects as sample forms that the Owner can review during contractual negotiations with the CxP. The Owner may also have their own test procedures and instead ask the CxP to price their efforts by following the Owner's preestablished set of procedures; this may be the case for large, established Owner organizations like developers or federal departments.

Test procedures should be repeatable and should provide set-up conditions, step-by-step instructions, and expected or required outcomes. When necessary to verify performance, test procedures should include monitoring performance parameters over a predetermined period of time (e.g., a concrete slump test takes just seconds while strength testing requires curing first and may take several weeks. Testing the control response of an air terminal may take a minute or so, while the control response for a building warmup cycle may take a whole weekend, followed by a cold morning, and may even require the team to wait until winter.)

Test procedures should be repeatable and should provide set-up conditions, step-by-step instructions, and expected or required outcomes. When necessary to verify performance, test procedures should include monitoring performance parameters over a predetermined period of time; for example, a concrete slump test takes just seconds while strength testing first requires curing and may take several weeks. Testing the control response of an air terminal may take a minute or so, while the control response for a building warmup cycle may take a whole weekend, followed by a cold morning, and may even require the team to wait until winter.

Construction observation focuses mostly on the visual inspection of whether a particular system or assembly is installed as specified. Great care should be taken where equipment has been substituted for the originally specified equipment to determine whether the correct components were selected and installed without damage, and whether the installation meets the criteria set forth in the OPR in terms of maintainability, access, etc.

A test is substantially different from an observation in that the performance of the system or assembly is examined rather than observing that it physically exists. Testing for performance frequently means altering the operation of the system or assembly to evaluate responses against expectations. Alternative approaches include testing when indoor/outdoor conditions are close to defined design conditions and/or artificially created conditions. Section 10.2 below clarifies the different types of testing that can be employed, along with protocols and related nomenclature that have evolved in the marketplace.

## 10.2 Risk Analysis

Risk analysis plays an important part in finding the appropriate test scope. It may be possible to test certain failure scenarios, but it may not be possible to do so without risk to elements of the systems being tested, to equipment installed by the Owner, or even to personnel. A test matrix scope drawn up by the CxP should therefore be reviewed during the design phase to determine what types of tests will incur an acceptable level of risk to the Owner. These become part of the Cx Plan and specifications.

A formal risk plan could also be developed; this typically places expected "worst case" scenarios into explicit view (such as in a tabular format) with resulting consequences spelled out, to estimate the impact of unexpected failures. A simple example might be to test cooling for Owner-purchased equipment that is already started. The worst-case scenario might be:

- "Fail chiller 1 — chiller 2 is meant to start but does not." "Consequence: Will lose servers after roughly 90 seconds on high temperature; warranty voided during installation."

  Possible results of this scenario might be:

  a. Proceed with test, ensuring that all servers are configured for auto-shutdown in case of high temperature.
  b. Proceed with test, but manually override first chiller back into operation after 60 seconds, with standby staff on site. Before starting test, ensure that the chiller is configured for rapid restart (test this function while both chillers are enabled).
  c. Do not proceed with failure test.
  d. Shut down servers and bring in load banks on a 1-day schedule. Execute test with load banks in place. On failure, go back to normal operations and reschedule and retest at a later date.

As with all testing, there are many approaches to meeting an OPR goal, but these should be discussed with the Owner during the design phase, since the agreed-upon test scope matrix will likely affect budgets for the contracting team.

## 10.3 Common Testing Terminology

Many terms related to testing are in use today. These may be used in certain systems, certain parts of the world, or in certain building types. ASHRAE SSPC 300 does not require the use of any of these nomenclatures but recognizes their existence. The overall process of testing requires distinction between elements of testing and has led to the emergence of various types of terminology in practice.

The sections below describe some well-known methods of identifying different types of testing.

## 10.4 Use of Listed Terminology

> ***NOTE:*** Terminology listed here is for informative purposes only. It is not necessary for any CxP to use any of the test terms or to execute any of the tests described here to comply with any ASHRAE standard or guideline. The roles and responsibilities of the CxP and other team members are described in the project specific Cx Plan and are defined individually for each project, independent of the terms listed in this informative annex.

None of the terms or methods listed below are considered to be more correct or valid than any others; Project Teams may choose to employ any of these terms or methods, or to employ others not listed. The basic requirement to execute tests to meet the OPR requirements does not change as a result, and different nomenclatures can serve this purpose equally well.

Also note that the same terminology may lead to slightly different interpretations in different system types. For example, a Level 3 test for a mechanical system may involve turning on power to equipment without yet running the equipment through all of its control functions. For an electrical system, the same action (turning on power) may constitute a Level 4 test.

The nomenclature listed below does not imply any roles or responsibilities by particular team members. Such roles are assigned in the Cx Plan on a project specific basis.

### 10.4.1 Construction Observation

Construction observation can take place outside of the testing realm. Construction observation can also take place as part of early-stage testing. A number of test descriptions below include such observation of equipment or systems as part of early-stage testing.

### 10.4.2 Functional Test

Functional tests demonstrate the correct operation of each material, product, assembly, component, subsystem or system, and system-to-system interface in accordance with the acceptance test requirements.

Functional testing reports should contain information addressing each of the building components listed, the testing methods utilized, and should include any readings and adjustments made.

There are many methods to test the function of a system, and these may or may not include Building Automation Systems (BAS), also known as Direct Digital Controls (DDC), or Energy Management and Control Systems (EMCS).

a. Where a control system is not involved, the functional test may test whether a system works as designed by overriding it through its various operating states; for example, a window may be opened or closed, and the maximum opening angle may be verified.
b. Where a control system is involved, functional tests will typically be written to create a system response for every section of the sequence of operations. For example, where the sequence of operations requires that a damper be closed when outside air temperatures exceed 75°F (24°C), the functional test might instruct the person executing the test to override the signal from the outdoor air sensor to a value above 75°F (24°C) and to verify that the damper closes.

Regardless of the system being tested, functional tests typically take the form of a series of steps, each written in a standardized format including the following information to allow verification of results by all Project Team members.

a. Instructions for a particular action to be taken
b. Expected response
c. Actual response
d. Author, date, time

Tests may be written in the form of text documents, spreadsheets, or in custom formats in a web browser for software dedicated to the execution of functional tests.

### 10.4.3 Performance Test

Performance tests are a subset of functional tests. Performance tests demonstrate the operation of a component or system according to a standardized method of test and return particular performance values in accordance with the test standard.

a. An example would be an AHRI 550/590 chiller performance test. This is a functional test since the chiller in question will be operated under load, and its operating states will be overridden to verify responses, as defined in the paragraph above for functional testing. However, this test occurs based on a standardized method rather than a custom method written for a particular project, and it returns standardized performance values such as IPLV (integrated part load value), which is a measure of chiller efficiency. This example involves the chiller's physical components and its control system.
b. An example not involving a control system would be the Miami Dade Testing for louvers (from Florida Code TAS 201) or AMCA 540 and 550 tests for louvers; both standards require that a missile be fired at the louver using an air cannon. The ability of the louver to withstand the resulting impact results in the louver either passing or failing the test. Both of these tests have similar purposes, and while they differ somewhat in the details, both result in a performance judgement based on a standardized test method.
c. Another example would be ASTM E1827, *Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door* (used to determine the building's leakage rate), which tests an assembly rather than a particular component or piece of equipment.

Performance tests may be conducted in the factory, by a manufacturer where they may also be witnessed by a Project Team as required by the OPR. They may also be conducted in the field, as illustrated by example c. above.

### 10.4.4 Functional Performance Test

At present, the terms "functional test" and "functional performance test" are often used interchangeably. The separation of the two terms as listed above may provide more clarity between performance tests (which tend to be more expensive due to adherence to predetermined test parameters), and functional tests (which are custom written per project).

### 10.4.5 Typical Progression of Testing

#### 10.4.5.1 Factory Witness/Factory Acceptance Testing and Inspections

This testing is carried out prior to delivery to the project and demonstrates compliance of the equipment with the specified requirements and performance parameters. Factory Witness Testing (FWT) is executed in the factory and witnessed by the Project Team. Factory Acceptance Testing (FAT) is executed in the factory and witnessed and signed off by the factory quality control personnel. Note that in data center commissioning, this type of testing may be referred to as "Level 1 Testing."

#### 10.4.5.2 Delivery, Installation Verification, and Static Testing

Once the equipment is on site, it is inspected by the contractor and CxP. This is to ensure that the equipment brought to the site meets the end user's specifications before its final installation. Upon installation, the contractor and CxP validate that the systems and equipment have been installed in accordance with the project requirements and approved design documents. In addition, as part of these testing activities, the contractor carries out various static tests such as pressure testing, hydrostatic testing, bus bar and cable torque testing, etc. This testing is witnessed and validated by the CxP. Note that in data center commissioning, this type of testing may be referred to as "Level 2 Testing."

#### 10.4.5.3 Mockup Testing

Where the function of a system can be tested before deployment or construction of the entire system, this is often done to ensure that the design or contractor implementation of the design is free of errors before expending the project budget and to prevent re-work. For example, this can apply to partial sections of building exteriors in enclosure mockup testing.

#### 10.4.5.4 Benchtesting

For partial deployment of controllers and programming in building automation systems, testing of software sequences of operation can occur before installation on site.

#### 10.4.5.5 Start-Up and Pre-Functional Testing (PFT)

Upon successful static testing of the equipment, the contractor conducts start-up activities to ensure that all components and equipment are started up safely and in accordance with the manufacturer's instructions. In addition, Level 3 activities include air and water balancing of the HVAC systems. As a final step of the Level 3 activities, the contractor conducts the required Pre-Functional Testing of equipment and documents the records in Pre-Functional Checklists developed or approved by the CxP. Note that in data center commissioning, this type of testing may be referred to as "Level 3 Testing."

#### 10.4.5.6 Functional Testing

Functional Tests are dynamic tests intended to validate the function of equipment and systems, their performance, and rated capacity. Where control systems are involved, proper response to fault conditions and proving the interface with other systems such as BMS, fire alarm, etc. is usually part of functional testing. These tests are coordinated and managed by the CxP with the assistance of the contractor. While the Functional Test scripts are developed by the CxP, the contractor is responsible for reviewing and executing these tests. The CxP is responsible for review of contractor testing and for witness testing. Note that in data center commissioning, this type of testing may be referred to as "Level 4 Testing."

#### 10.4.5.7 Integrated Systems Testing (IST)

Integrated Systems Tests are the final tests that include all systems working together as designed. Numerous tests will occur to create a comprehensive test routine that is added to the Systems Manual. While the IST scripts are developed by the CxP, the contractor is responsible for review and execution of these tests. The CxP is responsible for review of contractor testing and for witness testing. Note that in data center commissioning, this type of testing may be referred to as "Level 5 Testing."

#### 10.4.5.8 Seasonal Testing

Where weather conditions affect test results, it may not be possible to obtain fully tested systems in a single season. In such cases, testing may have to be repeated in the opposite season (summer/winter) to witness equipment and systems operating correctly and at capacity. The requirement for seasonal testing should be included in the OPR.

### 10.4.6 Active and Passive Testing

Most of the testing referred to as "functional testing" or "field testing" refers to active testing. This involves purposely changing the operating state of an assembly or system to evoke a response and comparing the response to the expectation shown in the test protocol. Usually, this is done by physically being present at the system or assembly and observing the responses as they occur.

Examples of active tests include:

a. All openings (doors, windows) in a building are closed, and the building is pressurized with a blower assembly. The air passing through the blower/fan is measured, and the result is converted into an envelope leak rate for the building.
b. A person entered a room, and the lights turn on in response to the occupancy sensor. The person leaves the room, and the lights turn off again after the timer has elapsed.

It is possible to capture a large degree of functionality in this manner, but typically it is not possible to verify all of the performance that is desired in the OPR. To augment these tests, which rely on intentional interaction with systems and assemblies in the field, a second type of test is often required. This type of test is a passive test in which the performance of systems and assemblies is evaluated *without* intentional interaction by test personnel. In many cases, this type of testing involves more long-term results, which are not practically obtainable in the field.

Examples of passive tests include:

a. The actual efficiency of solar panels on a daily cycle is tested for comparison against manufacturer data and expectations on which the design is based. Irradiation meters record the solar intensity over a period of several weeks, and the power output of the panels is measured using a power meter with the ability to communicate with the building management system or with its own data logging capabilities. Several weeks of data are examined, and the panel performance is evaluated for sunny and cloudy conditions.
b. The scheduling system in a building is examined after turnover to the customer. Using data loggers or the building control system, the status of selected lighting, security, mechanical, and electrical systems is recorded to determine whether systems shut off as desired when schedules command and whether the use of local overrides and adjustments by tenants causes unintended interactions that result in systems remaining in operation. Several weeks of operation, including changes between weekdays and weekends, can be examined to verify overall performance.

As the examples above illustrate, the methods employed in executing an active and a passive test are substantially different and require different tools. The types of performance that can be measured with active and passive tests may overlap but are often complementary. Both types of tests are usually required to comprehensively address the ability of systems and assemblies to meet the OPR.

### 10.4.7 Location Specific Test Terms

#### 10.4.7.1 California T24: NRCC/NRCI/NRCA/NRCV

California Energy Code (Title 24 Part 6) requires that commissioning include a number of formal tests. These have to be executed using pre-defined test forms that encompass commissioning steps from design through acceptance. The protocols are a minimum requirement for new systems in Mechanical, Electrical, Plumbing, Process, and Enclosure disciplines. The types of documents are as follows:

**Non-Residential:**

- **NRCC:** Non-Residential Certificates of Compliance, to be completed by the Engineer of Record.
- **NRCI:** Non-Residential Certificates of Installation, to be completed by the installing contractor.
- **NRCA:** Non-Residential Certificates of Acceptance, to be completed by a licensed Acceptance Test Technician.
- **NRCV:** Non-Residential Certificates of Verification, to be completed by HERS rater.

**Residential:**

- **CF1R:** Residential Certificates of Compliance, to be completed by the Engineer of Record.
- **CF2R:** Residential Certificates of Installation, to be completed by the installing contractor.

- **CF3R:** Residential Certificates of Verification, to be completed by HERS rater.

**10.4.8 ASHRAE Guideline 36 Test**

ASHRAE Guideline 36, *High Performance Sequences of Operation for HVAC Systems* contains sequences of operation for mechanical and control systems. Standardized test protocols may be developed in the future to match these sequences. Once that occurs, these could be used without having to be custom written by the CxP (such as CA T24 NRCA tests).

**10.4.9 Building Enclosure Tests**

**10.4.9.1** The type and frequency of building enclosure testing is established during the development of Owner's Project Requirements (OPR) for new buildings, and Current Facility Requirements (CFR) for existing buildings, including modifications requiring design and construction activities. The Owner and the CxP begin the process by defining the acceptable level of risk associated with the building envelope assemblies. Based on the building assemblies and the level of risk which the Owner will accept, the Owner and CxP determine the building enclosure assemblies to be tested, and the frequency of testing. There are several organizations that define building envelope test procedures, which include the following:

- ASTM (American Society of Testing Materials): provides numerous testing procedures used in evaluating building enclosure assemblies that are either performed in a laboratory or in the field. ASTM Standard E2813, *Standard Practice for Building Enclosure Commissioning*, provides a list of test procedures for evaluating airflow, air leakage, air permeance, condensation resistance, insulation, thermal performance, dewpoint of insulated glass, water penetration, structural parameters of fenestration systems, durability and appearance of materials, adhesion of materials, solar optical properties of glazing, moisture content of building materials, and impact/ballistic/blast resistance of glazing. The standard also references test procedures by other organizations.
- AMMA (American Architectural Manufacturers Association): provides testing standards for building enclosure fenestration systems.
- ISO (International Organization for Standardization): provides a standard for determining level of building envelope testing.
- ABAA (Air Barrier Association of America): provides testing and inspection criteria for air barriers.
- CAN/CGSB (Canadian General Standards Board): provides a Manual for Thermographic Analysis of Building Enclosures.
- CEN (European Committee for Standardization): provides testing and classification of resistance against bullet attack.
- CSA (Canadian Standards Association): provides a Standard Test Method for the Dynamic Wind Uplift Resistance of Membrane-Roofing Systems
- GANA (Glass Association of North America): provides test procedures to evaluate impact resistance for glazing.
- NFRC (National Fenestration Rating Council): provides test procedures to evaluate thermal and optical performance for glazing materials and systems.

**10.4.9.2** Building enclosure testing is performed to evaluate that the material and assembly of building enclosure systems meet the OPR/CFR and design intent. Materials and products used in building envelope construction are also tested using ASTM standards to evaluate material characteristics and durability. The characteristics of the materials define compatibility with other building envelope materials, suitability with installation practices, geographical weather conditions, and exposure limits during construction. These tests define material tensile strength, elasticity, permanence, expansion and contraction with temperature, puncture resistance, resistance to the elements, etc., which are just a few of the most common parameters considered by designers in building enclosure material selection and building enclosure commissioning evaluation of building enclosure design and construction.

**10.4.9.2.1 AAMA Standards**

These standards promote the safety and quality of window, door, curtain wall, storefront, and skylight products. Common tests performed using these standards include:

- Spray Test: AAMA 501.1, *Standard Test Method for Water Penetration of Windows, Curtain Walls, and Doors Using Dynamic Pressure*. This test sprays a uniform spray of water driven by high powered fans capable of producing wind loads of 50 mph (80 kph) or more to evaluate the fenestration systems' ability to prevent water infiltration during storm events. This test is performed in both laboratories and field applications.
- Host Test: AAMA 501.2, *Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems*. Commonly referred to as a hose test, it is used to evaluate continuity of the water barrier formed by the exterior window assembly.
- Condensation Resistance Factor Test: AAMA 1503, *Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors, and Glazed Wall Sections.* A method to predict if interior condensation will form on the interior of the window assembly during cold weather.

### 10.4.9.2.2 ASTM Standards

These standards cover materials as well as building envelope assemblies. Common tests performed using these standards include:

- Air Leakage Test:
  - Chamber Test: ASTM E779, *Test Method for Determining Air Leakage Rate by Fan Pressurization*, to determine the amount of air leakage coming through the building enclosure assembly.
  - Chamber Test: ASTM E783, *Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors*, to determine air leakage through the window or door.
  - ASTM E1186, *Test Method for Field Measurement of Air Leakage Through Exterior Windows and Doors*, to pinpoint areas of air leakage in the assembly.
- Blower Door Test: ASTM E1827, *Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door*, is used to determine the building's leakage rate with all HVAC openings sealed and unsealed with all dampers closed.
- Infrared Test: ASTM C1153, *Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging*, is used to identify locations in the roof assembly where water is trapped under the roof membrane to facilitate identification of where water is penetrating the roof membrane.
- Flood Test: ASTM D5957, *Guide for Flood Testing Horizontal Waterproofing Installations*, is to test the integrity of the roof installation.
- Chamber Test with Spray Rack: ASTM E1105, *Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference*, tests the integrity of the glazing assembly and identifies the location if water is detected infiltrating through the assembly.
- Coating Pull Test: ASTM D4541, *Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers*, is used to test the bonding of coating adhering to the substrate.
- Fastener Load Test: ASTM E488/E488M, *Test Methods for Strength of Anchors in Concrete Elements*, tests the structural integrity of the connect.
- EFIS Insulation Board Pull Test: ASTM E2570/E2359M, *Test Method for Field Pull Testing of an In-Place Exterior Insulation and Finish System Clad Wall Assembly*, is to test the adhesive bond to the substrate.
- Sealant Pull Test:
  - ASTM C794, *Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants*, tests the adhesion of the sealant bond to the substrates.
  - ASTM C1193-11a, Appendix X1-Method, *A Guide for Use of Joint Sealants: Field-*

*Applied Sealant Joint Hand Pull Tab*, tests the adhesion of the sealant bond to the substrates.

## 10.5 Special Test Scenarios

### 10.5.1 Emergency vs. Normal Operation

For many facilities with reliability requirements, emergency modes must be tested; these may include items such as running under local emergency power or running with the failure of a major utility, such as water (in the case of a water-cooled data center, backup water supply may be required and tested, or backup air-cooled units may have to run). Specific test protocols (often called "pull the plug – testing" for loss of utility power) have to be created to address these modes.

### 10.5.2 Natural or Man-Made Disaster

In addition to the failure of utilities, emergencies may include disasters such as earthquakes, fires, hurricanes, wildfires (smoke in outside air), active shooter scenarios or response to epidemics which may require a number of system responses and testing of such responses. Tests are required to ensure a facility meets the OPR under such conditions.

### 10.5.3 Phased Testing (Shell and Core vs. Tenant Improvement Phasing)

Depending on the type of construction project, a shell and core phase may be completed several months or years before tenant improvements take place. During shell and core construction, it may not be possible to conduct testing beyond the startup phase because systems are not complete. For an HVAC system, duct systems and terminal units may not be installed. For electrical systems, lighting for most of the areas may not be installed. For security systems, most tenant demising walls and doors will not be installed.

However, central systems may in fact be installed during this phase (e.g., transformers, switchgear, central chiller plant, air handling units, etc.). In this case, the shell and core team will complete their work without conducting complete functional testing or inter-systems testing. When tenant improvements take place, teams installing these systems will typically not expect to have to test central systems as part of the build-out of a single floor or tenant suite. Unless the Owner and CxP have formulated clear plans for comprehensive testing, this means that main MEP systems may never get tested, either during the shell and core (S&C) or the tenant improvements (TI) phase. This realization may only occur during the final phases of tenant improvement work at which point it may be too late to provide an acceptable solution to the Owner without significant and unforeseen budget impacts. Therefore, when a construction project with S&C and TI phasing is being addressed, a test scope matrix should include the following steps:

a. The scope of systems to be tested, and the level of testing during the S&C phase.
b. The scope of systems to be tested, and the level of testing for TI contractors.
c. An approach for comprehensive testing of central and TI systems.

Item a above may include requirements for temporary construction elements for the purpose of testing equipment during the S&C phase (such as duct loops with dampers to simulate system resistance), the cost of which has to be included solely for the purpose of testing.

Item c above may include testing systems after completion of the first TI suite, or it may require a certain minimum square footage to be built out to meet the minimum turndown capacity of central systems or even include a requirement to test (at part load) with the first suite, and then again (at full load) upon complete buildout. This minimum turndown (the ability to serve just a portion of the building, such as a single tenant) should be a key criterion for testing in any case.

The step of comprehensively testing systems may fall to the TI team, or the S&C team may be brought in for this work; alternatively, an entirely separate team may be charged with this task. Regardless, the overall plan should include details of how to implement all of the above and should be prepared by the CxP in coordination with the Owner before any of the construction phases go to bid. This way, budgets can be set for a comprehensive test of all building components that are included in commissioning.

### 10.5.4 Testing of Factory-Built Skids

Testing may require the inclusion of built-up systems or systems assembled in a shop and equipped with local controls. Such skids are neither single pieces of equipment with integral controls (such as a chiller or boiler) which factory-trained staff can start on site, nor are they systems in the testing scope for the installing contractor (like Division 25 Building Automation Systems or Division 26 Lighting Control Systems). Instead, they fall into a grey area where neither factory technicians nor the project contactors are the correct resource for testing (both will exclude aggregate functions found in a skid from their scope). The builder of the skids may not be used to providing any field support for their equipment.

**Example:** Boiler, pump, and filter skid with local PLC controls is shipped to the site by a boiler rep with a shop that allows assembly of limited-size custom skids.

This skid would normally require the contractor (in this case, the skid builder) to come to the site after the factory technicians for boiler startup have completed their activities (for the boilers only). A skid builder may not be equipped for this occurrence, since they may have no field staff, and they may not historically have been involved in formal Cx Activities. Therefore, where this kind of equipment is specified, an agreement should exist between the engineer of record and the CxP on how to accomplish testing of local controls; this may include a requirement for shop-testing the skid (possibly in the presence of the CxP, depending on location of the shop), or the mandatory inclusion of a shop representative, or representative of the panel builder (this may be a subcontractor to the shop building the skid) to be present on-site and capable of providing testing of the custom controllers for the skid.

Bid specifications for such skids (in the equipment specification section and in the Cx specification related to testing this equipment) need to include scope for field staff capable of taking part in the test procedures, rather than just the cost of providing equipment. Refer to ASHRAE SSPC 300 Informative Annex 07, "Commissioning Specifications" for further information.

#### 10.5.5 Testing of Equipment with Factory-Mounted Controls

In many instances, modern equipment is shipped with factory-installed controllers which are covered under equipment warranty and are configured either in the factory or by factory-trained field technicians. The test scope matrix may include overrides to such equipment to allow the contracting team and CxP to verify operation in particular states as part of functional testing; however, this may or may not be feasible. There appears to be a trend in the industry to limit the ability of stakeholders to transmit override commands to such equipment, either through hardwired points or through controls gateways like BACnet, Lon, or Modbus.

**Example:** A package unit with economizer and integral outside air sensor cannot be forced into economizer because an override of the integral outside air sensor or return air sensors is not possible.

This provides a conundrum for the CxP since the test scope matrix may not have foreseen such inability to conduct planned tests. Changing any of the integral logic of the equipment (even if expertise to do exists) may not be acceptable to the Owner since the fear of voiding warranties when changing factory settings may be present. Specifications should include the requirement that (at minimum) a factory technician with the appropriate user level be present during testing to assist the CxP Team in completing tests. Where this is not possible for the equipment or vendor, the Owner may consider excluding such vendors which should be recorded in the OPR. In such a case, the test scope matrix may have to be changed during testing (with review and approval by the Owner) to use long-term trends to monitor equipment performance and capture a sufficiently wide time window that the expected operation occurs in real life rather than through forced overrides. This may alter the schedule over which substantial completion, code compliance or Owner acceptance is achieved. It may also result in budget impacts due to the changed nature of testing; for example, it may incur an additional trend review at a later date while a planned trend review for the purpose of substantial completion sign-off still proceeds as scheduled.

### 10.6 Acceptance

Acceptance criteria should be defined in the OPR; however, it is often possible that OPR requirements are not detailed enough to formulate particular pass/fail criteria for individual tests. Therefore, the CxP should provide a series of acceptance criteria as they relate to tests during the specification phase so that the Design Team and the Owner can review these for completeness, and to determine what monitoring systems or mechanisms may be required for testing. These acceptance criteria should explicitly address the questions:

- "What is it we are trying to verify?"

- "How will the verification occur?"
- "Which result will mean successful completion and acceptance?"

This may lead to a number of different test scenarios, with different costs, which will have to be discussed early on (ideally before going to bid) and captured in the Cx Plan, or in a separate test scope matrix, as well as including specifications to ensure any equipment or third-party contractors are included in budgets. For example, the Owner may require that a new system be capable of maintaining a certain room humidity under design conditions:

- Scenario A: Team will wait for a design weather day (cold winter day where ambient humidity is low) and the Owner will remove any sources of moisture in the room to ensure that MEP systems alone are capable of meeting minimum humidity levels.
- Scenario B: Team will obtain a factory test of the humidifier under test conditions to witness actual output. This may or may not be witnessed by the Owner, and added costs vary as a result.
- Scenario C: Team will test system functions and programming in line with the construction schedule. Neither internal room loads nor the weather may be at design at that time. The ability of the system to maintain conditions under full load will instead be tested by trending equipment and room functions over several months during winter in the warranty period after substantial completion.

For the above example, with a selection of Option C, the acceptance criteria would look as follows:

| What is to be verified? | How will verification occur? | Which result constitutes acceptance? |
|---|---|---|
| Ability of the system to maintain minimum humidity levels at all times | a. Field testing of humidifier functions, failure alarms, and shut-off on high reading at humidistat<br>b. Trending of actual room humidity level during December and January | Minimum humidity level of 20% RH 24/7 during occupied and unoccupied hours for all rooms with humidification (no sampling) |

There are likely other possible choices on completing testing for this example, but the listed choices show that there can be very different approaches to meeting the same goal. The CxP plays an important role in using their experience to advise the Owner on possible alternates and to establish expectations for testing of the entire project. As with other planning examples shown above, the definition of what constitutes acceptance and how this is tested should be defined in the design phase before going to bid because it may affect project specifications and bid pricing.

These acceptance criteria are still at a higher level than typical functional test scripts which will be a more step-by-step prescriptive list. To formulate choices for test strategies, however, a more high-level approach should be selected to allow the Owner and other executive staff to take part in discussions about which options to select (or simply to agree to suggested test methods from the CxP). Actual test scripts will likely be too lengthy and detailed to facilitate such a discussion.

## 10.7 Reporting

### 10.7.1 Preparation

The descriptions in preceding sections show that preparation for testing well in advance of actual site activities is key to a successful project. The CxP should therefore create several reports that allow the Design Team and Owner to determine how testing should occur as a foundation for the construction phase. These should include:

a. Risk analysis (where appropriate)
b. Acceptance criteria (what constitutes satisfying the OPR/BOD requirements)
c. Test scope matrix (overall description of what systems will be tested and how, what sampling rates will be used by the contractor and by the CxP during witness testing)

These acceptance criteria and test scope matrix may be combined into a single document. There are no standard versions of these; their creation will be up to each CxP Team for a particular project. An example test scope matrix is included in this annex.

These documents need to be developed before going to bid to ensure that third-party test firms and equipment required for testing are included in the project cost. These plans should also allow the contractors to have a good idea of the effort required of them during the test phase and to include this in the cost for their labor projections.

### 10.7.2 Execution

Once the construction phase proceeds (and usually after the approval of submittals for a system), the CxP will create detailed functional test scripts for that system. It is theoretically possible to create detailed test scripts during the final design phase, but any substitutions or alterations (due to RFIs, etc.) may change the test scripts and thus create additional overhead. Timing for detailed test script creation should also be discussed between the Owner and CxP.

Reporting on testing progress should allow various stakeholders to determine whether further action is required from them, and what the overall status of the project is at any given point in time. The larger and more complex the facility, the more time will elapse from the start of testing to completion. In addition, different systems may undergo testing at very different times during construction; enclosure mockup testing will occur long before mechanical or electrical testing occurs. For each system, multiple test sequences may occur over time, and each test sequence may require several days and may be executed by different technicians. Reporting should therefore include the following:

a. Overall progress status: this may be a count (x of y tests completed), or a percentage complete, including clarification on failed tests and tests which have not yet been attempted. Together with the overall project schedule, this serves to give the team, and in particular the Owner, an idea of how the project test phase is progressing. This is a fairly high-level report for executive Project Team members.
b. Details of each test: individual test scripts should be available with results found in the field, along with the date of testing, the technicians involved in testing, and a review by the CxP to evaluate acceptability. Where a test has failed, an explanation or comment should be provided as to what corrective action is required and when re-tests are scheduled. This is a low-level report with technical details which will likely not be read by team members unless they wish to spot-check the diligence of the CxP Team, are involved in the testing, or are tasked with testing a related system and need to understand details of test results. Test reports may be created by multiple Project Team members; for example, a startup report will be completed by the contractor responsible for startup, while a TAB report will be completed by a different contractor, and a witness report will be completed by the CxP.
c. In between the two reports (high-level overview and low-level technical detail), there may be other reports that the contracting team or CxP Team provide to the Owner as part of clarifying progress. The fact that certain tests did not meet passing requirements will typically also be recorded in the issues log, so that an issues log report may accompany updates to the field test reports.

There are no exact rules for the type and frequency of such reports, but these can be developed by the Owner and CxP during the OPR phase, and again during the Cx kick-off meeting with contractors after the completion of the bidding phase and assignment of contracts.

**10.8 Example Testing Scope Matrix (Attached to Cx Plan).** Refer to following "Example Testing Scope Matrix".

**10.9 Example Lighting Test Protocol (Blank, for test or re-test).** Refer to following "Example Lighting Test Protocol".

**10.10 Example Mechanical Test Protocol (Completed, for Owner Review).** Refer to following "Completed Mechanical Test Protocol."

# 8. Example Testing Scope Matrix (attached to Cx Plan)

**Example Test and Acceptance Plan**

| N | Division | System | Equipment | Design Intent | Test description | Sequence (required test nr. Completed before this test) | Sampling during Contractor Field test | Trend Review | Sampling during trend review | Activity Name for scheduling purposes | Approx. Duration | Additional Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | Enclosure | Façade | Glazing Fenestration Testing | Static Water Penetration Testing (ASTM E1105 - Procedure A) for each unique fenestration assembly (e.g., Windows, curtainwalls, storefronts) | Testing needs to be built into the construction schedule to prioritize the testing at each install milestone | 1. Stand-Alone Mock up Location (or first install), 2. Two areas for each unique fenestration assembly shall be tested upon 10% completion and 50% completion. | | | Water Penetration Testing - ASTM E1105 | To Be Verified by Third Party Testing Agency | Third Party Testing Agency to perform this testing and Enclosure Commissioning Agent to Observe and document the testing |
| 2 | 7 | Enclosure | Façade | Glazing Fenestration Testing, Metal Panel, and GFRC Systems | AAMA Nozzle Testing (AAMA 501.2) for each unique fenestration assembly (e.g., Windows, curtainwalls, storefronts), Metal Panel system joints and transitional joints, and GFRC system and transitional joints | See Item 1 | 1. Stand-Alone Mock up Location (or first install) -Test all exposed sealant joints,<br>2. 75 lf for each unique fenestration assembly and 25 lf at system perimeter conditions upon 10% completion and 50% completion. | | | Water Penetration Testing - Nozzle Testing | To Be Verified by Third Party Testing Agency | Third Party Testing Agency to perform this testing and Enclosure Commissioning Agent to Observe and document the testing |
| 3 | 7 | Enclosure | Façade | Glazing Fenestration Testing | Quantitative Air Leakage Testing (ASTM E783) - of each unique fenestration assembly | See Item 1 | 1. Only perform at Stand-Alone Mock up Location (or first install) | | | Fenstration Air Leakage Testing | To Be Verified by Third Party Testing Agency | Third Party Testing Agency to perform this testing and Enclosure Commissioning Agent to Observe and document the testing |
| 4 | 7 | Enclosure | Façade | Primary Weather Sealant Joints at Façade | Sealant Adhesion Testing (ASTM C1521 - Method A) | See Item 1 | 1. Mock-up Minimum of one test between each sealant substrate combination<br>2. Insitu Locations: minimum of three tests between each sealant substrate combination. Perform at a rate of one test per 1000 lf of installed sealant for the first 1000 lf of joint. perform one test per 1000 lf thereafter, or once per floor per elevation. | | | Sealant Adhesion Testing | To Be Verified by Third Party Testing Agency | Third Party Testing Agency to perform this testing and Enclosure Commissioning Agent to Observe and document the testing |
| 5 | 7 | Enclosure | Air Barrier | Primary weather barrier adhesion testing | Air Barrier Membrane Adhesion and Durability Testing (ASTM D4541) | See Item 1 | Testing should only occur on Stand alone mock-up as testing can damage substrate: Minimum of three tests between each membrane-substrate combination after air and water performance testing. | | | Air Barrier Adhesion Testing | To Be Verified by Third Party Testing Agency | Third Party Testing Agency to perform this testing and Enclosure Commissioning Agent to Observe and document the testing |
| 20 | 21 | Fire Protection | | | Not formally commissioned under this proposal | | | | | | | |
| 40 | 22 | All plumbing systems required for T24 compliance | As shown by design engineer in NRCC forms | Comply with testing requirements for Title 24 Energy code, NRCA forms | Follow insturctions on relevant tests for T24 compliance - design engineer specifies which NRCA forms apply | Startup and TAB of related equipment | No sampling | Yes | 100% test (no sampling, all equipment listed is reviewed) | Central Air System Fx Test<br><br>Trend Collection | ~1 days<br><br>3 weeks | NRCA tests executed by contractor |
| 41 | 22 | Plumbing | DHWHX-1, RCP-1, RCP-2 | Ensure that DW heating system is operating | - Run-test hot water heater by changing HW setpoints and ensuring that unit operates to maintain setpoints.<br>- Verify in trends the time it takes to charge storage tank from a cold start, ensure interval is acceptable<br>- Ensure that circulation pump RCP-1 operates and that master mixing valve TMV-1 maintains Hot water temperature at setpoint (DHW), change setpoint and ensure unit maintains this<br>- Ensure that circulation pump RCP-2 operates and that IHW temperature is maintained at 140F<br>- Fail equipment and verify alarm generation | Pipe pressure test and chlorination, Equipment startup for HX, RCP and associated controls | None, all equipment is tested | Yes | No | DHW Fx Test<br>(Witness Test)<br><br>Trend Collection | 8 hours<br>4 hours<br><br>3 weeks | |
| 42 | 22 | Plumbing | Fixtures | Ensure that hot and cold water is available within acceptable timeframe | - Test automatic activation (touchless) and test temperatures over time, DHW should be roughly 120F within 5-10 seconds (before fixture shutoff occurs again), HW should be 140F within 5-10 seconds | DHW heater start, | 5% initially - on failure, expand to 10%, and on repeat failure, expand to 100% | No | No | DHW/DCW POU Fx Test<br>(Witness Test)<br><br>Trend Collection | 8 hours<br>2 hours<br><br>N/A | |
| 43 | 22 | Plumbing | Grease interceptor | Ensure accessibility / Serviceability | Verify access with truck for pump-out (will require coordinating a truck through LBL), otherwise just visually inspect and go through access protocol without truck | DHW/DCW POU Fx Test | None, all equipment is tested | No | N/A | GI Fx test<br>(Witness Test)<br>Trend Collection | 2 hours<br>1 hours<br>N/A | |
| 44 | 22 | Plumbing | Irrigation | None shown | No test planned at present, no irrigation shown | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| **60** | 22 | Process | Nitrogen | Ensure that N2 is available at points of use | Process systems not present | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| **80** | 23, 25 | All mechanical systems required for T24 compliance | As shown by design engineer in NRCC forms | Comply with testing requirements for Title 24 Energy code, NRCA forms | Follow instructions on relevant tests for T24 compliance - design engineer specifies which NRCA forms apply | Startup and TAB of related equipment | No sampling | Yes | 100% test (no sampling, all equipment listed is reviewed) | Central Air System Fx Test<br><br><br>Trend Collection | ~4 days<br><br><br>3 weeks | NRCA tests executed by contractor |
| **80** | 23, 25 | Central Air System | 92-AHU-1, AHU-2 | AHU systems provide airflow for ventilation, comfort and pressurization. | Ensure code compliance with respect to demand-based resets. Ensure that air systems are capable of providing required air flows and pressures<br>- Test supply fan operation in response to VAV demand (supply pressure reset)<br>- Test supply temperature reset in response to VAV demand<br>- Test 5 AHU Modes (Heating w HR, Heating w/o HR, Economizer, Cooling w.o HR, Cooling w HR) with respective coil and bypass damper operation<br>- Test dehumidification mode (triggered by any humidity sensor in the building)<br>- Fail one Supply fan VFD, ensure automatic switchover (2 VFD's per AHU, serving 3 fans each, with redundant VFD for 4 VFDs per AHU on 6 supply fans per AHU)<br>- Fail one AHU unit, ensure other unit speeds up to maintain design redundancy (75% Redundancy), for each unit<br>- Test freeze protection mode<br>- Trigger AHU related alarms (Maintenance, Filter dp, Bldg press, VFD fault, Disch temp, Hi/lo static safety, FA shutdown, Loss of power (local/global), VFD in hand, valve leakage | AHU and Central plant startup. Pipe pressure testing and water treatment. Ability of central plant to produce HW and CHW (at least in manual override) | 50% test (one AHU's fully tested, programming is the same ) | Yes | 100% test (no sampling, all equipment listed is reviewed) | Central Air System Fx Test (Witness test)<br><br>Trend Collection | 2 day<br>6 hours<br><br>3 weeks | |
| **81** | 23, 25 | Central exhaust | 92-BL-501, 502, 503<br>92-GP-110, 111 | Exhaust fans maintain building pressure and sufficient exhaust for hood face velocity control, Heat Recovery (HR) reduces energy use | - Test fan staging up and down after tuning by controls contractor has made iso damper and fan speed up/slow down work with minimum plenum pressure changes (note this took several months at recent Li Ka Shing retrofit with Sunbelt, data available for review, and would be resolved by use of backdraft dampers)<br>- Test HR operation (triggered by call from AHU)<br>- Test lead/lag logic<br>- Test fan failure and backup operation | EF startup, HR circuit completion, pipe pressure test, water treatment | None, all 3 fans tested | Yes | 100% test (no sampling, all equipment listed is reviewed) | Central Air System Fx Test (Witness test)<br><br>Trend Collection | 2 days<br>3 hours<br><br>3 weeks | |
| **82** | 23, 25 | Fancoil units | 92-FCU-xx (17 total) | Condition 24/7 equipment rooms | Test:<br>- Cooling (all units)<br>- Heating (4 units)<br>- Airside Economizer (4 units)<br>- Variable speed operation (1 unit) | HW/CHW piping system completion, pressure test, water treatment, central plant operation (manual at min.) | 2 units per programming type (8 total) | Yes | 100% test (no sampling, all equipment listed is reviewed) | FCU Fx test (Witness test)<br><br>Trend collection | 2 days<br>6 hours<br><br>3 weeks | |
| **83** | 23, 25 | Labs with Chilled beams | 92-VAV-S-xxx<br>92-VAV-E-xxx<br>92-CHB-xxx (205 total) | Provide airflow to control room pressure and supply air for hood exhaust, heating and cooling for labs<br>Central air provides base cooling/heating, chilled beams provide supplemental heating/cooling | Test:<br>- Hood operation (ASHRAE 110 test by specialty contractor)<br>- Heating mode (htg design airflow, VAV supply temp reset up, heating demand signal to AHU, raised HW valve for CH beam)<br>- Deadband (min airflow, CHW/HW valves for CH Beam closed)<br>- Cooling mode (clg design airflow, VAV supply temp reset down, clg demand signal to AHU, raised CHW valve for CH beam)<br>- Hood open/closed and associated supply/exhaust VAV reaction to maintain 0.025" pressurization while maintaining hood face velocity at 100 fpm,<br>- Trigger alarms (Loss of power loca/global, loss of communications, Fire alarm, condensation alarm) | HW/CHW piping system completion, pressure test, water treatment, central plant and AHU operation (manual at min.) | 3 Labs min, 1 lab per configuration type, whichever is larger | Yes | 100% test (no sampling, all equipment listed is reviewed) | Lab CHB Fx test (Witness test)<br><br>Trend collection | 3 days<br>6 hours<br><br>3 weeks | ASHRAE 110 test by specialty TAB contractor<br><br>Clean room particle count by TAB or specialty TAB contractor |
| **84** | 23, 25 | Labs with Radiant Panels | 92-VAV-S-xxx<br>92-VAV-E-xxx<br>92-RP-xxx (3 total) | Provide airflow to control room pressure and supply air for hood exhaust, heating and cooling for labs<br>Central air provides base cooling/heating, radiant panels provide supplemental heating/cooling | As above but with radiant panels instead of chilled beams | HW/CHW piping system completion, pressure test, water treatment, central plant and AHU operation (manual at min.) | 1 lab per configuration type | Yes | 100% test (no sampling, all equipment listed is reviewed) | Lab RP Fx test (Witness test)<br><br>Trend collection | 1 days<br>2 hours<br><br>3 weeks | ASHRAE 110 test by specialty TAB contractor<br><br>Clean room particle count by TAB or specialty TAB contractor |
| **85** | 23, 25 | Labs with Fancoils | 92-VAV-S-xxx<br>92-VAV-E-xxx<br>92-FCU-xxx (2 total) | Provide airflow to control room pressure and supply air for hood exhaust, heating and cooling for labs<br>Central air provides base cooling/heating, radiant panels provide supplemental heating/cooling | As above but with fancoil units instead of chilled beams | HW/CHW piping system completion, pressure test, water treatment, central plant and AHU operation (manual at min.) | 1 lab per configuration type | Yes | 100% test (no sampling, all equipment listed is reviewed) | Lab FCU Fx test (Witness test)<br><br>Trend collection | 1 days<br>2 hours<br><br>3 weeks | ASHRAE 110 test by specialty TAB contractor<br><br>Clean room particle count by TAB or specialty TAB contractor |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 86 | 23, 25 | Labs with Reheat coils | 92-VAV-S-xxx<br>92-VAV-E-xxx<br>92-HC-xxx (16 total) | Provide airflow to control room pressure and supply air for hood exhaust, heating and cooling for labs<br>Central air provides base cooling/heating, radiant panels provide supplemental heating/cooling | As above but with heating coils instead of chilled beams (supplemental heating mode only) | HW/CHW piping system completion, pressure test, water treatment, central plant and AHU operation (manual at min.) | 1 lab per configuration type | Yes | 100% test (no sampling, all equipment listed is reviewed) | Lab RH Fx test<br>(Witness test)<br><br>Trend collection | 1 days<br>2 hours<br><br>3 weeks | ASHRAE 110 test by specialty TAB contractor<br><br>Clean room particle count by TAB or specialty TAB contractor |
| 87 | 23, 25 | Offices with Chilled beams and ceiling fans | 92-VAV-S-xxx<br>92-CHB-xxx<br>92-CGF-xxx (30 tot) | Provide airflow to control room temperature, chilled beams provide supplemental heating/cooling, ceiling fans increase comfort range | Test:<br>- Heating mode (htg design airflow, VAV supply temp reset up, heating demand signal to AHU, raised HW valve for CH beam)<br>- Deadband (min airflow, CHW/HW valves for CH Beam closed)<br>- Cooling mode1 (clg fans enabled, VAV supply temp reset down, clg demand signal to AHU, raised CHW valve for CH beam)<br>- Cooling mode2 (clf fans enabled, clg design airflow, VAV supply temp reset down, clg demand signal to AHU, raised CHW valve for CH beam)<br>- Local tenant override for ceiling fans<br>- Trigger alarms (Loss of airflow, loss of power local/global, low/high suppy temperature, loss of communications, Fire alarm, condensation alarm) | HW/CHW piping system completion, pressure test, water treatment, central plant and AHU operation (manual at min.) | 3 Labs min, 1 lab per configuration type, whichever is larger | Yes | 100% test (no sampling, all equipment listed is reviewed) | Office CHB Fx test<br>(Witness test)<br><br>Trend collection | 1 days<br>4 hours<br><br>3 weeks | |
| 88 | 23, 25 | Offices with reheat coils and ceiling fans | 92-VAV-S-xxx<br>92-HC-xxx<br>92-CGF-xxx (30 tot) | Provide airflow to control room temperature, chilled beams provide supplemental heating/cooling, ceiling fans increase comfort range | x | HW/CHW piping system completion, pressure test, water treatment, central plant and AHU operation (manual at min.) | 3 Labs min, 1 lab per configuration type, whichever is larger | Yes | 100% test (no sampling, all equipment listed is reviewed) | Office VAVRH Fx test<br>(Witness test)<br><br>Trend collection | 1 days<br>3 hours<br><br>3 weeks | |
| 89 | 23, 25 | Offices without reheat coils and ceiling fans | 92-VAV-S-xxx | Provide airflow to control room temperature (cooling only) | Test:<br>- Deadband (min airflow)<br>- Cooling mode (clg design airflow, clg demand signal to AHU)<br>- Trigger alarms (Loss of airflow, loss of power local/global, loss of communications, Fire alarm) | HW/CHW piping system completion, pressure test, water treatment, central plant and AHU operation (manual at min.) | 3 Labs min, 1 lab per configuration type, whichever is larger | Yes | 100% test (no sampling, all equipment listed is reviewed) | Office VAVCO Fx test<br>(Witness test)<br><br>Trend collection | 1 days<br>3 hours<br><br>3 weeks | |
| 90 | 23, 25 | Dehumidiifer | 92-ADR-xxx (3 total) | Reduce moisture content of air for cryo rooms | Test:<br>- Maintain room dewpoint at 40F (change SP, watch unit change operation under local mfg controller accordingly, close wheel bypass, speed up)<br>- Door opening results in unit max. speed<br>- Supply Air temperature control to setpoint with CHW<br>- Trigger Alarms: High temp, high dewpoint, gen. failure, Local/global loss of power, Loss of comm., fire alarm | CHW piping system completion, pressure test, water treatment, central plant and AHU operation (manual at min.) | 1 unit (33%) | Yes | 100% test (no sampling, all equipment listed is reviewed) | Dehum ADR Fx test<br>(Witness test)<br><br>Trend collection | 1 days<br>2 hours<br><br>3 weeks | |
| 91 | 23, 25 | Server Room | 92-RC-001, 002<br>92-AC-103, 104 | Keep Compute Racks at low temperature. Rear-door racks are primary cooling mechanism. In case of rear-door coil failure, CRAC units are redundant backup system. | Test:<br>- Maintain neutral room temperature (rear-door coils eliminate load from server discharge) - possible test with load banks, requires coordination with LBL and load bank rental<br>- Change load on loadbanks and monitor performance and leaving temperature to ensure load response is correct<br>- Failure test: Fail each rear door coil in sequence (simulate failure or override control valve shut, manual or in software). Ensure that CRAC standby unit comes online and alarms are triggered. | CHW piping system completion, pressure test, water treatment, central plant and AHU operation (manual at min.) | All units (no sampling) | Yes | 100% test (no sampling, all equipment listed is reviewed) | Server room Fx test<br>(Witness test)<br><br>Trend collection | 2 days<br>2 hours<br><br>3 weeks | Possible rental of load banks required to test rear door coil capacity and operation. |
| 92 | 23, 25 | Central Chilled and Hot Water (Roof) | 92-HP-101 to 103 (air source)<br>92-HP-104 to 106 (water source)<br>GP-104 to 106 (HHW)<br>GP-107, 108 (LCHW)<br>GP-115 to 117 (MCHW) | Low temp CHW and Heating HW are both available 24/7 - Low temp CHW is made by the watercooled chiller (rejecting heat into the HHW circuit). Remaining heat is provided by air source heat pumps.<br>The medium temperature CHW loop | - Ensure code compliance with respect to demand-based resets for both HHW and LCHW circuits. Check response to zone-level generated requests for temperature and pressure.<br>- Test staging of air-source heat pumps to ramp up to 3 units by overriding requestes. Possible false loading with manual overrides to AHU coils to remove generated heat from HHW circuit.<br>- Check pressure control across water source chiller (requires constant dp, controlled with bypass valve)<br>- Check operation of WS chiller, ramping up capacity (again, use AHU's to false load system and simultaneously heat/cool to provide a way to ramp up all cells of chiller, simultaneously charging LCHW and HHW circuits with chiller, and dissipating energy in AHU coils)<br>- Provide unbalanced loads to main WS chiller to see source/sink operation where heat is rejected to MCHW if more LCHW is needed than hot water, and where heat is absorbed from MCHW if more HHW is required than LCHW. Verify that heat balance is maintained for steady-state operation - this will result in MUP having to balance MCHW temperatures.<br>- Check pump staging and failure on each of the 3 circuits (MCHW, LCHW, HHW), and check pump speed control to maintain circuit dp<br>- Check alarm generation for various temperature, pressure and failure alarms.<br>- Test power loss response and alarms (see global "pull the plug" test) | Heat pump, Water pump, VFD and AHU unit startup. Pipe pressure testing and water treatment. | ~80% test (some sampling - not every piece of equipment will be failed and not every staging combination of pumps, heat pumps and chiller cells will be tested) | Yes | 100% test (no sampling, all equipment listed is reviewed) | B92 Central Plant Fx test<br>(Witness test)<br><br>Trend collection | 3 days<br>1 day<br><br>3 weeks | |
| 93 | 23, 25 | IHW | 92-IHP-001,002<br>92-GP-113, 114 | Provide 140F Industrial hot water | 2 heat pumps in master/slave configuration<br>- Test response to setpoint and ability to maintain storage tank at 140F<br>- Test staging (may be limited because of "black box" master/slave approach<br>- Test unit lead/lag, failure and response (again, built-in master/slave logic may mean little possibility for adjustment)<br>- Test alarm generation | IHW and MCHW circuits completed, MUP running to maintain MCHW | 100% test (no sampling, all equipment listed is tested) | Yes | 100% test (no sampling, all equipment listed is reviewed) | IHW Fx test (Witness test)<br><br>Trend collection | 1 days<br>3 hours<br><br>3 weeks | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **94** | 23, 25 | DHW | 92-DHP-001,002<br>92-GP-111, 112 | Provide 140F Domestic hot water | 2 heat pumps in master/slave configuration<br>- Test response to setpoint and ability to maintain storage tank at 140F<br>- Test staging (may be limited because of "black box" master/slave approach<br>- Test unit lead/lag, failure and response (again, built-in master/slave logic may mean little possibility for adjustment)<br>- Test electric heat coil in storage tank to ensure it can boost temperature as required.<br>- Test alarm generation | DHW and MCHW circuits completed, MUP running to maintain MCHW | 100% test (no sampling, all equipment listed is tested) | Yes | 100% test (no sampling, all equipment listed is reviewed) | DHW Fx test (Witness test)<br><br>Trend collection | 1 days<br>3 hours<br><br>3 weeks | |
| **95** | 23, 25 | Medium temp CHW loop | 92-GP-101 to 103 | Medium temperature water serves as both a supply of heating (for HHW, IHW and DHW) and a supply of cooling (for LCHW) like a condenser water loop in a traditional heat pump system. Pumps serve the various chilled beams on floors. Heat pumps have their own MCHW pumps | - Test pump speed/staging control and ability to maintain pressure at setpoint on all floors<br>- Test pump failure and response (backup, alarms) | MCHW loop completed, pressure tested, MUP operational, MCHW pumps started | 100% test (no sampling, all equipment listed is tested) | Yes | 100% test (no sampling, all equipment listed is reviewed) | MCHW Pump Fx test (Witness test)<br><br>Trend Collection | 1 day<br>2 hours<br><br>3 weeks | Unclear if test of temporary chiller connection is required |
| **96** | 23, 25 | Performance Metrics | Controls Interface (Skyspark) | Ensure that performance metrics shown on M8.3.2 are programmed into the system and are active / in alignment with values from BAS | - Check presence of required metrics, ensuring they are configured in Skyspark, and that results match BAS values (testing for presence on interface, testing for results match using trends) | BAS completed, electrical metering completed | 100% test (no sampling, all equipment listed is tested) | Yes | 100% test (no sampling, all equipment listed is reviewed) | Metrics test<br>(Witness test)<br><br>Trend Collection | 2 day<br>2 hours<br><br>3 weeks | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| **100** | 26 | All electrical systems required for T24 compliance | As shown by design engineer in NRCC forms | Comply with testing requirements for Title 24 Energy code, NRCA forms | Follow insturctions on relevant tests for T24 compliance - design engineer specifies which NRCA forms apply | Startup of related equipment | No sampling | Yes | 100% test (no sampling, all equipment listed is reviewed) | Central Air System Fx Test<br><br>Trend Collection | ~4 days<br><br>3 weeks | NRCA tests executed by contractor |
| **101** | 26 | Electrical | UPS/Battery storage System | 50% backup of 800A EM branch distribution | Equipment verification of operation upon power outage.<br>- Transfer of power upon power outage<br>- Charging of batteries<br>- Temperature control, heat rejection<br>- Trouble and emergency alarms when system is compromised. | Electrical energization | No, all equipment is tested. | no | 100% test (no sampling, all equipment listed is reviewed) | UPS Battery Test | 1/2 day | |
| **102** | 26 | Electrical | Portable Generator 2000A 480V 3 phase | 50% backup of Normal power 4000A distribution | Equipment verification.<br>- Proper terminals for portable cable connections<br>- Kirk key operation | Electrical energization | No, all equipment is tested. | no | 100% test (no sampling, all equipment listed is reviewed) | Portable Generator connection test | 2 hours | |
| **103** | 26 | Electrical | Lighting Controls | Ensure that lighting systems meet code requirements and design requirements | - Test main lighting control panel functions<br>- Test zone override controls<br>- Test occupancy sensor and daylight dimming responses.<br>- Test interlock with HVAC system (occupancy sensing based) | Electrical energization | 5% of fixtures for each control/programming type. | Yes | 100% test (no sampling, all equipment listed is reviewed) | Lighting Fx test<br>(contractor and Witness)<br><br>Trend Collection | 3 days<br>1 day<br><br>3 weeks | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| **125** | 28 | Telecom | Horizontal cabling | Ensure that the cabling meets the industry standards and UCSF standards | -Test point to point continuity and bandwidth performance. | Final Telecom terminations | None - review of contractor test results only. | Yes | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| **140** | 28 | (FA) | | | Not being commissioned under this proposal | | | | | | | |
| **141** | 28 | | | | | | | | | | | |
| **142** | | | | | | | | | | | | |
| | | | | | | | | | | | | |

## 9. Example Lighting Test Protocol (Blank, for test or re-test)

INTRODUCTION

### Assumptions

Test requirements – See 260800.4.3.D (general)

Sequence of operations – 260923.3.3 (occupancy sensors) and drawing E3.1 to E3.3

See bulletins 18, 18A, 50 and 96 for lighting changes.

Wall Switches – see spec 262726.2.1, Occupancy sensors: 260923.1.3.A and 2.2.A , see Electrical drawing legend (copied below) and location of switches and sensors on E3.1.1.C, E3.1.2.C (floor 1), E3.2.1.C, E3.2.2.C, (floor 2) and E3.3.1.C, E3.3.2.C, (floor 3)

See submittals 265000-01 and 265092-01 for switches.

All pre-requisites for functional testing are completed, including sensor calibration, pre-functional tests, start-up, all sequences tested and validated, etc.

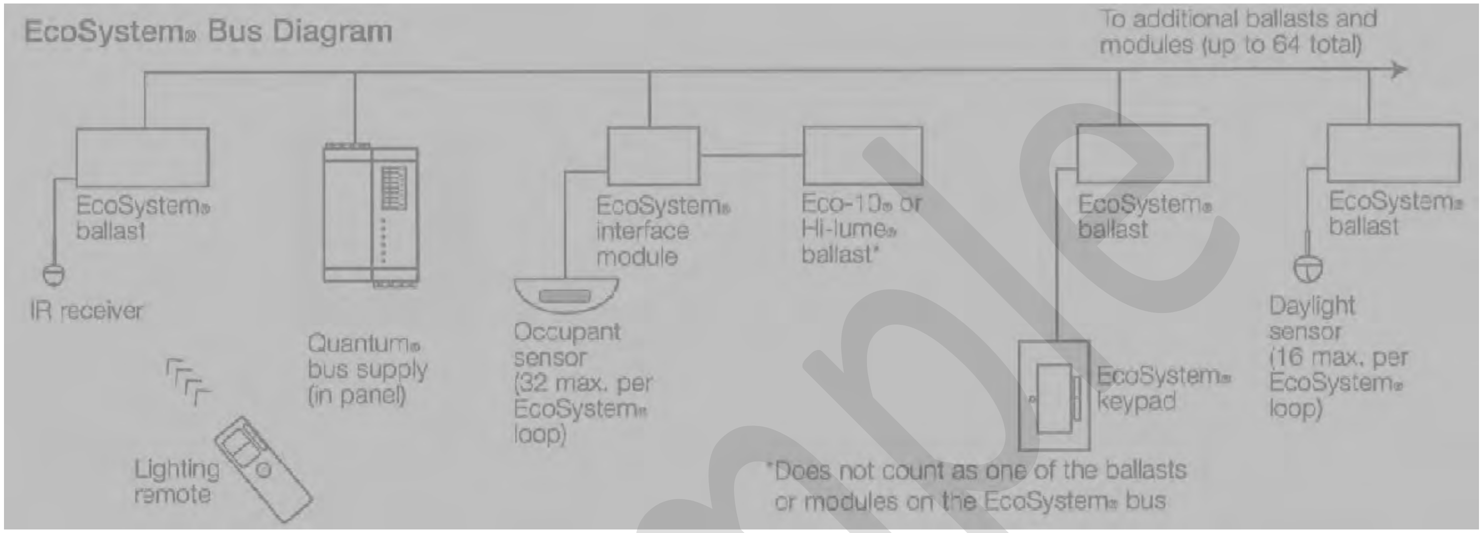
Verify Connectivity of Lighting Control System with FMCS per 255000.1.4.A.10.

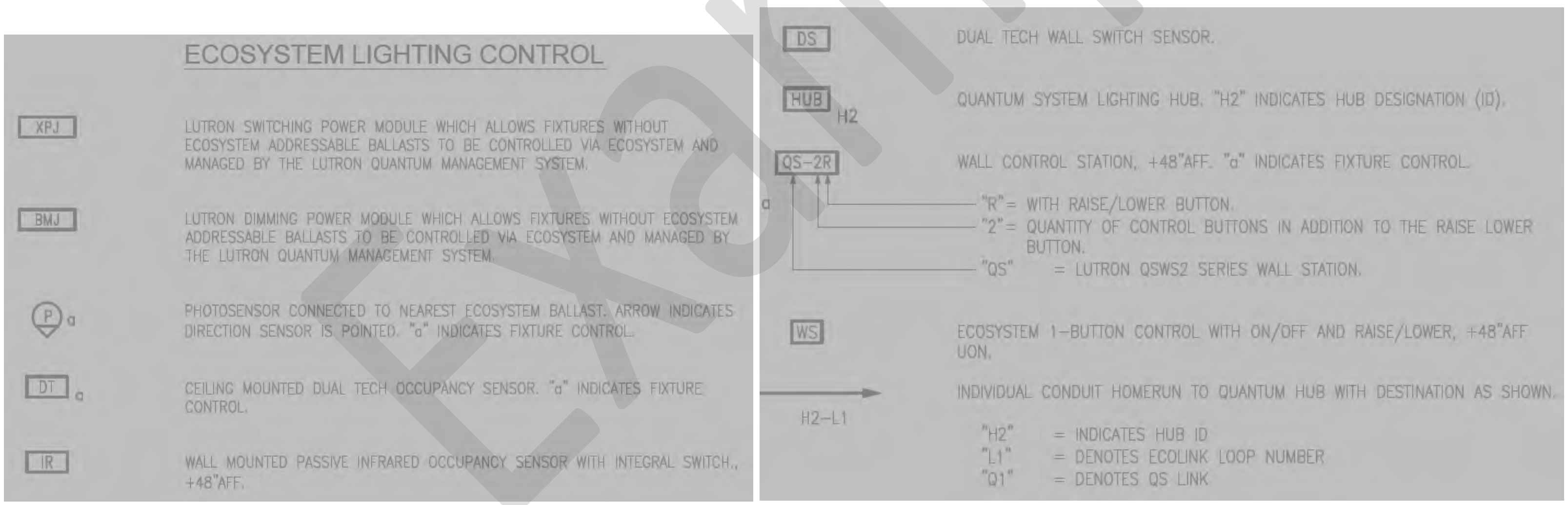
Lighting panels: clearly marked as such per 260553.3.3

### Instructions

Provide an observed response for every item in the Expected Response column as well as all additional relevant observations. Observed responses shall be entered electronically into this Word document.

Test instructions are intended to be followed in sequential order for each respective piece of equipment. Some tests, such as emergency power may be tested in parallel for multiple pieces of equipment. Please read through all test instructions to identify these areas.






Lighting System Components from electrical drawing set

(1) FIXTURES WITH ECOSYSTEM DIMMING BALLAST AND CONNECTED TO QUANTUM LIGHTING CONTROL. DUAL–TECH OCCUPANCY SENSOR AND WALL SWITCH PROVIDE MANUAL–ON / AUTO–OFF CONTROL. PHOTOSENSOR PROVIDES CONSTANT DIMMING OF FIXTURES.

(2) FIXTURES WITH ECOSYSTEM DIMMING BALLAST AND CONNECTED TO QUANTUM LIGHTING CONTROL. DUAL–TECH OCCUPANCY SENSOR AND WALL SWITCH PROVIDE MANUAL–ON / AUTO–OFF CONTROL.

(3) FIXTURES WITH ECO NON–DIM BALLAST AND CONNECTED TO QUANTUM LIGHTING CONTROL. FIXTURES WILL STAY ON DURING BUSINESS HOURS. DUAL–TECH OCCUPANCY SENSORS PROVIDE AUTO–ON / AUTO–OFF DURING AFTER HOURS.

(4) FIXTURES WITH ECOSYSTEM DIMMING BALLAST AND CONNECTED TO QUANTUM LIGHTING CONTROL. FIXTURES WILL STAY ON DURING BUSINESS HOURS. LOCAL SWITCH ALLOWS MANUAL DIMMING/OFF CONTROL DURING BUSINESS HOURS. DURING AFTER HOURS, DUAL–TECH OCCUPANCY SENSOR AND LOCAL SWITCH PROVIDE MANUAL–ON / AUTO–OFF CONTROL.

(5) FIXTURES WITH ECOSYSTEM DIMMING BALLAST AND CONNECTED TO QUANTUM LIGHTING CONTROL. FIXTURES WILL STAY ON DURING BUSINESS HOURS AND WILL DIM TO 1–FOOTCANDLE OUTPUT DURING AFTER HOURS. FIXTURES WILL GO TO FULL BRIGHTNESS WHEN OCCUPANT IS DETECTED BY THE DUAL–TECH OCCUPANCY SENSOR DURING AFTER HOURS.

(6) FIXTURES WITH ECO NON–DIM BALLAST AND CONNECTED TO QUANTUM LIGHTING CONTROL. DUAL–TECH OCCUPANCY SENSOR PROVIDES AUTO–ON / AUTO–OFF CONTROL.

(7) FIXTURES WITH ECO NON–DIM BALLAST AND CONNECTED TO QUANTUM LIGHTING CONTROL. DUAL–TECH OCCUPANCY SENSOR AND WALL SWITCH PROVIDE MANUAL–ON / AUTO–OFF CONTROL.

(8) FIXTURES WITH ELECTRONIC BALLAST AND ARE NOT CONNECTED TO QUANTUM LIGHTING CONTROL. WALL SWITCH PROVIDES MANUAL–ON / MANUAL–OFF CONTROL.

(9) FIXTURES WITH ELECTRONIC BALLAST AND ARE NOT CONNECTED TO QUANTUM LIGHTING CONTROL. OCCUPANCY SENSOR WITH INTEGRAL WALL SWITCH PROVIDES MANUAL–ON / AUTO–OFF CONTROL.

(10) FIXTURES WITH ECOSYSTEM DIMMING BALLAST AND CONNECTED TO QUANTUM LIGHTING CONTROL. DUAL–TECH OCCUPANCY SENSOR AND WALL SWITCH PROVIDE MANUAL–ON / AUTO–OFF CONTROL. TWO SETS OF OCCUPANCY SENSORS ARE PROVIDED IN THE SPACE; THE "PRIMARY" SENSORS WILL TURN OFF 50% OF THE FIXTURES WHEN NO OCCUPANT IS DETECTED, THE "SECONDARY" SENSORS WITH 5 MINUTES DELAY WILL TURN OFF REMAINING 50% WHEN NO OCCUPANT IS DETECTED.

(11) PHOTOSENSOR WILL PROVIDE CONSTANT DIMMING OF FIXTURES.

(12) CANOPY AND SITE LIGHTING: FIXTURE CONNECTED TO QUANTUM LIGHTING CONTROL. TIME CLOCK IN LIGHTING CONTROL PANEL PROVIDE AUTO–ON / AUTO–OFF.

Lighting System Control Sequence from drawing E3.1

## Lighting Control System

### Sequence 1 (conference rooms, manual-on / auto-off with automatic daylight dimming)

| Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|
| 1. Dimming function<br>a. Shine light on photo sensor<br>b. Cover photo sensor | • Lights dim<br>• Brightness of lights increases | Date: Time:<br>Room nr: | |
| 2. If possible, close blinds to darken room | • Brightness of lights increases to produce 45 foot candles at 30" work surface per basis of design | Date: Time:<br>Room nr: | |

| Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|
| 3. Schedule lights off | • Lights flicker, then turn off | Date: Time:<br><br>Room nr: | |
| 4. Override off schedule (locally turn lights on) | • Lights turn on at scheduled time | Date: Time:<br><br>Room nr: | |
| 5. After scheduling lights off again, move in room | • Occupancy sensor triggers to turn lights on | Date: Time:<br><br>Room nr: | |
| 6. After scheduling lights off again, move past room (open doorway) | • No nuisance trip from over-sensitive occupancy sensor adjustment | Date: Time:<br><br>Room nr: | |

**Sequence 2 (interior offices, manual-on / auto-off with manual dimming)**

| Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|
| 1. Dimming function<br>a. Manually adjust brightness up and down | • Lights dim/brightness of lights increases | Date: Time:<br><br>Room nr: | |
| 2. Schedule lights off | • Lights flicker, then turn off | Date: Time:<br><br>Room nr: | |

| Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|
| 3. Override off schedule (locally turn lights on) | • Lights turn on at scheduled time | Date: Time:<br>Room nr: | |
| 4. After scheduling lights off again, move in room | • Occupancy sensor triggers to turn lights on | Date: Time:<br>Room nr: | |
| 5. After scheduling lights off again, move past room (open doorway) | • No nuisance trip from over-sensitive occupancy sensor adjustment | Date: Time:<br>Room nr: | |

**Sequence 3 (hallways, auto-on / auto-off without dimming)**

| Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|
| 1. Schedule lights off | • Lights flicker, then turn off | Date: Time:<br>Room nr: | |
| 2. After scheduling lights off, move in room | • Occupancy sensor triggers to turn lights on | Date: Time:<br>Room nr: | |

| Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|
| 3. After scheduling lights off again, move in adjacent room (open doorway) | • No nuisance trip from over-sensitive occupancy sensor adjustment | Date: Time:<br>Room nr: | |
| 4. Schedule lights on | • Lights turn on at scheduled time | Date: Time:<br>Room nr: | |

**Sequence 4 &10 (perimeter labs, daylight dimming w manual override, manual-on/auto off after hours)**

| | | | |
|---|---|---|---|
| 1. Dimming function<br>a. Shine light on photo sensor<br>b. Cover photo sensor | • Lights dim<br>• Brightness of lights increases | Date: Time:<br>Room nr: | |
| 2. If possible, close blinds to darken room | • Brightness of lights increases to produce 45 foot candles at 30" work surface per basis of design | Date: Time:<br>Room nr: | |
| 3. Manual change dimming level | • Brightness control of daylight sensor is overridden to manual settting | Date: Time:<br>Room nr: | |
| 4. Schedule lights off | • Lights flicker, then turn off | Date: Time:<br>Room nr: | |

| | | | |
|---|---|---|---|
| 5. Override off schedule (locally turn lights on) | • Lights turn on at scheduled time | Date: Time:<br>Room nr: | |
| 6. After scheduling lights off again, move in room | • Occupancy sensor triggers to turn lights on | Date: Time:<br>Room nr: | |
| 7. After scheduling lights off again, move past room (open doorway) | • No nuisance trip from over-sensitive occupancy sensor adjustment | Date: Time:<br>Room nr: | |

**Sequence 5 &11 (emergency exits, on during business hours, 1 ft candly w auto-on after hours)**

| | | | |
|---|---|---|---|
| 1. Schedule lights on | • Lights turn on at scheduled time | Date: Time:<br>Room nr: | |
| 2. Schedule lights off | • Lights dim to 1 ft candle | Date: Time:<br>Room nr: | |
| 3. After scheduling lights off, move in room | • Occupancy sensor triggers to turn lights on | Date: Time:<br>Room nr: | |

| | | | |
|---|---|---|---|
| 4. After scheduling lights off again, move past room (open doorway) | • No nuisance trip from over-sensitive occupancy sensor adjustment | Date: Time:<br>Room nr: | |

**Sequence 6 (restrooms, auto on/off, no schedule)**

| | | | |
|---|---|---|---|
| 1. Wait for timeout period without moving | • Lights turn off | Date: Time:<br>Room nr: | |
| 2. Move in room | • Occupancy sensor triggers to turn lights on | Date: Time:<br>Room nr: | |

**Sequence 7 (interior low occupancy rooms, auto on/off + manual override, no schedule)**

| | | | |
|---|---|---|---|
| 3. Wait for timeout period without moving | • Lights turn off | Date: Time:<br>Room nr: | |
| 4. Move in room | • Occupancy sensor triggers to turn lights on | Date: Time:<br>Room nr: | |

| | | | |
|---|---|---|---|
| 5. After auto-off period, Override (locally turn lights on w switch) | • Lights turn on | Date: Time:<br>Room nr: | |

## Sequence 9 (Janitor closet, manual on/auto-off, no schedule)

| | | | |
|---|---|---|---|
| 1. Locally turn lights on w switch | • Lights turn on | Date: Time:<br>Room nr: | |
| 2. Locally turn lights off w switch | • Lights turn off | Date: Time:<br>Room nr: | |
| 3. With light switch on, wait for timeout period | • Lights turn off | Date: Time:<br>Room nr: | |
| 5. After timer turns lights off, move in room | • Occupancy sensor triggers to turn lights on | Date: Time:<br>Room nr: | |
| 6. After timer turns lights off again, move past room (open doorway) | • No nuisance trip from over-sensitive occupancy sensor adjustment | Date: Time:<br>Room nr: | |

Part 1 INTRODUCTION

1.01 Assumptions

A. All pre-requisites for functional testing are completed, including sensor calibration, pre-functional tests, start-up, test and balance, all sequences tested and validated, etc.

1.02 Instructions

B. Provide an observed response for every item in the Expected Response column as well as all additional relevant observations. Observed responses shall be entered electronically into this Word document.

C. Test instructions are intended to be followed in sequential order for each respective piece of equipment. Some tests, such as emergency power or smoke detection modes of operation may be tested in parallel for multiple pieces of equipment. Please read through all test instructions to identify these areas.

## Part 2 NOTES FOR TESTING

### 2.01 Items for clarification prior to testing on AC units

A. Supply air temperature reset function test B (AC-01), H (AC-02) and N (AC-03): See also submittal Rev.4 comments and answers section, comment 3B: The zone requiring "most cooling" is the zone that is furthest from setpoint.

B. AC unit and exhaust fan interlock test A (AC-01), G (AC-02) and M (AC-03): If only one or two of the exhaust fans are running (example – disconnect off on fans), the respective AC unit is allowed to continue operation.

C. FSDs in supply duct from AC-01 shown on M4.1 serving floors 1 and 2:

1. These FSD's close on local heat activation only.
2. When FSD's served by a lab AC unit close, the respective lab unit (AC-01/02) shuts down and the roof bypass opens.
3. In this condition, general exhaust VAV's close and lab hood sashes close. Hood sashes should close within 5-10 seconds per design intent.
4. Note FSD's are not powered with E-power and will close on loss of power.

D. Emergency power mode

1. The AC unit SOP states that the units themselves will limit their airflow. This is not actually the case: (1) The [redacted] mechanism that controls airflow with a CFM input does not work, and should be disabled. [redacted] has acknowledged this in the past. Per discussion with [redacted] on [redacted], 2012, AC units will not be commanded to a particular airflow, but will simply meet static setpoint.
2. Limiting the hot water coil for emergency power is not possible. So no limit will be placed on HW valves in emergency power mode.

### 2.02 Items for clarification on VAV testing

A. Test series 4.05 on VAV's serving labs with hoods: Sequence of operation does not clearly state how supply airflow is modulated during normal operation, but this should be lower of min airflow = 1 cfm/sqft, load and hood airflow requirements. Supply volume must adjust to load conditions / hood airflow automatically.

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

2.03 Witness Test Dates

A. [redacted], 2012 (HVAC / Controls test)

1. [redacted]
2. 
3. Step 1, [redacted], 2012: Set all trends to 1 minute intervals ([redacted] present for setup only, verify database has sufficient room).
4. Start with testing on AC-19, [redacted]. Electrical contractor will upgrade fume hood controllers to emergency power starting Monday, and we will not test units in that area- instead, move to AC-18 and/or AC-20 on Mon/Tue until electrical is complete

B. [redacted], 2012 (HVAC / Controls testing)

1. [redacted]
2. 

C. [redacted], 2012 (pull the plug witness test)

1. [redacted]
2. 
3. 
4. 
5. 
6. 
7. 

D. [redacted], 2012 (pull the plug witness test)

1. [redacted]
2.
3.
4.
5.
6.
7.
8.
9.
10

E. [redacted] 2013 (pull the plug witness test)

11. [redacted]
12.
13.
14.
15.
16.
17.
18.

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

## Contents

Part 3 AIR HANDLERS

**AC-01** [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| A. Lab SF and EF Operational Interlock. | 1. With exhaust fans BL-001, BL-002, and BL-005 and AC-01 initially running, turn off BL-001, BL-002, and BL-005. | a. Exhaust fans BL-001, BL-002, and BL-005 are off.<br>b. AC-01 is off.<br>c. AC-01 make-up air damper is closed. | | |
| | 2. With exhaust fans BL-001, BL-002, and BL-005 initially turned off, enable all of these exhaust fans to operate. Confirm that AC-01 is initially turned off prior to beginning this test. | 1. Exhaust fans BL-001, BL-002, and BL-005 are enabled to operate.<br>2. AC-01 is enabled.<br>3. AC-01 make-up air damper is open. | | |
| B. Supply Air Temperature Reset Function | 3. Manually adjust AC-01 Supply Air Temperature setpoint to 40°F. | AC-01 Supply Air Temperature setpoint changes to 40°F.<br>AC-01 HW control valve is fully closed.<br>AC-01 DX coil is active.<br>AC-01 Supply Air Temperature approaches setpoint. | | |
| | 4. Manually adjust AC-01 Supply Air Temperature setpoint to 80°F. | a. AC-01 Supply Air Temperature setpoint changes to 80°F.<br>b. AC-01 DX coil is inactive.<br>c. AC-01 HW control valve modulates open.<br>d. AC-01 Supply Air Temperature approaches setpoint. | | |
| | 5. Enable the AC-01 Supply Air Temperature automatic-reset function. Adjust a downstream zone VAV terminal unit space temperature set point so that it becomes the zone requiring the most cooling. | a. Supply air temperature setpoint resets downwards by at least 25% of the difference between the design supply air temperature and design room air temp. (Note: this is best done with a trim and respond reset mechanism, actual mechanism not described in SOP). | Record time for reset across full range, and criteria for reset (i.e. effect of number of zones requesting reset and exact nature of "most cooling" criterion)<br>[redacted]12 8AM heat requests have driven unit to max. SAT in auto, see Figure 1 and Figure 2. | Y |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | | b. AC-01 HW valve is closed.<br>c. AC-01 DX coil is activated after HW valve has closed, but not before.<br>d. Room cooling request is shown on DDC graphics. | Manually override requests to zero – unit setpoint immediately "jumps" to 65°F as initial temperature of cooling loop, see Figure 2. Note that cooling and heating loop setpoints are discontinuous, so switching from one mode to the other will cause issues. This issue fixed through both re-programming supply air temperature setpoint and changing reset parameters, see Figure 4 to Figure 7.<br><br>After implementing changes, at 9:17, re-test: 0 cooling requests [redacted]12 9:20AM), witness setpoint (65°F at[redacted]12 9:29AM), then change to Cool RQ = 0, Heat RQ = 10, system goes into heating mode and supply temp initially goes to 65°F.<br>At 9:56AM, SP is 70, change Heat RQ to zero, flips SP back to 65°F, (with slow ramp function)<br>Ramp function is then sped up, and requests changed to 5 HT RQ and 5 CL RQ, net result 0 requests<br>4 HT RQ and 5 CL RQ net result 1 CL RQ<br>7 HT RQ and 5 CL RQ net result 2 HT RQ so request pattern math is now correct | <br><br><br><br><br>Y |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | | | [redacted]12 at 10:24AM - VAV 20 override zone SP to go from 0 cool and 2 heat to 0 heat and 2 cool requests. See this go up to AC-18, Then back to htg 10:30 AM. See Figure 12.<br>Temporarily override HT airflow to 4,000 cfm to see damper open<br>See press RQ from zone, and AC18 press RQ goes from 1 to 2. See Figure 13.<br>Allow rogue zones to be overridden by making the multipliers for requests visible on summary screens, see Figure 3. | Y |
| | 6. Use operator lockout on zone used in Test #5 above. | a. Supply air temperature setpoint ceases downward reset. | | |
| C. Supply Air Pressure Control | 7. Confirm that Supply Air Duct Static Pressure setpoint is initially at 1.0” w.c. and change the Supply Duct Static Pressure High-Limit alarm to 1.5” w.c. Manually adjust AC-01 Supply Air Duct Static Pressure setpoint to 2.0” w.c. | a. AC-01 Supply Air Duct Pressure Hi-Limit is set to 1.5” w.c.<br>b. Supply Fan VFD ramps fan speed up until 1.5” w.c. is achieved.<br>c. At 1.5” w.c., SA Duct High-Limit Alarm is tripped and shuts down AC-01 Supply Fan. | | |
| | 8. Manually input a Supply Air Duct Static Pressure setpoint of 1.0” w.c. and restart AC-01. | a. AC-01 SF is enabled.<br>b. Supply Fan VFD ramps fan speed up until 1.0” w.c. is achieved. | | |
| | 9. Manually adjust AC-01 Supply Air Duct Static Pressure High-Limit to 4.0” w.c. and then input a Supply Air Duct Static Pressure setpoint of 2.0” w.c. | 4. AC-01 Supply Air Duct Pressure setpoint changes to 2.0” w.c.<br>5. Supply Fan VFD ramps fan speed up until 2.0” w.c. is achieved.<br>6. SA Duct High-Limit Alarm does not trip. | | |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 10. Manually adjust AC-01 Supply Air Duct Static Pressure setpoint to 0.5" w.c. | a. AC-01 Supply Air Duct Pressure setpoint changes to 0.5" w.c.<br>b. Supply Fan VFD ramps fan speed down until 0.5" w.c. is achieved. | | |
| | 11. Enable the AC-01 Supply Air Duct Pressure automatic-reset function. Adjust a downstream zone VAV terminal unit airflow set point, so that the primary air damper position exceeds 85% open or directly override damper position. | a. Supply air duct static pressure setpoint increases according to trim-and-respond reset schedule<br>b. Supply Fan VFD ramps fan speeds up to maintain SP as it changes. | Record trim-and-respond parameters for increase and decrease values used, and time intervals<br>N[redacted]/12 7:45 AM Reset range 0.08" up per request, trim by 0.04" every 5 minutes.<br>Change to 5 requests, every 1 minutes.<br>See Figure 8 to Figure 10 | Y |
| | 12. Enable the AC-01 Supply Air Duct Pressure automatic-reset function. Override VAV terminals airflow set point, so that the primary air damper position is below 85% open or directly override damper position, for all terminals. | c. Supply air duct static pressure setpoint decreases according to trim-and-respond reset schedule<br>d. Supply Fan VFD ramps fan speeds down to maintain SP as it changes. | [redacted]12 at 7:50AM override to 0 static requests. System winds down from 1.75" to 1.47" in 8 minutes. | Y |
| D. Shutdown Operation | 13. Shutdown AC-01 through DDC workstation interface. | a. AC-01 is disabled.<br>b. AC-01 Supply Fan is off.<br>c. AC-01 HW valve is closed.<br>d. AC-01 DX coil is inactive. | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

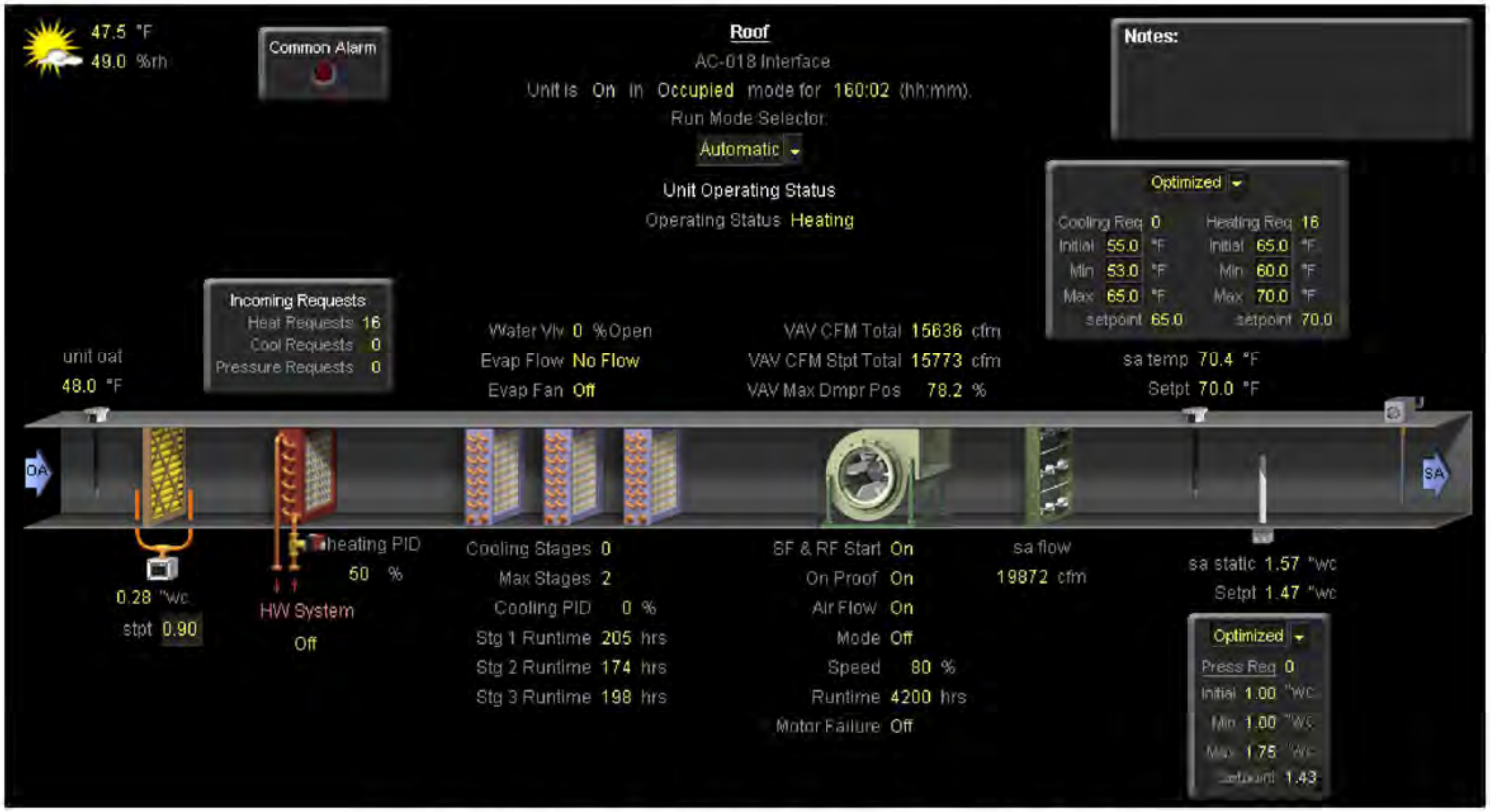



**Figure 1: AC-018 in auto, with 16 heat requests, [redacted] 2012 at 7:57AM**

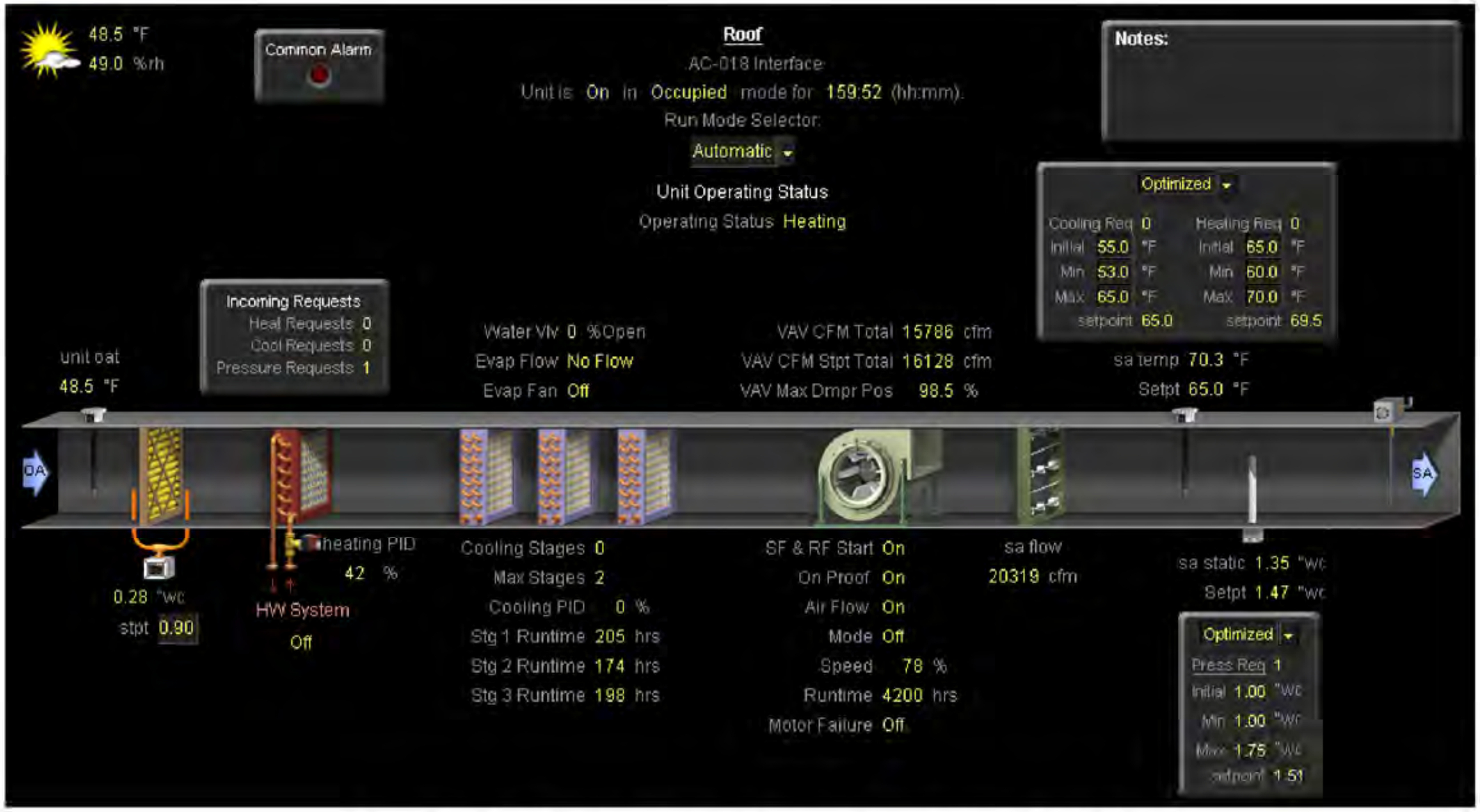



**Figure 2: AC-018 without heat/cool requests,[redacted]2012 at 8:07AM**

Additional Notes

Discussed rogue zones on site: lockout (blanket ignore), importance multiplier per zone and targeted ignore. [redacted] will add a multiplier per zone on VAV summary screen tonight (Mon [redacted] 12)

To: HVAC Summary
VAV Summary First Floor
VAV Summary Second Floor
VAV Summary Third Floor

First Floor VAV Summary

| | AHU | Schedule | Zone Temp (°F) | Setpt Adj (°F) | Clg Setpt (°F) | Htg Setpt (°F) | DAT (°F) | Dmpr (%) | Flow (cfm) | Flow Setpt (cfm) | HW (%) | Request Multiplier: Cool Req | Heat Req | Press Req |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VAV-001 | AC-020 Interface | Unoccupied | 70.0 | 0.0 | 85.0 | 55.0 | 74.7 | 0 | -10 | 0 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-003 | AC-020 Interface | Unoccupied | 73.0 | 0.0 | 85.0 | 55.0 | 73.9 | 0 | 12 | 0 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-004 | AC-020 Interface | Unoccupied | 69.3 | 0.0 | 85.0 | 55.0 | 72.6 | 0 | 0 | 0 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-005 | AC-020 Interface | Unoccupied | 69.6 | 0.0 | 85.0 | 55.0 | 73.8 | 0 | 0 | 0 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-006 | AC-020 Interface | Unoccupied | 69.8 | 0.0 | 85.0 | 55.0 | 73.8 | 0 | -12 | 0 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-002 | AC-018 Interface | Occupied | 68.3 | -2.0 | 72.0 | 68.0 | 71.1 | 100 | -5 | 875 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-007 | AC-018 Interface | Occupied | 71.4 | -2.0 | 72.0 | 68.0 | 72.1 | 100 | 1 | 100 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-009 | AC-018 Interface | Occupied | 68.9 | -2.0 | 72.0 | 68.0 | 71.8 | 100 | -8 | 150 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-011 | AC-018 Interface | Occupied | 70.4 | 2.0 | 76.0 | 72.0 | 77.1 | 100 | -43 | 150 | 100 | 1.0 | 1.0 | 1.0 |
| VAV-059 | AC-018 Interface | Occupied | 71.0 | 0.0 | 74.0 | 70.0 | 82.2 | 100 | -6 | 140 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-016 | AC-018 Interface | Occupied | 70.7 | 0.0 | 85.0 | 60.0 | | 100 | -3 | 75 | | 1.0 | 0.0 | 1.0 |
| VAV-013 | AC-018 Interface | Occupied | 67.2 | | 74.0 | 70.0 | | 100 | 57 | 640 | 100 | 1.0 | 1.0 | 1.0 |
| VAV-017 | AC-018 Interface | Occupied | 71.6 | | 74.0 | 70.0 | | 100 | 84 | 1000 | 40 | 1.0 | 1.0 | 1.0 |
| VAV-020 | AC-018 Interface | Occupied | 69.3 | 0.0 | 74.0 | 70.0 | 75.8 | 100 | -10 | 310 | 100 | 1.0 | 1.0 | 1.0 |
| VAV-061 | AC-018 Interface | Occupied | 68.7 | 0.0 | 74.0 | 70.0 | | 100 | -28 | 150 | | 1.0 | 1.0 | 1.0 |
| /114 | AC-018 Interface | Occupied | 70.7 | 0.0 | 85.0 | 60.0 | 71.7 | 100 | 3 | 125 | 0 | 1.0 | 1.0 | 1.0 |
| VAV-024 | AC-018 Interface | Occupied | 70.3 | 0.0 | 74.0 | 70.0 | 70.6 | 100 | 84 | 150 | 0 | 1.0 | 1.0 | 1.0 |

**Figure 3: Added summary screens for VAV terminals showing main zone parameters, and also showing multipliers for heating/cooling/pressure requests. Setting multipliers to zero on summary screen allows elimination of rogue zones.**

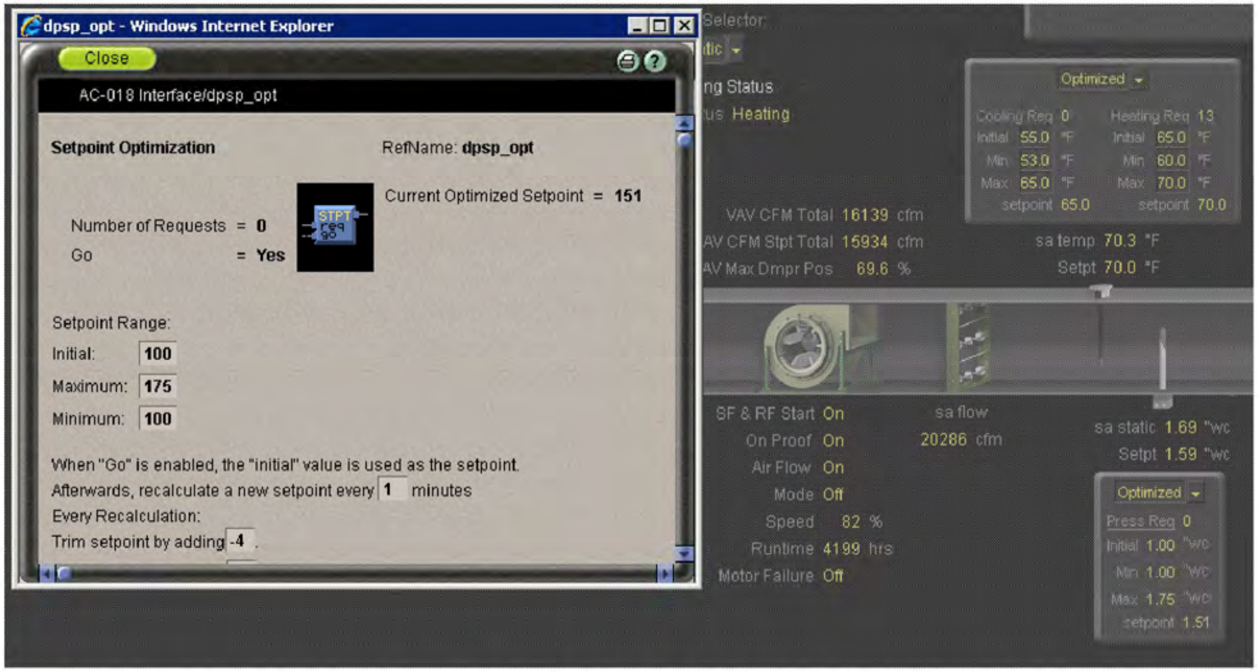



**Figure 4: Pressure request optimization mechanism – should not be open to lowest level user, changed to higher-level password editing**

Reset mechanism for temp not working – See Figure 5 and Figure 6 "flip" between hot and cold not correct, need to add heating and cooling requests so that summary is roughly zero or slight values around zero, not a flip back and forth between heat and cool.
Changed the mechanism to add heating and cooling requests (one with positive sign, one with negative) so they come out to a small (almost zero) sum when heating and cooling requests are almost in balance (i.e. 4 heat requests 5 cool requests make a net total of 1 cool requests, and do not flip from 5 cool request with cooling wound up to sudden heat if the total changes to 5 heat and 5 cool requests, but instead end up going from one net cool request to zero overall, a very slight change). Re-programmed on[redacted]12 from about 8:10 AM to 9:00 AM. See test #B5 above, and also Figure 20 and Figure 21 below for AC-20.

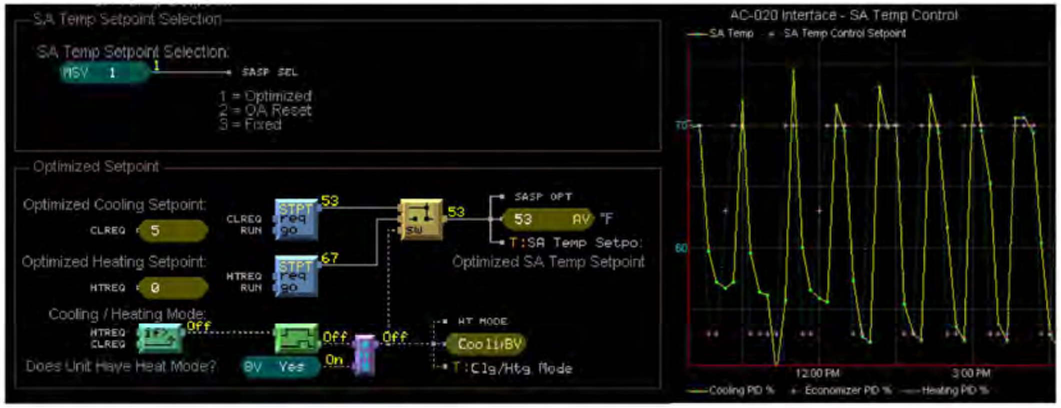



**Figure 5: Pressure request optimization mechanism – flipping between heating and cooling modes causes jumps in Supply Air Temperature**

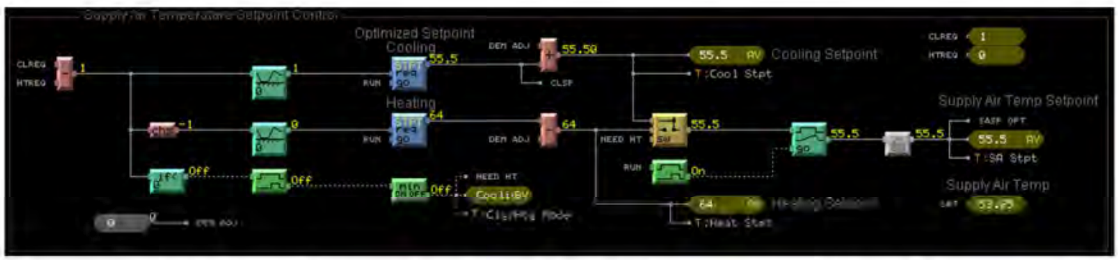



**Figure 6: Revised pressure request optimization mechanism – heating and cooling requests are subtracted from one another, leaving the difference as the driver of the reset mechanism**

Note delays in ramp functions mean that optimized SP and actual SP can "drift" apart during very rapid changes. These will not occur in normal operation, but only during testing where we suddenly override requests. Also note that the cooling and heating optimization loops should "meet" in the middle, ie. the cooling max should equal the heating min (65°F in this example) and the initial values should be the same, namely that middle , because as the unit flips from heating to cooling, these initial values are what the loops start with, and as we go from heat to cool, we'll be at 65°F, so we don't want a sudden change as we go from heat to cool or vice versa.


**Figure 7: Original (Left) and revised (Right) supply air temperature optimization mechanism. The revised selection will operate much more smoothly because jumps in temperatures are avoided when switching from heating to cooling**

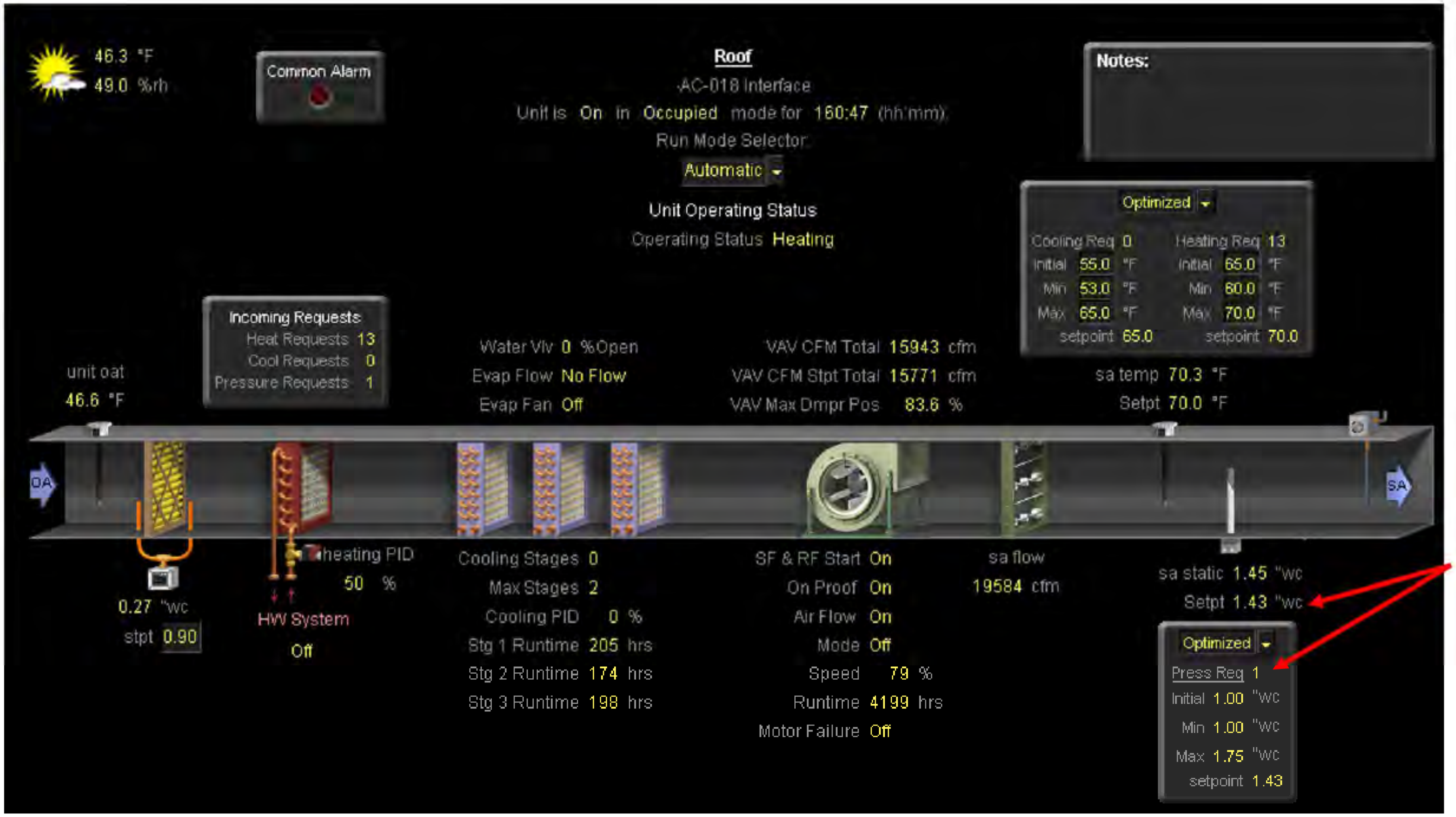
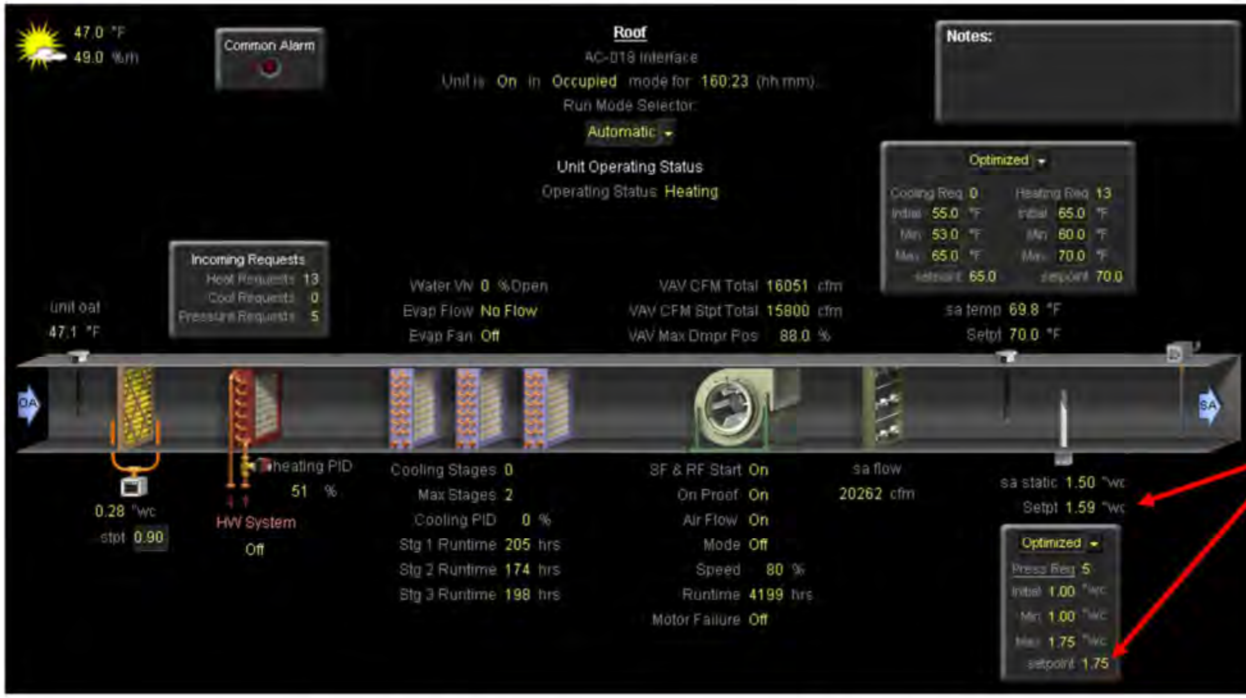



**Figure 8: AC-18 static pressure reset test (1 of 3), see 1.45" original pressure with 1 request.**




Note that the setpoint command (bottom of screen) that goes out from ALC is not immediately reflected in the current actual setpoint feedback from the Mammoth unit interface (setpoint displayed below duct). There is a delay of ~1-2 minutes before the Mammoth interface reflects the setpoint which is sent from ALC.

**Figure 9: AC-18 static pressure reset test (2 of 3), see 1.59" setpoint with 5 requests after 2 minutes**

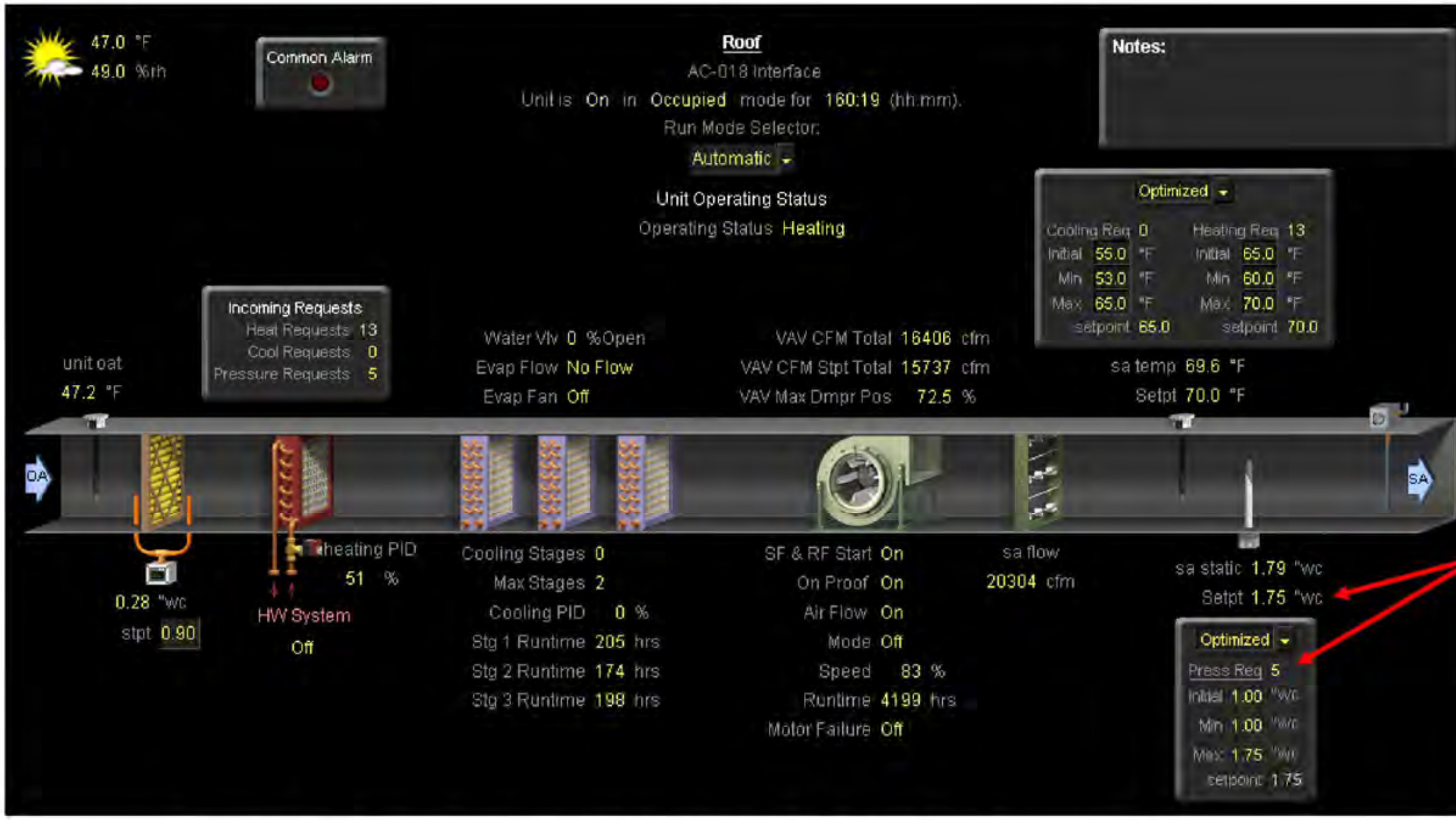



**Figure 10: AC-18 static pressure reset test (2 of 3), see 1.75" setpoint with 5 requests after 6 minutes**

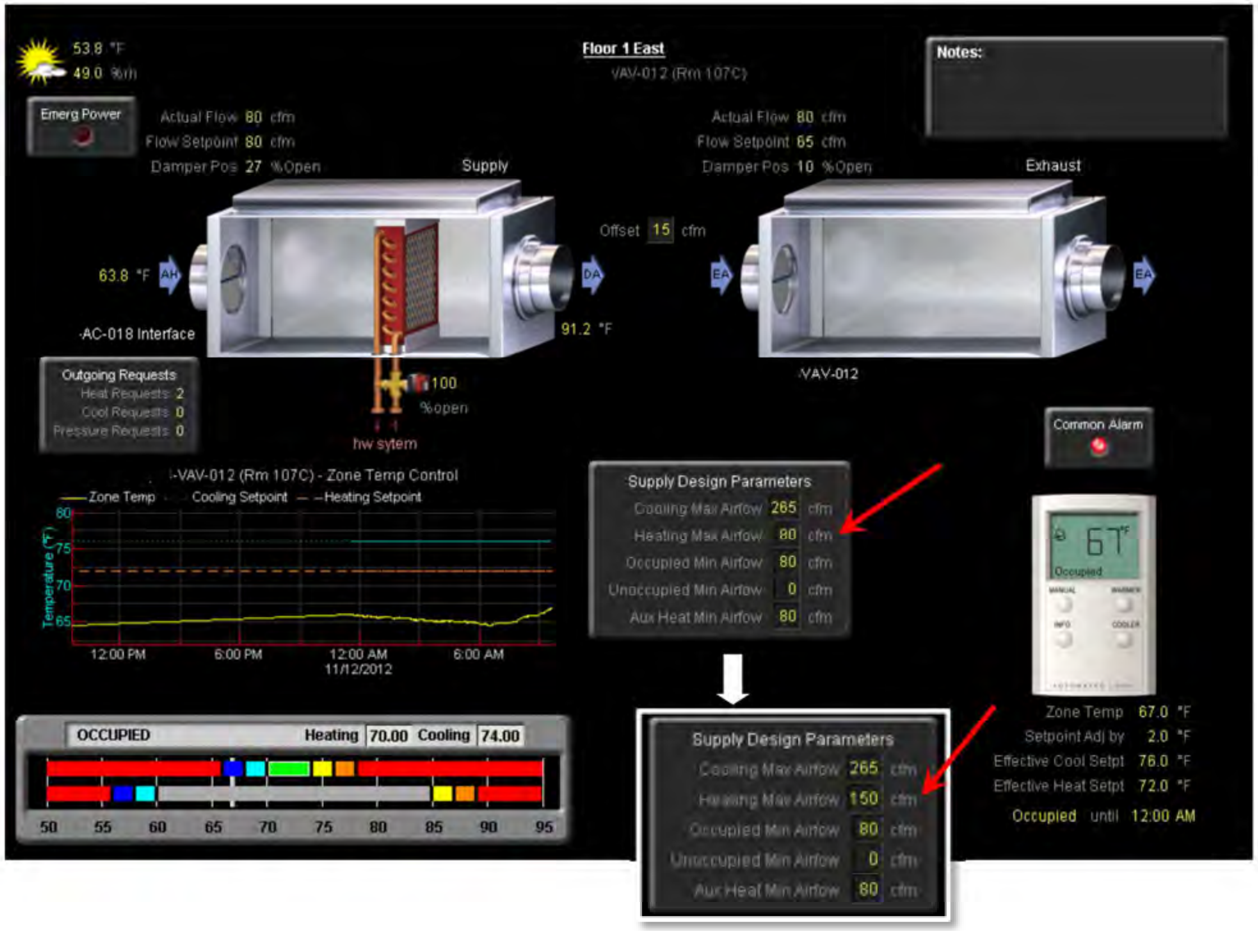



**Figure 11: Office 107 C – too little heating airflow on cold Monday morning – changed heating SP from 80 cfm (per design docs) to 150 cfm**

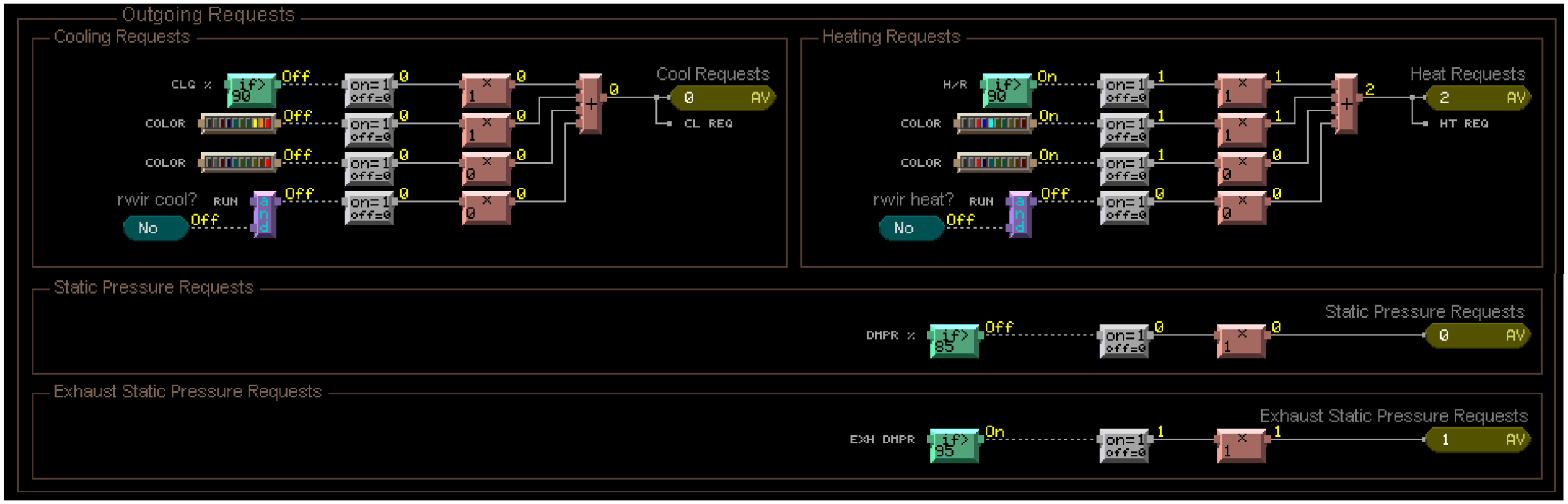



**Figure 12: Zone heat/cool requests and static pressure requests. Temp requests (0 to 3) triggered by PID loop output > 90%, temperature hi/low and temperature very hi/low. Cumulative signal from all three triggers "trickles" up to AC unit. Pressure requests (0 or 1) based on damper position > 85%.**

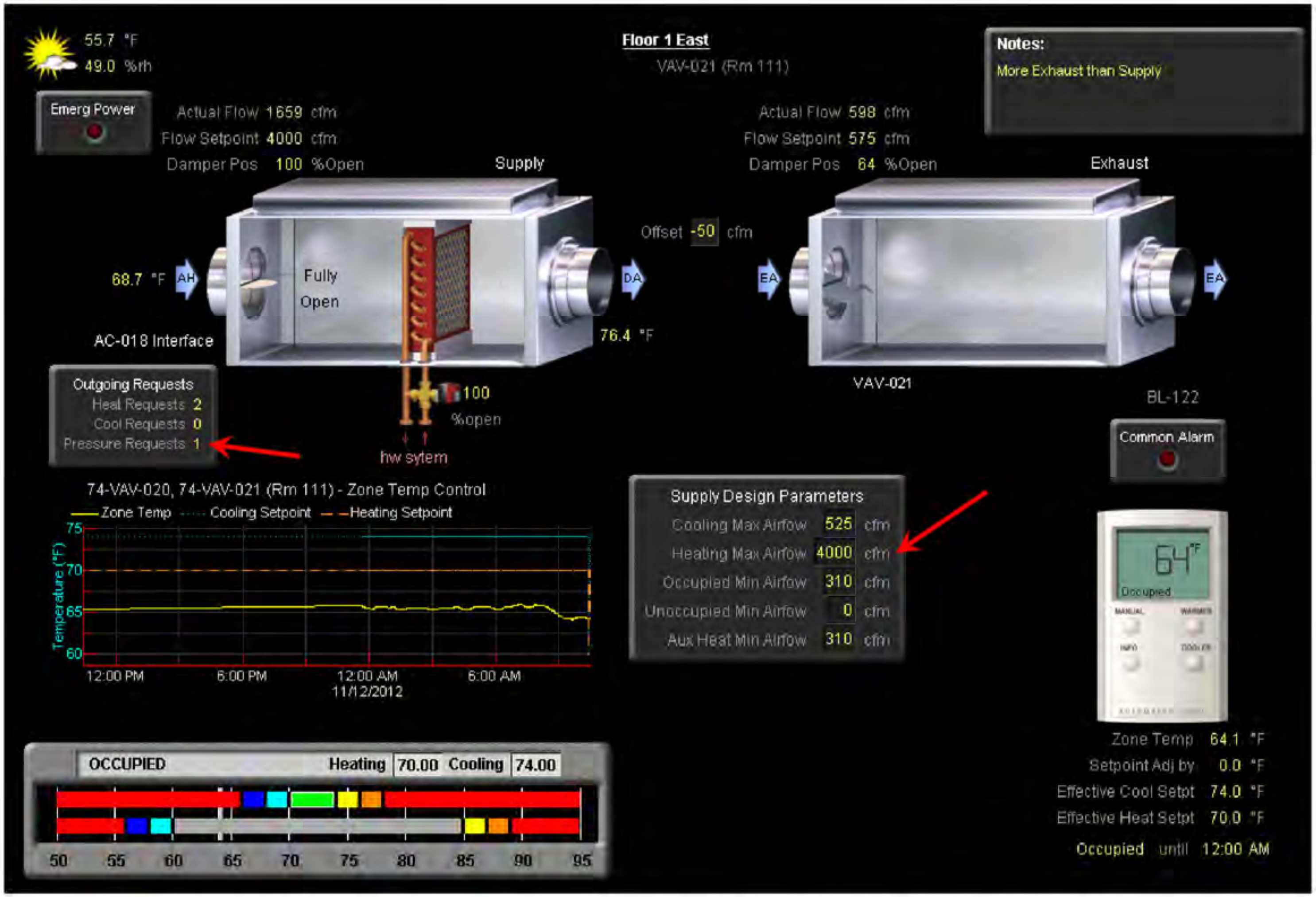



**Figure 13: entered 4,000 cfm as heating airflow, zone goes to 100% open damper (impossible to meet airflow), and pressure request shown on screen, also trickles up to AC unit.**

**AC-02** [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| E. Lab SF and EF Operational Interlock. | 1. With exhaust fans BL-003, BL-004, and AC-02 initially running, turn off BL-003 and BL-004. | a. Exhaust fans BL-003 and BL-004 are off.<br>b. AC-02 is off.<br>c. AC-02 make-up air damper is closed. | Nov 9, 3:43PM<br><br>Not tested | |
| | 2. With exhaust fans BL-003 and BL-004 initially turned off, enable all of these exhaust fans to operate. Confirm that AC-02 is initially turned off prior to beginning this test. | 7. Exhaust fans BL-003 and BL-004 are enabled to operate.<br>8. AC-02 is enabled.<br>9. AC-02 make-up air damper is closed. | Not tested | |
| F. Supply Air Temperature Reset Function | 3. Manually adjust AC-02 Supply Air Temperature setpoint to 40°F. | AC-02 Supply Air Temperature setpoint changes to 40°F.<br>AC-02 HW control valve is fully closed.<br>AC-02 DX coil is active.<br>AC-02 Supply Air Temperature approaches setpoint. | (AC-18 cooling lockout released [redacted]12 at 3:44 PM)<br>From initial heating 34% open valve, unit goes to cooling.<br>(Note: testing AC 19 and 20 in parallel). See Figure 14 to Figure 16 | Y |
| | 4. Manually adjust AC-02 Supply Air Temperature setpoint to 80°F. | a. AC-02 Supply Air Temperature setpoint changes to 80°F.<br>b. AC-02 DX coil is inactive.<br>c. AC-02 HW control valve modulates open.<br>d. AC-02 Supply Air Temperature approaches setpoint. | Change to 80°F [redacted]12 at 4:06PM Initially, still wound up in cooling, w new SP of 80°F) then raises SAT by shutting off cooling and RH valve goes back to 63% open.<br>OK, see Figure 17 to Figure 18 | Y |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 5. Enable the AC-02 Supply Air Temperature automatic-reset function. Adjust a downstream zone VAV terminal unit space temperature set point so that it becomes the zone requiring the most cooling. | a. Supply air temperature setpoint resets downwards by at least 25% of the difference between the design supply air temperature and design room air temp.<br>b. AC-02 HW valve is closed.<br>c. AC-02 DX coil is activated after HW valve has closed, but not before.<br>d. Room cooling request is shown on DDC graphics. | Record time for reset across full range, and criteria for reset (i.e. effect of number of zones requesting reset and exact nature of "most cooling" criterion)<br>[redacted]12 8AM: nine heat requests peg unit at max. SAT of 70°F in automatic mode.<br>Manually override heating requests to zero. Unit goes to 65°F setpoint immediately. Closer look at reset strategy causes revision of request math for all units, see Figure 5 and Figure 6. | Y |
| | 6. Use operator lockout on zone used in Test #5 above. | a. Supply air temperature setpoint ceases downward reset. | | |
| G. Supply Air Pressure Control | 7. Confirm that Supply Air Duct Static Pressure setpoint is initially at 1.0" w.c. and change the Supply Duct Static Pressure High-Limit alarm to 1.5" w.c. Manually adjust AC-02 Supply Air Duct Static Pressure setpoint to 2.0" w.c. | a. AC-02 Supply Air Duct Pressure Hi-Limit is set to 2.0" w.c.<br>b. Supply Fan VFD ramps fan speed up until 1.5" w.c. was achieved.<br>c. At 1.5" w.c., SA Duct High-Limit Alarm is tripped and shuts down AC-02 Supply Fan. | | |
| | 8. Manually input a Supply Air Duct Static Pressure setpoint of 1.0" w.c. and restart AC-02. | a. AC-02 SF is enabled.<br>b. Supply Fan VFD ramps fan speed up until 1.0" w.c. is achieved. | | |
| | 9. Manually adjust AC-02 Supply Air Duct Static Pressure High-Limit to 4.0" w.c. and then input a Supply Air Duct Static Pressure setpoint of 2.0" w.c. | 10. AC-02 Supply Air Duct Pressure setpoint changes to 2.0" w.c.<br>11. Supply Fan VFD ramps fan speed up until 2.0" w.c. is achieved.<br>12. SA Duct High-Limit Alarm does not trip. | | |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 10. Manually adjust AC-02 Supply Air Duct Static Pressure setpoint to 0.5" w.c. | a. AC-02 Supply Air Duct Pressure setpoint changes to 0.5" w.c.<br>b. Supply Fan VFD ramps fan speed down until 0.5" w.c. is achieved. | | |
| | 11. Enable the AC-02 Supply Air Duct Pressure automatic-reset function. Adjust a downstream zone VAV terminal unit space temperature set point, other than the one used for Tests #5 and #6, so that the primary air damper position exceeds 85% open. | a. Supply air duct static pressure setpoint is incrementally increased.<br>b. Supply Fan VFD ramps fan speed up. | Record trim-and-respond parameters for increase and decrease values used, and time intervals<br>Mon [redacted] 2012 7:45AM Reset range 0.08" up per request, trim by 0.04" every 5 minutes.<br>Change to 5 requests, every 1 minutes. See Figure 19. | Y |
| | 14. Enable the AC-02 Supply Air Duct Pressure automatic-reset function. Override VAV terminals airflow set point, so that the primary air damper position is below 85% open or directly override damper position, for all terminals. | e. Supply air duct static pressure setpoint decreases according to trim-and-respond reset schedule<br>f. Supply Fan VFD ramps fan speeds down to maintain SP as it changes. | | |
| H. Shutdown Operation | 12. Shutdown AC-02 through DDC workstation interface. | 13. AC-02 is disabled.<br>14. AC-02 Supply Fan is off.<br>15. AC-02 HW valve is closed.<br>16. AC-02 DX coil is inactive. | | |

Additional Notes

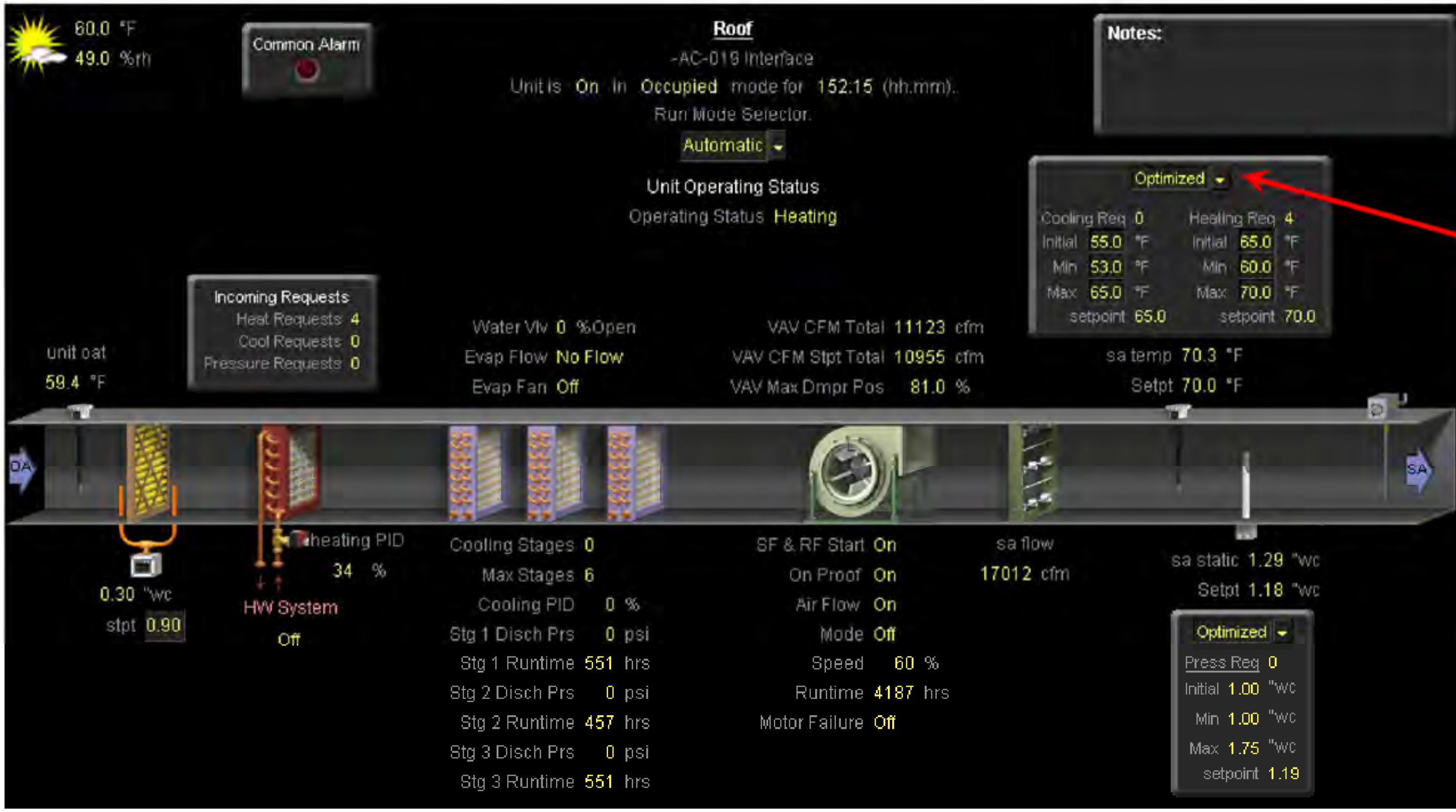



**Figure 14: AC-19 supply air temperature in automatic mode[redacted]12 at 3:45PM, in heating mode with cooling off.**

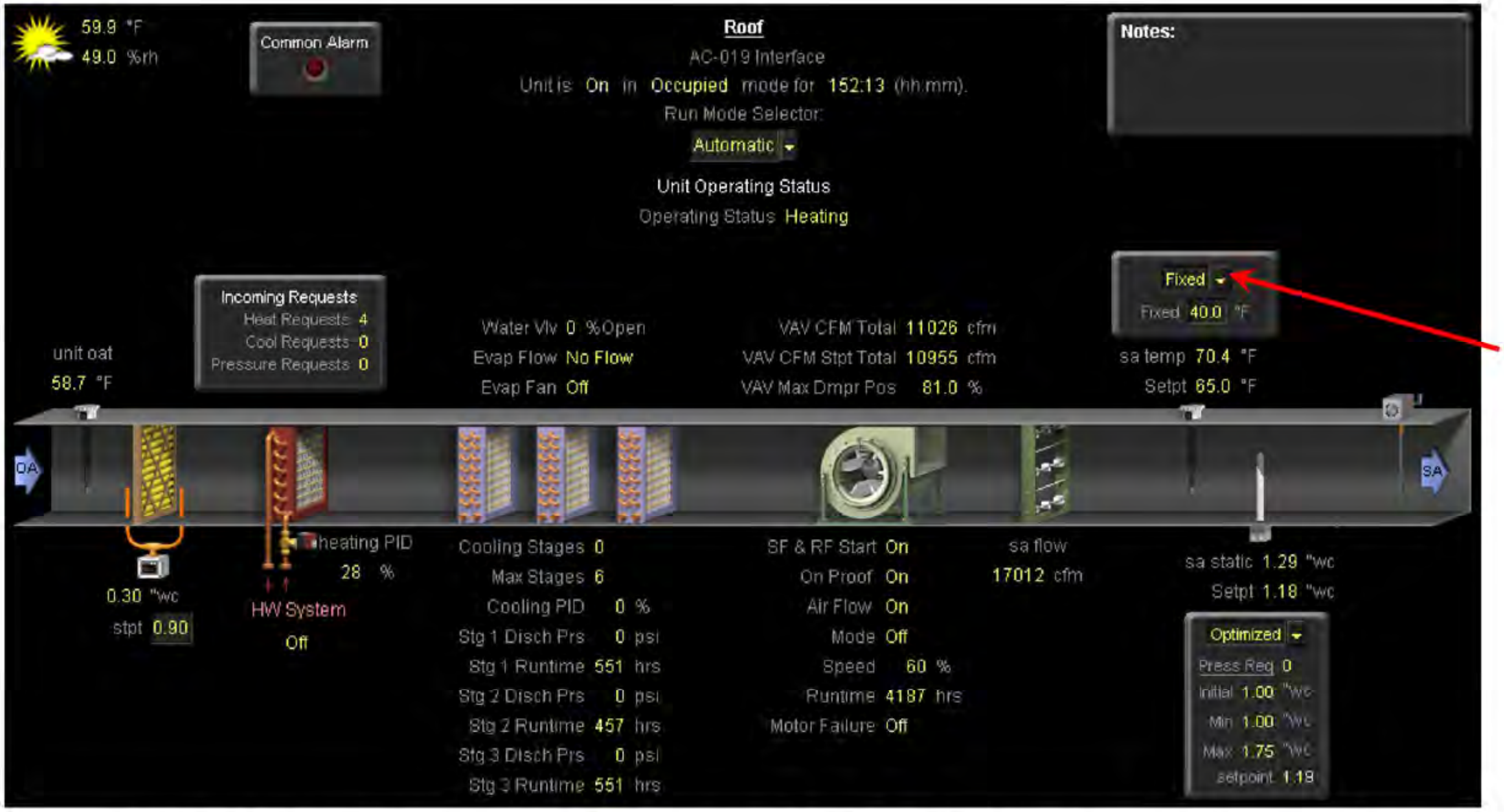



**Figure 15: AC-19 supply air temperature in fixed setpoint mode [redacted]12 at 3:47PM, in cooling mode with cooling off.**

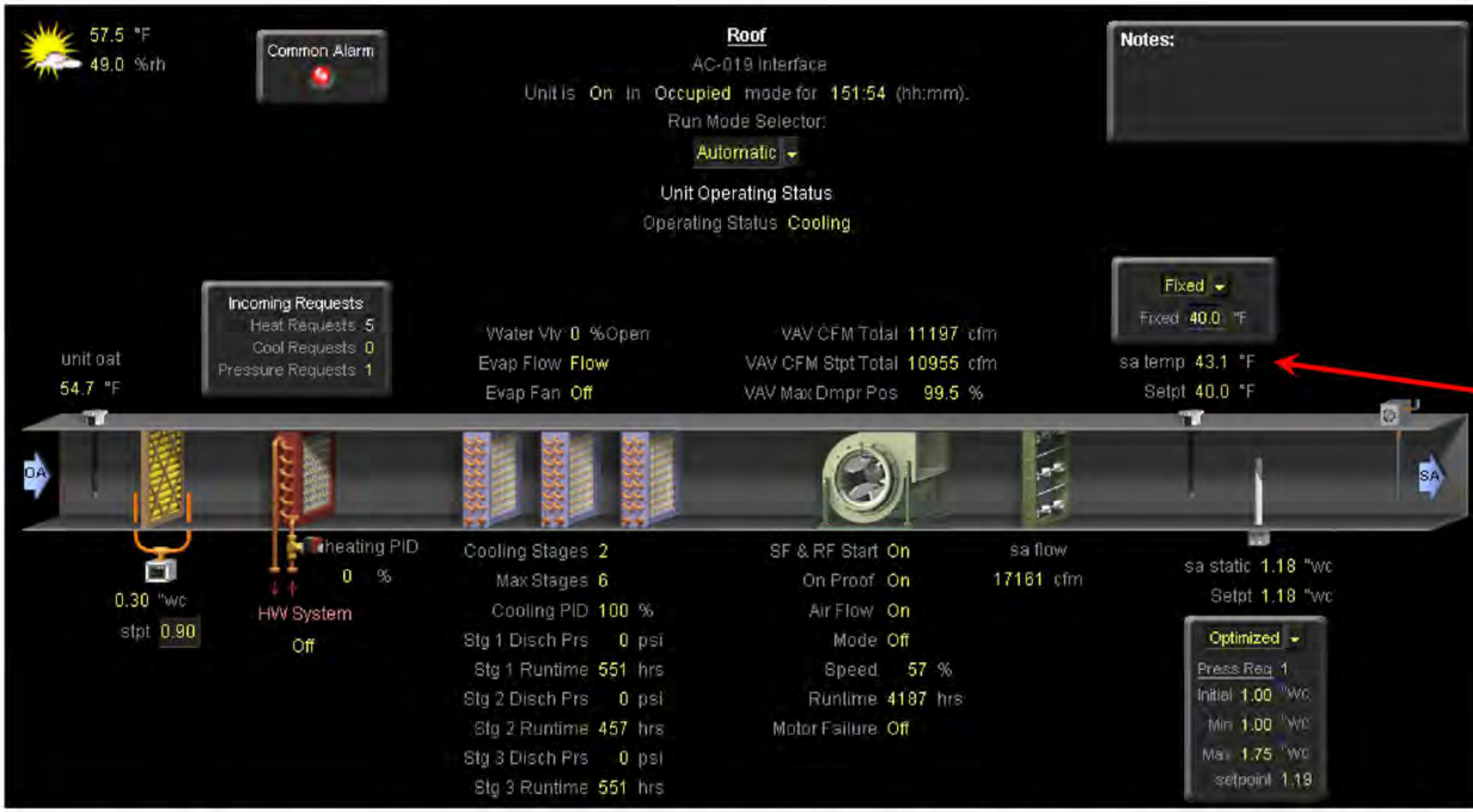



**Figure 16: AC-19 supply air temperature in fixed setpoint mode [redacted]12 at 4:06PM, in cooling mode with 2 stages of cooling, close to meeting setpoint**

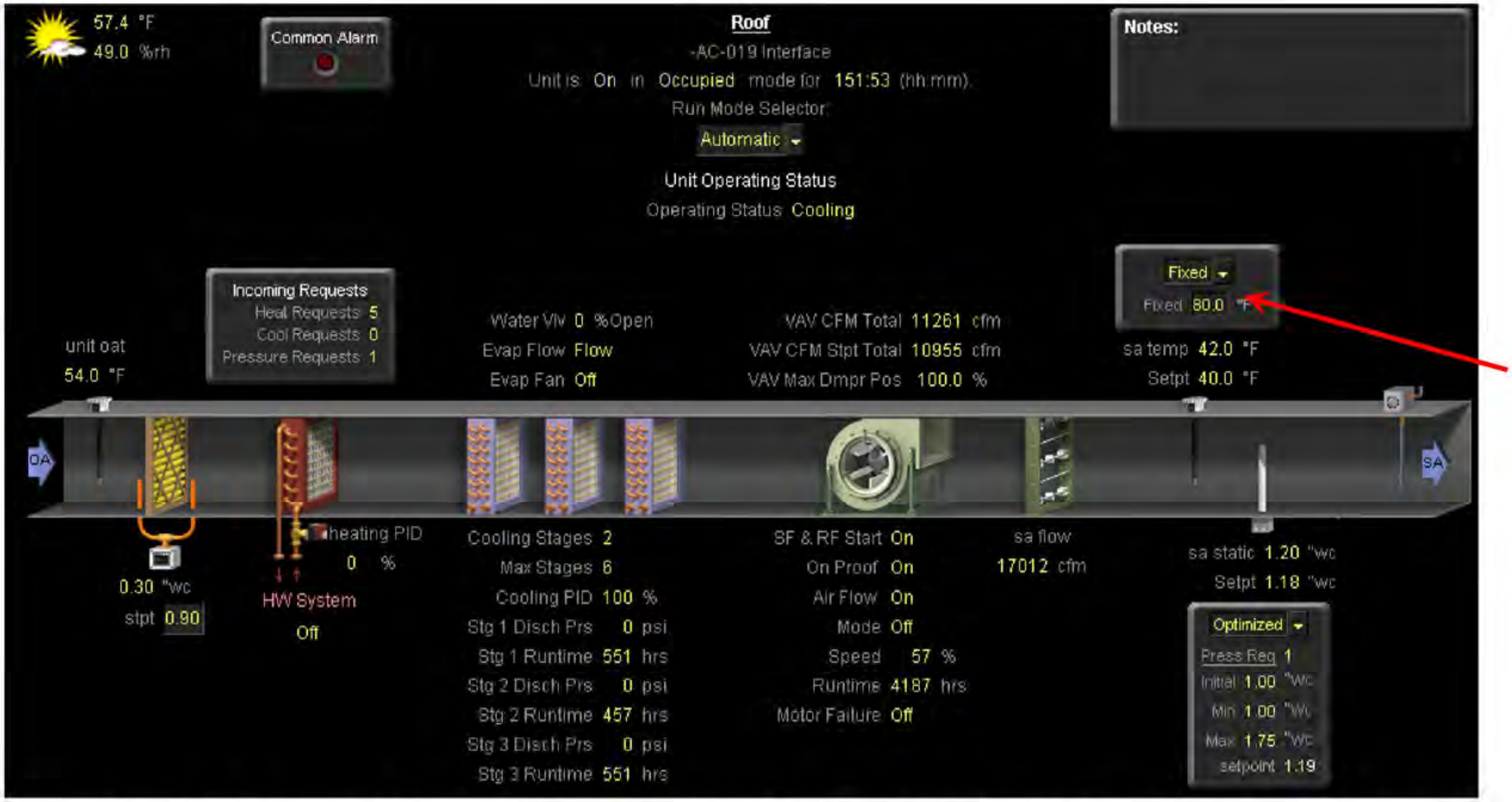



**Figure 17: AC-19 supply air temperature in fixed setpoint mode [redacted]12 at 4:07PM, switched back to heating by setting temperature setpoint at 80°F**

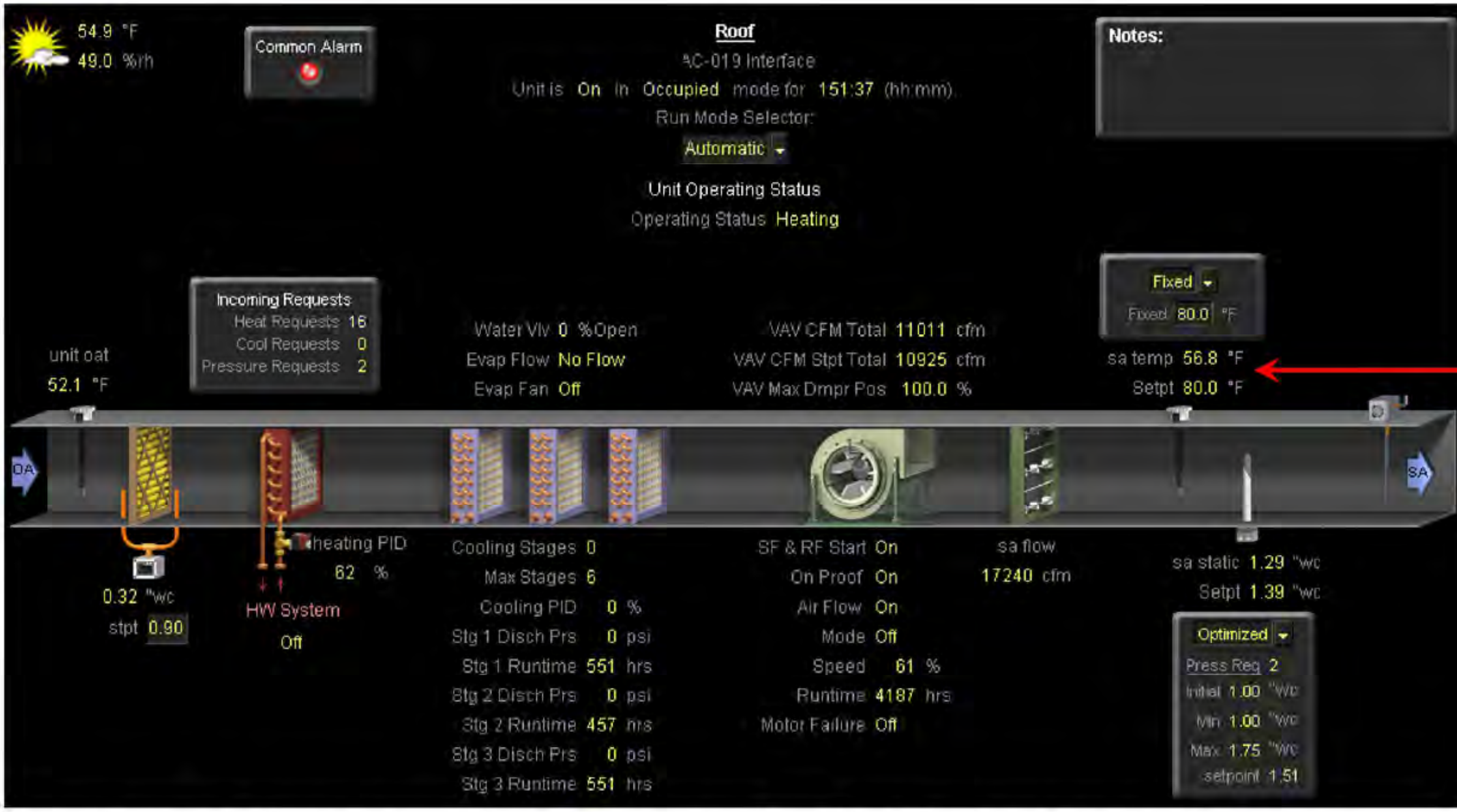



**Figure 18: AC-19 supply air temperature in fixed setpoint mode [redacted]12 at 4:22 PM, switched back to heating by setting temperature setpoint at 80°F. Cooling section off again, heating valve open to 62%.**


**Figure 19: AC-19 supply static reset: at [redacted]12 7:14AM (left), 7:37AM (middle) and 7:41AM (right). Note overall airflow remains the same despite change in air pressure due to (overridden) requests for pressure. Fan speed goes from 60% to 66% in test.**

**AC-03** [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| I. Occupancy Schedule and Set-Back Operation | 1. Schedule AC-03 to end occupied mode of operation at the nearest future time slot of the present date. | a. AC-03 shuts down at selected time slot.<br>b. Set-back heating and cooling temperatures are shown through DDC workstation. | [redacted]12 @ 11:30AM<br>Schedule unit off – note there is no unit schedule for the unit itself, use schedule for zone groups instead. Current selection is 6AM to 6PM for weekdays on AC-20, other units are 24/7<br><br>Schedule zone group off at 11:40AM, disconnect from building schedule (and leave disconnected)<br><br>Appears there is someone in room 205 who hits the override button– unit remains enabled, and airflows remain occupied while temp Setpoints go to unoccupied.<br>See Figure 22 to Figure 24.<br><br>Manually walk to room 205, turn override off, see unit AC20 turn off.<br>See Figure 25 and Figure 26. | Y |
| | 2. Adjust unoccupied set-back heating temperature to a value that is high enough to trigger set-back heating mode. | a. Zones calling for set-back heating and the designated isolation zone have their VAV terminal units enabled.<br>b. AC-03 Supply and Return Fans are running.<br>c. AC-03 HW valve opens.<br>d. AC-03 DX coil is inactive.<br>e. AC-03 min. OA damper remains closed.<br>f. AC-03 economizer OA damper remains | [redacted]12 12:10 PM<br>Override zone VAV-005 to 73 unocc. Heating SP – zone wakes up, and so does unit. Blue zone on floor plan, and 2 HT requests to unit AC-20. See Figure 27 to Figure 29. | Y |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | | closed.<br>g. AC-03 RA damper is fully open. | Clear override, see unit AC20 shut off gain and see zone airflows go to zero. | |
| | 3. Return unoccupied set-back heating temperature to a value that would not require heating from AC-03. | a. AC-03 Supply and Return Fans are off.<br>b. AC-03 HW valve is closed.<br>c. AC-03 DX coil is inactive.<br>d. AC-03 min. OA damper remains closed.<br>e. AC-03 economizer OA damper remains closed.<br>f. AC-03 RA damper is fully open. | | |
| | 4. Adjust unoccupied set-back cooling temperature to a value equal to the present outside air temperature. | a. Zones calling for set-back cooling and the designated isolation zone have their VAV terminal units enabled.<br>b. AC-03 Supply and Return Fans are running.<br>c. AC-03 HW valve is closed.<br>d. AC-03 DX coil is inactive.<br>e. AC-03 min. OA damper remains closed.<br>f. AC-03 economizer OA and RA dampers are modulating. | | |
| | 5. Adjust unoccupied set-back cooling temperature to a value that is lower than the present outside air temperature. | a. Zones calling for set-back cooling and the designated isolation zone have their VAV terminal units enabled.<br>b. AC-03 Supply and Return Fans are running.<br>c. AC-03 HW valve is closed.<br>d. AC-03 DX coil is active.<br>e. AC-03 min. OA damper remains closed.<br>f. AC-03 economizer OA and RA dampers are modulating. | | |
| | 6. Return unoccupied set-back cooling temperature to a value that would not require cooling from AC-03. | a. AC-03 Supply and Return Fans are off.<br>b. AC-03 HW valve is closed.<br>c. AC-03 DX coil is inactive.<br>d. AC-03 min. OA damper remains closed.<br>e. AC-03 economizer OA damper is closed.<br>f. AC-03 RA damper is fully open. | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 7. Schedule AC-03 to start occupied mode of operation at the nearest future time slot of the present date. | Part 1 AC-03 starts up at selected time slot. | | |
| J. Supply Air Temperature Control | 8. Manually adjust AC-03 Supply Air Temperature setpoint to 40°F. | 1.01 AC-03 Supply Air Temperature setpoint changes to 40°F.<br>1.02 AC-03 HW valve is closed.<br>1.03 AC-03 DX coil is active.<br>1.04 AC-03 economizer OA and RA dampers modulate.<br>1.05 AC-03 min. OA is maintained above 0 CFM.<br>1.06 AC-03 Supply Air Temperature approaches setpoint. | 3:48PM [redacted] .<br>Override SP to 40°F.<br>Unit goes from heat (maintaining SP of 53°F without heating coil open thanks to 59°F OAT) to cooling, 84% cooling PID and 2 of 2 stages enabled at 3:59PM, 43°F actual supply temp.<br><br>Release SP at 4PM | Y |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 9. Manually adjust AC-03 Supply Air Temperature setpoint to 80°F. | 1.07 AC-03 Supply Air Temperature setpoint changes to 80°F.<br>1.08 AC-03 HW valve opens.<br>1.09 AC-03 DX coil becomes inactive.<br>1.10 AC-03 economizer OA damper fully closes.<br>1.11 AC-03 RA damper fully opens.<br>1.12 AC-03 min. OA is maintained above 0 CFM.<br>1.13 AC-03 Supply Air Temperature approaches setpoint. | [redacted]12 4:02 PM.<br>Immediately from cooling go to 80°F SAT SP<br><br>Responds correctly, by 4:18PM, unit is at 82% heating valve, cooling at 0%. Actual temperature has climbed from 43°F to 57°F.See Figure 30 to Figure 32.<br><br>Unit should no longer be in full economizer though, see Figure 33. | Y<br><br>N |
| | 10. Manually adjust AC-03 Supply Air Temperature setpoint to the same value as current outside air temperature. | a. AC-03 Supply Air Temperature setpoint changes to inputted value.<br>b. AC-03 HW valve is closed.<br>c. AC-03 DX coil is inactive.<br>d. AC-03 economizer OA and RA dampers modulate.<br>e. AC-03 Supply Air Temperature approaches setpoint. | | |
| | 11. Enable AC-03 Supply Air Temperature automatic-reset function. Adjust a downstream zone VAV terminal unit space temperature set point so that it becomes the zone requiring the most cooling. | a. Supply air temperature setpoint resets downwards by at least 25% of the difference between the design supply air temperature and design room air temp.<br>b. AC-03 HW valve is closed.<br>c. AC-03 DX coil is activated after HW valve has closed, but not before.<br>d. Room cooling request is shown on DDC graphics. | Record time for reset across full range, and criteria for reset (i.e. effect of number of zones requesting reset and exact nature of "most cooling" criterion)<br>[redacted]/12 8AM automatic mode, heat requests peg unit at max. SAT of 70°F..<br>Manually override requests to zero. Note immediate flip to cooling, make correction in reset mechanism, see notes below. See Figure 5 to Figure 6 and also Figure 20 to Figure 21. | First N then Y |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 12. Use the operator lockout on the zone used in Test #11 above. | a. Supply air temperature ceases downward reset. | | |
| K. Supply Air Pressure Control | 13. Confirm that Supply Air Duct Static Pressure setpoint is initially at 1.0" w.c. and change the Supply Duct Static Pressure High-Limit alarm to 1.5" w.c. Manually adjust AC-03 Supply Air Duct Static Pressure setpoint to 2.0" w.c. | 1. AC-02 Supply Air Duct Pressure Hi-Limit is set to 2.0" w.c.<br>2. Supply Fan VFD ramps fan speed up until 1.5" w.c. was achieved.<br>3. At 1.5" w.c., SA Duct High-Limit Alarm is tripped and shuts down AC-03 Supply Fan. | | |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 14. Manually input a Supply Air Duct Static Pressure setpoint of 1.0” w.c. and restart AC-03. | AC-03 SF is enabled.<br>Supply Fan VFD ramps fan speed up until 1.0” w.c. is achieved. | | |
| | 15. Manually adjust AC-03 Supply Air Temperature Pressure High-Limit to 4.0” w.c. and then input a Supply Air Duct Static Pressure setpoint of 2.0” w.c. | a. AC-03 Supply Air Duct Pressure setpoint changes to 2.0” w.c.<br>b. Supply Fan VFD ramps fan speed until 2.0” w.c. is achieved.<br>c. SA Duct High-Limit Alarm does not trip. | | |
| | 16. Manually adjust AC-03 Supply Air Duct Static Pressure setpoint to 0.5” w.c. | a. AC-03 Supply Air Pressure setpoint changes to 0.5” w.c.<br>b. Supply Fan VFD ramps fan speed down until 0.5” w.c. is achieved. | | |
| | 17. Enable the AC-03 Supply Air Duct Pressure automatic-reset function. Adjust a downstream zone VAV terminal unit space temperature setpoint, other than the one used for Tests #11 and #12, so that the primary air damper position exceeds 85% open. | a. AC-03 Supply Air Duct Pressure setpoint is incrementally increased.<br>b. Supply Fan VFD ramps fan speed up. | Record trim-and-respond parameters for increase and decrease values used, and time intervals<br>Mon[redacted]2012 7:45AM Reset range 0.08” up per request, trim by 0.04” every 5 minutes.<br>Change to 5 requests, every 1 minutes. | Y |
| | 15. Enable the AC-03 Supply Air Duct Pressure automatic-reset function. Override VAV terminals airflow set point, so that the primary air damper position is below 85% open or directly override damper position, for all terminals. | a. Supply air duct static pressure setpoint decreases according to trim-and-respond reset schedule<br>b. Supply Fan VFD ramps fan speeds down to maintain SP as it changes. | 7:50AM override to 0 requests, watch setpoint drop from 1.59” at 7:50 AM to 0.87” at 8:08AM, or 0.04” * 18 = 0.72”.<br>See Figure 34.<br>Remainder see AC-18 (same program block all 3 units) | Y |
| L. Building Pressure Control | 18. Set all downstream terminal VAV units to minimum primary airflow setpoints. Lockout OA economizer and confirm that minimum ventilation OA is maintained at | a. Average building pressure in locations served by AC-03 is maintained slightly positive with respect to the outdoors (~0.02” w.c.). | | |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | AC-03. | | | |
| | 19. Set all downstream terminal VAV units to maximum primary airflow setpoints. Force AC-03 into 100% OA economizer operation. | a. Average building pressure in locations served by AC-03 is maintained slightly positive with respect to the outdoors (~0.02" w.c.). | | |
| | 20. Restore downstream terminal VAV units and AC-03 economizer to normal operation. | a. Average building pressure in locations served by AC-03 is maintained slightly positive with respect to the outdoors (~0.02" w.c.). | | |
| M. By-pass Fan Operation (After-Hours Use) | 21. Set AC-03 into unoccupied mode through DDC workstation and activate the by-pass timer at a room thermostat. | a. AC-03 is enabled and runs in occupied mode.<br>b. Downstream VAV terminal unit operation is limited to zone where by-pass timer was activated and the designated isolation zone to ensure that minimum DX coil airflow requirements are satisfied at AC-03. | See test I.1 above, actual override from tenant in room 205 shows correct unit operation. | Y |
| | 22. Return AC-03 to occupied mode of operation. | a. AC-03 is enabled to run in occupied mode.<br>b. Minimum OA is maintained.<br>c. Supply Fan is running.<br>d. Automatic SAT Reset is enabled.<br>e. Automatic SA-Pressure Reset is enabled.<br>f. Previously selected zones for operator lockout remain locked out. | | |
| N. Fire and Smoke Alarm Operations | 23. Override fire alarm status to simulate the fire alarm being activated by means other than duct smoke detection. | a. AC-03 remains enabled. | | |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 24. While fire alarm status remains, override duct smoke detector status to simulate smoke detection from AC-03 Supply Fan. | a. AC-03 is disabled.<br>b. Supply and Return Fans are first turned off, and then supply air discharge duct smoke damper is closed.<br>c. All corresponding exhaust fans are off.<br>d. Fire alarm system closes all fire/smoke dampers associated with AC-03. | | |
| | 25. Manually reset AC-03 duct smoke detectors to clear smoke detector and fire alarms. Place AC-03 into occupied mode of operation. | a. AC-03 is enabled.<br>b. Fire alarm system opens all fire/smoke dampers associated with AC-03 prior to running AC-03 Supply and Return Fans.<br>c. All corresponding exhaust fans are on. | | |
| O. Shutdown Operation | 26. Shutdown AC-03 through DDC workstation interface. | a. AC-03 is disabled.<br>b. AC-03 Supply and Return Fans are off.<br>c. AC-03 HW valve is closed.<br>d. AC-03 DX coil is inactive. | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

Additional Notes

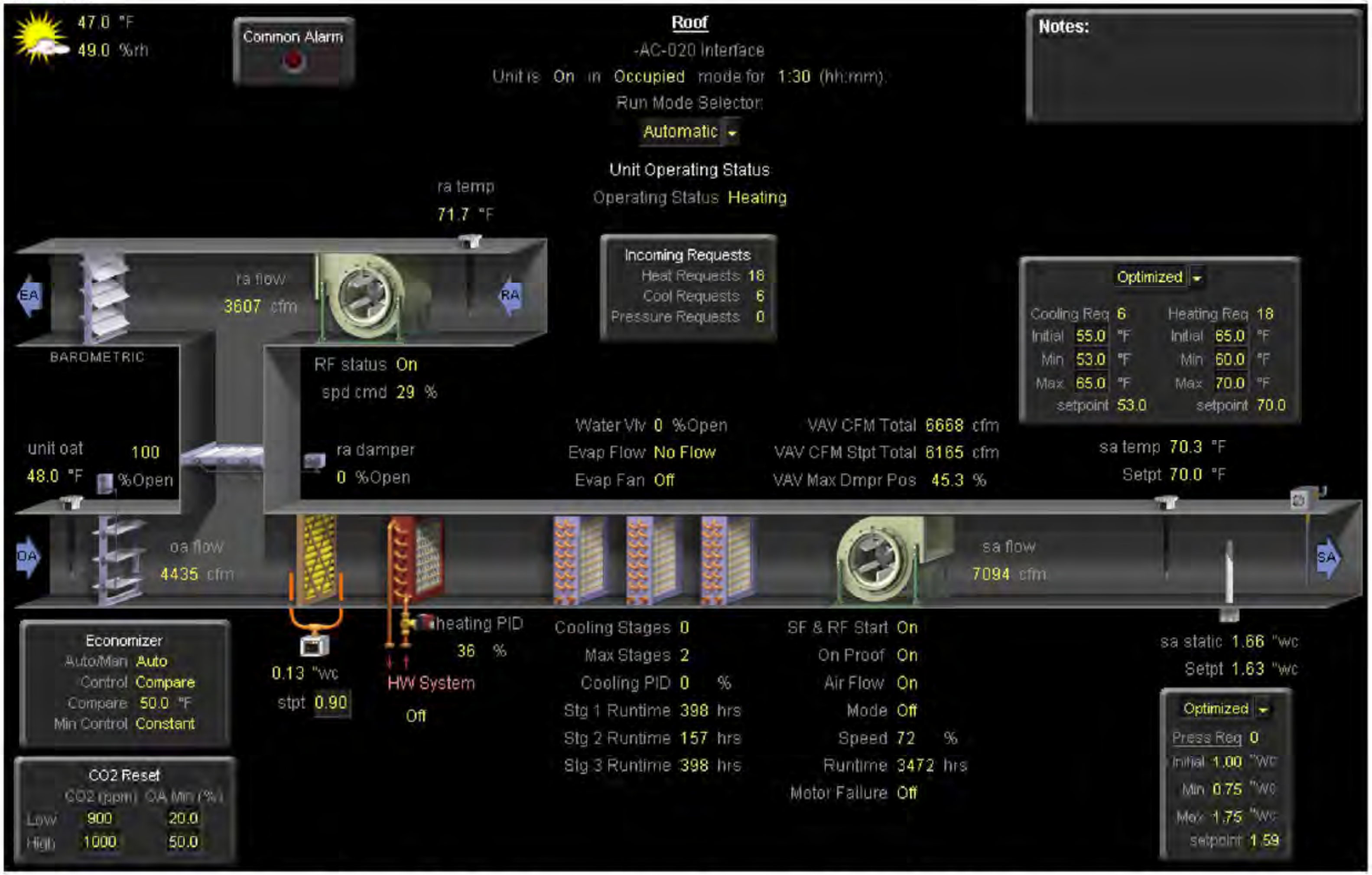



**Figure 20: AC-20 on [redacted]12 at 7:50 AM. Note incorrect request summary, 18 heating and 6 cooling requests from zones (left) equal the same at AC unit temperature control instead of a total of 12 heating requests.**

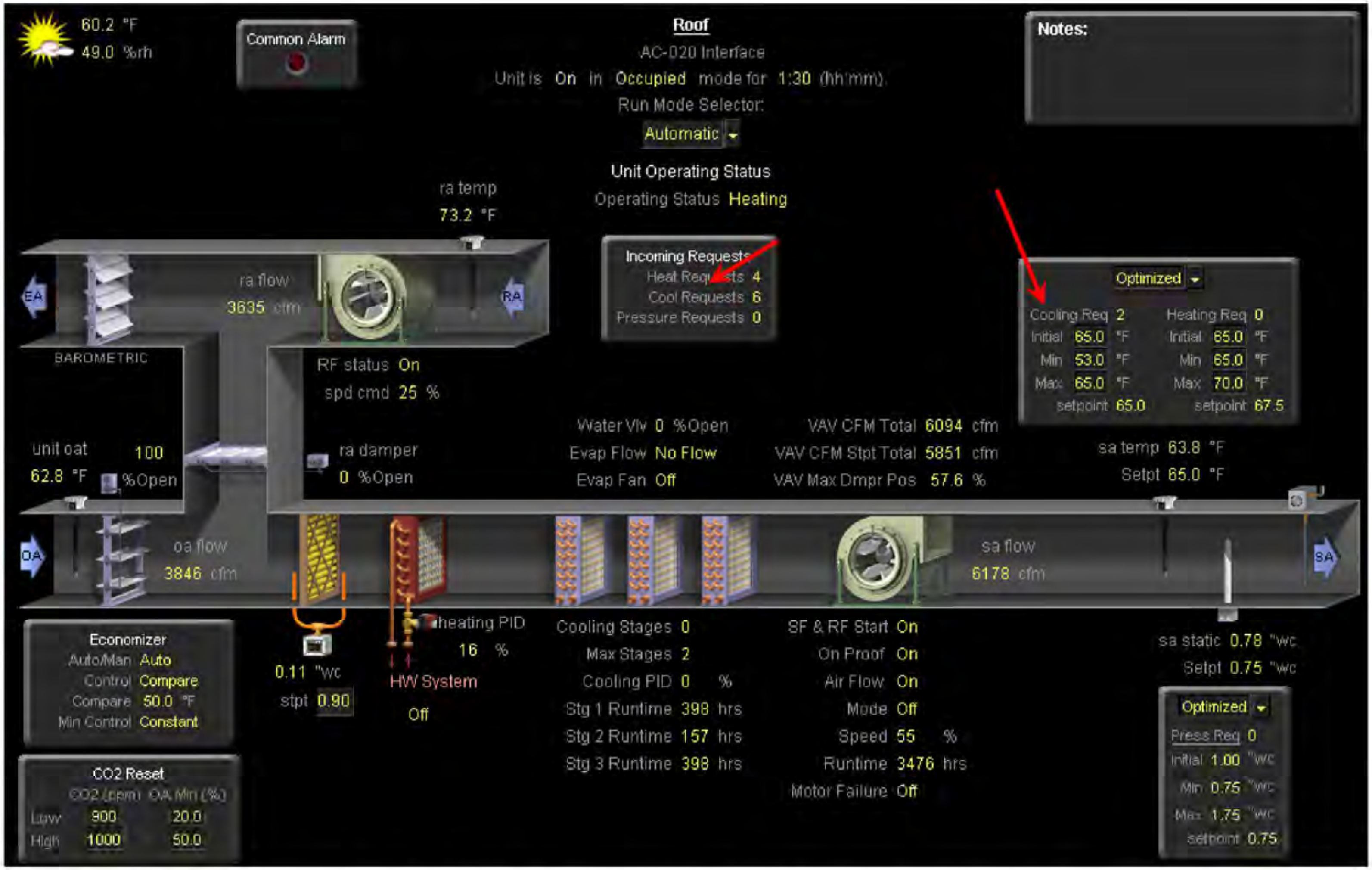



**Figure 21: AC-20 on [redacted]12 at 11:38AM just before occupancy test. Note corrected request summary, 4 heating and 6 cooling requests from zones (left) equal a total of 2 cooling requests at AC unit temperature control.**


**Figure 22: AC-20 zones scheduled off on [redacted]12 at 11:50AM. Note that zone 30 (room 205) remains occupied – override was triggered locally by actual tenant.**

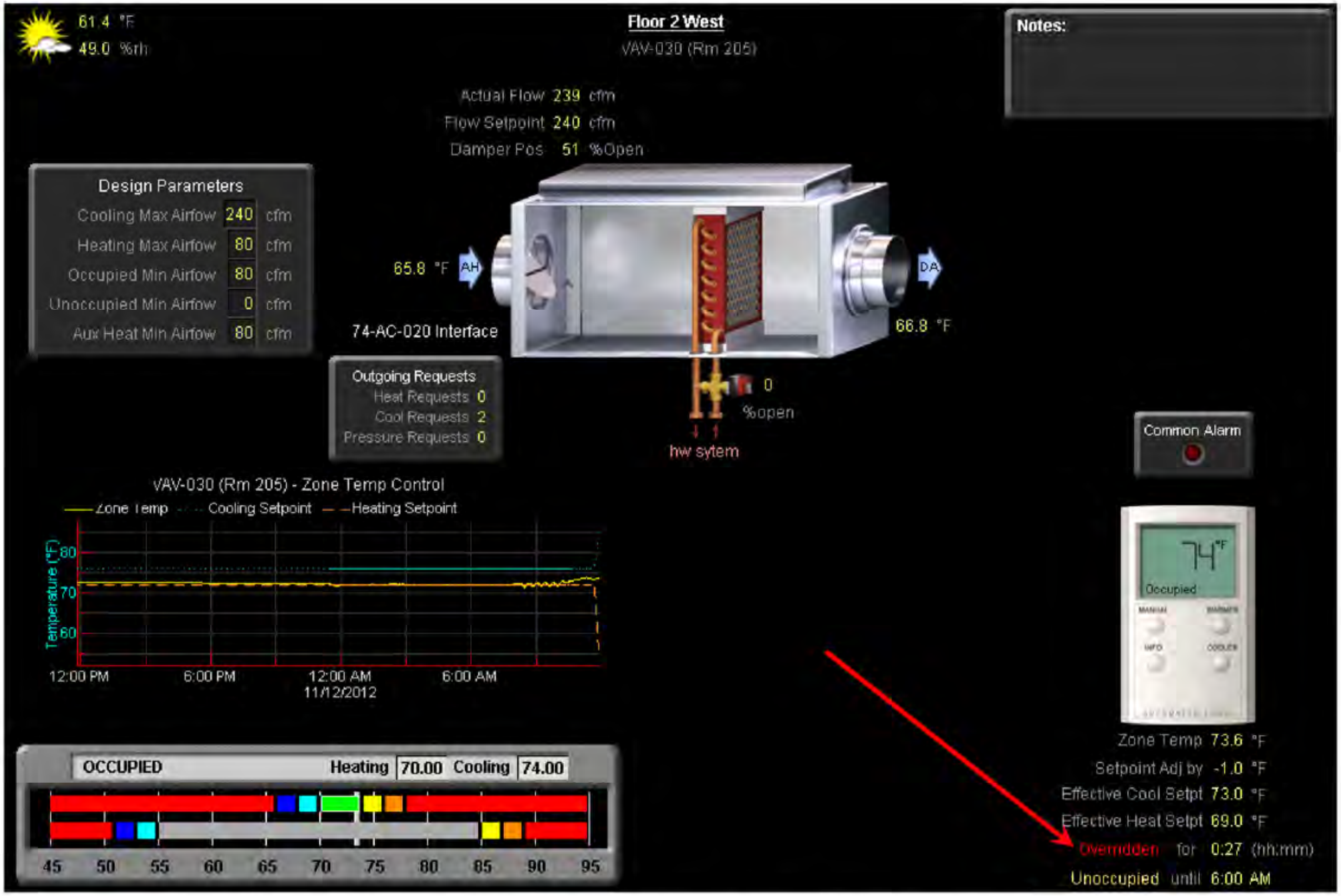



**Figure 23: Zone 30 (room 205) remains occupied – override was triggered locally by actual tenant.**

To: HVAC Summary
VAV Summary First Floor
VAV Summary Second Floor
VAV Summary Third Floor

Second Floor VAV Summary

| AHU | Schedule | Zone Temp (°F) | Setpt Adj (°F) | Clg Setpt (°F) | Htg Setpt (°F) | DAT (°F) | Dmpr (%) | Flow (cfm) | Flow Setpt (cfm) | HWV (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| AC-020 Interface | Unoccupied | 77.1 | 0.0 | 85.0 | 55.0 | 66.5 | 44 | 202 | 200 | 0 |
| AC-020 Interface | Unoccupied | 73.2 | 0.0 | 85.0 | 55.0 | 68.7 | 26 | 47 | 45 | 0 |
| AC-020 Interface | Unoccupied | 70.3 | 0.0 | 85.0 | 55.0 | 67.6 | 30 | 83 | 80 | 0 |
| AC-020 Interface | Unoccupied | 73.4 | -1.0 | 73.0 | 69.0 | 66.6 | 51 | 239 | 240 | 0 |
| AC-020 Interface | Unoccupied | 73.0 | 0.0 | 85.0 | 55.0 | 65.7 | 32 | 252 | 170 | 0 |
| AC-020 Interface | Unoccupied | 72.3 | 0.0 | 85.0 | 55.0 | 67.1 | 29 | 157 | 150 | 0 |
| AC-020 Interface | Unoccupied | 71.6 | 0.0 | 85.0 | 55.0 | 68.6 | 27 | 68 | 60 | 0 |
| AC-020 Interface | Unoccupied | 67.2 | 0.0 | 85.0 | 60.0 | | 31 | 69 | 60 | |
| AC-020 Interface | Unoccupied | 74.1 | 0.0 | 85.0 | 55.0 | 66.5 | 27 | 204 | 200 | 0 |
| AC-020 Interface | Unoccupied | 73.8 | 0.0 | 85.0 | 55.0 | 66.2 | 28 | 226 | 210 | 0 |
| AC-019 Interface | Occupied | 70.5 | 0.0 | 74.0 | 70.0 | 72.2 | 26 | 303 | 300 | 0 |
| AC-019 Interface | Occupied | 72.1 | | 74.0 | 70.0 | | 46 | 847 | 880 | 15 |
| AC-019 Interface | Occupied | 72.8 | | 74.0 | 70.0 | | 51 | 731 | 750 | 0 |
| AC-019 Interface | Occupied | 72.3 | | 74.0 | 70.0 | | 28 | 838 | 860 | 6 |
| AC-019 Interface | Occupied | 72.4 | | 74.0 | 70.0 | | 37 | 2183 | 2230 | 24 |
| AC-019 Interface | Occupied | 70.1 | 0.0 | 74.0 | 70.0 | 71.1 | 28 | 155 | 150 | 24 |
| AC-019 Interface | Occupied | 64.5 | 0.0 | 74.0 | 70.0 | 70.4 | 42 | 358 | 360 | 100 |
| AC-019 Interface | Occupied | 71.9 | 0.0 | 74.0 | 70.0 | 71.8 | 86 | 412 | 420 | 0 |
| AC-018 Interface | Occupied | 67.3 | 0.0 | 74.0 | 70.0 | 100.6 | 25 | 306 | 270 | 100 |
| AC-018 Interface | Occupied | 72.9 | | 74.0 | 70.0 | | 14 | 1560 | 1560 | 0 |

| AHU | Schedule | Zone Temp (°F) | Setpt Adj (°F) | Clg Setpt (°F) | Htg Setpt (°F) | DAT (°F) | Dmpr (%) | Flow (cfm) | Flow Setpt (cfm) | HWV (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| -AC-018 Interface | Occupied | 72.6 | | 74.0 | 70.0 | | 21 | 1585 | 1560 | 34 |
| -AC-018 Interface | Occupied | 70.3 | | 74.0 | 70.0 | | 35 | 280 | 280 | 100 |
| -AC-018 Interface | Occupied | 72.0 | | 74.0 | 70.0 | | 35 | 145 | 140 | 18 |
| -AC-018 Interface | Occupied | 72.0 | | 74.0 | 70.0 | | 36 | 978 | 1006 | 21 |
| -AC-018 Interface | Occupied | 70.8 | 0.0 | 74.0 | 70.0 | 70.1 | 30 | 142 | 140 | 0 |
| -AC-018 Interface | Occupied | 72.1 | 0.0 | 74.0 | 70.0 | 70.0 | 30 | 154 | 140 | 0 |
| -AC-018 Interface | Occupied | 71.1 | | 74.0 | 70.0 | | 36 | 145 | 140 | 100 |
| -AC-018 Interface | Occupied | 70.4 | 0.0 | 80.0 | 60.0 | | 25 | 50 | 50 | |

**Figure 24: Result of zone 205 override is that AC-29 zones operate at occupied airflows (ie, min.) to prevent AC unit freezing, but temperature setpoints are unoccupied values (55°F / 85°F) except zone 30 which is occupied (69°F/73°F)**


**Figure 25: AC-20 zones scheduled off on [redacted]12 at 12:03PM.**

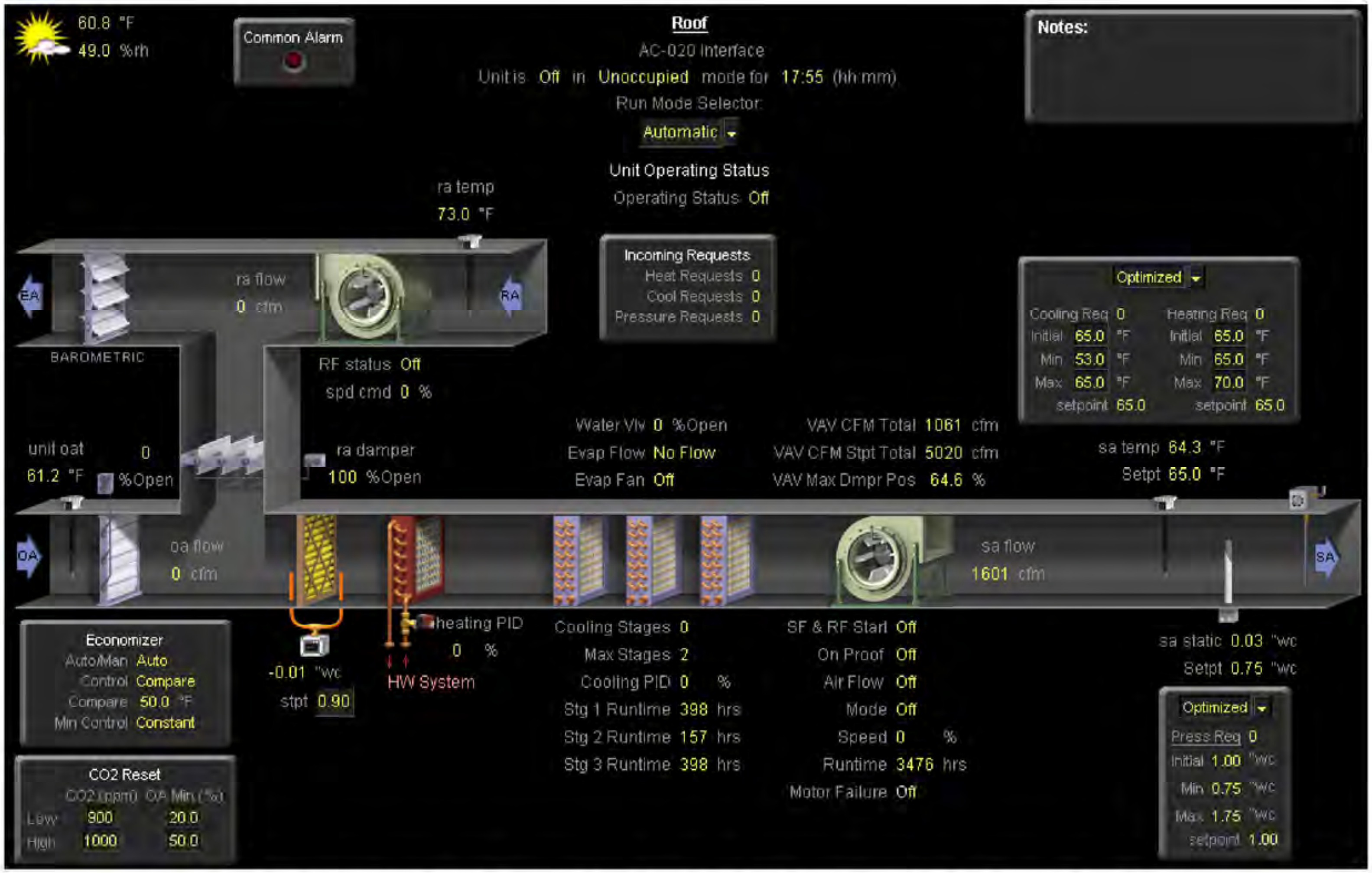



**Figure 26: With override of zone 30 (room 205) cleared, AC-20 shuts off on schedule, [redacted]12 at 12:04PM.**

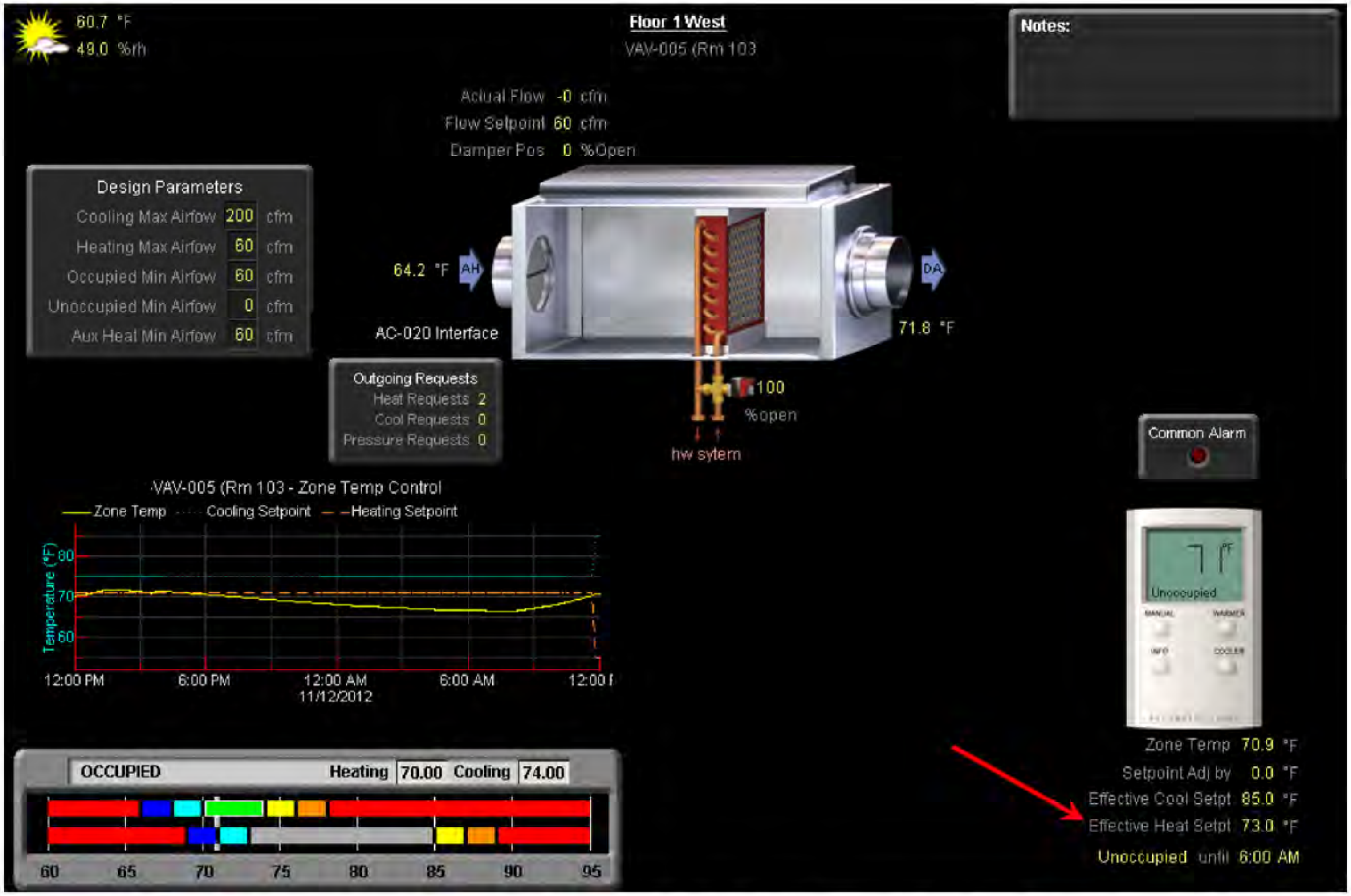



**Figure 27: Override effective heat setpoint of zone 005 (room 103) to 73°F to force it to "wake up" and go into setback mode.**


**Figure 28: Override effective heat setpoint of zone 005 to 73°F to force it to "wake up" and go into setback mode. Result is blue zone on floor plan, and AC-20 re-enabled.**

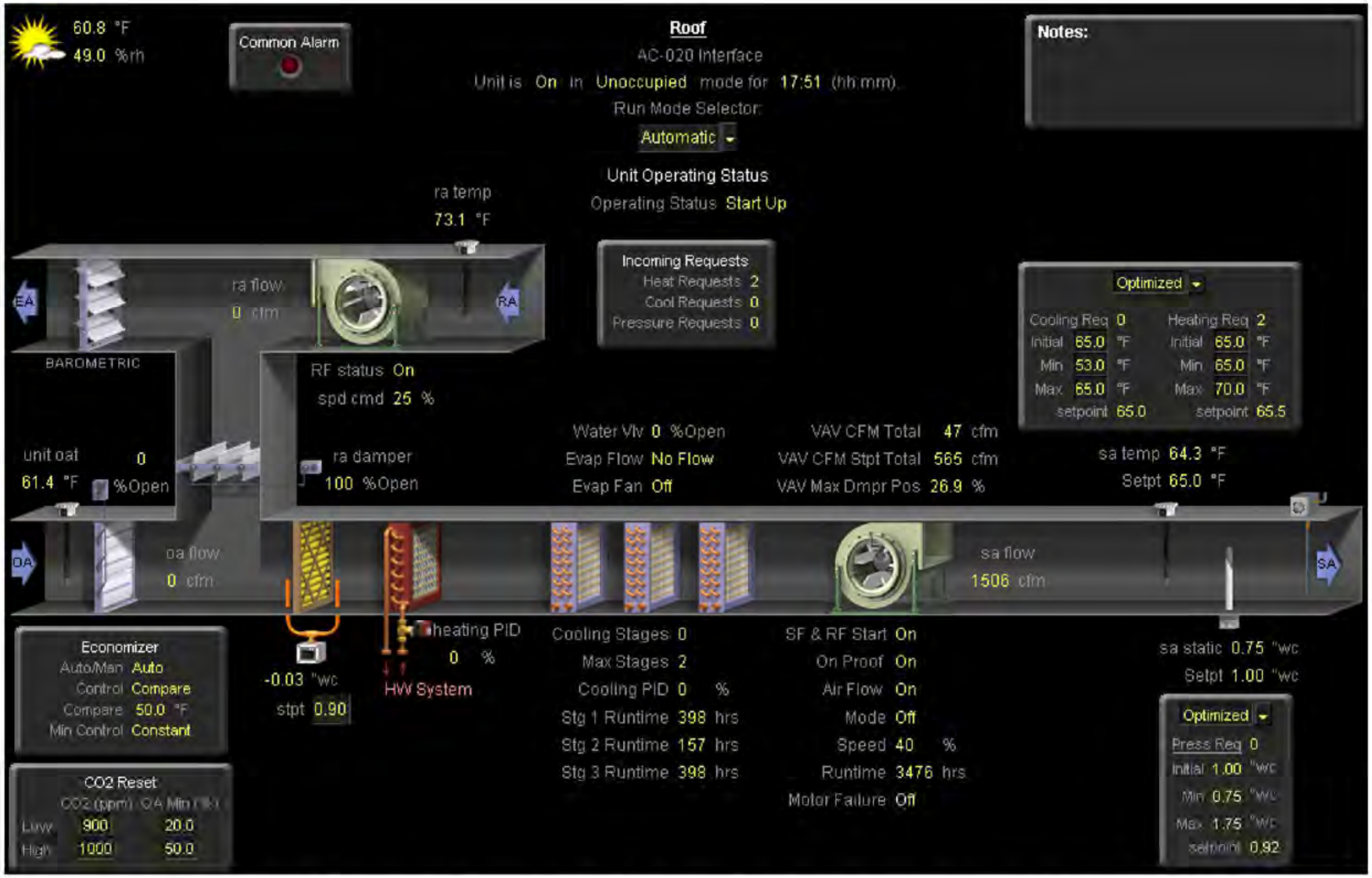



**Figure 29: Override effective heat setpoint of zone 005 to 73°F to force it to "wake up" and go into setback mode. Result is blue zone on floor plan, and AC-20 re-enabled at lowest static pressure.**

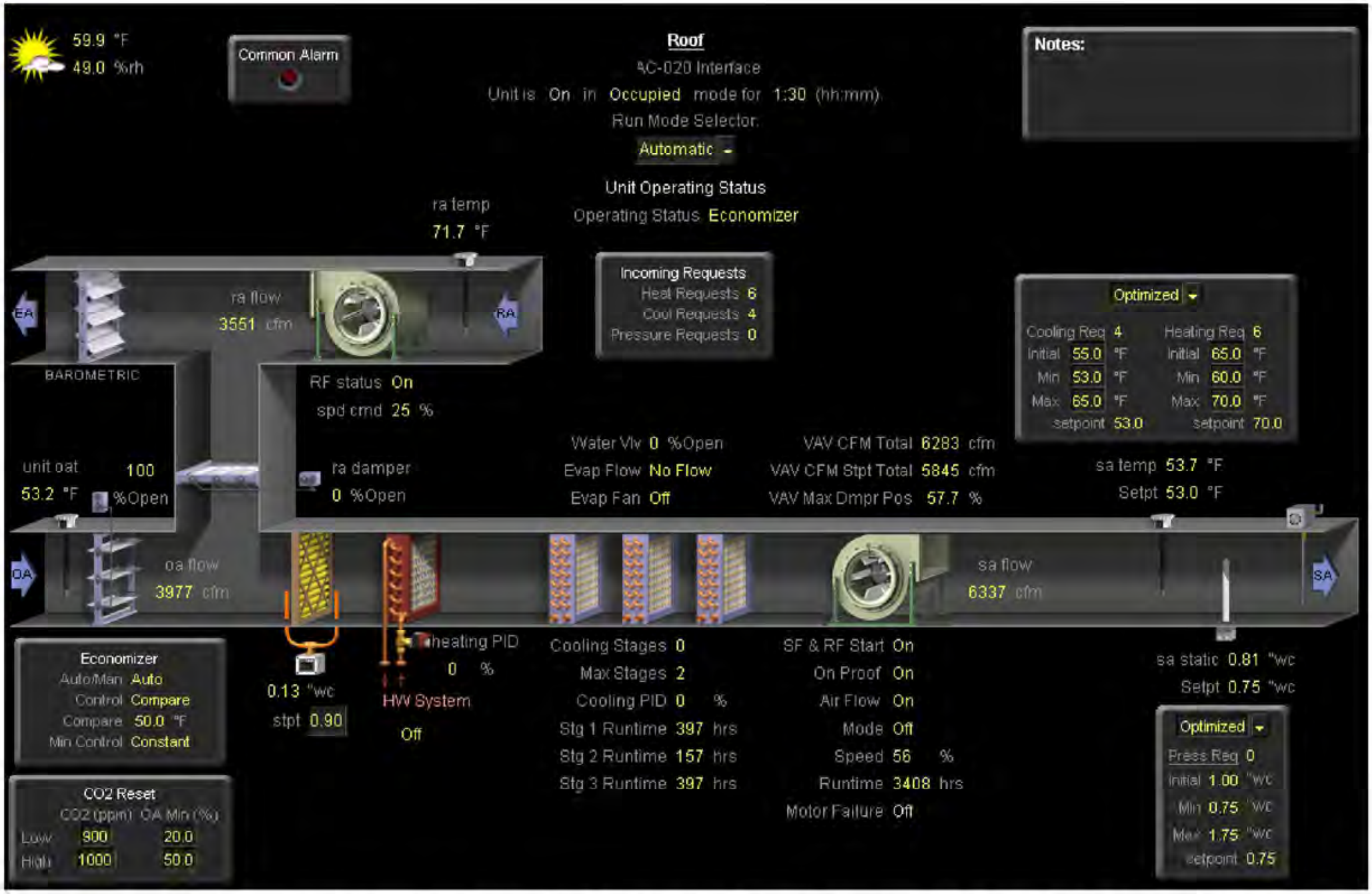



**Figure 30: AC-20 supply temperature test: [redacted]12 just before test at 3:47PM, temp setpoint in auto, and unit in full economizer**

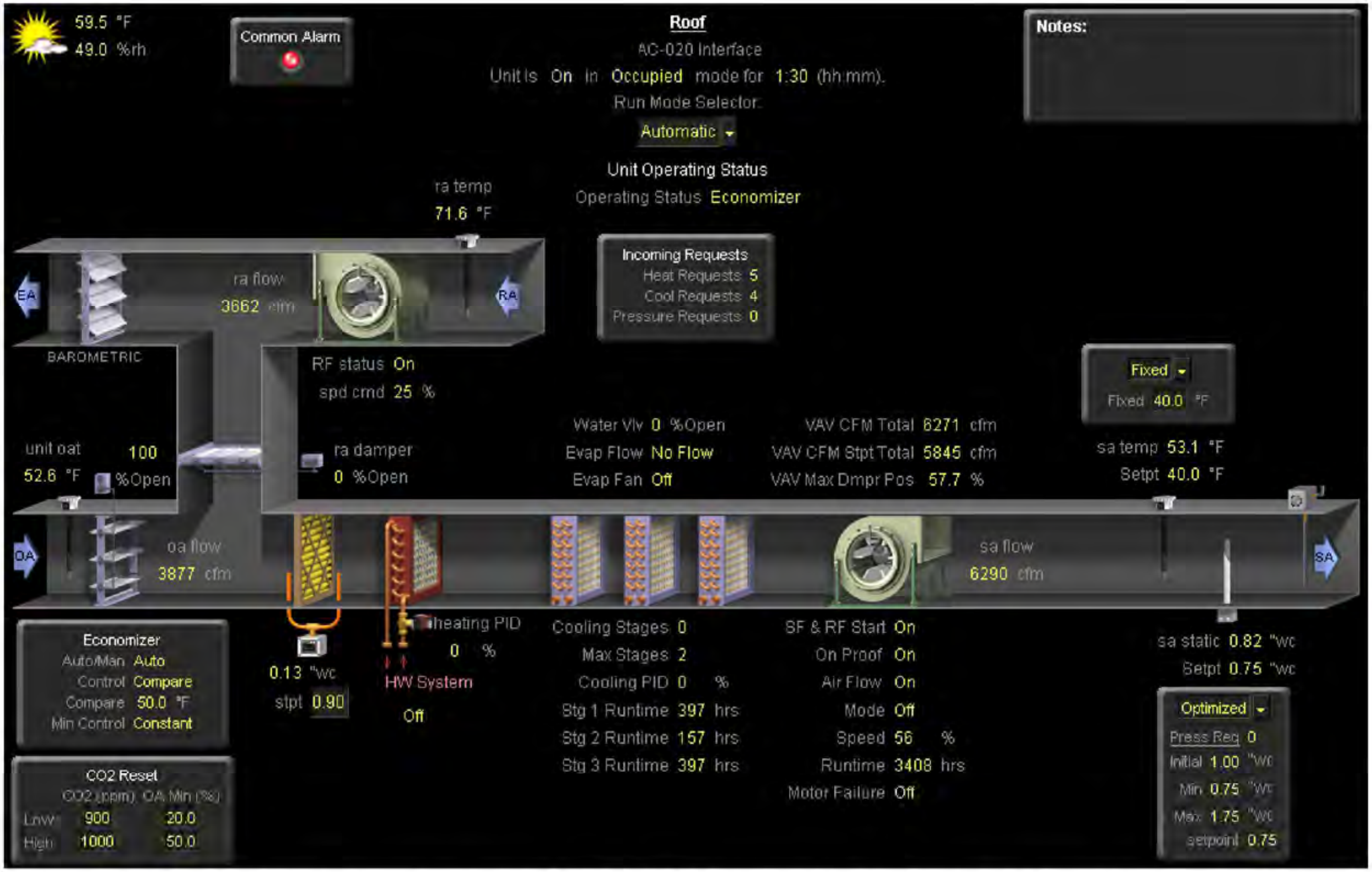



**Figure 31: AC-20 supply temperature test: 11/9/12 at 3:52PM, temp setpoint at 40°F, unit in full economizer, cooling off**

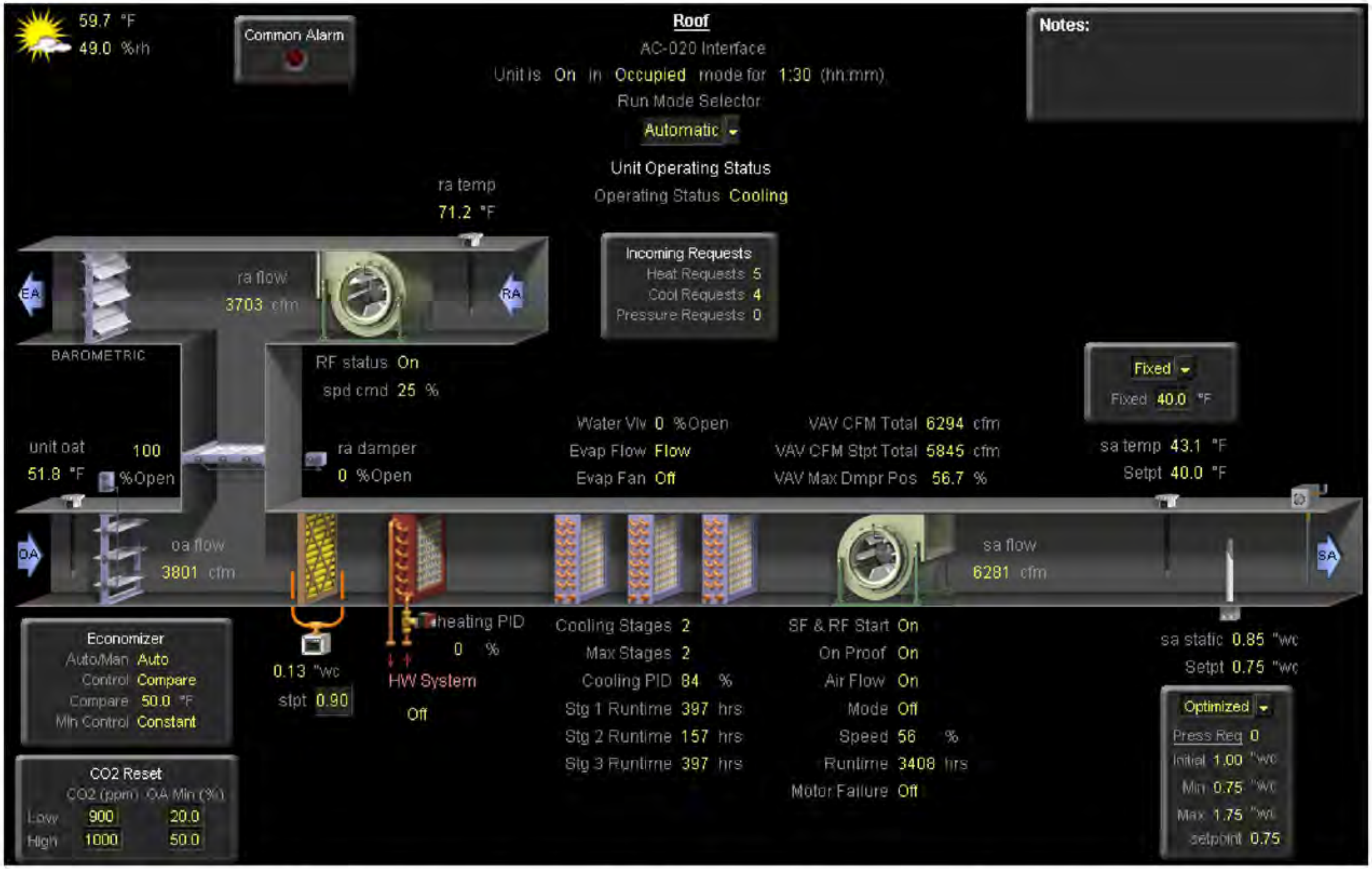



**Figure 32: AC-20 supply temperature test: [redacted]12 at 3:59PM, temp setpoint at 40°F, unit in full economizer, cooling 2/2 stages**

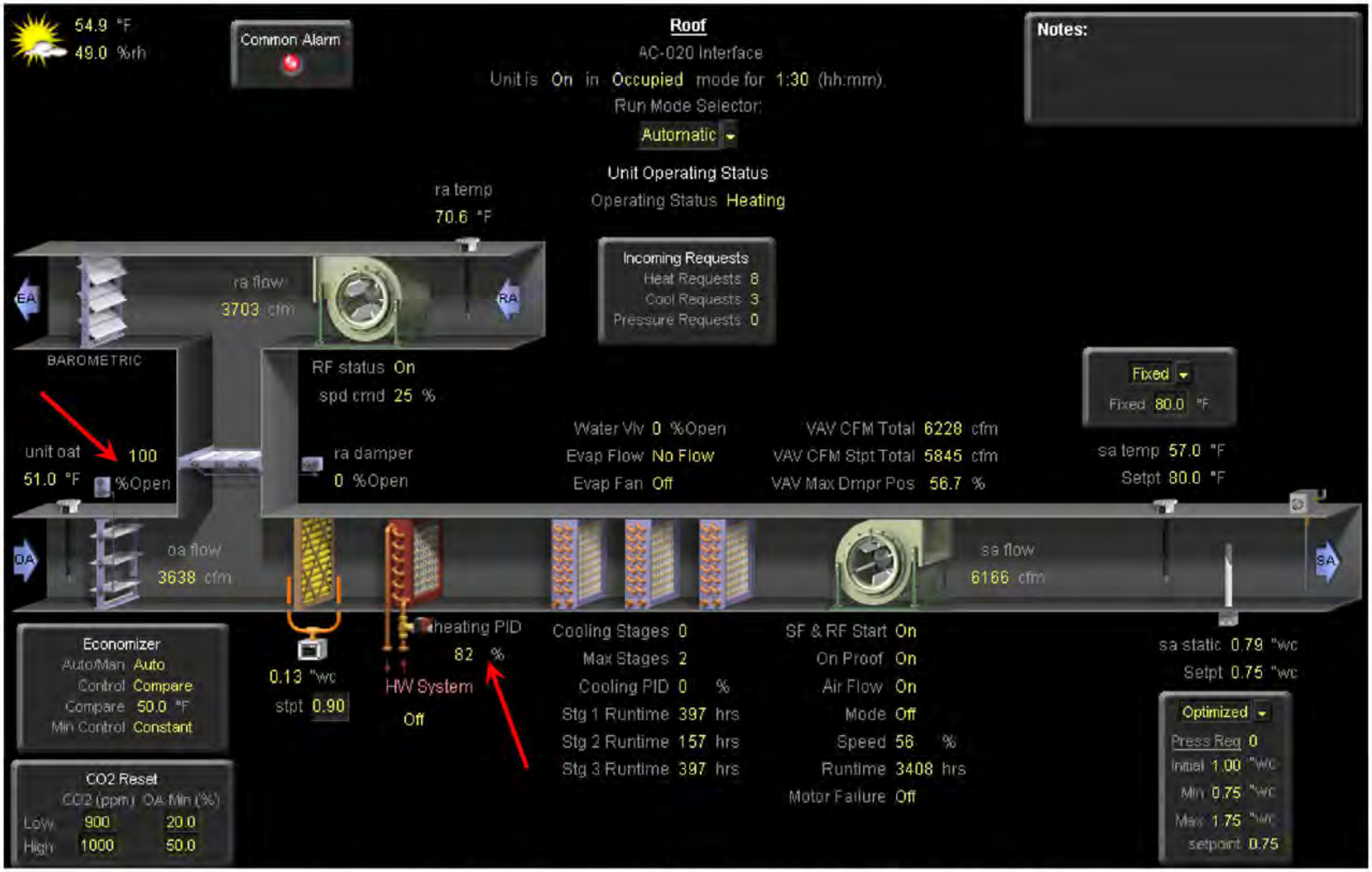



**Figure 33: AC-20 supply temperature test: [redacted]12 at 4:18PM, temp setpoint at 80°F, unit still in in full economizer, cooling off, heating at 82%**

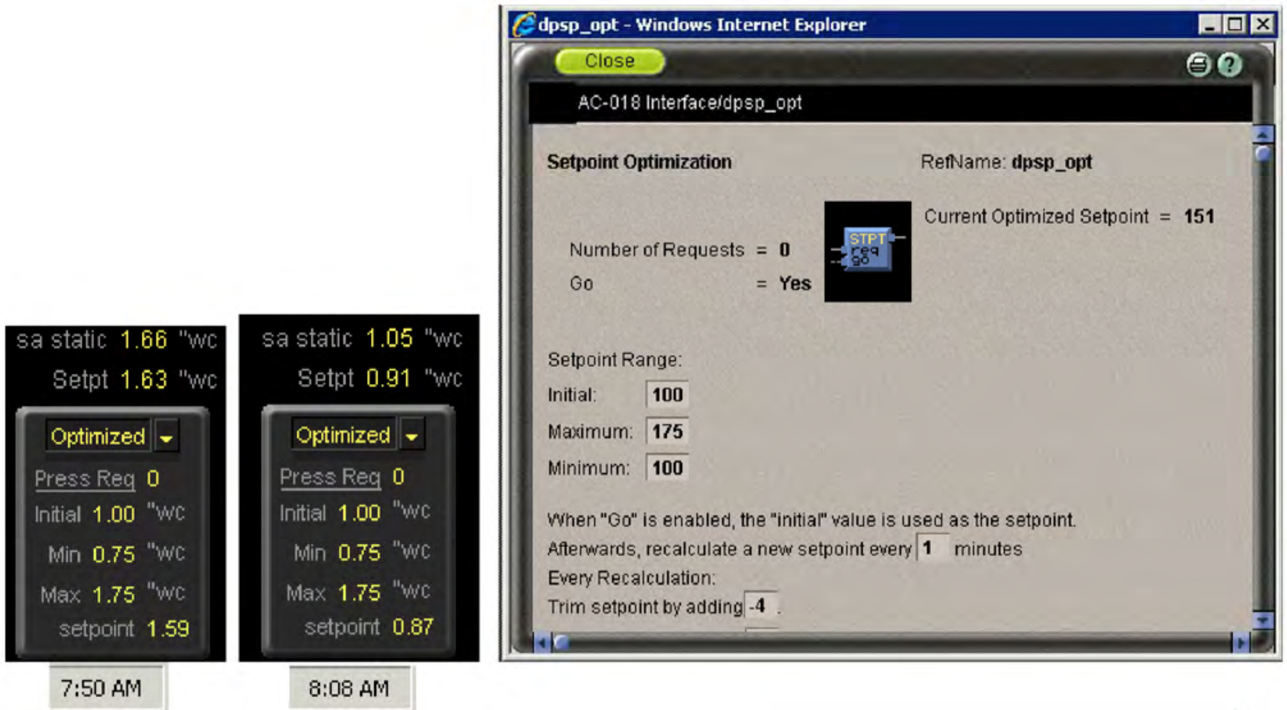



**Figure 34: AC-20 Supply pressure reset mechanism. Overridden to 0 requests at 7:50 AM on [redacted]/12, in line with 0.04” pressure trim set up in trim/respond block.**

AC-5 no connection to DDC
AC-7 and 8 (20 and 21) monitoring only, humidity and general alarm (dry contact)

**AC-04** [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| P. Enable Operation | 1. Enable AC-04 through DDC workstation. | a. AC-04 is enabled.<br>b. AC-04 Supply Fan runs.<br>c. Supply Air Temperature data is available from DDC workstation.<br>d. Room Temperature is available through DDC workstation. | | |
| Q. High Room Temperature Alarm | 2. Change High Room Temperature Alarm trigger to a value that is lower than the current room temperature. | a. High Room Temperature Alarm is triggered. | | |
| R. High Supply Air Temp Alarm | 3. Change High Supply Air Temperature Alarm trigger to a value that is lower than the current supply air temperature. | a. High Supply Air Temperature Alarm is triggered. | | |
| S. AC Unit Failure Alarm | 4. Cause AC Unit failure. | a. AC Unit Failure Alarm is triggered. | | |
| T. Shutdown Operation | 5. Re-enable AC-04. Once AC-04 is confirmed to be operational, shutdown AC-04 through DDC | a. AC-04 is disabled. | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| | | | | |
|---|---|---|---|---|
| | workstation. | b. AC-04 Supply Fan does not run. | | |

Additional notes

Part 4 VAV TERMINAL UNITS

Perform each test on a sample group of terminal units serving office areas. List terminals served, and complete table below for each terminal or list terminals individually in "Observed response" column. Word file available from CxA for editing. Test at least 10% of terminals with the same program.

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| U. Heating Operation | 1. Adjust zone temperature set point to force zone VAV terminal unit into heating mode. | a. SA VAV terminal unit primary airflow is at min. setpoint.<br>b. SA HW valve opens.<br>c. General Exhaust VAV terminal unit modulates EA flow to maintain airflow offset. | | |
| V. Dead-band Operation | 2. Adjust zone temperature setpoint so that existing zone temperature is within zone temperature dead-band range. | a. VAV terminal unit primary airflow remains at min.setpoint.<br>b. SA HW valve is closed.<br>c. General Exhaust VAV terminal unit modulates EA flow to maintain airflow offset. | | |
| W. Cooling Operation | 3. Adjust zone temperature setpoint to force zone VAV terminal unit into cooling mode. | a. VAV terminal unit primary airflow increases beyond minimum airflow setpoint.<br>b. SA HW valve is closed.<br>c. General Exhaust VAV terminal unit modulates EA flow to maintain airflow offset. | | |

Perform each test on a sample group of terminal units serving laboratories/pressurized rooms without hoods. List terminals served, and complete table below for each terminal or list terminals individually in “Observed response” column. Word file available from CxA for editing. Test at least 10% of terminals with the same program

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| X. Heating Operation | 1. Adjust zone temperature set point to force zone VAV terminal unit into heating mode. | a. SA VAV terminal unit primary airflow is at min. setpoint.<br>b. SA HW valve opens (only where terminal units are equipped with heating coils).<br>c. General Exhaust VAV terminal unit modulates EA flow to maintain airflow offset. | Set point for flow offset:<br>Set point for room pressure: | |
| Y. Dead-band Operation | 2. Adjust zone temperature setpoint so that existing zone temperature is within zone temperature dead-band range. | a. VAV terminal unit primary airflow remains at min.setpoint.<br>b. SA HW valve is closed (only where terminal units are equipped with heating coils). | | |
| Z. Cooling Operation | 3. Adjust zone temperature setpoint to force zone VAV terminal unit into cooling mode. | a. VAV terminal unit primary airflow increases beyond minimum airflow setpoint.<br>b. SA HW valve is closed (only where terminal units are equipped with heating coils).<br>c. General Exhaust EA VAV terminal unit modulates EA flow to maintain airflow offset. | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

Perform each test on a sample group of terminal units serving laboratories with hoods. Test all terminals and Supply/exhaust modes for terminals listed plus any other rooms with hoods that may be present (1 hood per supply / exhaust VAV combination unless otherwise noted): VAV 108, 110, 214A, 214B, 222, 223, 229 (2 Hoods), 320B (2 Hoods), 320C, 320D, 320E (2 Hoods), 327A, 327J, 327H.

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| AA. Heating Operation | 1. Adjust zone temperature set point to force zone VAV terminal unit into heating mode. | a. SA VAV terminal unit primary airflow is at min. setpoint.<br>b. SA HW valve opens (only where terminal units are equipped with heating coils).<br>c. General Exhaust VAV terminal unit modulates EA flow to maintain airflow offset (and, if provided with adaptive controller, also pressure differential) | Testing: Room 320D, [redacted], 1:40PM<br>Unit already in heating mode @SP72, change to SP 75<br>Note cooling and heating are both at 600 cfm for supply.<br>Last VAV schedule from Gayner dated 8/31 shows 835 cfm for VAV-107<br><br>Confirmed heating mode (valve from 32% to 92%), no change in air volumes. See Figure 35 to Figure 37 | Y |
| BB. Dead-band Operation | 2. Adjust zone temperature setpoint so that existing zone temperature is within zone temperature dead-band range. | a. VAV terminal unit primary airflow remains at min.setpoint.<br>b. SA HW valve is closed (only where terminal units are equipped with heating coils). | N/A, no airflow changes (CV setup) | |
| CC. $CO_2$-DCV Mode (where applicable) | 3. Confirm that zone is within temperature dead-band. Release $CO_2$ of known concentration at $CO_2$ sensor test port to exceed zone $CO_2$ concentration setpoint value. | a. VAV terminal unit primary airflow modulates to increase airflow to limit the zone $CO_2$ concentration to setpoint.<br>b. General exhaust terminal opens to maintain pressure flow differential (and, if provided with adaptive controller, also pressure differential) | N/A, no airflow changes (CV setup) | |
| DD. Cooling Operation | 4. Adjust zone temperature setpoint to force zone VAV terminal unit into | d. VAV terminal unit primary airflow increases beyond minimum airflow setpoint.<br>e. SA HW valve is closed (only where terminal units are equipped with heating coils). | [redacted]/12 Force into cooling, verify HW valve strokes shut. See Figure 38. | Y |

| | | | | |
|---|---|---|---|---|
| | cooling mode. | | | |
| EE. Hood tracking operation | 5. Open Fume hood to full sash stop position (where multiple fume hoods exist, open all but one hood to 18” sash height, and last hood to full 28.5” height) | f. Fume hood airflow monitor maintains 100 fpm after no more than 10 second instability due to sash movement<br>g. Supply airflow ramps up to maintain minimum required air volume, larger of hood airflow and 1 cfm/sqft<br>h. Exhaust terminal maintains room airflow differential (typ. slight negative)<br>i. Room pressure remains at setpoint | [redacted]12 Door open: room press sensor reads -0.0005, door closed: sensor reads -0.01 (actual sensor at door), fluctuations occur very rapidly and room pressure essentially neutral regardless of door position, going from -0.01 to -0.003. | Y |
| FF. Hood tracking operation | 6. Close fume hood(s) to minimum sash stop position (where multiple fume hoods exist, close all hoods) | j. Fume hood airflow monitor maintains 100 fpm after no more than 10 second instability due to sash movement<br>k. Supply airflow ramps down to maintain minimum required air volume, larger of hood airflow and 1 cfm/sqft (load overridden to deadband)<br>l. Exhaust terminal maintains room airflow differential (typ. slight negative)<br>m. Room pressure remains at setpoint | Dampers react correctly to maintain hood airflows and room air balance. Hood airflow stabilizes in < 10 seconds, overall room cfm/damper offsets take about 5-10 minutes to stabilize (2:04PM to 2:13PM for room 320D on hood fully closed to fully open, see Figure 38 to Figure 40) | Y |
| | Release Room SP override | 14:17 [redacted] | | |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| GG. Heating Operation | 7. Adjust zone temperature set point to force zone VAV terminal unit into heating mode. | SA VAV terminal unit primary airflow is at min. setpoint.<br>SA HW valve opens (only where terminal units are equipped with heating coils).<br>General Exhaust VAV terminal unit modulates EA flow to maintain airflow offset (and, if provided with adaptive controller, also pressure differential) | Test at 2:25PM: 320E VAV 108 and 320B (VAV-103, 2 hoods)<br>Pic 12-16<br>(Close door for 320K)<br>Set setpoints to 75F for more heat<br>2:28 8PM<br>Confirmed heating opens up. | Y |

| | | | | |
|---|---|---|---|---|
| HH. Dead-band Operation | 8. Adjust zone temperature setpoint so that existing zone temperature is within zone temperature dead-band range. | VAV terminal unit primary airflow remains at min.setpoint.<br>SA HW valve is closed (only where terminal units are equipped with heating coils). | Set SP to 72.4 and 72.0 (actual room temps).<br>Note: AC-18 in heating because SAT locked to prevent compressors from running (see issues log 109. New disconnect on unit so need power on but compressors off for 24 hours.) so return to ~original heat. | |
| II. $CO_2$-DCV Mode (where applicable) | 9. Confirm that zone is within temperature dead-band. Release $CO_2$ of known concentration at $CO_2$ sensor test port to exceed zone $CO_2$ concentration setpoint value. | VAV terminal unit primary airflow modulates to increase airflow to limit the zone $CO_2$ concentration to setpoint.<br>General exhaust terminal opens to maintain pressure flow differential (and, if provided with adaptive controller, also pressure differential) | | |
| JJ. Cooling Operation | 10. Adjust zone temperature setpoint to force zone VAV terminal unit into cooling mode. | VAV terminal unit primary airflow increases beyond minimum airflow setpoint.<br>SA HW valve is closed (only where terminal units are equipped with heating coils). | Tested hood changes in 320B to see they do not affect pressurization and airflows in the adjacent 320E, since the spaces are effectively one space thanks to large connections. Simultaneously looked at heating and cooling responses, all check out, see Figure 42 to Figure 44.<br><br>Note that when hoods in room 320B are wide open, one reports almost twice the airflow of the other (Figure 44 shows 1,521 cfm on VAV-104 and 837 cfm on VAV-105, both at full open position – would expect to see the same airflow). | Y |

| | | | | | |
|---|---|---|---|---|---|
| KK. Hood tracking operation | 11. Open Fume hood to full sash stop position (where multiple fume hoods exist, open all but one hood to 18" sash height, and last hood to full 28.5" height) | | p. Fume hood airflow monitor maintains 100 fpm after no more than 10 second instability due to sash movement<br>q. Supply airflow ramps up to maintain minimum required air volume, larger of hood airflow and 1 cfm/sqft<br>r. Exhaust terminal maintains room airflow differential (typ. slight negative)<br>s. Room pressure remains at setpoint | Note different pressure readings from 2 controllers 320E and B are actually the same (tested at physical displays) but show up at different times at ALC and thus look like different readings, actually ok.<br>Room pressure is slightly positive during this test.<br>Open 105 – immediate reaction<br>Confirm both sets of controllers react, also confirm in full cooling<br><br>Next, open all hoods 18" and one to 25". Means 104, 105 open to sash stop, 110 open to 6" above sash stop, all airflows ok (hood speeds maintained) | Y |
| LL. Hood tracking operation | 12. Close fume hood(s) to minimum sash stop position (where multiple fume hoods exist, close all hoods) | | t. Fume hood airflow monitor maintains 100 fpm after no more than 10 second instability due to sash movement<br>u. Supply airflow ramps down to maintain minimum required air volume, larger of hood airflow and 1 cfm/sqft (load overridden to deadband)<br>v. Exhaust terminal maintains room airflow differential (typ. slight negative)<br>w. Room pressure remains at setpoint | After stabilization, record the following:<br>Hood sash height 1: in<br>Hood ex.damper: %<br>Hood sash height 2: in<br>Hood ex.damper: %<br><br>Supply terminal 1 flow: cfm<br>Damper pos: %<br>Supply terminal 2 flow: cfm<br>Damper pos: %<br><br>Exhaust terminal 1 flow: cfm<br>Damper pos: % | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

Additional notes

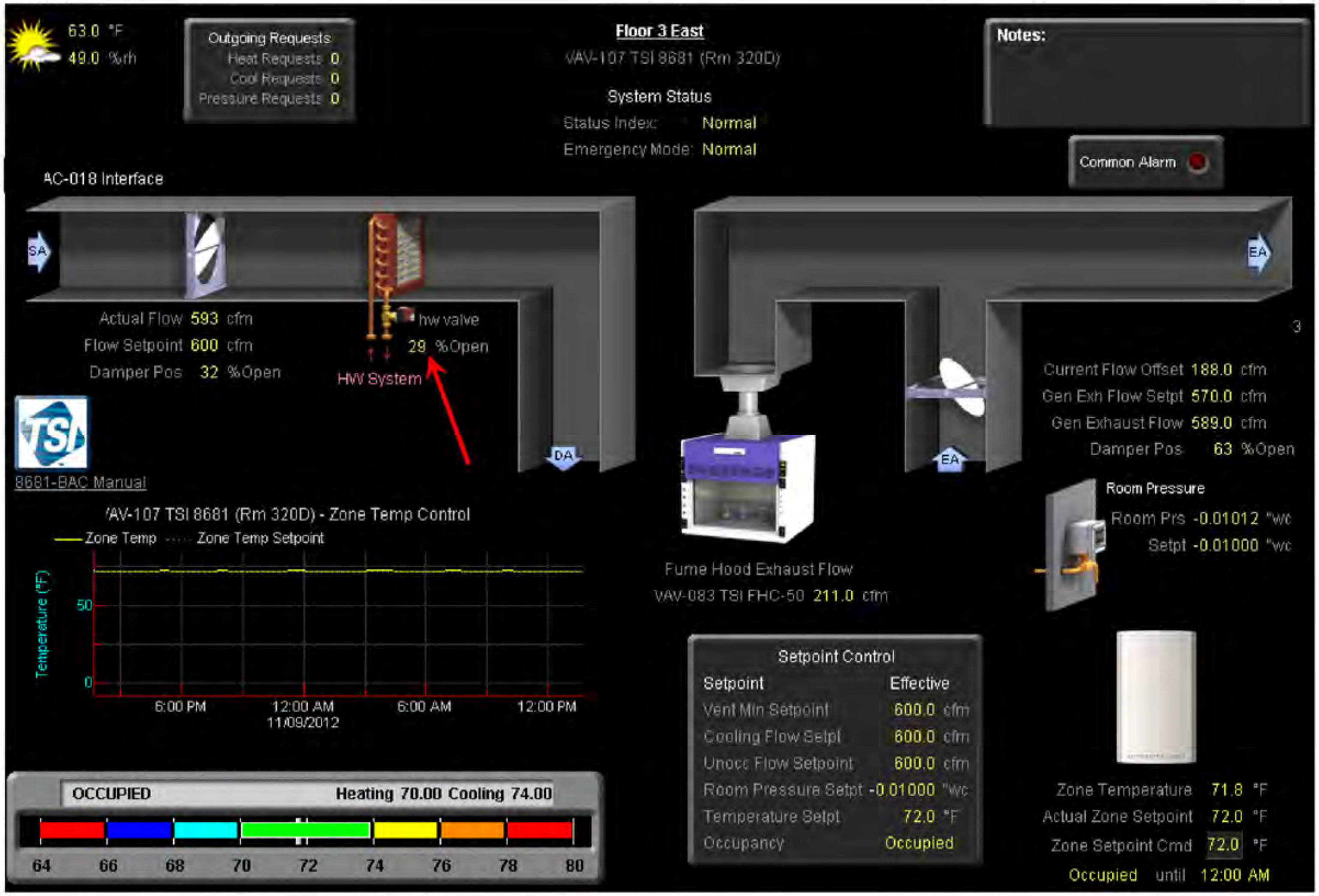



**Figure 35: Room 320D, supply terminal VAV 107, in heating mode (auto), heating valve 29% open**

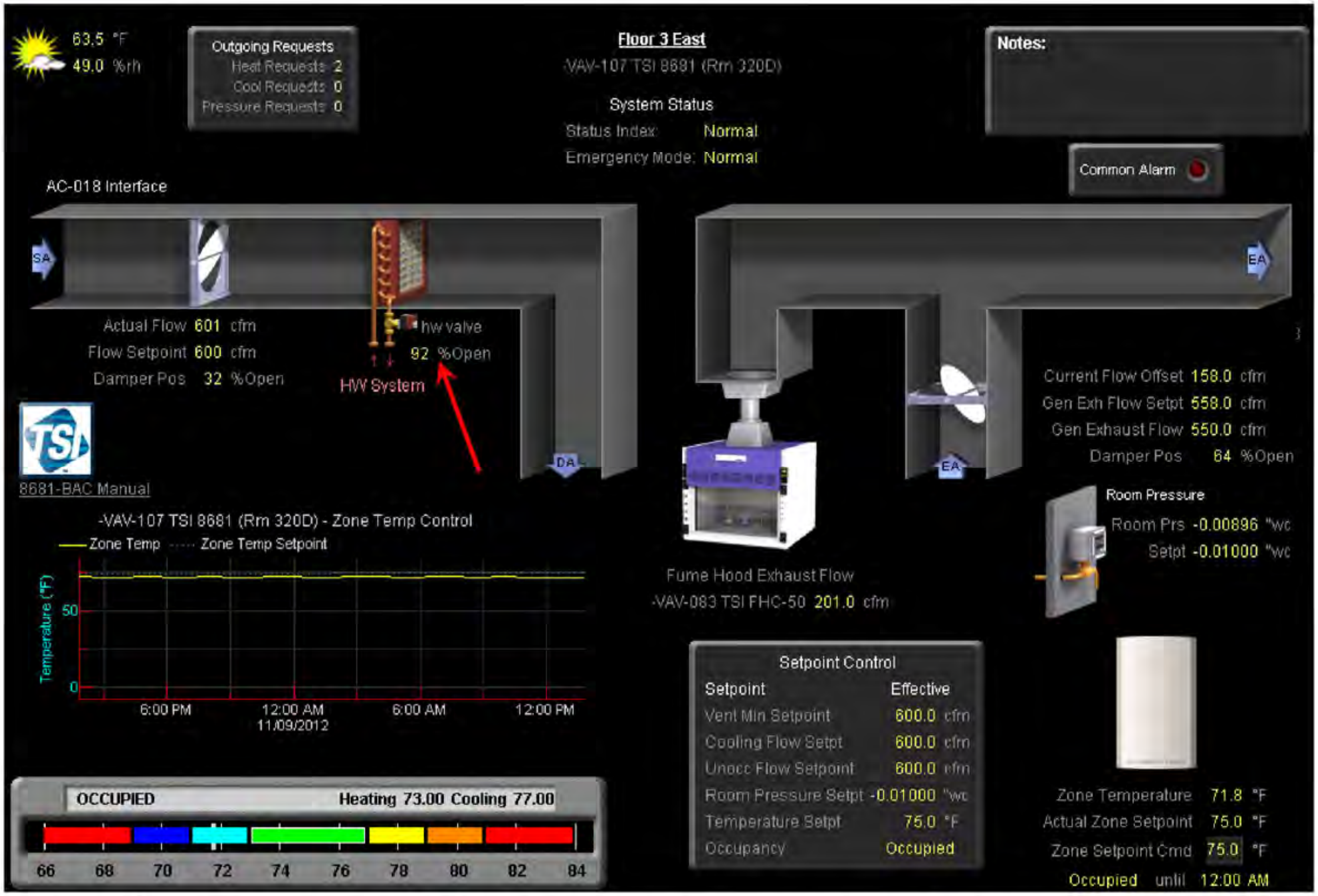



**Figure 36: Room 320D, supply terminal VAV 107, in full heating mode (overridden heating setpoint to 75°F), heating valve 92% open. Air volumes stay constant. Note airflow schedule (600 cfm for all modes) does not match last VAV schedule from 8/31, bulletin 65 which shows 835 cfm, but not changed in bulletin 65..**

| SUPPLY AIR SIDE | | | | | |
|---|---|---|---|---|---|
| LBNL EQUIP TAG | SUPPLY VAV TERMINAL TAG | INLET SIZE IN. ROUND | CFM RANGE MIN. | CFM RANGE MAX. | MAX. S.P. "W.G. |
| [redacted] VAV–101 | VAV– 320A | 24x16 | 1,845 | 1,890 | 0.11 |
| [redacted] VAV–103 | VAV– 320B | 24x16 | 1,845 | 1,890 | 0.11 |
| [redacted] VAV–106 | VAV– 320C | 7 | 150 | 260 | 0.06 |
| [redacted] VAV–107 | VAV– 320D | 12 | 835 | 835 | 0.14 |
| [redacted] VAV–108 | VAV– 320E | 24x16 | 1,745 | 2,360 | 0.16 |

[redacted]

| EXHAUST AIR SIDE | | | | | |
|---|---|---|---|---|---|
| LBNL EQUIP TAG | EXHAUST VAV OR FUME EXHAUST TERMINAL TAG | INLET SIZE IN. ROUND | CFM RANGE MIN. | CFM RANGE MAX. | MAX. S.P. "W.G. |
| [redacted] VAV–102 | EVAV– 320A | 24x16 | 2170 | 3040 | 0.02 |
| [redacted] VAV–104 | FET– 320A | | 395 | 785 | |
| [redacted] VAV–105 | FET– 320B | | 395 | 785 | |
| [redacted] VAV–080 | EVAV– 320C | 5 | 200 | 310 | 0.05 |
| [redacted] VAV–081 | EVAV– 320D | 8 | 150 | 540 | 0.01 |
| [redacted] VAV–083 | FET– 320D | | 395 | 785 | |
| [redacted] VAV–109 | EVAV– 320E | 16 | 1010 | 2,015 | 0.02 |
| [redacted] VAV–110 | FET– 320E | | 390 | 785 | |

**Figure 37: Bulletin 65 airflow changes**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

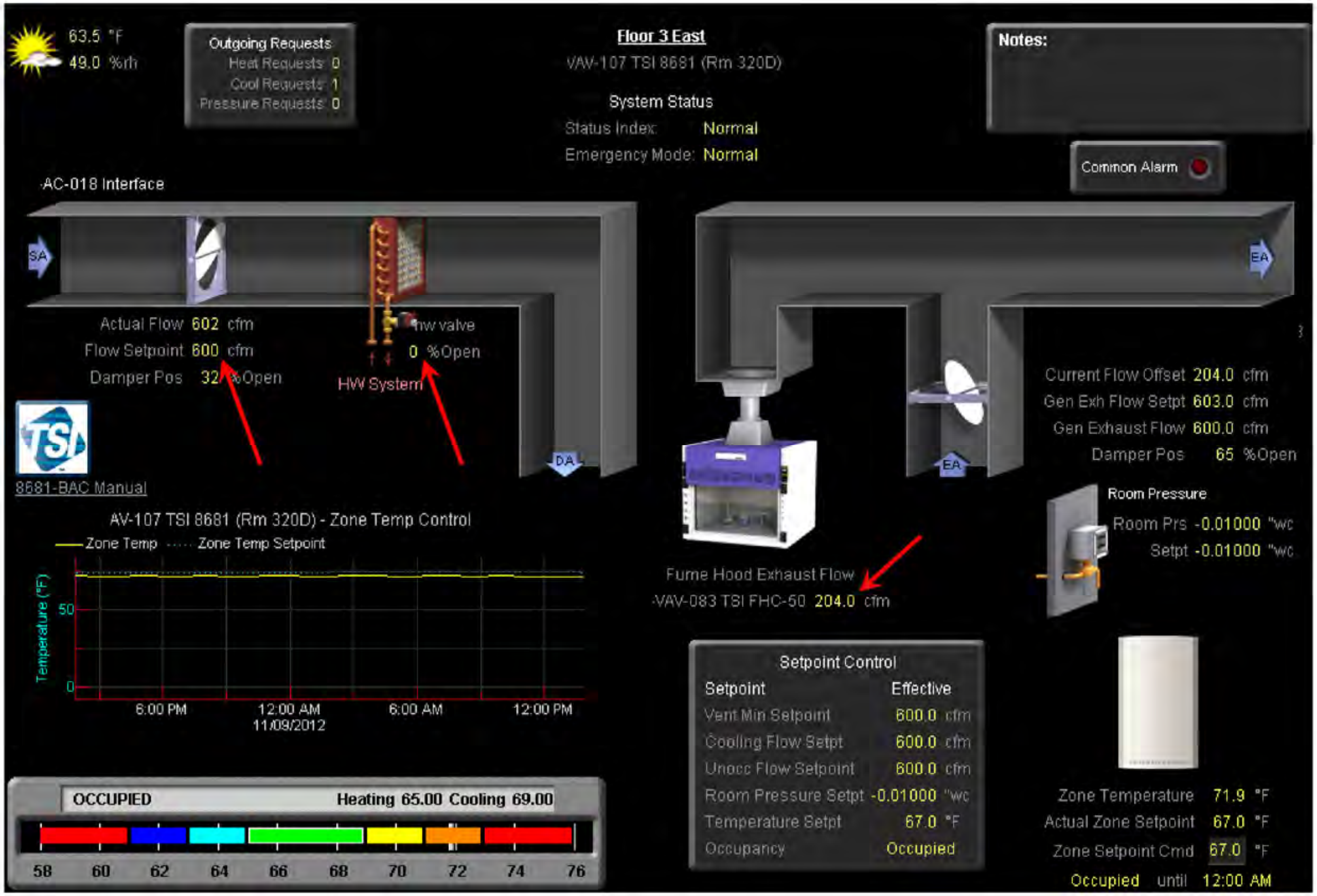



**Figure 38: Cooling test just before Hood test, 1:51PM on [redacted], 2012. Note RH valve shut with 67°F room setpoint, and hood closed (204 cfm). Supply air flow at setpoint (600 cfm), general exhaust at setpoint (600 cfm.)**

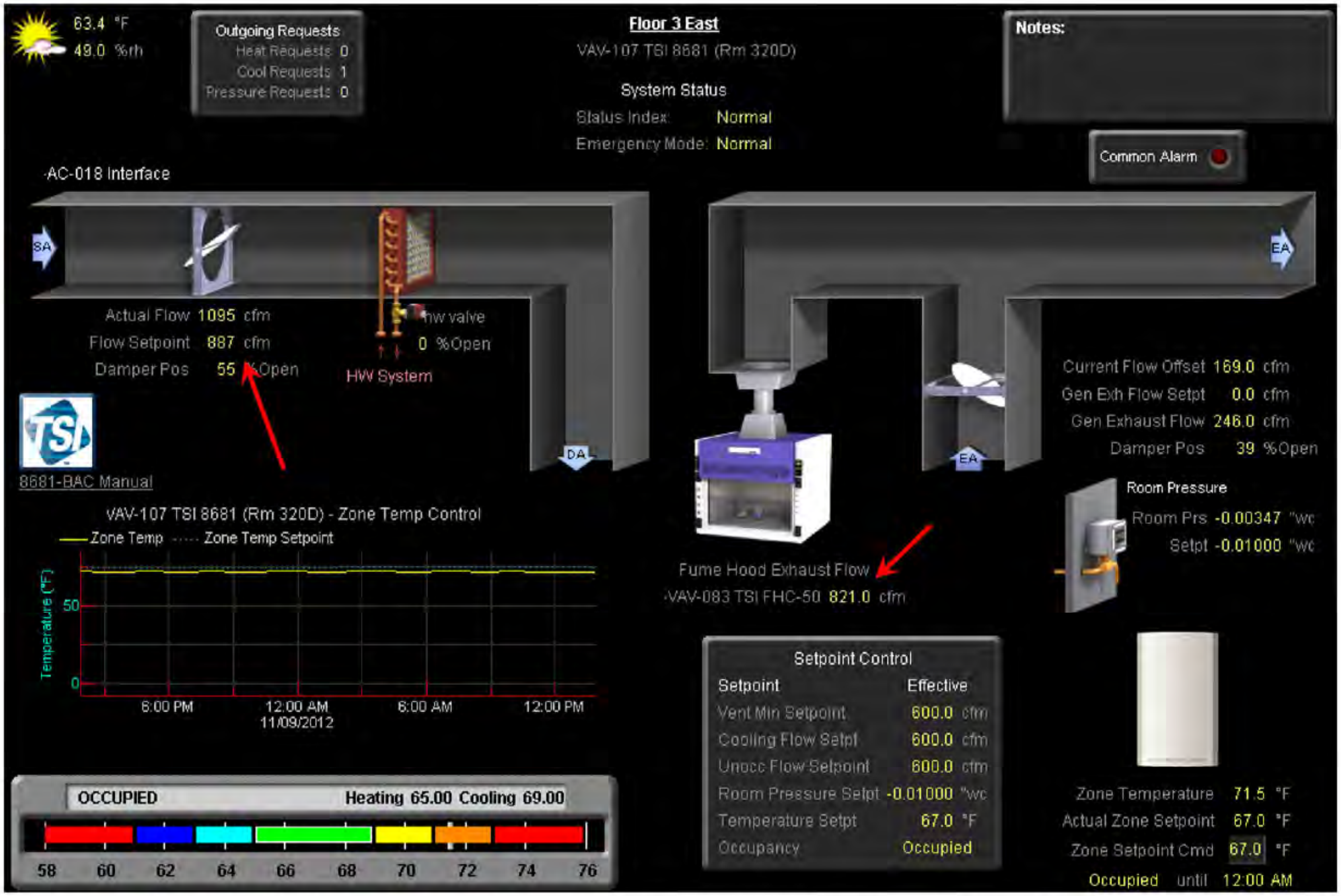



**Figure 39: Hood test, 2:04PM on [redacted], 2012. Hood open (820 cfm). Supply air flow above setpoint (1095 cfm) to compensate since general exhaust still at 246 cfm**

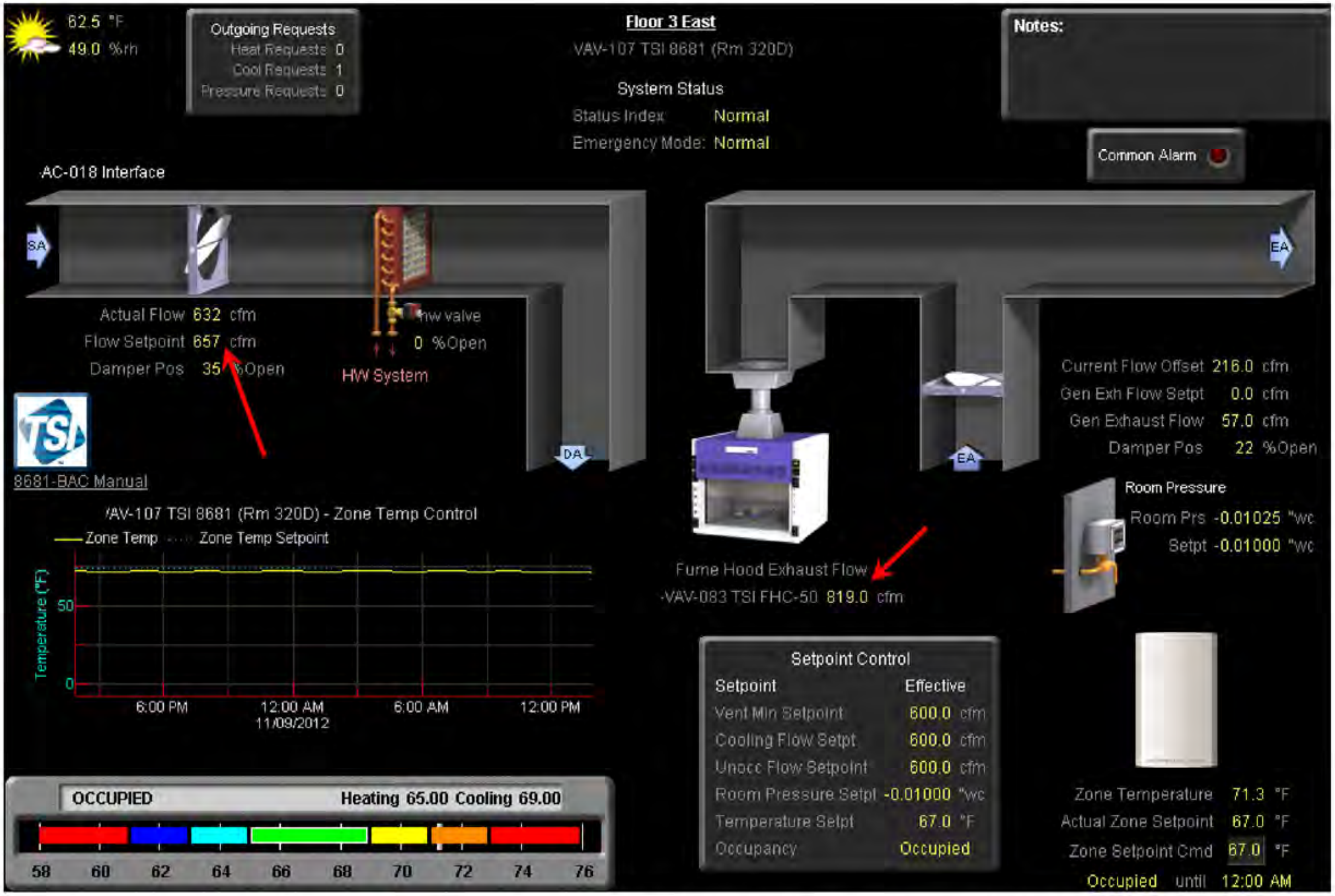



**Figure 40: Hood test, 2:13PM on [redacted] 2012. Hood open (819 cfm). Supply air flow back at setpoint (632 cfm) and general exhaust down to 57 cfm (~ zero)**

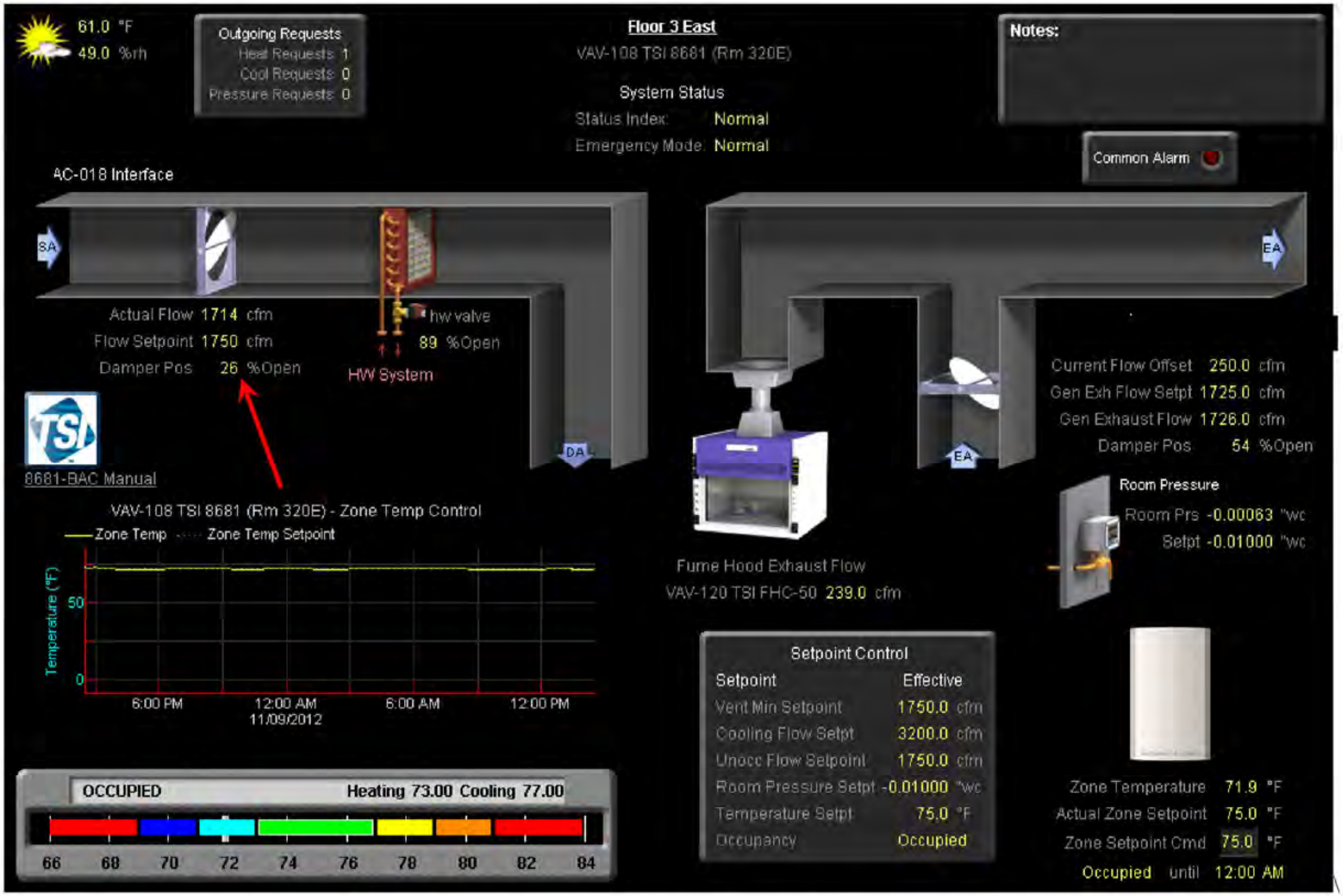



**Figure 41: Hood test, 2:31PM – Room 320E maintaining air flows at design, see supply air damper open 26%**

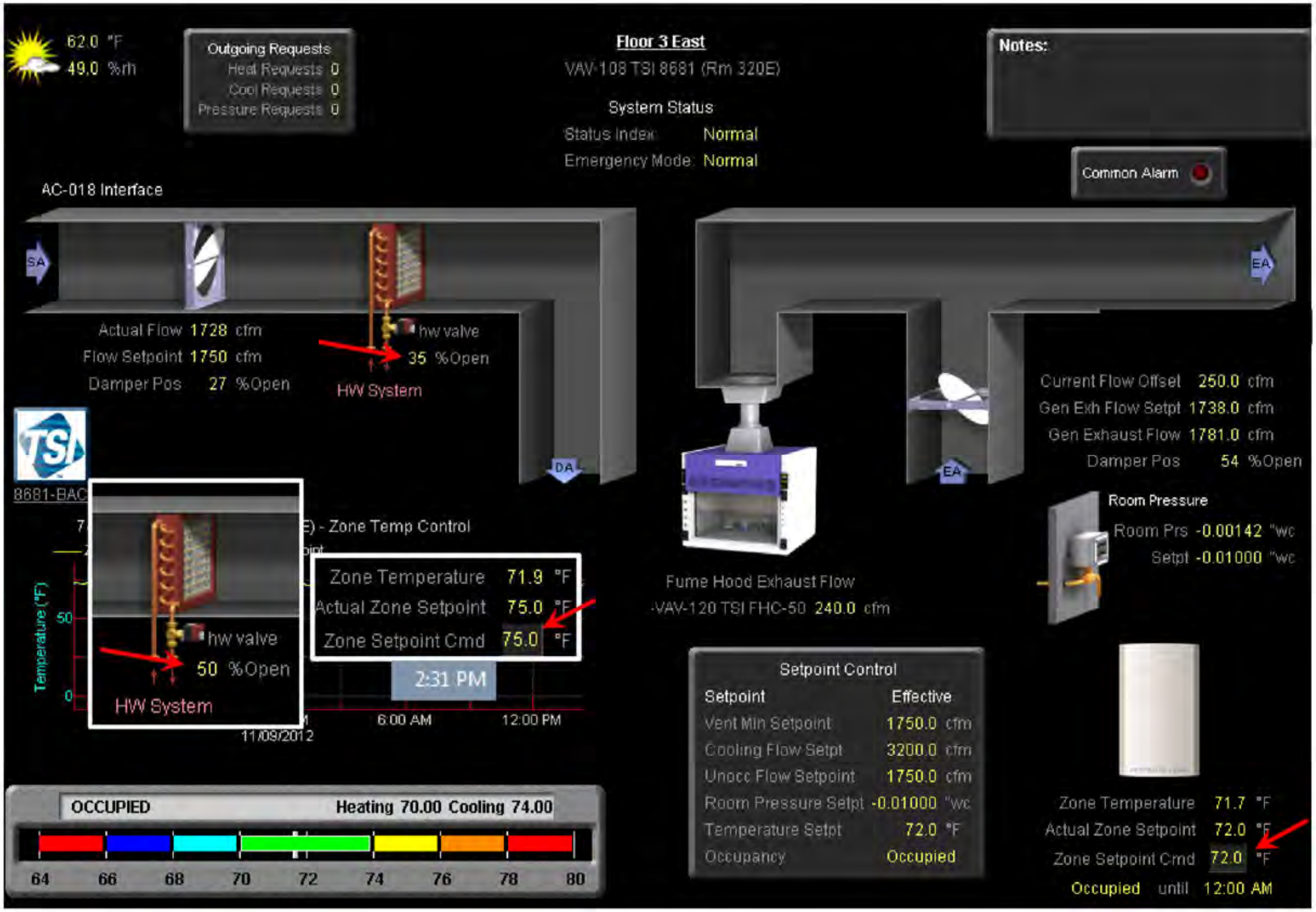



**Figure 42: Temp. test, [redacted]12 at 2:22PM– Room 320B with 72°F SP (auto), 35% HW Valve and 2:31PM with 75°F setpoint (override) and 50%HW Valve**

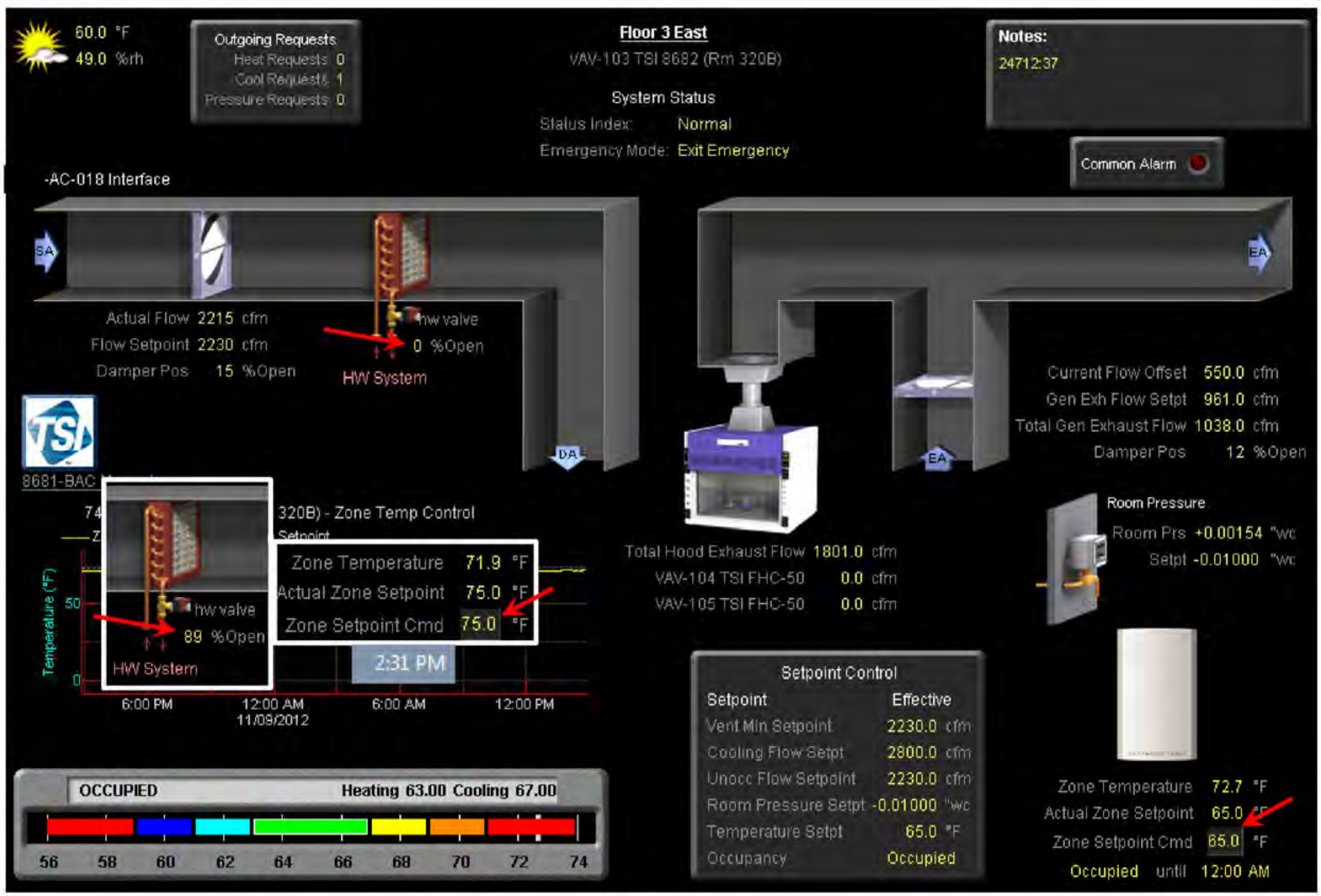



**Figure 43: Temperature test, [redacted]12 at 2:31PM in heating mode, then cooling at 2:55PM – Room 320B first maintaining air flows at vent design, see supply air damper open 13%**

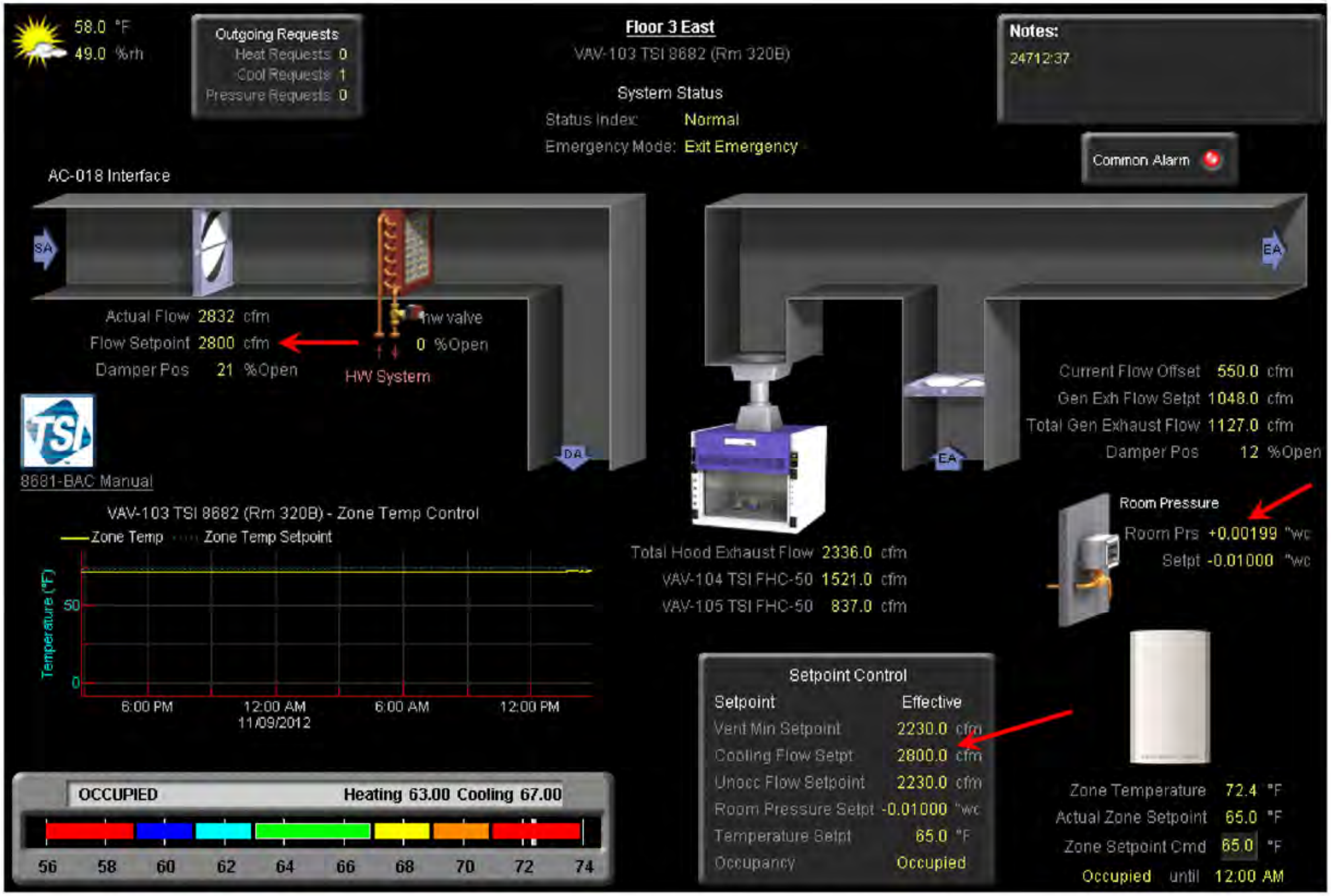



**Figure 44: Temperature test, [redacted]12 at 3:09PM in cooling mode, now maintaining almost max flows, hoods opened and gen exhaust increased. Note pressure is reversed, now positive 0.001", but both negative and positive pressures which occur are so low room is essentially neutral most of the time**


**Figure 45: Temperature test,[redacted]12 at 3:09PM terminals for hoods in 320B report very different airflows at sash max. position for both hoods and face velocities of 111 fpm vs 102 fpm**

Part 5 EXHAUST FANS

**BL-01 and BL-02** [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| MM. Operational Schedule | 1. Schedule exhaust fans BL-001 and BL-002 to run. | a. Exhaust fans BL-001 and BL-002 are enabled.<br>b. BL-001 isolation damper is open prior to start of exhaust fan BL-001.<br>c. BL-002 isolation damper is open prior to start of exhaust fan BL-002. | | |
| | 2. Schedule exhaust fans BL-001 and BL-002 to stop. | a. Exhaust fans BL-001 and BL-002 are disabled.<br>b. BL-001 exhaust fan stops prior to isolation damper closing.<br>c. BL-002 exhaust fan stops prior to isolation damper closing.<br>d. OA bypass damper is closed. | | |
| NN. Isolation Damper Alarm | 3. Disconnect communication signal from BL-001 and BL-002 isolation dampers to simulate damper failure. | a. Isolation damper alarm is triggered for BL-001 and BL-002 separately. | | |
| | 4. Schedule exhaust fans BL-001 and BL-002 to run. | a. Isolation damper alarm remains active.<br>b. Exhaust fans BL-001 and BL-002 fail to start, but do not send fan failure alarms.<br>c. OA bypass damper is closed. | | |
| | 5. Schedule exhaust fans BL-001 and BL-002 to stop. Reconnect communication signal from BL-001 and BL-002 isolation dampers. | a. Isolation damper alarm is no longer active. | | |
| OO. Pressure and Minimum Discharge Airflow Control Operation | 6. Re-schedule exhaust fans BL-001 and BL-002 to run. Adjust static pressure set point. | a. Exhaust fan BL-001 is enabled to run.<br>b. Exhaust fan BL-002 is enabled to run.<br>c. Exhaust fan BL-001 VFD modulates fan speed to maintain new setpoint value.<br>d. Exhaust fan BL-002 VFD modulates fan speed to maintain new setpoint value. | [redacted]12 fans run 89% in auto at -1.3” pressure sp. | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| | | | | |
|---|---|---|---|---|
| | | e. Exhaust fan BL-001 discharge airflow is at least 50% of full design value.<br>f. Exhaust fan BL-002 discharge airflow is at least 50% of full design value. | | |
| | 7. Adjust static pressure setpoint to a value that is low enough to result in a discharge airflow that is less than 50% of full design value. | a. Exhaust fan VFDs reduce fan speed until discharge airflow is at 50% of full design value.<br>b. Bypass damper opens to reduce air volume exhausted from building while keeping fan exhaust volume at 50% min. | Bypass opens as expected, see Figure 46 | Y |
| | 8. Reset static pressure setpoint back up and then change lead/lag sequence | a. Both fans run<br>b. Both fans speed up to meet static setpoint | | |
| | 9. Adjust static pressure setpoint to a value that is low enough to result in a discharge airflow that is less than 50% of full design value. | a. Exhaust fan VFDs reduce fan speed until discharge airflow is at 50% of full design value.<br>b. Bypass damper opens to reduce air volume exhausted from building while keeping fan exhaust volume at 50% min. | | |
| | 10. Reset static pressure setpoint back up and then release lead/lag sequence override | a. Both fans run<br>b. Both fans speed up to meet static setpoint | | |
| | 11. While BL-001 and BL-002 are both running, disable BL-001 either at local VFD HOA (preferable) which should result in a mismatch between status and command and consequent alarm, or (less preferable) at disconnect if for some reason VFD HOA is not accessible/operable. | a. Exhaust fan BL-001 is disabled.<br>b. Exhaust fan BL-001 isolation damper is closed after exhaust fan has stopped.<br>c. Exhaust fan BL-001 Alarm is triggered.<br>d. Exhaust fan BL-002 VFD modulates fan speed to maintain setpoint value.<br>e. Exhaust fan BL-002 maintains discharge airflow of at least 50% of full design airflow. | [redacted]12 2:40PM -<br>Fail BL-122, by manually hitting "OFF" on variable speed drive for BL-122 in roof penthouse.<br><br>Followed by low pressure alarm for about 5 minutes. Sequence as intended, damper closes and BL-123 speeds up.<br>Requires manual reset alarm at front end to get both fans running again, so just re-enabling drive does not work.<br>See Figure 47 to Figure 49 | Y |

| | | | | |
|---|---|---|---|---|
| | 12. Re-enable BL-001 while BL-002 continues to run. | a. Exhaust fan BL-001 is enabled.<br>b. Exhaust fan BL-001 isolation damper opens prior to exhaust fan start.<br>c. Exhaust fan BL-001 VFD modulates fan speed to maintain setpoint value.<br>d. Exhaust fan BL-002 VFD modulates fan speed to maintain setpoint value.<br>e. Exhaust fan BL-001 maintains discharge airflow of at least 50% of full design airflow.<br>f. Exhaust fan BL-002 maintains discharge airflow of at least 50% of full design airflow. | [redacted]/12 2:45 PM Check – blower starts first at 20%, then after 30 seconds, damper open command is given.<br>After damper is open > 50%, VFD allowed to ramp up.<br>VAVs close down again as plenum pressure buildings up | Y |
| | 13. While BL-001 and BL-002 are both running, disable BL-002 either at local VFD HOA (preferable) which should result in a mismatch between status and command and consequent alarm, or (less preferable) at disconnect if for some reason VFD HOA is not accessible/operable. | a. Exhaust fan BL-002 is disabled.<br>b. Exhaust fan BL-002 isolation damper is closed after exhaust fan has stopped.<br>c. Exhaust fan BL-002 Alarm is triggered.<br>d. Exhaust fan BL-001 VFD modulates fan speed to maintain setpoint value.<br>e. Exhaust fan BL-001 maintains discharge airflow of at least 50% of full design airflow. | [redacted]12 2:56PM<br>Fail BL-123<br>Blower failure and plenum pressure alarm ok, failure complete, damper closed. Note fan calibration of airflow seems incorrect, see also issues log #84, report dated [redacted]2012.<br><br>See Figure 50 to Figure 51 | Y |
| | 14. Re-enable BL-002 to operate while BL-001 continues to run. | a. Exhaust fan BL-002 is enabled.<br>b. Exhaust fan BL-002 isolation damper opens prior to exhaust fan start.<br>c. Exhaust fan BL-002 VFD modulates fan speed to maintain setpoint value.<br>d. Exhaust fan BL-001 VFD modulates fan speed to maintain setpoint value.<br>e. Exhaust fan BL-001 maintains discharge airflow of at least 50% of full design airflow.<br>f. Exhaust fan BL-002 maintains discharge airflow of at least 50% of full design airflow. | [redacted]/12 3:05 PM Check – blower starts first at 20%, then after 30 seconds, damper open command is given.<br>After damper is open > 50%, VFD allowed to ramp up.<br>VAVs close down again as plenum pressure buildings up | |

Additional Notes

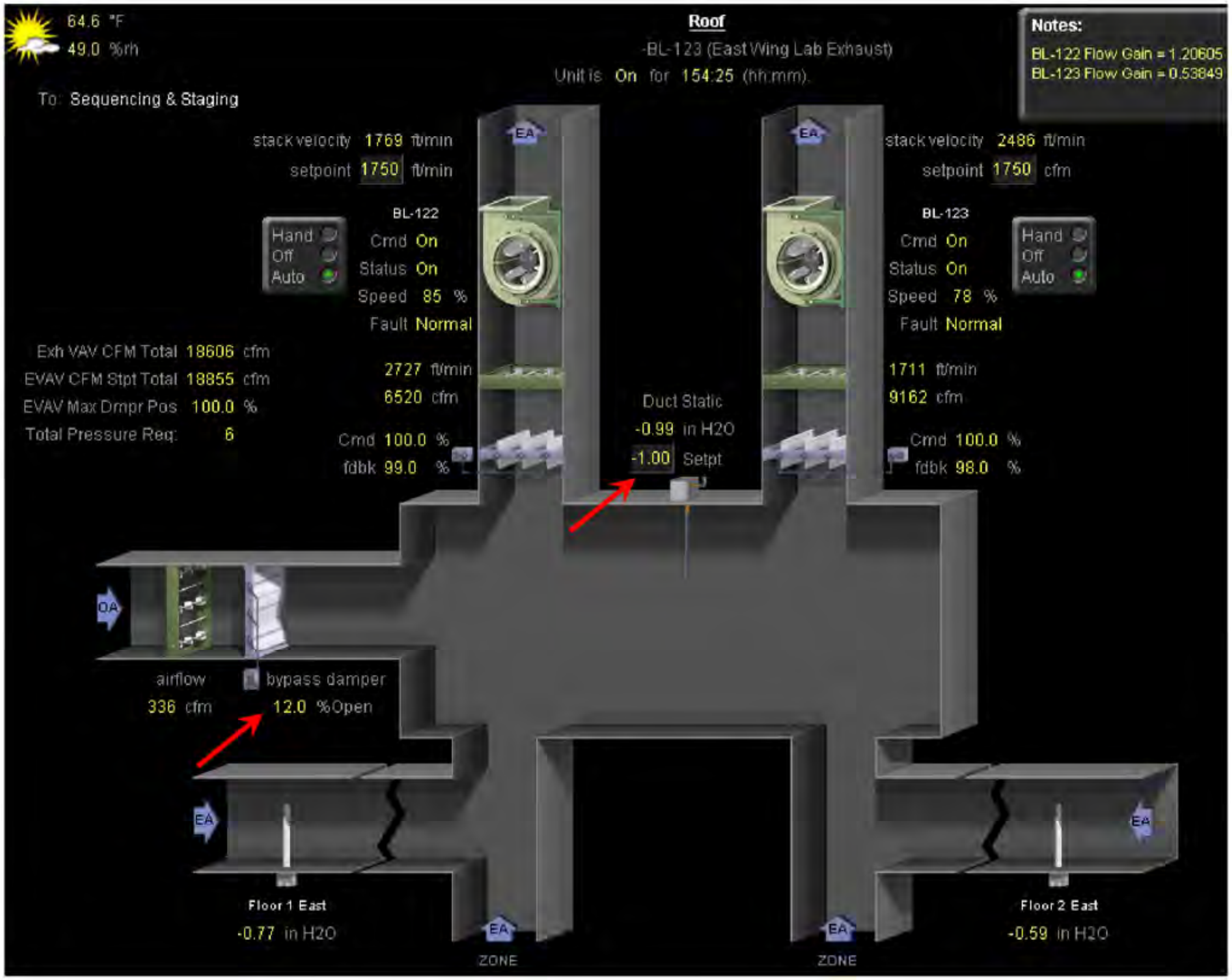



**Figure 46: Bypass test, [redacted]/12 at 1:34PM , reduction of plenum pressure to 1" SP causes bypass damper to open slightly to maintain stack velocity**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

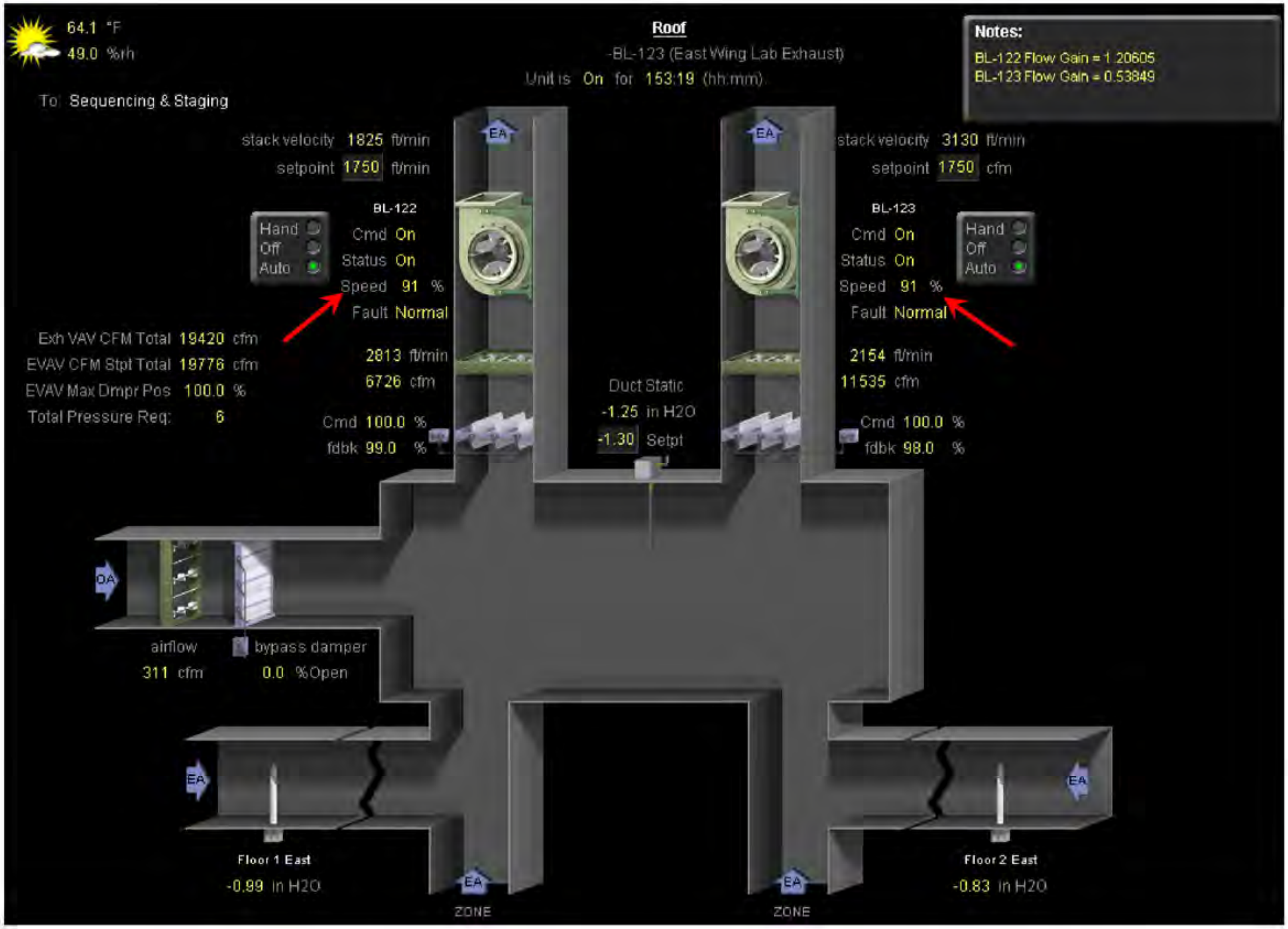



**Figure 47: Fan failure test, [redacted]/12 at 2:39PM , both fans on East exhaust plenum running in auto at 91%**

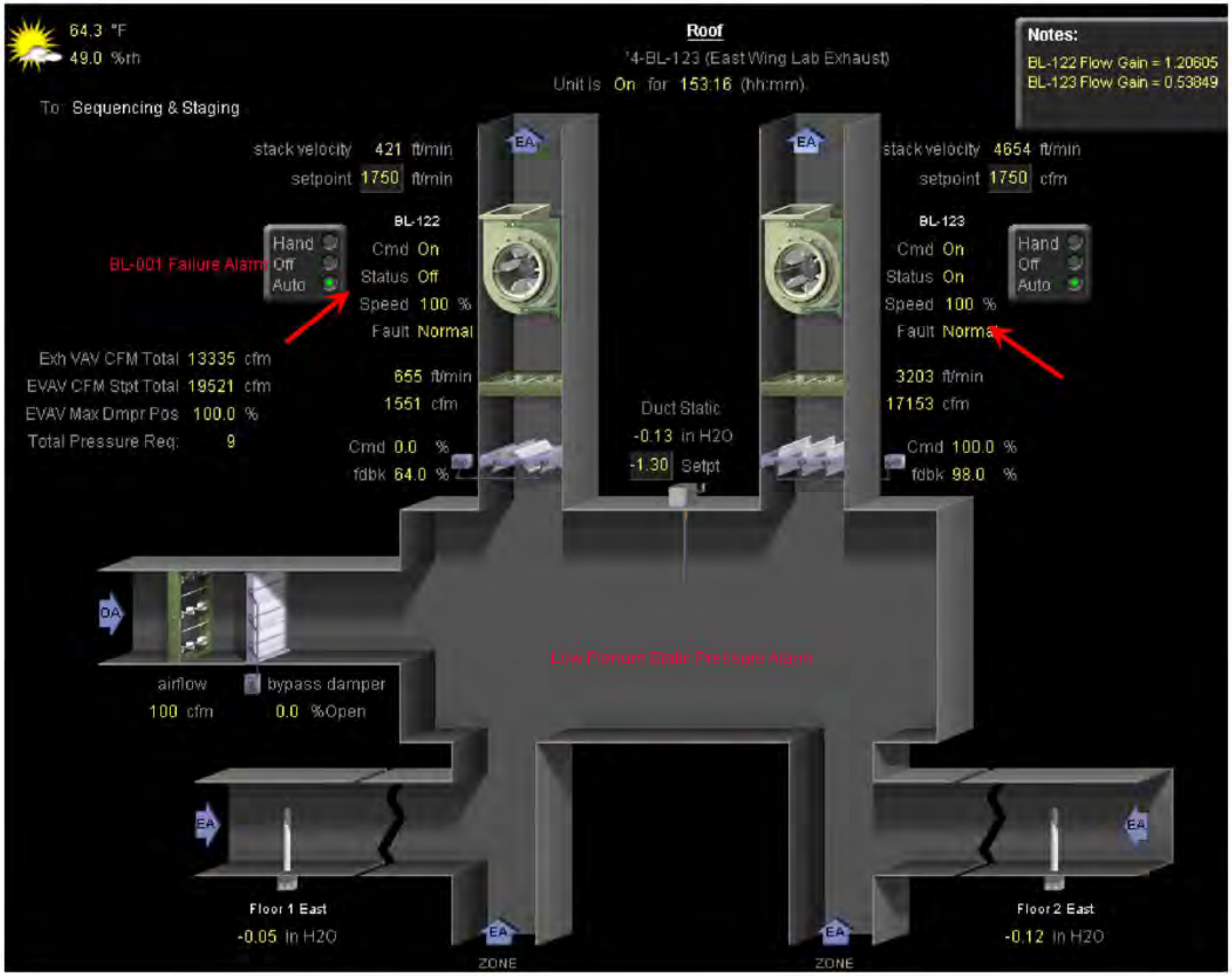



**Figure 48: Fan failure test, [redacted]12 at 2:42PM , failed BL-122 on East exhaust plenum, isolation damper closing. Note plenum pressure drop and alarm (unavoidable), and cfm summary still incorrect (13,335 reported from zones, 17,153 reported from fan airflow sensor, see also test report dated [redacted]2012 and issues log #84**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

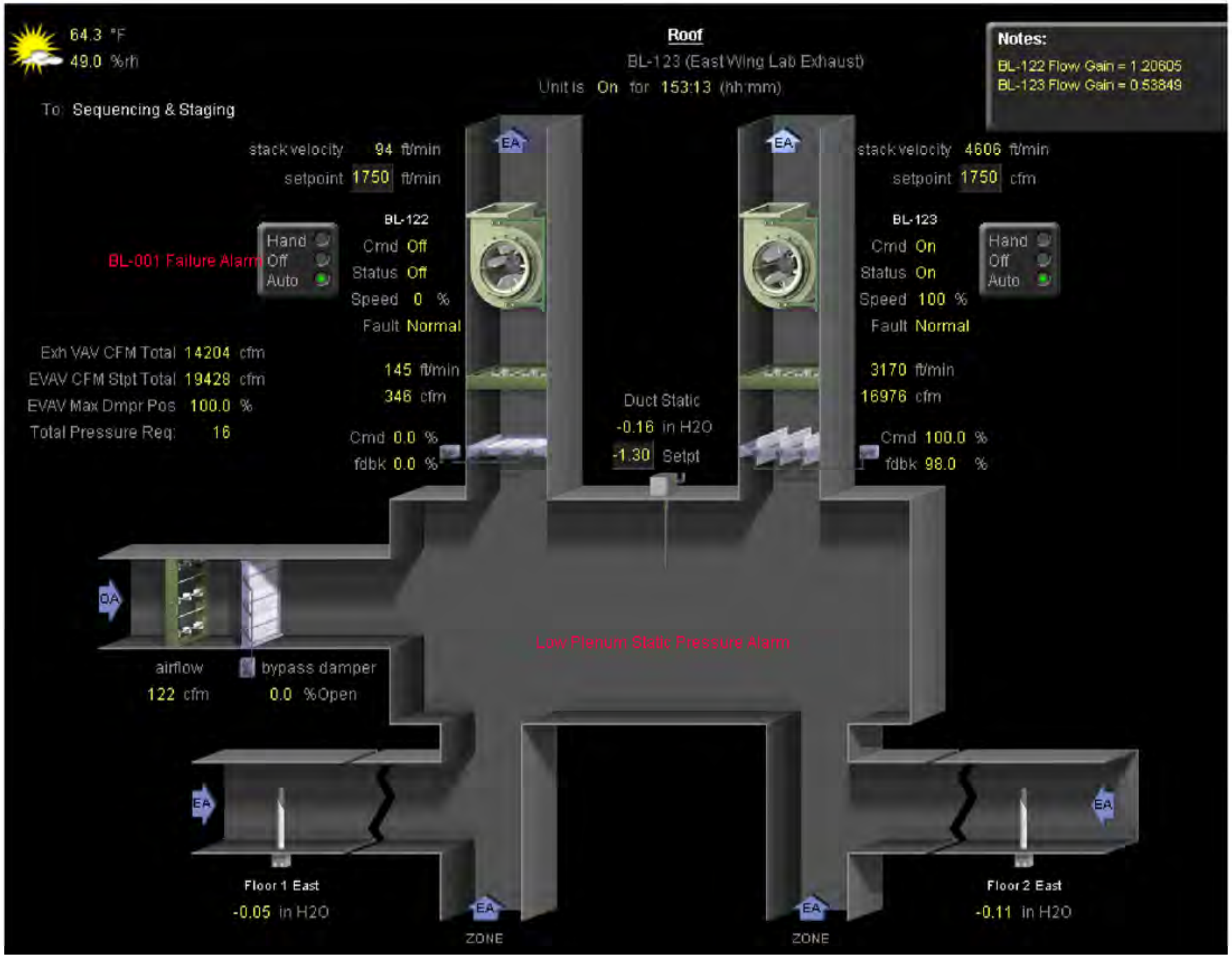



**Figure 49: Fan failure test, [redacted]/12 at 2:46PM, failed BL-122 on East exhaust plenum, isolation damper shut. Note plenum pressure still low, at -0.16" (about 4 minutes of low pressure)**

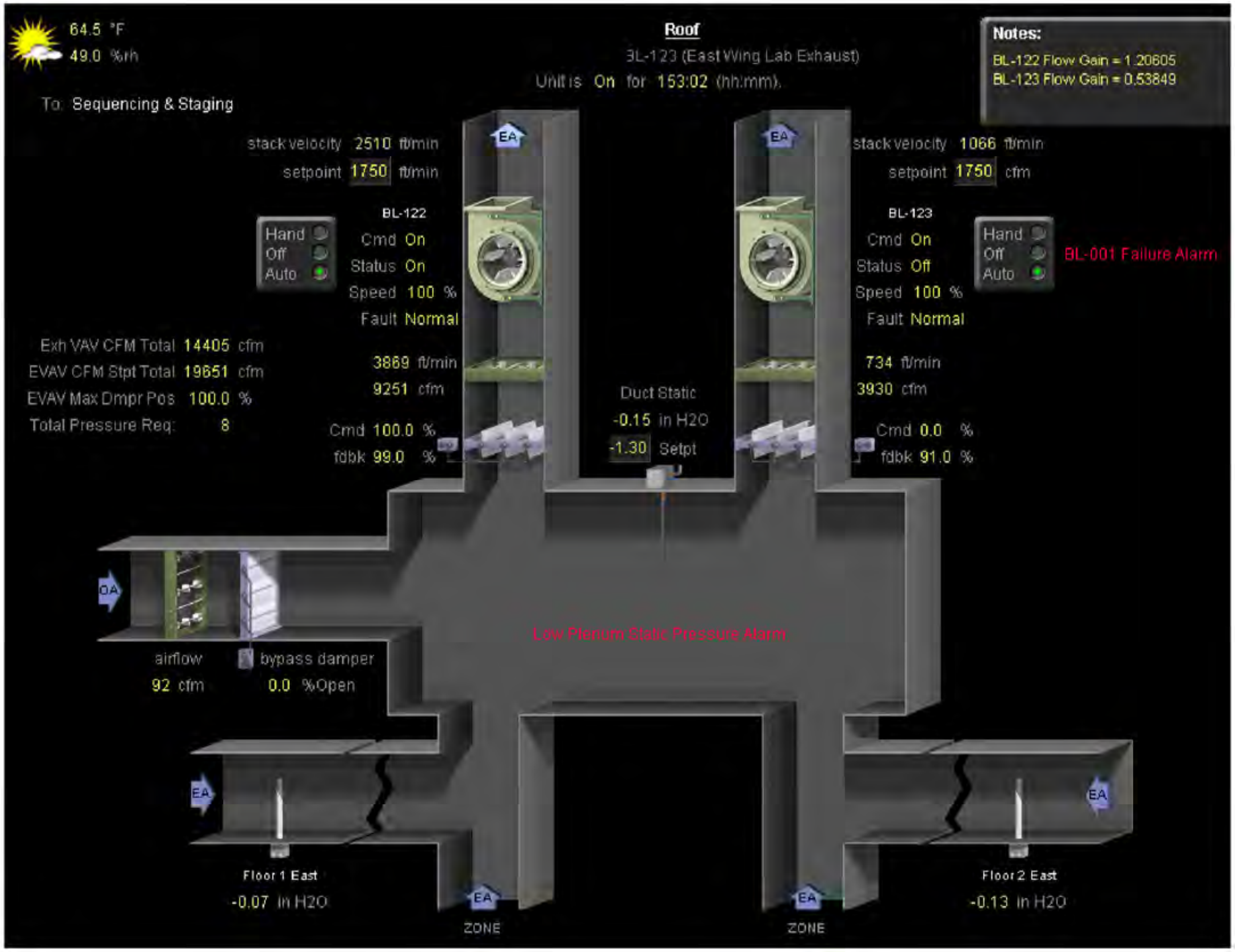



**Figure 50: Fan failure test, [redacted]/12 at 2:57PM, failed BL-123 on East exhaust plenum, isolation damper closing. Note plenum pressure drop and alarm (unavoidable), and cfm summary still incorrect (13,405 reported from zones, 9251+3930 reported from fan airflow sensors, see also test report dated [redacted]2012 and issues log #84**

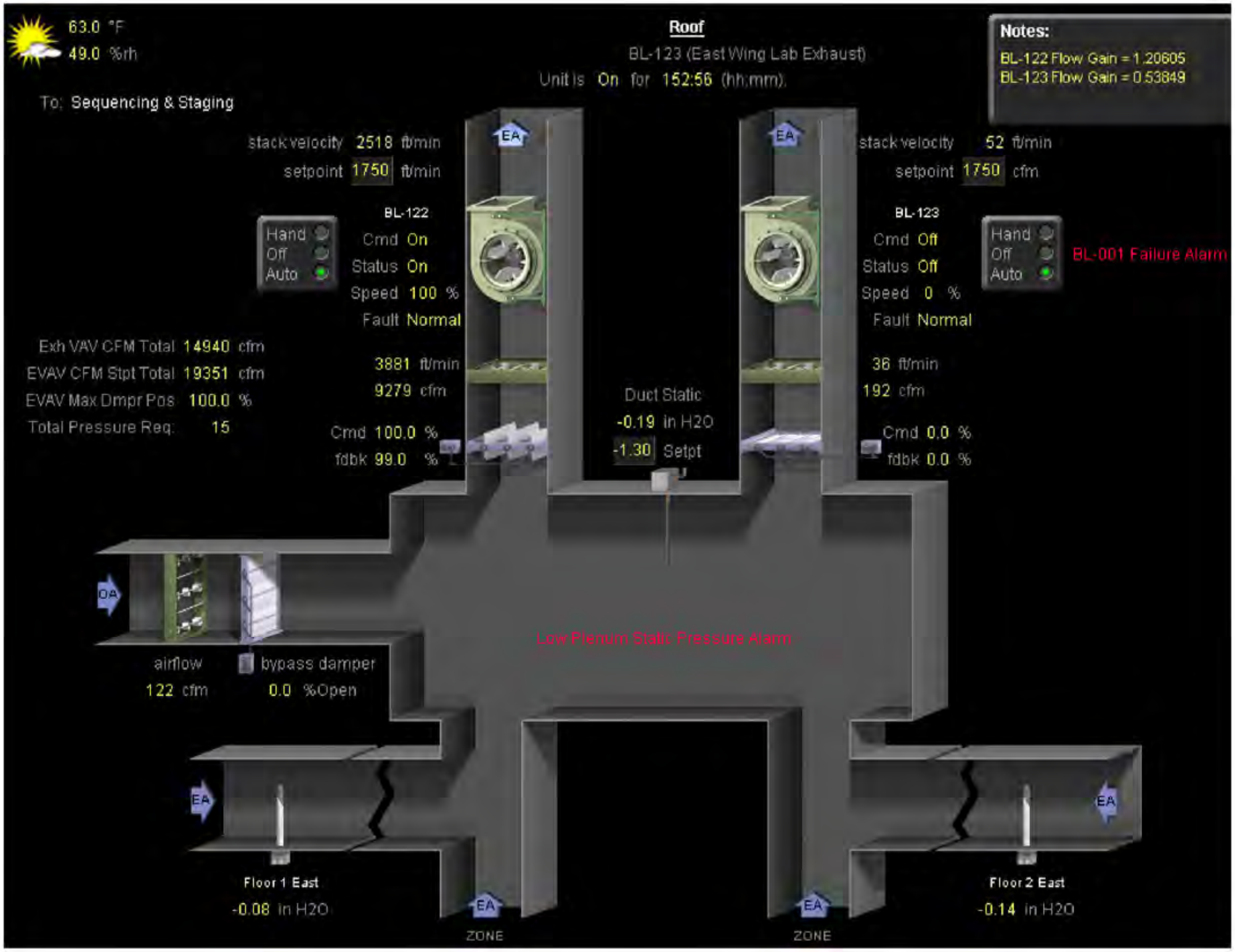



**Figure 51: Fan failure test, [redacted]/12 at 3:04PM, failed BL-123 on East exhaust plenum, isolation damper shut. Note plenum pressure still low, at -0.18" (about 7 minutes of low pressure) – pressure does not stabilize with one fan**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

**BL-03 and BL-04 [redacted]**

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| PP. Operational Schedule | 1. Schedule exhaust fans BL-003 and BL-004 to run. | d. Exhaust fans BL-003 and BL-004 are enabled.<br>e. BL-003 isolation damper is open prior to start of exhaust fan BL-003.<br>f. BL-004 isolation damper is open prior to start of exhaust fan BL-004. | | |
| | 2. Schedule exhaust fans BL-003 and BL-004 to stop. | e. Exhaust fans BL-003 and BL-004 are disabled.<br>f. BL-003 exhaust fan stops prior to isolation damper closing.<br>g. BL-004 exhaust fan stops prior to isolation damper closing.<br>h. OA bypass damper is closed. | | |
| QQ. Isolation Damper Alarm | 3. Disconnect communication signal from BL-003 and BL-004 isolation dampers to simulate damper failure. | b. Isolation damper alarm is triggered for BL-003 and BL-004 separately. | | |
| | 4. Schedule exhaust fans BL-003 and BL-004 to run. | d. Isolation damper alarm remains active.<br>e. Exhaust fans BL-003 and BL-004 fail to start, but do not send fan failure alarms.<br>f. OA bypass damper is closed. | | |
| | 5. Schedule exhaust fans BL-003 and BL-004 to stop. Reconnect communication signal from BL-003 and BL-004 isolation dampers. | b. Isolation damper alarm is no longer active. | | |
| RR. Pressure and Minimum Discharge Airflow Control Operation | 6. Re-schedule exhaust fans BL-003 and BL-004 to run. Adjust static pressure set point. | g. Exhaust fan BL-003 is enabled to run.<br>h. Exhaust fan BL-004 is enabled to run.<br>i. Exhaust fan BL-003 VFD modulates fan speed to maintain new setpoint value.<br>j. Exhaust fan BL-004 VFD modulates fan speed to maintain new setpoint value.<br>k. Exhaust fan BL-003 discharge airflow is at least 50% of full design value. | [redacted]/12 at 3:11PM Both fans running ~65% at 1.3" SP. Set point has been set to 1.3" by [redacted] in previous tests as the lowest plenum pressure that can be maintained by 1 fan, see Figure 52 | N/A |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| | | | | |
|---|---|---|---|---|
| | | l. Exhaust fan BL-004 discharge airflow is at least 50% of full design value. | However, at this pressure, a number of exhaust terminals are starved and have dampers 100% open. See Figure 53.<br><br>VAV-140 (room 327J) flow SP 860, actual 850 and VAV-56 (Room 223), flow SP 972 and actual 923 cfm (both 100% damper pos.). | |
| | 7. Adjust static pressure setpoint to a value that is low enough to result in a discharge airflow that is less than 40% of full design value. | c. Lag exhaust fan stages off<br>d. Lead exhaust fan VFD reduces fan speed until discharge airflow is at 40% of full design value.<br>e. Bypass damper opens to reduce air volume exhausted from building while keeping fan exhaust volume at 50% min. | | |
| | 8. Reset static pressure setpoint back up and then change lead/lag sequence | c. Both fans run<br>d. Both fans speed up to meet static setpoint | | |
| | 9. Adjust static pressure setpoint to a value that is low enough to result in a discharge airflow that is less than 40% of full design value. | c. Lag exhaust fan stages off (the other fan, compared to test above)<br>d. Lead exhaust fan VFD reduces fan speed until discharge airflow is at 50% of full design value.<br>e. Bypass damper opens to reduce air volume exhausted from building while keeping fan exhaust volume at 50% min. | Cannot do this – 1.3" is bare minimum (2 exhausts already starved), so reducing SP will result in more exhaust VAVs and possibly hoods starved.<br><br>These fans will never stage down to one fan. | Y |
| | 10. Reset static pressure setpoint back up and then release lead/lag sequence override | c. Both fans run<br>d. Both fans speed up to meet static setpoint | | |

| | | | | |
|---|---|---|---|---|
| | 11. While BL-003 and BL-004 are both running, disable BL-003 either at local VFD HOA (preferable) which should result in a mismatch between status and command and consequent alarm, or (less preferable) at disconnect if for some reason VFD HOA is not accessible/operable. | f. Exhaust fan BL-003 is disabled.<br>g. Exhaust fan BL-003 isolation damper is closed after exhaust fan has stopped.<br>h. Exhaust fan BL-003 Alarm is triggered.<br>i. Exhaust fan BL-004 VFD modulates fan speed to maintain setpoint value.<br>j. Exhaust fan BL-004 maintains discharge airflow of at least 50% of full design airflow. | [redacted]/12 3:12PM<br><br>Fail BL-124<br><br>Blower failure and plenum pressure alarm ok, failed complete, damper closed, see Figure 54<br><br>3 min delay means no low plenum press alarm – one fan sufficient. | Y |
| | 12. Re-enable BL-003 while BL-004 continues to run. | g. Exhaust fan BL-003 is enabled.<br>h. Exhaust fan BL-003 isolation damper opens prior to exhaust fan start.<br>i. Exhaust fan BL-003 VFD modulates fan speed to maintain setpoint value.<br>j. Exhaust fan BL-004 VFD modulates fan speed to maintain setpoint value.<br>k. Exhaust fan BL-003 maintains discharge airflow of at least 50% of full design airflow.<br>l. Exhaust fan BL-004 maintains discharge airflow of at least 50% of full design airflow. | Staging back up even though one fan is above 90%, but holding plenum pressure. Staging up because flag that caused stage-up initially was not cleared on fan failure of BL-124.<br><br>Staging down, reaching > 2" plenum pressure on the way, see Figure 56 | Y |
| | 13. While BL-003 and BL-004 are both running, disable BL-004 either at local VFD HOA (preferable) which should result in a mismatch between status and command and consequent alarm, or (less preferable) at disconnect if for some reason VFD HOA is not accessible/operable. | f. Exhaust fan BL-004 is disabled.<br>g. Exhaust fan BL-004 isolation damper is closed after exhaust fan has stopped.<br>h. Exhaust fan BL-004 Alarm is triggered.<br>i. Exhaust fan BL-003 VFD modulates fan speed to maintain setpoint value.<br>j. Exhaust fan BL-003 maintains discharge airflow of at least 50% of full design airflow. | [redacted]/12 Fail BL-125 at 3:32PM<br><br>See VAVs reporting about 9,000 cfm while fan reports 14,000 cfm and a little later 17,000 cfm<br><br>Figure 60 – stabilized w one fan, | Y |

| | | | | |
|---|---|---|---|---|
| | | | 94%<br><br>Clear flag for stag-up manually, this will bring only one fan back up, but the lead/lag mechanism should try to make that BL-125 | |
| | 14. Re-enable BL-004 to operate while BL-003 continues to run. | g. Exhaust fan BL-004 is enabled.<br>h. Exhaust fan BL-004 isolation damper opens prior to exhaust fan start.<br>i. Exhaust fan BL-004 VFD modulates fan speed to maintain setpoint value.<br>j. Exhaust fan BL-003 VFD modulates fan speed to maintain setpoint value.<br>k. Exhaust fan BL-004 maintains discharge airflow of at least 50% of full design airflow.<br>l. Exhaust fan BL-003 maintains discharge airflow of at least 50% of full design airflow. | [redacted]/12 @ 3:42PM alarm cleared<br><br>BL-125 comes online (20%, then damper after 30 sec delay), while BL-124 stages off because only one fan required.<br><br>One fan running at 5kW,<br><br>Both fans run at about 1.6kW ea,<br><br>So run 3.2kW total<br><br>Running both fans is more efficient | Y |

Additional Notes

Exhaust fan air volumes still not correct, see Figure 52 to Figure 58 from [redacted]/12. Make a new summary screen for exhaust VAVs and hoods, and run test first thing tomorrow morning to determine whether some zones are mis-mapped, then turn off exhaust plenums one at a time.

[redacted]BL-128: triggered off mechanical room temp: SP currently 85°F, 74°F in room , [redacted]/12 at 2PM – lower SP to 65°F, Fan Starts. OK
BL-129: triggered off electrical room temp: SP currently 85°F, 69°F in room , [redacted]/12 at 2PM – lower SP to 65°F, Fan Starts. OK

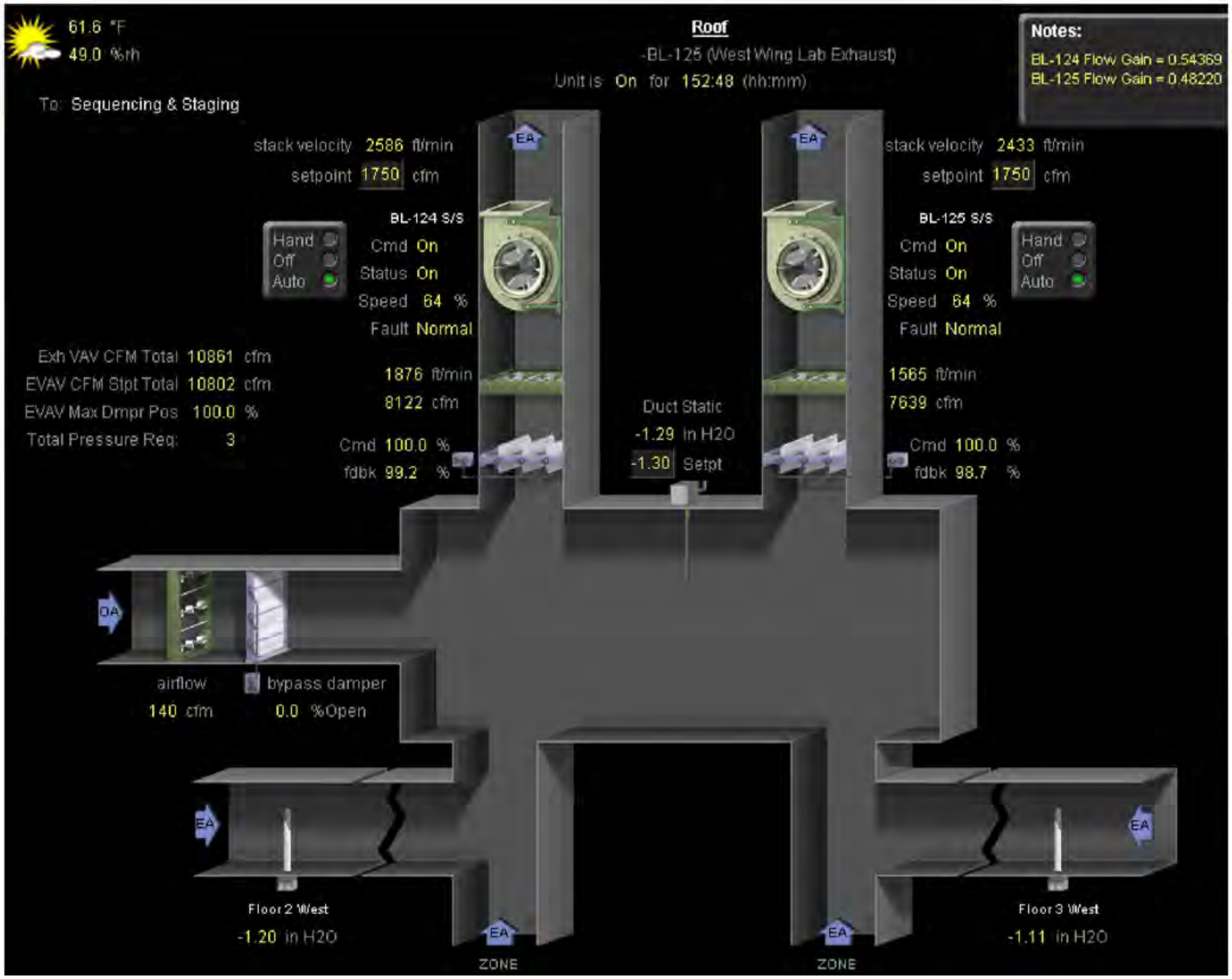



**Figure 52: Fan failure test, [redacted]/12 at 3:11PM , fans still in auto and running at 64%Note cfm summary still incorrect (10,861 reported from zones, 8122+7639 reported from fan airflow sensors, see also test report dated [redacted]/2012 and issues log #84**


**Figure 53: Exhaust dampers in 327J and 223 both starved - 100% open and slightly short of setpoint, at 1.3" exhaust plenum pressure setpoint**

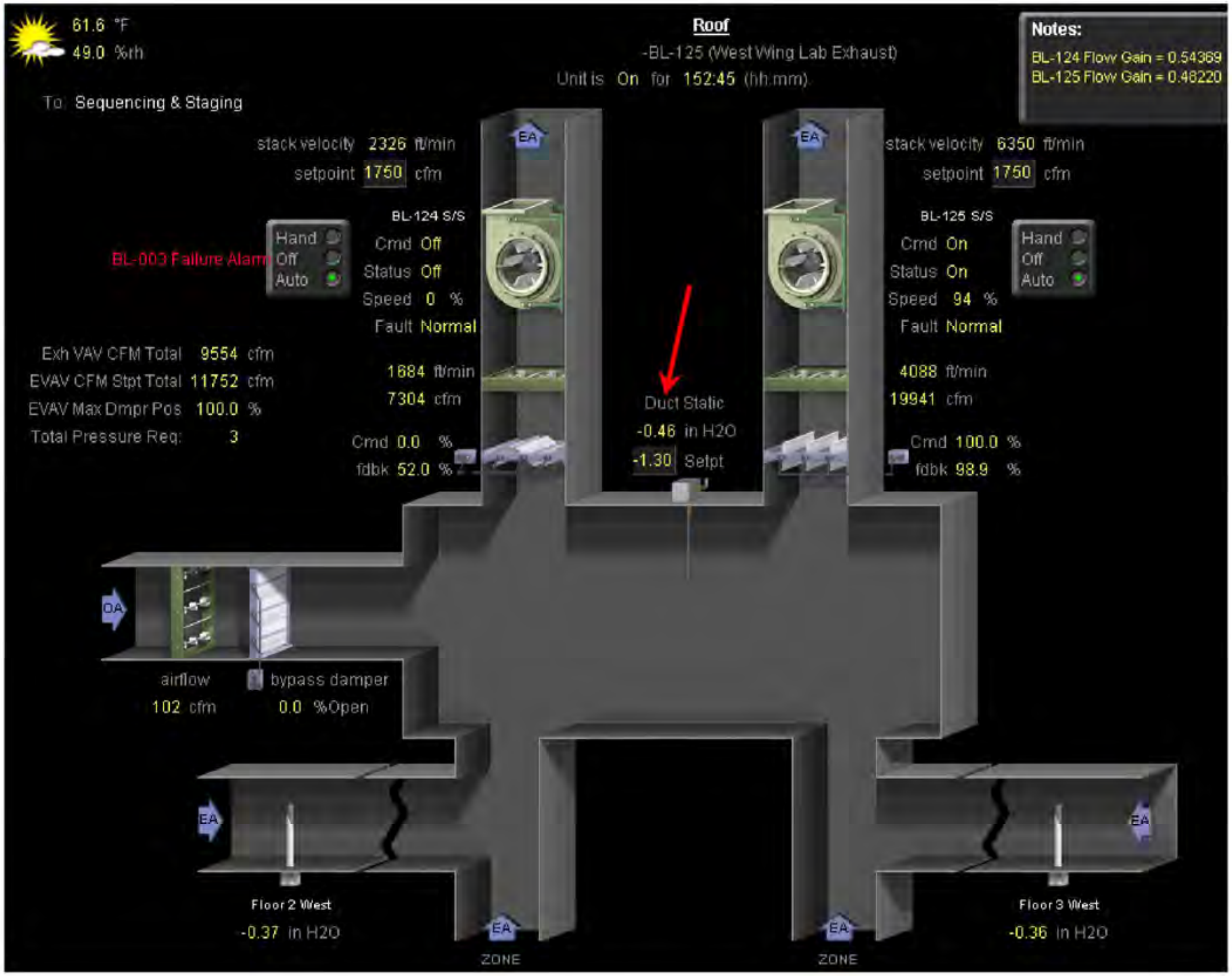



**Figure 54: Fan failure test, [redacted]/12 at 3:14PM , right after failure, plenum pressure drops to -0.46" but then rises again, so no continuous loss of pressure as witnessed on East plenum**

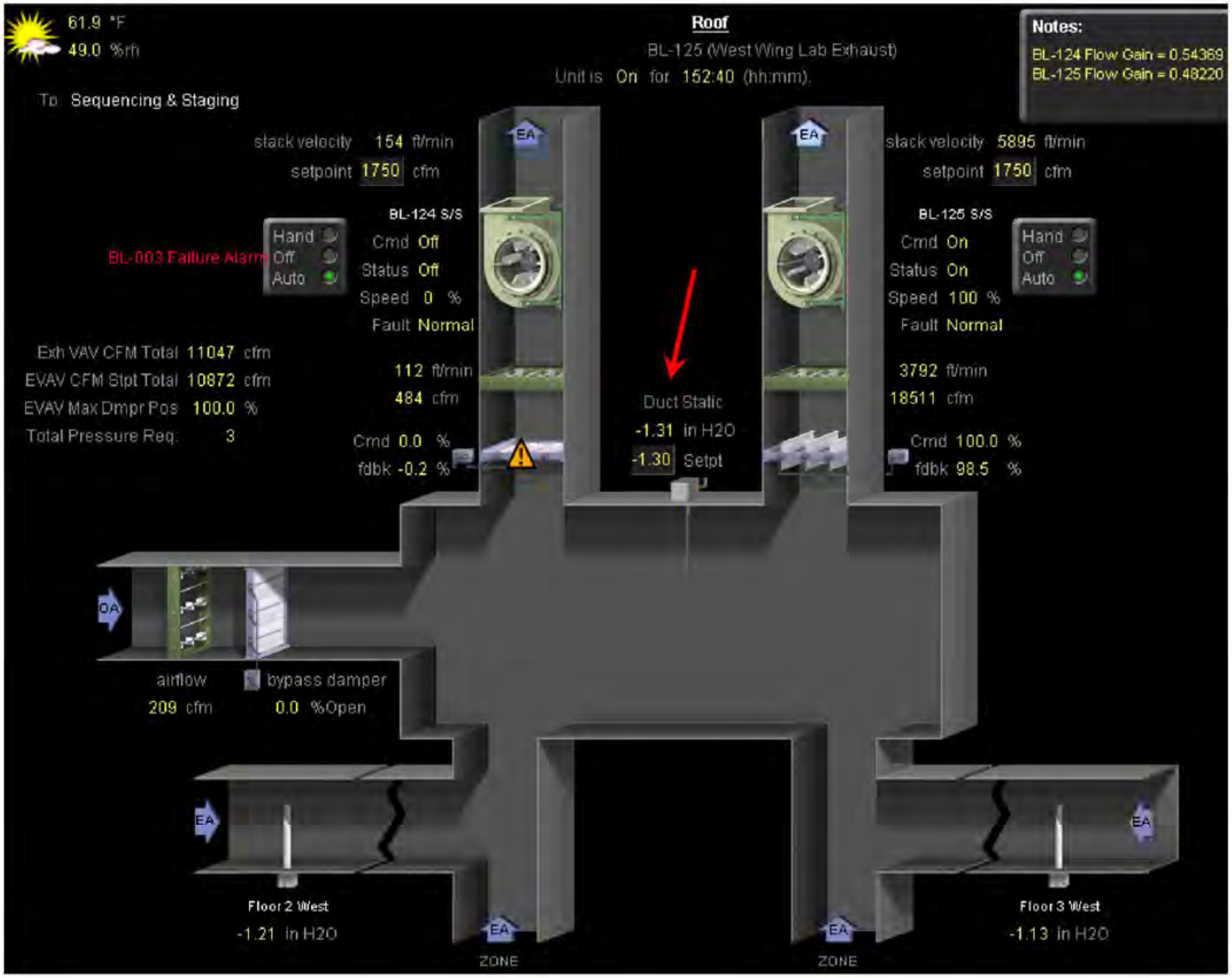



**Figure 55: Fan failure test, [redacted]/12 at 3:19PM , 5 minutes after failure, plenum pressure back to -1.31". Damper error signal occurs because of very slight position feedback calibration error (-0.2% position reported)**

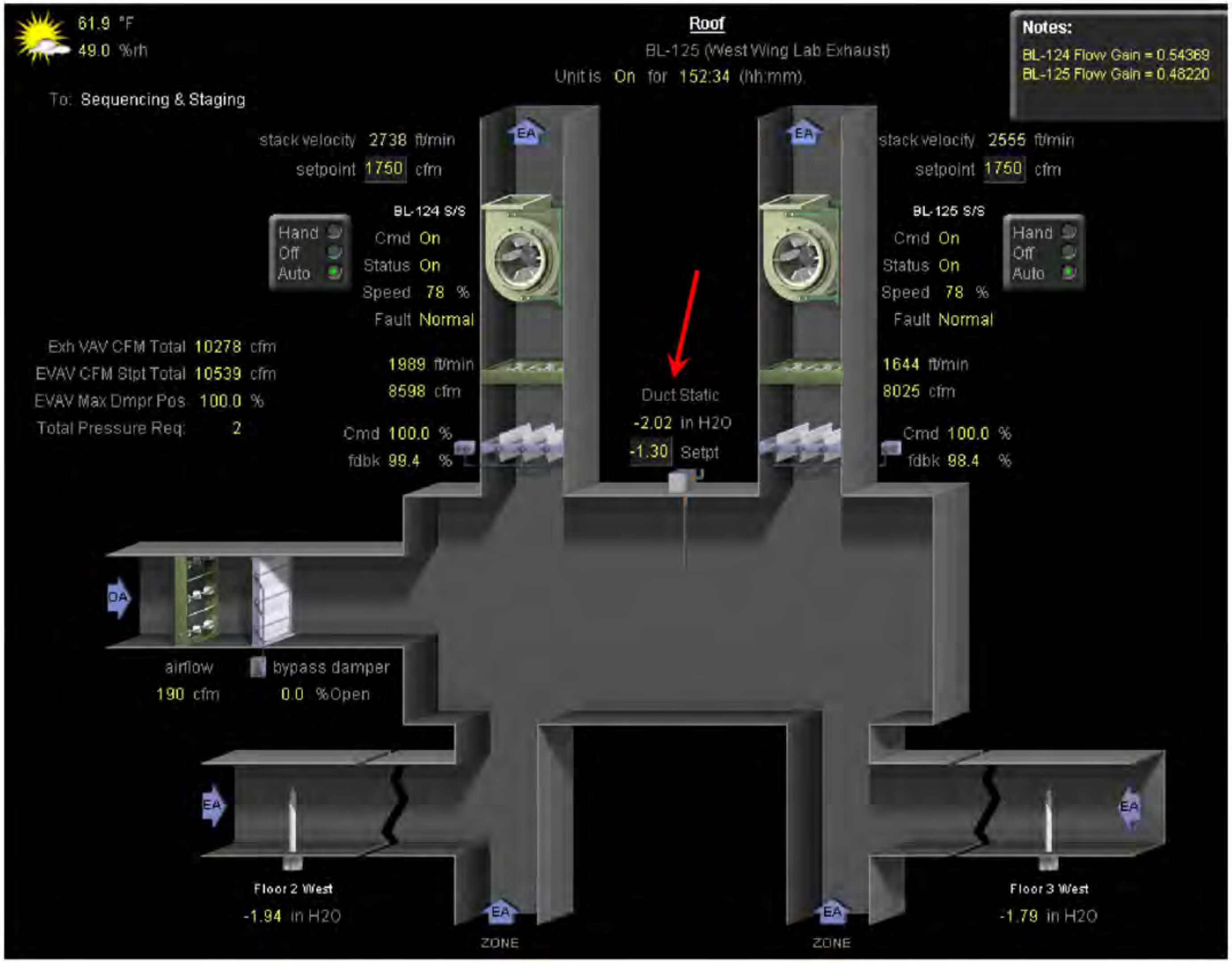



**Figure 56: Fan failure test, [redacted]/12 at 3:25PM as both fans ramp up, pressure exceeds setpoint (2" negative), should not pose any issues for operations. Pressure stabilizes within ~ 5 minutes.**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

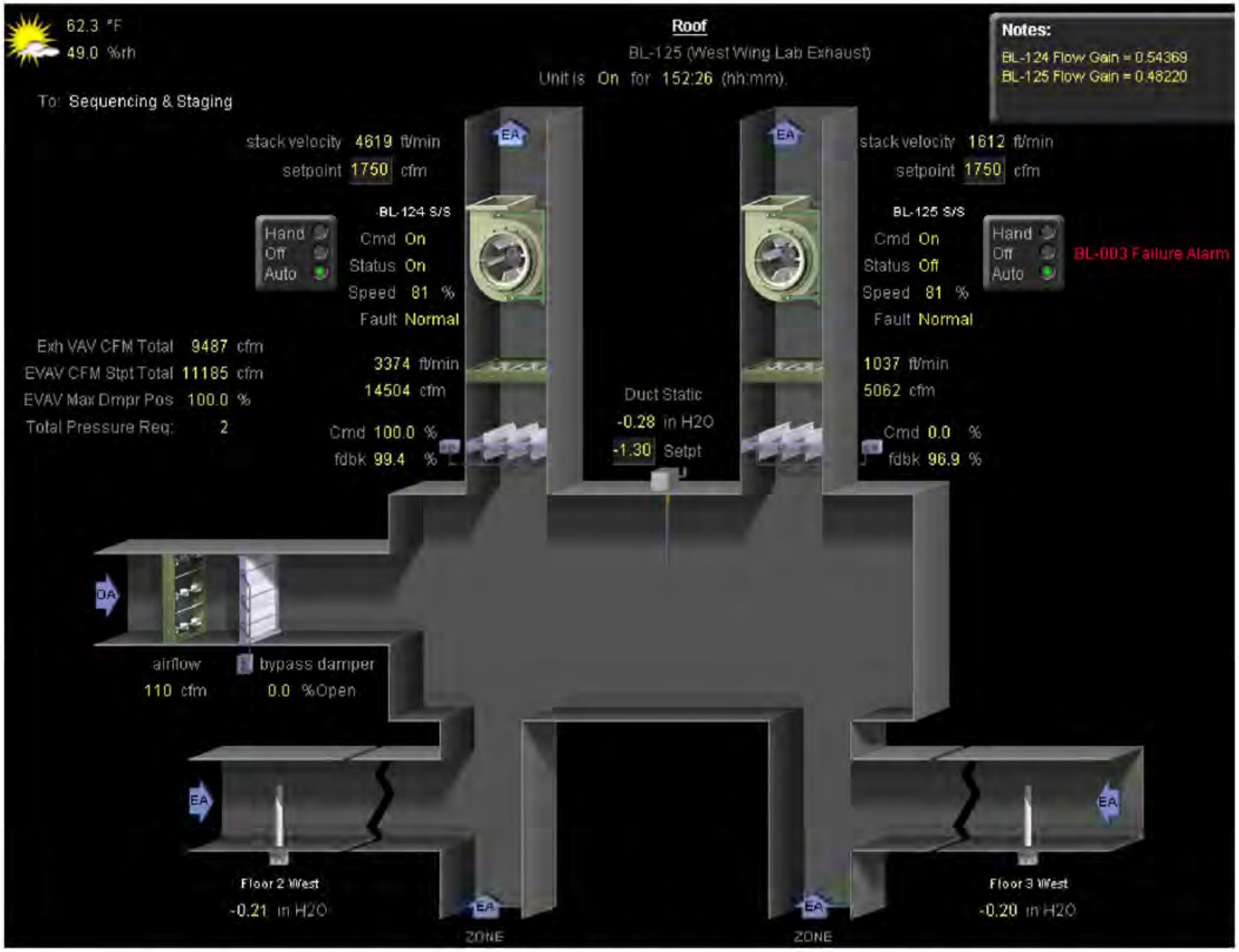



**Figure 57: Fan failure test, [redacted]/12 at 3:33PM note pressure drops to -0.28” in plenum.**

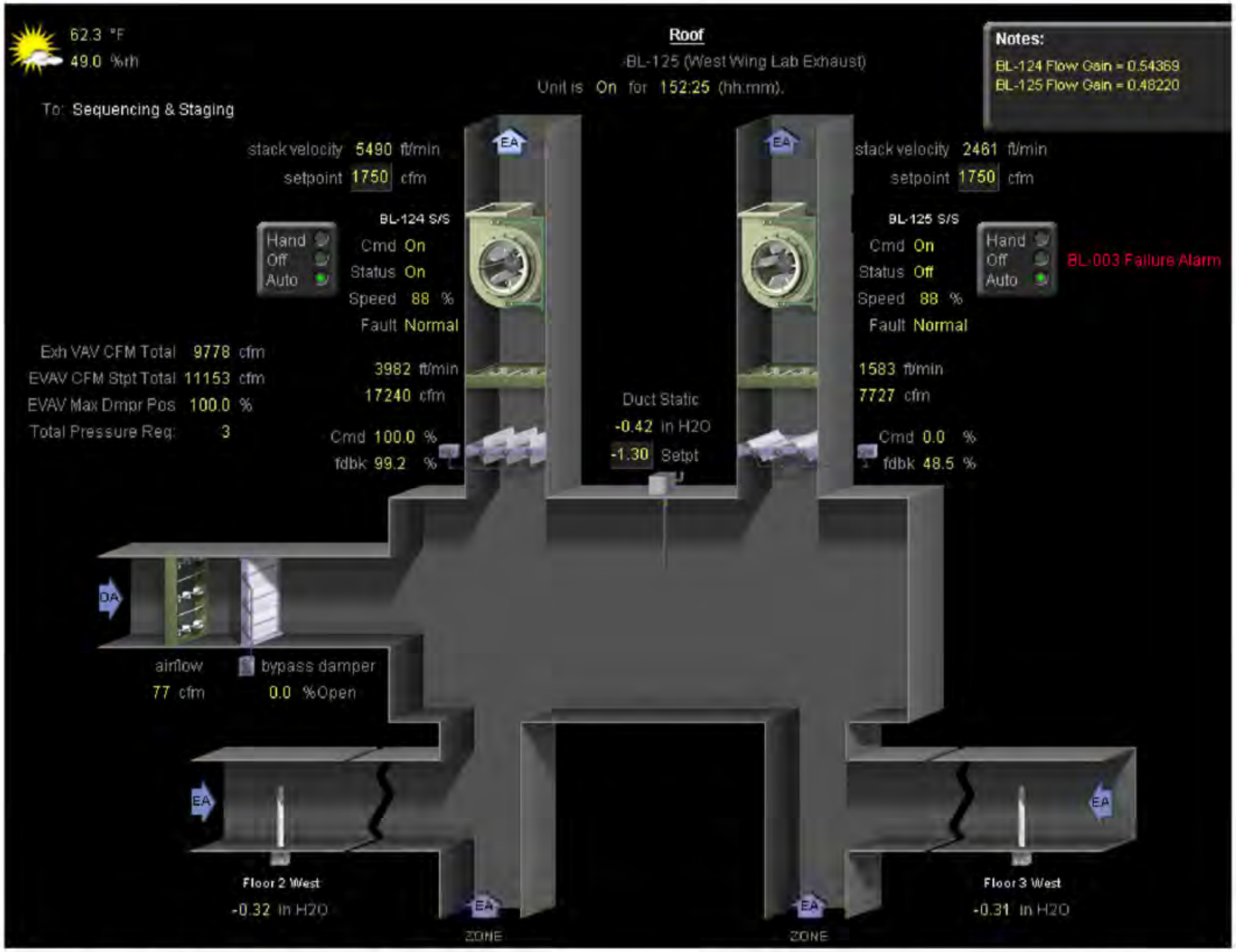



**Figure 58: Fan failure test, [redacted]/12 at 3:34PM note pressure back to -0.42" in plenum within 1 minute**

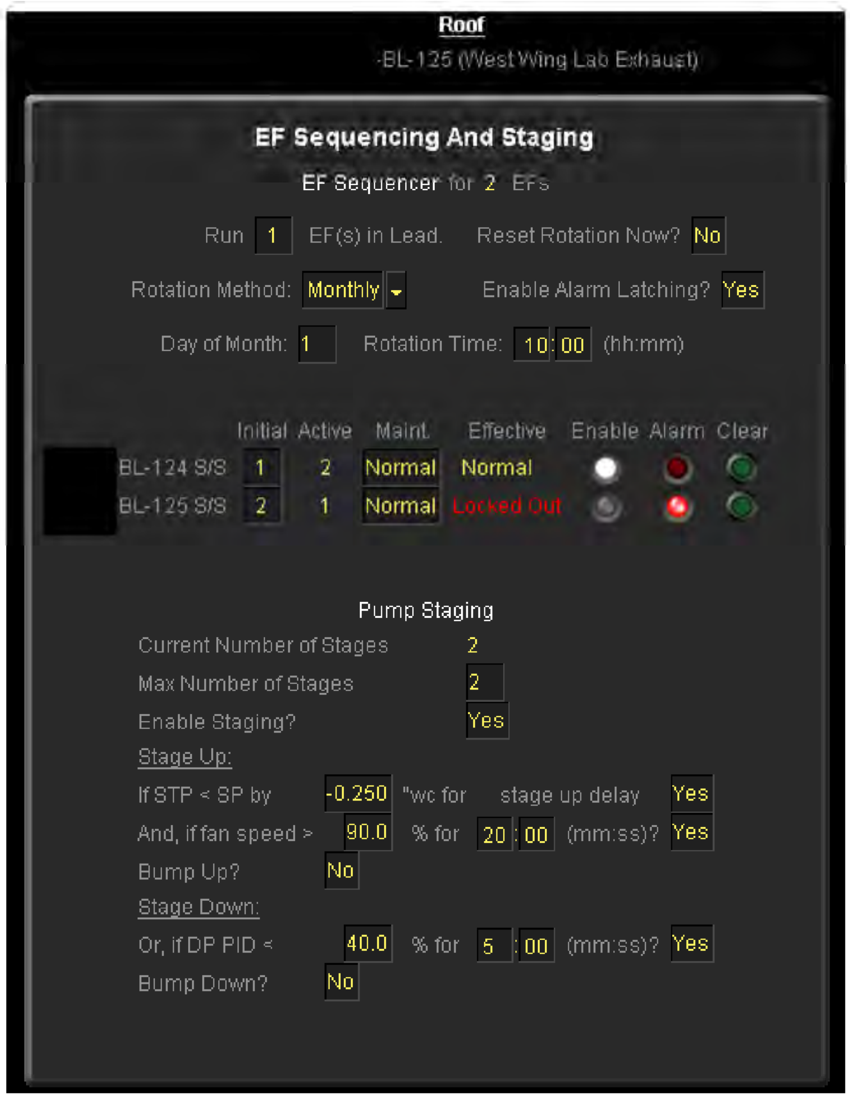



**Figure 59: Front end dialog for manual reset of fans after failure**

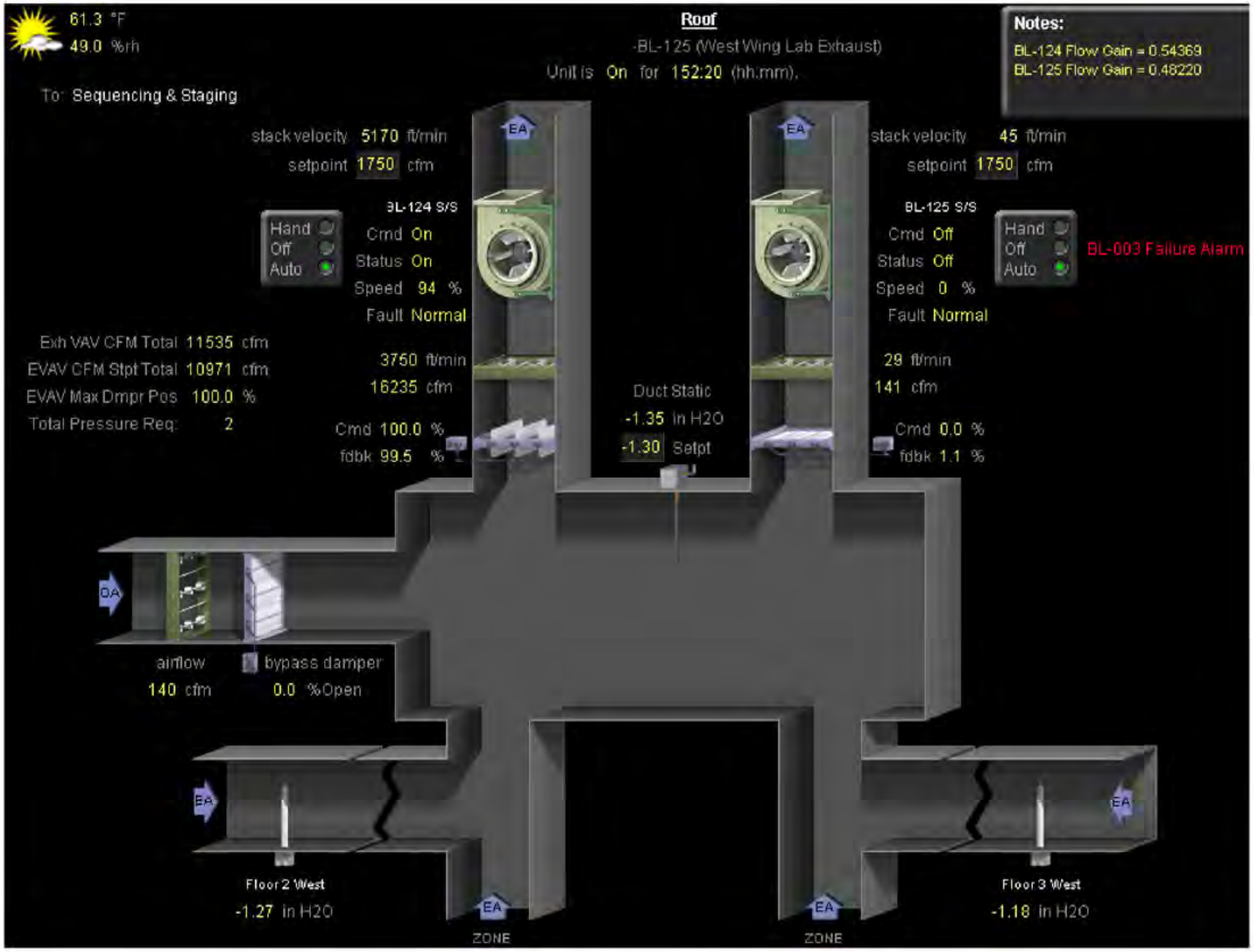



**Figure 60: [redacted]/12 at 3:39PM - plenum pressure restored with one fan at 94%**

**BL-05 [redacted]**

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| SS. Operational Schedule | 1. Enable AHU AC-01 to run. | a. Exhaust fan BL-005 runs. | | |
| | 2. Disable AHU AC-01. | a. Exhaust fan BL-005 stops. | | |
| TT. Fan Status Alarms | 3. Disconnect exhaust fan BL-005 and command BL-005 to run through DDC workstation. | a. Exhaust fan BL-005 does not run.<br>b. Exhaust Fan BL-005 Failure Alarm triggered. | | |
| | 4. Reconnect exhaust fan BL-005 and schedule BL-005 to be off. Locally enable fan to run. | a. Exhaust fan BL-005 runs.<br>b. Exhaust fan BL-005 in Hand Alarm triggered. | | |
| | 5. Set exhaust fan BL-005 status run time to 1 minute and run fan beyond 1 minute. | a. Exhaust fan BL-005 runs.<br>b. Exhaust fan BL-005 Runtime Exceeded Alarm triggered. | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

**BL-09 [redacted]**

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| UU.Operational Schedule | 1. Enable exhaust fan and set zone temperature cooling setpoint to a value that is above current zone temperature. | a. Exhaust fan is enabled to run.<br>b. Exhaust fan does not run. | Check | Y |
| | 2. Set zone temperature cooling setpoint to a value that is below current zone temperature. | a. Exhaust fan is enabled to run.<br>b. Exhaust fan runs until zone temperature is below cooling setpoint.<br>c. Exhaust fan stops after zone temperature is below cooling setpoint. | Exhaust fan runs – do not wait until SP reached. | Y |
| | 3. Disable exhaust fan through DDC workstation. | a. Exhaust is disabled. | | |
| VV.Fan Status Alarms | 4. Disconnect exhaust fan and command exhaust fan to run through DDC workstation. | a. Exhaust fan does not run.<br>b. Exhaust Fan Failure Alarm triggered. | | |
| | 5. Set High Zone Temp Alarm to a value that is lower than current zone temperature. | a. High Zone Temp Alarm is triggered. | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| | | | | |
|---|---|---|---|---|
| | 6. Reconnect exhaust fan and schedule exhaust fan to be off. Locally enable fan to run. | a. Exhaust fan runs.<br>b. Exhaust Fan in Hand Alarm triggered. | | |
| | 7. Set exhaust fan status run time to 1 minute and run fan beyond 1 minute. | a. Exhaust fan runs.<br>b. Exhaust Fan Runtime Exceeded Alarm triggered. | | |

**BL-015 and BL-016 [redacted]**

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| WW. Operational Schedule | 1. Enable AHU AC-03 to run. | a. Exhaust fan BL-015 runs.<br>b. Exhaust fan BL-016 runs. | | |
| | 2. Disable AHU AC-03. | a. Exhaust fan BL-015 stops.<br>b. Exhaust fan BL-016 stops. | | |
| XX. Fan Status Alarms | 3. Disconnect exhaust fan BL-015 and command BL-015 to run through DDC workstation. | a. Exhaust fan BL-015 does not run.<br>b. Exhaust fan BL-015 Failure Alarm triggered. | | |
| | 4. Disconnect exhaust fan BL-016 and command BL-016 to run through DDC workstation. | a. Exhaust fan BL-016 does not run.<br>b. Exhaust fan BL-016 Failure Alarm triggered. | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| | | | | |
|---|---|---|---|---|
| | 5. Reconnect exhaust fan BL-015 and schedule BL-015 to be off. Locally enable fan to run. | a. Exhaust fan BL-015 runs.<br>b. Exhaust fan BL-015 in Hand Alarm triggered. | | |
| | 6. Reconnect exhaust fan BL-016 and schedule BL-016 to be off. Locally enable fan to run. | a. Exhaust fan BL-016 runs.<br>b. Exhaust fan BL-016 in Hand Alarm triggered. | | |
| | 7. Set exhaust fan BL-015 status run time to 1 minute and run fan beyond 1 minute. | a. Exhaust fan BL-015 runs.<br>b. Exhaust fan BL-015 Runtime Exceeded Alarm triggered. | | |
| | 8. Set exhaust fan BL-016 status run time to 1 minute and run fan beyond 1 minute. | a. Exhaust fan BL-016 runs.<br>b. Exhaust fan BL-016 Runtime Exceeded Alarm triggered. | | |

Part 6 BOILER PLANT

[redacted]BR-01 and 02)

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| YY.Boiler Run Conditions | 1. Set the definable number of hot water coils to trigger boiler system enable to 1 and adjust boiler lockout OAT to 80°F. Force at least one zone into heating operation. | a. Lead boiler is enabled and running.<br>b. Lead heating water pump is enabled and running. | | |
| | 2. Force all zones out of heating operation. | a. Lead boiler is enabled, but not running.<br>b. Lead heating water pump is enabled, but not running. | | |
| | 3. Set boiler lockout OAT to a value below current OAT. | a. All boilers are disabled.<br>b. All heating water pumps are disabled. | | |
| | 4. Set freeze protection operation OAT to a value above current OAT. | a. Lead boiler is enabled.<br>b. Lead heating water pump is enabled. | | |
| | 5. Set freeze protection operation OAT to a value below current OAT. | a. All boilers are disabled.<br>b. All heating water pumps are disabled. | | |

| | | | | |
|---|---|---|---|---|
| ZZ. Lead/Lag Operation | 6. Set boiler lockout OAT to a value below current OAT and force a number of zones into heating operation. | a. Lead boiler is enabled and running.<br><br>b. Lead heating water pump is enabled and running. | | |
| | 7. Change date on calendar to the next month and set boiler lockout OAT to a value below current OAT. | a. All boilers are disabled.<br><br>b. All heating water pumps are disabled. | | |
| | 8. Set boiler lockout OAT to a value above current OAT. | a. Lead boiler is enabled and has rotated to a different boiler.<br><br>b. Lead heating water pump is enabled and has rotated to a different boiler. | | |
| AAA. Hot Water Differential Pressure Control | 9. Force several zones into heating mode so that the lead heating water pump VFD exceeds 90%. | a. Lead heating water pump VFD increases pump speed until lag heating water pump is enabled.<br><br>b. Lag heating water pump is enabled and has its VFD match the speed of the lead heating water pump VFD.<br><br>c. Lead and lag heating water pumps operate in parallel to maintain the hot water differential pressure setpoint. | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| | | | | |
|---|---|---|---|---|
| | 10. Reduce the number of zones in heating mode so that the VFD speed of both heating water pumps drops below 60%. | a. Lag heating water pump stages off.<br>b. Lead heating water pump VFD modulates pump speed to maintain the hot water differential pressure setpoint. | | |
| BBB. Hot Water Supply Temperature Reset Function | 11. Set the lower room temperature to a value greater than the current temperature of a selected zone. Set upper room temperature value 10°F higher than the lowest value. Force selected zone into heating operation. Confirm that the upper heating water supply temperature reset value is 160°F and that the lower boundary is 135°F. | a. Lead boiler is enabled and running.<br>b. Lead pump is enabled and running.<br>c. Heating water supply temperature is 160°F. | | |

| | | | | |
|---|---|---|---|---|
| | 12. Set the lower room temperature to a value below the current room temperature. Confirm that zone is still in heating operation. | a. Lead boiler is enabled and running.<br>b. Lead pump is enabled and running.<br>c. Heating water supply temperature is between 160°F and 135°F. | | |
| | 13. Set the upper room temperature to a value below the current room temperature. Set the lower room temperature to a value 10°F below the upper room temperature value. Confirm that zone is still in heating operation. | a. Lead boiler is enabled and running.<br>b. Lead pump is enabled and running.<br>c. Heating water supply temperature is 135°F. | | |
| | 14. Restore all overrides | | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

Part 7 SMOKE TEST

1.14 Preparatory discussions

1.15 [redacted]/12 Capture summary screens (1 West, 1 East) showing fume hood airflows before and during test. See Figure 63 to Figure 65

1.16 At 1PM, verified that exhaust fan VFDs are reconfigured for ride-through and work.

1.17 Then pic 49-53 (after E-power, before smoke test, around 3PM) supply and 54 to 56 exhaust

1.18 Changed West plenum pressure back to 2.5" per TAB report. See 4.5+4.3kW = 8.8 kW instead of previous 5kW at 1.3" with one fan.

**AC-01** [redacted]

| | | | | |
|---|---|---|---|---|
| CCC. AC-01 Smoke test | 1. Open all hoods to wide open (18") sash stop position. Activate smoke detector signal in AC-01 (either by actual smoke bomb, preferred, or by fire control system software override) | a. AC-01 shuts down.<br>b. AC-02 and 03 continue to run.<br>c. AC-01 Roof make-up air damper opens<br>d. General exhaust terminals in rooms served by ALC for AC-01 close fully<br>e. Fume hood face velocity drops to 60 fpm for all hoods in the building.<br>f. General exhaust terminals in rooms served by TSI for AC-01 continue to modulate to maintain room pressure.<br>g. AC-01 supply duct FSD's close<br>h. Exhaust systems respond to lower exhaust volume by ramping down.<br>i. Exterior door to 214B opens per bulletin 71R<br>j. All systems resume stable operation<br>k. Note fume hood alarms where present, clear hood alarms<br>l. All rooms maintain pressurization at setpoint.<br>m. Maintain this mode for 15 min. at least to | [redacted]/2012 at 3:30 PM [redacted] on site – actually trigger smoke alarm w smoke bomb<br><br>40 seconds later, both dampers open on AC-18. There is a 5 minute delay on supply fan iso damper, because initial tests showed high static trip.<br><br>Max. door opening force was 28 lbs Test overall ok, but [redacted] saw one hood in alarm Room 320E unit 1 [redacted] VAV-110<br><br>FSDs 1-5 and 2-7 open, as is 1-6, so all three dampers remained open. | Y |

| | | | | |
|---|---|---|---|---|
| | | ensure results are captured in trends. | | |
| | 2. Close FSDs in supply duct of AC-01 to simulate fire condition, caused either by smoke from AC-01 (which triggers the roof smoke detector in AC-01 in a real fire and then trips the downstream FSD smoke detectors) or local fire | a. Room pressurization of rooms in floor 1 and 2 is maintained | 4:04PM manually close dampers, then re-check door 214B pressures.<br><br>No excessive pressures on 1st floor as a result. Door to outside is 15 lbs on first floor.<br><br>Room 214B pressure is > 35 lbs on exterior door, 28 lbs on corr. door. The exterior door will be re-tested as soon as the door operator installation is completed.<br><br>See Figure 92 and Figure 93. Exact pressure drop is unknown because trends run at 5 minute intervals, but likely that both rooms dropped to about -0.2" vs corridor. On a 3'x'7' door, that means about 22 lbs door force when pushing in the center of the door (panic bar). Add about 8 lbs for door closer, and you get 30 lbs. So any pressure > 0.2" negative will cause exiting issues.<br><br>No issues 2nd floor West. | Y (retest req'd for 214B door) |
| | 3. After stable operation for some time (min. 15 mins) in smoke mode, clear alarms | a. AC-01 resumes operation<br>b. Makeup air damper closes<br>c. Fume hoods return to 100 fpm operation<br>d. Exhaust fans speed up<br>e. All VAV terminals return to normal operation<br>f. All room pressures maintained at setpoint | [redacted]/12 back to normal operation around 4:30PM, see Figure 66 | Y |
| | 4. With AC-01 operating normally, close FSDs in supply duct of AC-01 to simulate local fire condition | a. AC-01 continues to run, ramps down to provide air for just 3rd floor as supply | 12/8 at 10:10 AM Manual stroke of FSDs causes some pressure change but controls react, did not read front | Y |

| | | | | |
|---|---|---|---|---|
| | | pressure rises<br>b. General exhaust terminals in rooms served by ALC for AC-01 close fully on floor 1 and 2<br>c. General exhaust terminals in rooms served by TSI for AC-01 continue to modulate to maintain room pressure<br>d. All chemical fume hood sashes in areas served by AC-01 drop face velocity to 60 fpm.<br>e. Exhaust systems respond to lower exhaust volume by ramping down.<br>f. All systems resume stable operation<br>g. Note fume hood alarms where present, clear hood alarms<br>h. All rooms maintain pressurization at setpoint.<br>i. Maintain this mode for 15 min. at least to ensure results are captured in trends. | end at that point. No fire alarm created, manually closed FSDs with override key at firestat.<br><br>So remaining points at left do not apply (c-i) | |
| | 5. After stable operation for some time (min. 15 mins) in smoke mode, clear alarms | a. AC-01 resumes operation<br>b. Makeup air damper closes<br>c. Exhaust fans speed up<br>d. All VAV terminals return to normal operation<br>e. All room pressures maintained at setpoint | No alarms generated, manually closed FSDs with override key at firestat. | Y |

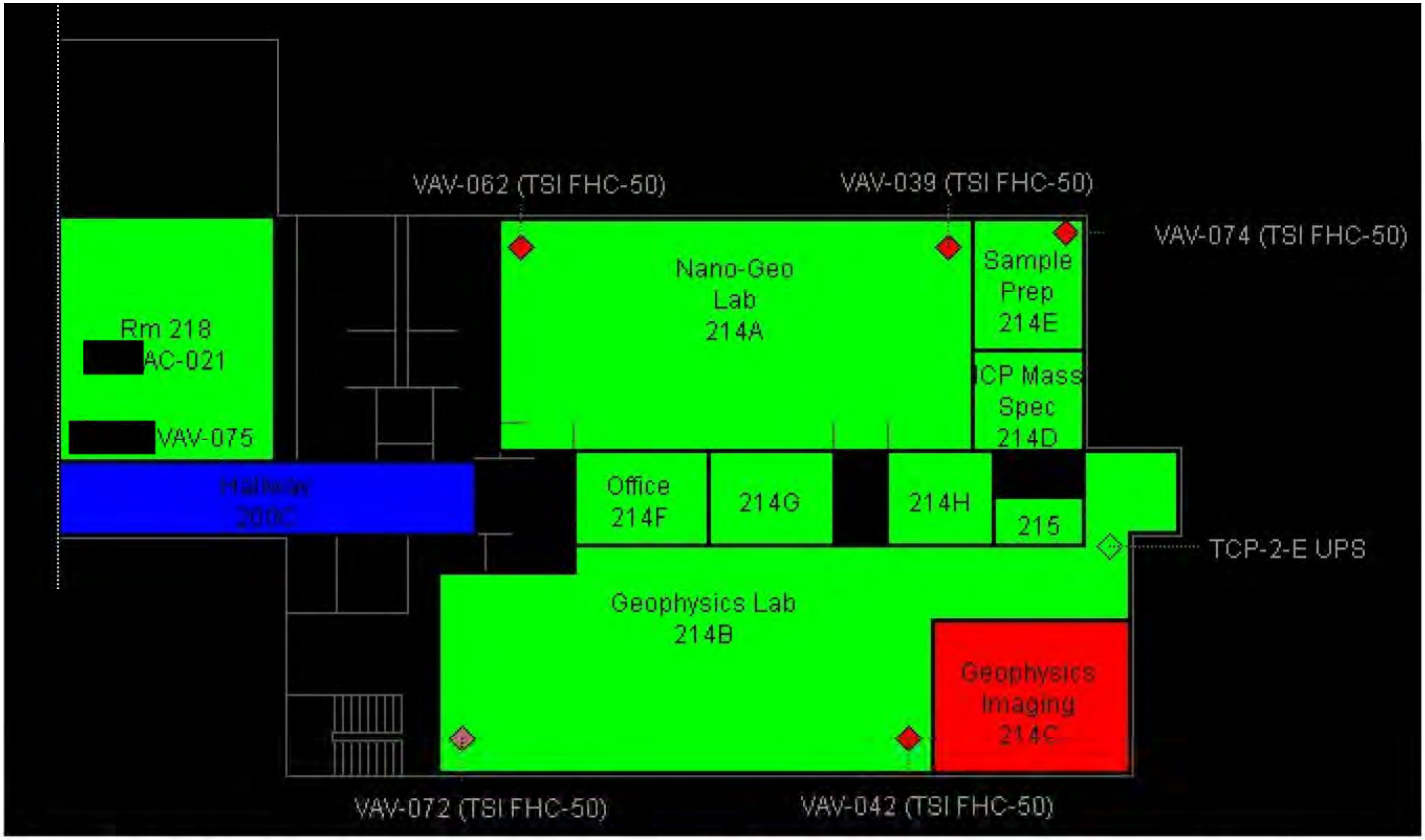



**Figure 61: Second Floor East layout, room 214A and B with combined opening at East end to exterior for pressure relief in smoke mode**

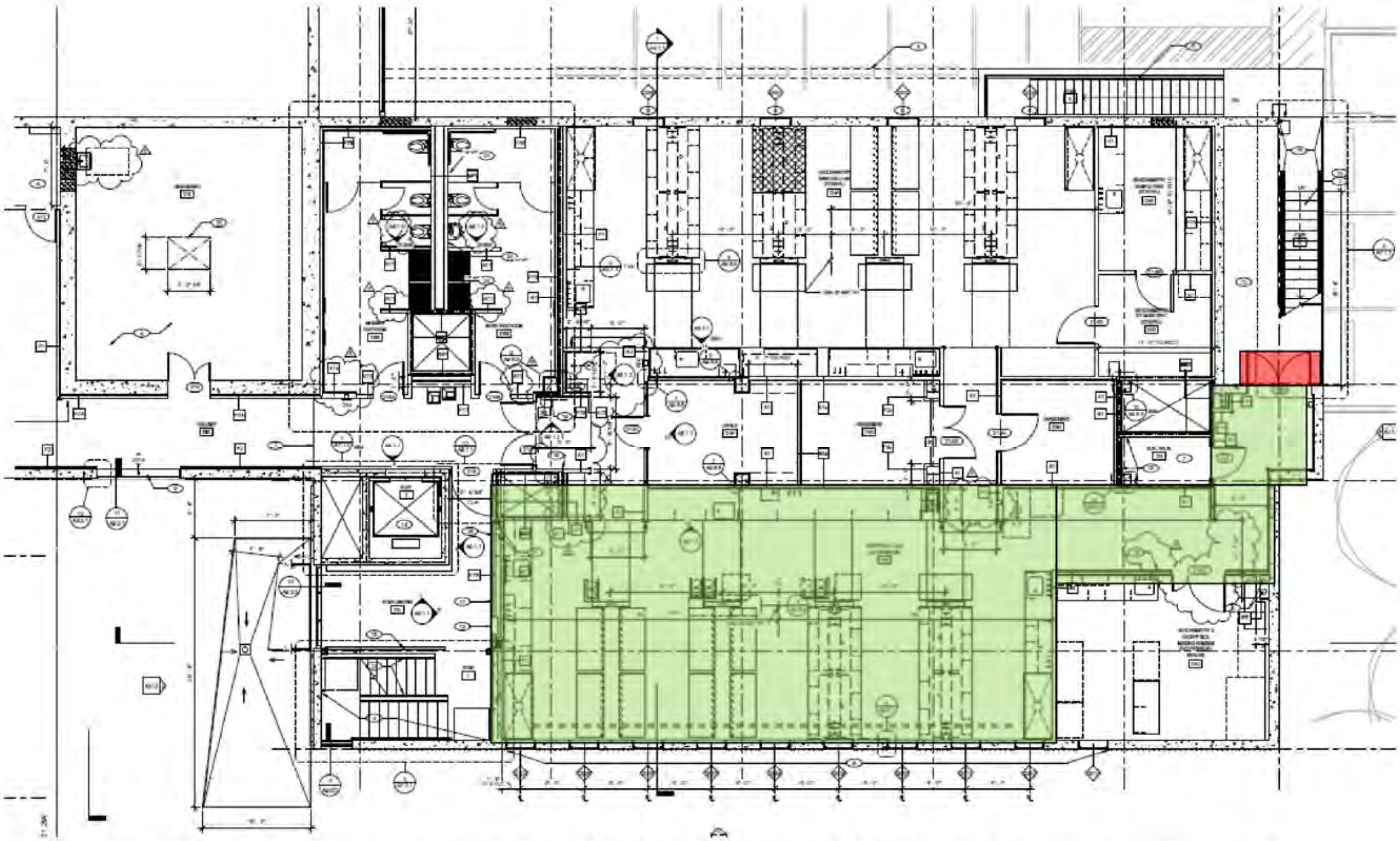


**Figure 62: Second Floor East layout, room 214A and B with combined opening at East end (red) to exterior for pressure relief in smoke mode**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

## 1 LABORATORY HVAC SYSTEM FIRE AND LIFE SAFETY OPERATION

SEQUENCE OF OPERATION:

1. UPON DETECTION OF SMOKE BY ANY DUCT SMOKE DETECTOR, THE FOLLOWING EVENTS SHALL OCCUR:

   A. THE AC UNIT SHALL STOP OPERATING AND ALL FIRE/SMOKE DAMPERS CONNECTED TO THE AC UNIT DUCT DISTRIBUTION SYSTEM SHALL CLOSE. THE AC UNIT SUPPLY AIR SMOKE DAMPER SHALL BE FULLY CLOSED AND THE MAKE-UP AIR SMOKE DAMPER SHALL BE FULLY OPEN.

   B. THE LAB GENERAL EXHAUST FAN SHALL CONTINUE TO OPERATE, MAINTAINING THE PRESET DUCT STATIC PRESSURE.

   C. UNLESS OTHERWISE NOTED, ALL ROOM GENERAL EXHAUST TERMINALS SHALL BE FULLY CLOSED (VIA THE BUILDING DDC SYSTEM).

   D. ALL CHEMICAL FUME HOODS SHALL OPERATE AT 60 FPM FACE VELOCITY (VIA THE FMCS SIGNAL TO THE FUME HOOD FACE VELOCITY CONTROLLER).

   E. AT 2ND FLOOR EAST LAB 214B, THE FIRE ALARM SYSTEM SHALL SEND SIGNAL TO OPEN THE POWER-ACTUATED EXTERIOR DOOR

2. 2. WHEN THE FIRE ALARM IS CLEAR, THE HVAC SYSTEM SHALL RETURN BACK TO NORMAL OPERATION BASED ON THE FOLLOWING PRIORITY:

   A. OPEN ALL SUPPLY DUCT FIRE/SMOKE DAMPERS.

   B. RESTORE ALL SUPPLY TERMINALS TO NORMAL OPERATION.

   C. RESTORE ALL ROOM EXHAUST TERMINALS TO NORMAL OPERATION.

   D. OPEN THE AC UNIT SUPPLY AIR SMOKE DAMPER AND CLOSE THE MAKE-UP AIR SMOKE DAMPER.

   E. START THE AC UNIT. THE AC UNIT SHALL NOT BE FULLY ENERGIZED UNTIL THE SUPPLY AIR DAMPER IS FULLY OPEN AND THE MAKE-UP AIR DAMPER IS FULLY CLOSED, AS SENSED BY THE DAMPER END SWITCHES.

   F. ~~RELEASE THE FUME HOOD~~ FACE VELOCITY OVERRIDE, AND RETURN TO THE NORMAL 100 FPM FACE VELOCITY.

   G. RELEASE THE OVERRIDE TO POWER-ACTUATED EXTERIOR DOOR AT LAB 214B.

3. 3. UPON ACTIVATION OF THE FIRE ALARM SYSTEM BY ANY OTHER MEANS, OTHER THAN THE DUCT SMOKE DETECTOR ACTIVATION, THE HVAC SYSTEM SHALL CONTINUE TO OPERATE IN NORMAL MODE.

## 2 OFFICE HVAC SYSTEM FIRE AND LIFE SAFETY OPERATION.

SEQUENCE OF OPERATION:

1. UPON DETECTION OF SMOKE BY ANY DUCT SMOKE DETECTOR, THE AC UNIT SHALL STOP OPERATING AND ALL FIRE/SMOKE DAMPERS CONNECTED TO AC-3 WILL CLOSE.

2. WHEN FIRE ALARM IS CLEAR, ALL FSD'S SHALL OPEN, AND THE AC UNIT SHALL RESTART AND OPERATE IN NORMAL MODE. RAMP UP AC UNIT SUPPLY AND RETURN FANS SLOWLY TO AVOID SUDDEN INCREASE IN SYSTEM PRESSURE WHILE THE FSD'S ARE STILL OPENING.

3. UPON ACTIVATION OF THE FIRE ALARM SYSTEM BY ANY MEANS, OTHER THAN DUCT SMOKE DETECTOR ACTIVATION, THE HVAC SYSTEM SHALL CONTINUE TO OPERATE IN NORMAL MODE.

From M5.4, see also bulletin 71 released 11-14-2012

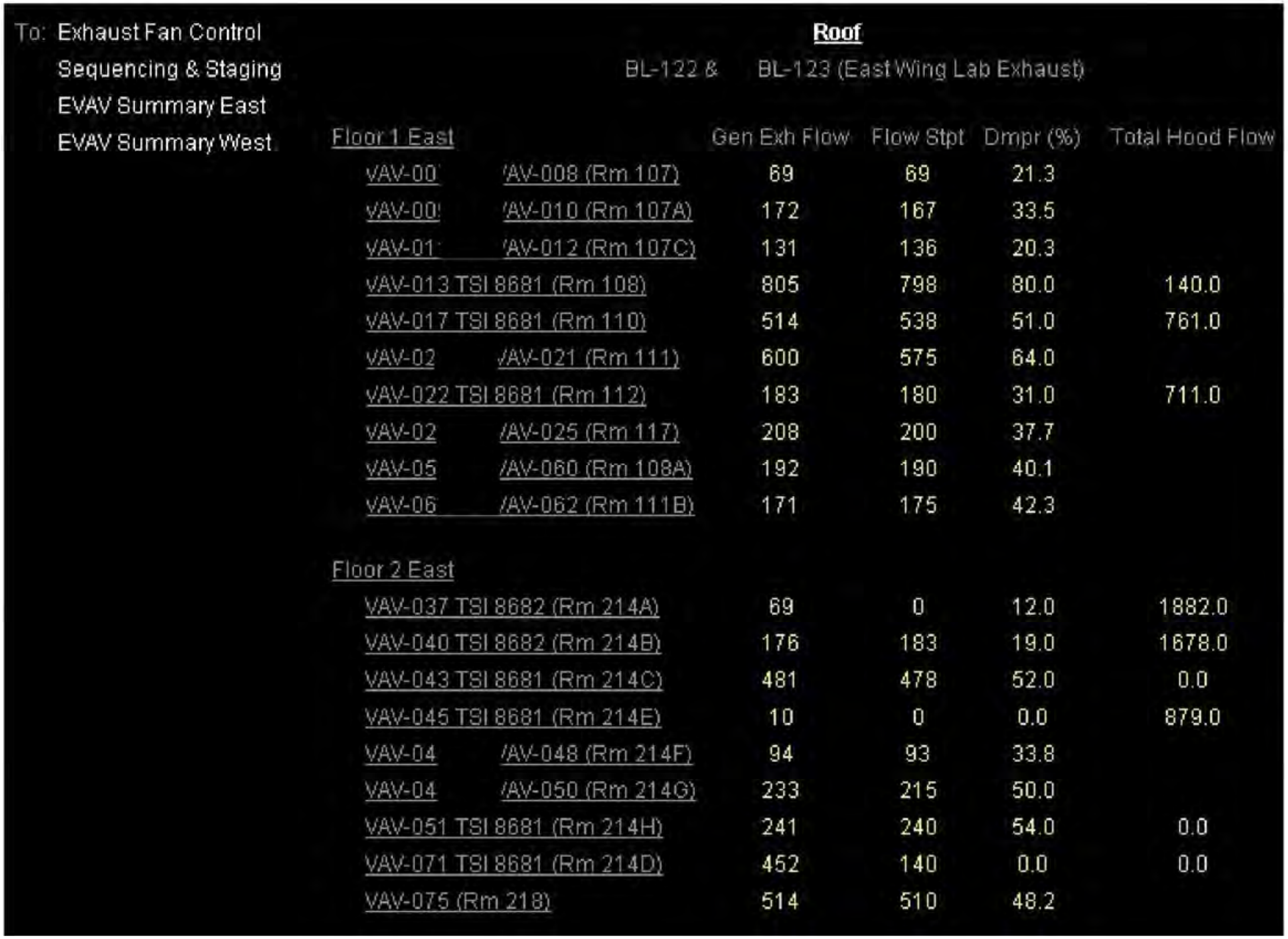
TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

**From:** [redacted]
**Sent:** [redacted]
**To:** [redacted]
**Cc:** [redacted]
**Subject:** [redacted] HVAC systems operations in E-power and Fire alarm system

B. Fire alarm mode ( Sequence is the same in normal or emergency power mode) :
1. When the Office AC unit ( AC-20) duct smoke detector or any Office AC unit system FSD Duct smoke detectors is on alarm, the AC unit and all FSD in the Office system shall close. The AC unit shall restart automatically when the fire alarm mode is clear.
2. When the Lab AC unit ( AC-18 and 19) duct smoke detector or any FSD duct smoke detector is on alarm, the following should occur:
    a. AC unit shall stop
    b. The main AC unit isolation damper shall close and the by-pass make up air isolation damper shall open
    c. The Lab Exhaust fan shall continue to run automatically
    d. The supply and general exhaust VAV terminals shall close
    e. The fume hood face velocity shall go to 60 feet per minute operation
    f. In the 2nd floor east lab, the Powered exterior door shall open

3. When the fire alarm is cleared:
    a. The supply duct FSD shall open
    b. The supply fan isolation damper shall open
    c. The make up by pass damper shall close
    d. The 2nd floor power door opener shall be released, i.e. door closed. I am not sure whether this will occur automatically or it has to be manually reset
    e. All VAV terminals shall go to Auto operations
    f. The fume hood face velocity control shall go to 100 feet per minute operation

4. On any other fire alarm condition, other that the Duct smoke detectors, the HVAC system shall run in normal mode



To: Exhaust Fan Control
Sequencing & Staging
EVAV Summary East
EVAV Summary West

Roof
BL-122 & BL-123 (East Wing Lab Exhaust)

| Floor 1 East | Gen Exh Flow | Flow Stpt | Dmpr (%) | Total Hood Flow |
|---|---|---|---|---|
| VAV-00' 'AV-008 (Rm 107) | 69 | 69 | 21.3 | |
| VAV-00' 'AV-010 (Rm 107A) | 172 | 167 | 33.5 | |
| VAV-01' 'AV-012 (Rm 107C) | 131 | 136 | 20.3 | |
| VAV-013 TSI 8681 (Rm 108) | 805 | 798 | 80.0 | 140.0 |
| VAV-017 TSI 8681 (Rm 110) | 514 | 538 | 51.0 | 761.0 |
| VAV-02 /AV-021 (Rm 111) | 600 | 575 | 64.0 | |
| VAV-022 TSI 8681 (Rm 112) | 183 | 180 | 31.0 | 711.0 |
| VAV-02 /AV-025 (Rm 117) | 208 | 200 | 37.7 | |
| VAV-05 /AV-060 (Rm 108A) | 192 | 190 | 40.1 | |
| VAV-06 /AV-062 (Rm 111B) | 171 | 175 | 42.3 | |
| **Floor 2 East** | | | | |
| VAV-037 TSI 8682 (Rm 214A) | 69 | 0 | 12.0 | 1882.0 |
| VAV-040 TSI 8682 (Rm 214B) | 176 | 183 | 19.0 | 1678.0 |
| VAV-043 TSI 8681 (Rm 214C) | 481 | 478 | 52.0 | 0.0 |
| VAV-045 TSI 8681 (Rm 214E) | 10 | 0 | 0.0 | 879.0 |
| VAV-04 /AV-048 (Rm 214F) | 94 | 93 | 33.8 | |
| VAV-04 /AV-050 (Rm 214G) | 233 | 215 | 50.0 | |
| VAV-051 TSI 8681 (Rm 214H) | 241 | 240 | 54.0 | 0.0 |
| VAV-071 TSI 8681 (Rm 214D) | 452 | 140 | 0.0 | 0.0 |
| VAV-075 (Rm 218) | 514 | 510 | 48.2 | |

**Figure 63: Exhaust flows at fully open hoods (except room 108, hood sash keeps dropping by itself). Typical exhaust flow ~750-850 cfm per hood. Larger numbers are the result of multiple hoods per room.**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| | | | | |
|---|---|---|---|---|
| Floor 3 East | | | | |
| VAV-103 TSI 8682 (Rm 320B) | 696 | 677 | 7.0 | 1794.0 |
| VAV-106 TSI 8681 (Rm 320C) | 171 | 159 | 44.0 | 0.0 |
| VAV-107 TSI 8681 (Rm 320D) | 41 | 75 | 20.0 | 813.0 |
| VAV-108 TSI 8681 (Rm 320E) | 966 | 977 | 40.0 | 944.0 |
| VAV-111 TSI 8681 (Rm 320K) | 14 | 0 | 0.0 | 854.0 |
| VAV-112, 'AV-113 (Rm 320F) | 96 | 99 | 30.8 | |
| VAV-114, 'AV-115 (Rm 320G) | 40 | 40 | 19.5 | |
| VAV-116 TSI 8681 (Rm 320H) | 320 | 0 | 52.0 | 0.0 |
| Roof | Total Exh Flow | Total Setpt | Max Dmpr | |
| BL-122 & BL-123 | 18251 | 17455 | 80.0 | |

**Figure 64: Exhaust flows at fully open hoods**

**Roof**

BL-124 & BL-125 (West Wing Lab Exhaust)

| Floor 2 West | Gen Exh Flow | Flow Stpt | Dmpr (%) | Total Hood Flow |
|---|---|---|---|---|
| VAV-054 TSI 8681 (Rm 222) | 259 | 237 | 34.0 | 782.0 |
| VAV-056 TSI 8681 (Rm 223) | 591 | 602 | 53.0 | 474.0 |
| VAV-063 TSI 8681 (Rm 227) | 54 | 80 | 14.0 | 929.0 |
| VAV-06 AV-069 TSI 8682 (Rm 229) | 26 | 10 | 0.0 | 2851.0 |
| VAV-07 /AV-077 (Rm 223) | 149 | 154 | 37.2 | |
| VAV-07 /AV-079 (Rm 234) | 368 | 367 | 50.7 | |
| **Floor 3 West** | | | | |
| VAV-087 AV-088 (Rm 301) | 233 | 228 | 37.7 | |
| VAV-089 AV-090 (Rm 303) | 266 | 281 | 42.8 | |
| VAV-122, 123, 124 (Rm 327A) | 1191 | 1215 | 43.5 | |
| VAV-126 TSI 8682 (Rm 327B) | 226 | 214 | 25.0 | 1751.0 |
| VAV-136 AV-137 (Rm 327G) | 124 | 122 | 33.6 | |
| VAV-140 TSI 8681 (Rm 327J) | 462 | 453 | 47.0 | 786.0 |

| Roof | Total Exh Flow | Total Setpt | Max Dmpr |
|---|---|---|---|
| BL-122 & BL-123 | 11940 | 11789 | 53.0 |

**Figure 65: Exhaust flows at fully open hoods. Note room 223 is a smaller hood and draws only 475 cfm when open.**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

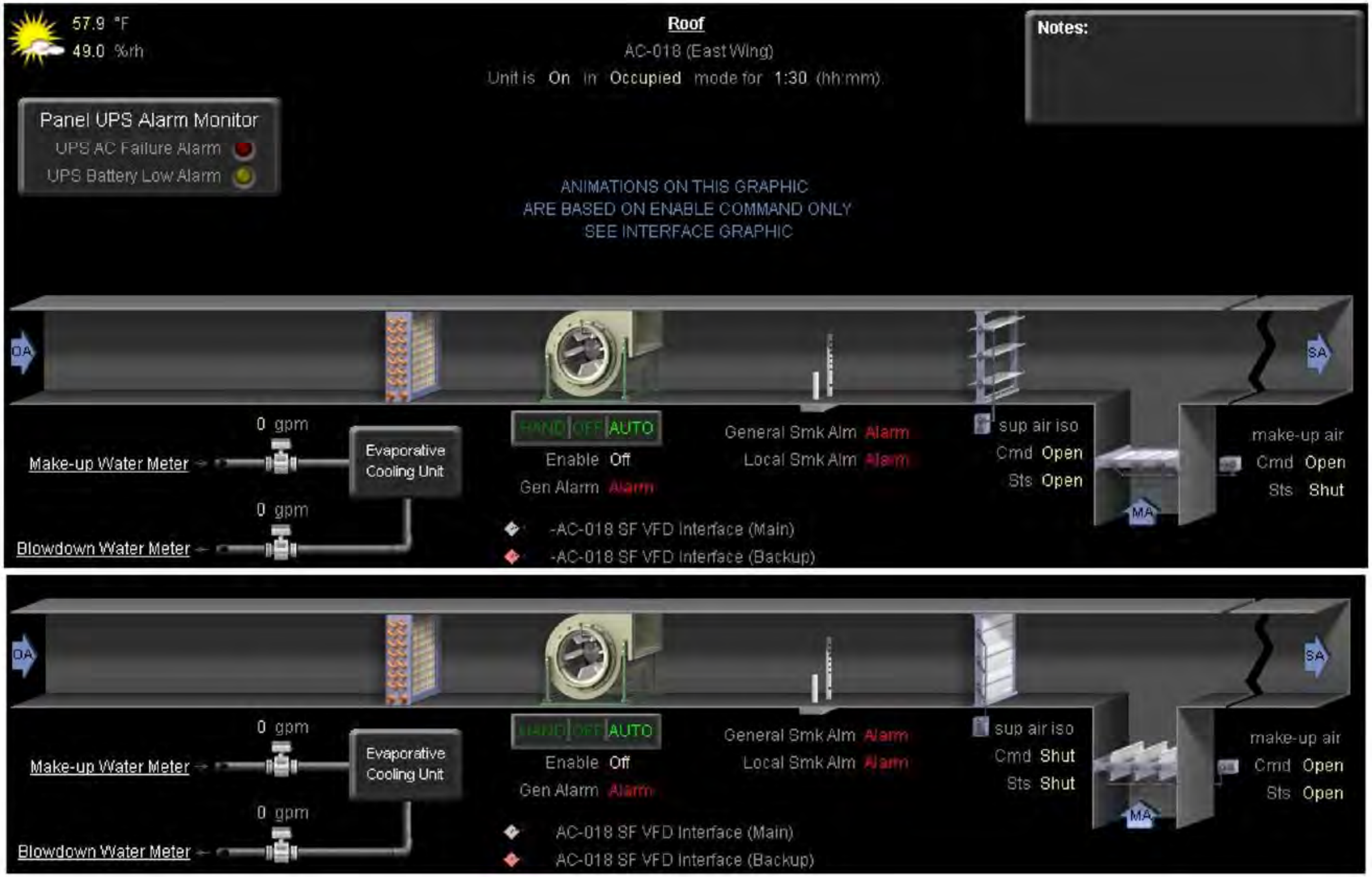



**Figure 66: AC-18 before smoke mode test ([redacted]12 at 3:31PM, top) and during smoke mode test (3:38PM, bottom)**

**AC-02** [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| DDD. AC-02 Smoke test | 1. Open all hoods to wide open (18") sash stop position. Activate smoke detector signal in AC-02 (either by actual smoke bomb, preferred, or by fire control system software override) | a. AC-02 shuts down.<br>b. AC-01 and 03 continue to run.<br>c. AC-02 Roof make-up air damper opens<br>d. General exhaust terminals in rooms served by ALC for AC-02 close fully<br>e. General exhaust terminals in rooms served by TSI for AC-02 continue to modulate to maintain room pressure.<br>f. Fume hoods go to 60 fpm throughout the building.<br>g. AC-01 supply duct FSD's are open to allow airflow to floor 1 and 2<br>h. Exhaust systems respond to lower exhaust volume by ramping down.<br>i. All systems resume stable operation<br>j. Note fume hood alarms where present, clear hood alarms<br>k. All rooms maintain pressurization at setpoint.<br>l. Maintain this mode for 15 min. at least to ensure results are captured in trends. | 3:45 PM smoke AC-19 (AC-18 still in smoke mode)<br><br>Room 108 making a lot of noise on sash? Trying to close fume hood , so this hood sash not disabled yet.<br><br>3:53 smoke AC-19<br>Room 222 shows invalid comm<br>And 327B also shows invalid comm<br>No excessive door pull forces<br><br>Note AC-19 still shows 17kcfm airflow despite isolation damper being closed (on display, [redacted] checking physically at 4:30PM)<br>4:35 not clear why only one fan is running on East plenum. Answer: Staged down because, during smoke mode, fans ran < 40% speed, and then staged down. Not staging back up because delay 20 minutes. Change delay to 30 seconds, change to 2 fans at all times. | Y |
| | 2. After stable operation for some time (min. 15 mins) in smoke mode, clear alarms | a. AC-02 resumes operation<br>b. Makeup air damper closes<br>c. Fume hood face velocity rises to 100 fpm.<br>d. Exhaust fans speed up<br>e. All VAV terminals return to normal operation<br>f. All room pressures maintained at setpoint | 4:40 PM Why do AC18 and AC19 not ramp up to meet duct static SP after smoke alarm is cleared? Answer: units remain at 50% fan speed for 5 minutes before going into fully automatic operation. Not clear why this occurs, but no impediment to operations. See Figure 68. | Y |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

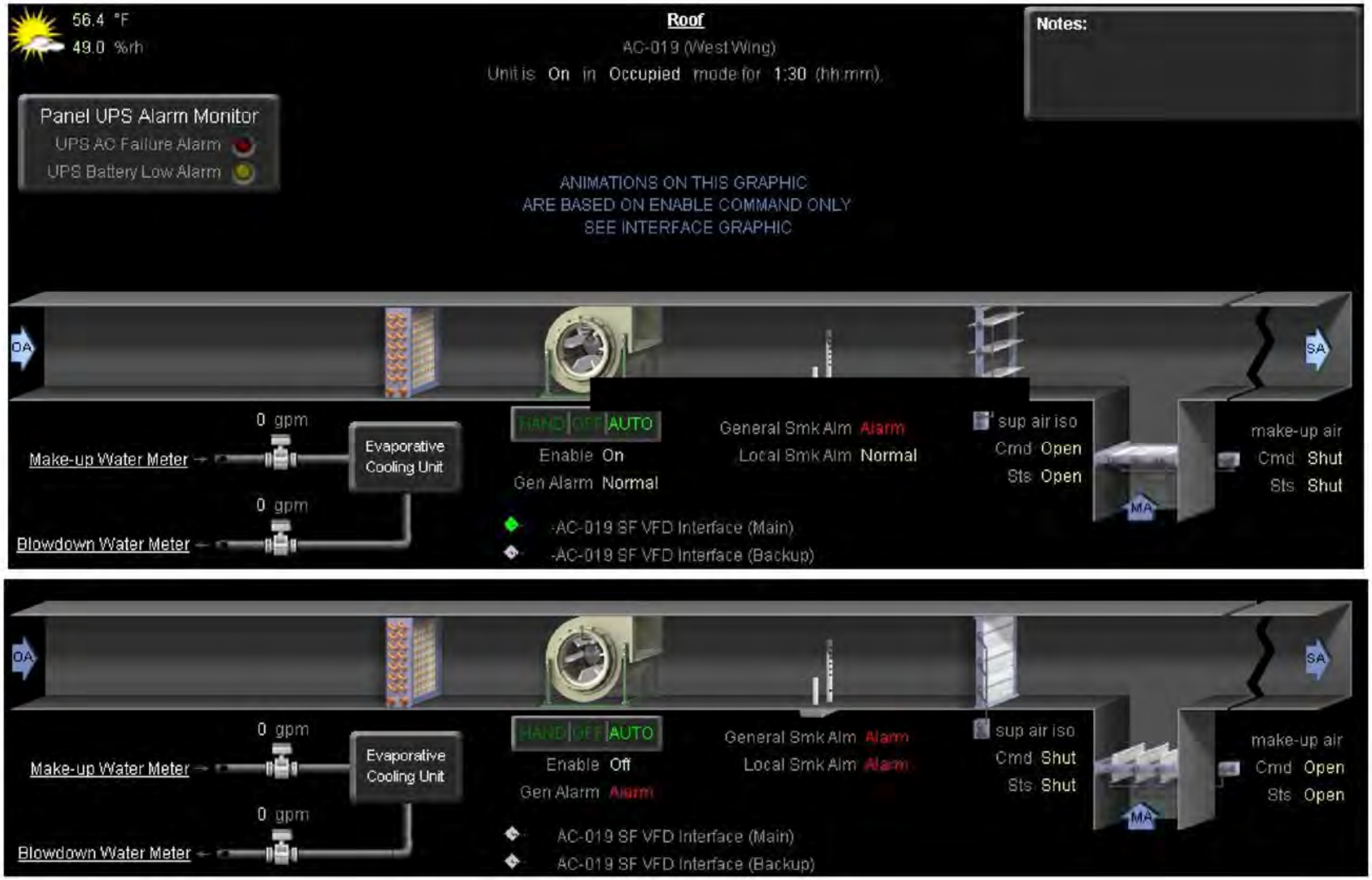



**Figure 67: AC-18 before smoke mode test ([redacted]12 at 3:51PM, top) and during smoke mode test (3:54PM, bottom)**


**Figure 68: AC-19 ramping back up after smoke alarm is cleared (same operation on AC-18)**

**AC-03 [redacted]**

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| EEE. AC-03 Smoke test | 3. Activate smoke detector signal in AC-03 (either by actual smoke bomb, preferred, or by fire control system software override) | a. AC-03 shuts down.<br>b. AC-01 and 02 continue to run.<br>c. Supply and exhaust terminals in rooms served by AC-03 close fully<br>d. AC-03 supply and return FSD's close<br>e. Maintain this mode for 15 min. at least to ensure results are captured in trends. | | |
| | 4. After stable operation for some time (min. 15 mins) in smoke mode, clear alarms | a. AC-03 resumes operation<br>b. Exhaust fans speed up<br>c. FSD's open<br>d. All VAV terminals return to normal operation | | |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

EMERGENCY POWER MODE:

THE SUPPLY AIR TERMINALS SHALL OPERATE AT HALF MODE. THE FUME HOOD EXHAUST TERMINALS SHALL OPERATE IN NORMAL MODE TO MAINTAIN T
VELOCITY SETPOINT. THE GENERAL EXHAUST AIR TERMINALS SHALL OPERATE NORMAL TO MAINTAIN THE SPACE STATIC PRESSURE AT THE SETPOINT.

ROOM 108A: THE GENERAL EXHAUST AND SUPPLY AIR TERMINALS SHALL OPERATE AT NORMAL MODE. 71
ROOM 110: THE GENERAL EXHAUST AIR TERMINAL SHALL SHUT DOWN, THE SUPPLY AIR TERMINAL SHALL MODULATE TO MAINTAIN ROOM PRESSURIZATI
ROOM 111: THE SUPPLY AND GENERAL EXHAUST AIR TERMINALS SHALL MODULATE DOWN TO THEIR MINIMUM AIRFLOW CONDITION.
ROOM 111B: THE SUPPLY AND GENERAL EXHAUST AIR TERMINALS SHALL SHUTDOWN.

From Bulletin 71

[redacted]

All:

Seems like there is a lot of confusion on the HVAC system operations during Emergency power and fire alarm condition.

A. Emergency power mode:

1. Office HVAC system AC-20 is not on emergency power. So on loss of power, the AC unit should stop
2. Half of the lab AC units supply fans ( AC-18 & 19) are connected to the emergency power, and all lab exhaust fans ( BL-122, 123, 124, & 125) are on emergency power.
    a. In a power failure, only half of the supply fan is running
    b. In a power failure, only one of the lab exhaust fans should be running ( it should be the lead fan), if the lead fan fail to run, then the FMCS should start the lag exhaust fan. According to the test results last Saturday, the emergency generator started 15 seconds after loss of power. If this is the case, the lead fan should start after 15 seconds of the power loss. The associated lead damper shall open first before operation of the lead fan. If within 15 seconds the lead fan fail to operate, then the lag fan should start. The associated lag damper shall open first before operation of the lag fan. If this condition occurred, the FMCS should immediately close the failed fan isolation damper and start the lag fan. If the lag fan fail to start after 15 seconds, the FMCS shall try to restart the lead fan again, and so forth. Do this up to 3 cycles, if both fans still fail to start, then send the alarm and latch the fan so that it require to manually restart the fan.
3. Other selected small AC units are also connected to the emergency power, Please refer to the M 0 series drawing schedules. The equipment are AC-22,23,24, & 25.
4. The FMCS and LMCS are connected to the emergency power, so in power failure that system should still be operational. According to control diagram 9/M5.2 the FMCS should be monitoring the ATS in order for the FMCS to know if the building is in normal or emergency power. They need this so they will provide the proper sequence.
    a. In loss of power, the Lab Supply and Lab general Exhaust terminal should be half mode, except for room 110 where the general exhaust VAV shall shut down, room 111 where the supply and general exhaust VAV terminals shall go to the minimum setting, and room 111B where the supply and general exhaust VAV terminals shall shut down . The fume hood face velocity control should be in full mode controlling the fume hood face velocity at 100 FPM. The lab room pressure control should control the lab Supply and General exhaust VAV terminals to maintain the room static pressure set point
    b. In loss of power in a non-fume hood lab, the supply and general exhaust VAV terminals should go to half mode and the CFM differential tracking should still work.
5. The FSD in the supply duct serving the lab should be connected to the emergency power. We found about 3 FSD in this system that are not connected to the E-power. We are in process of issuing a bulletin to correct this condition . Please note that this correction should not interfere with the HVAC operation testing in emergency power mode. It may affect the room pressure , but not the operations of the supply and exhaust fan operations.
6. The heating hot water boilers and heating hot water pumps are also connected to the emergency power system. This system should have the lowest priority in the equipment start sequence

Part 8 EMERGENCY POWER TEST

Failed test – [redacted], 2012

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| 1. | 2. Activate emergency power system by using "pull the plug" test – disable main utility power. Emergency power feeds from [redacted] are .enabled. | 3. Transfer switch TSW-2[redacted]changes position<br>4. Alarm generated in control system and ATS position visible in control system.<br>5. Main equipment is temporarily disabled, then re-enabled after short power dip (record outage duration with power testing equipment for Div 26) and re-enabled in 15-second intervals as follows (see sheet 50 of 57 in [redacted] submittal Rev 4):<br>BL-03 (124) and 04 (125) (one fan only)<br>BL-01 (122) and 02 (123) (one fan only)<br>AC-01(18) and 02 (19) 50% design airflow, 50% cooling<br>Other exhaust fans BL- 05 (126), 07 (128), 08 (129), 09 (130), 15 (136) and 16 (137)<br>HW system<br>AC-22, 23, 24, 25<br>6. All downstream terminal units served by AC-01 and 02 limit their primary airflow to ½ of design. (verify with status screen or trends) with the exception of terminals 108A (gen exh wide open, supply tracks pressure), 111 (min.airflow) and 111B (shut).<br>7. Exhaust terminals continue to modulate airflow to maintain their respective CFM | 11/17 ~8am<br>Prior to test, fan speeds as follows:<br>[redacted]BL-125 39hz<br>BL-124 39 hz<br>BL-123 47 hz<br>BL-122 54 hz<br>No remote access to ALC<br>Power pulled at ~9:00 am<br>Power restored in 15.3 seconds. 3 of 4 drives show a speed signal, BL-124 had a 0 speed signal. After ~ 45 seconds all drives showed 0 speed signal.<br>Could not login to the server remotely despite internet connection on [redacted]<br>[redacted]BL-125 51hz after restart others not listed.<br>Roof inspection:<br><br>Unable to check zones because no remote access to server.<br>At the EMCS terminal in boiler room none of the exhaust fans reported a fault. The inlet dampers were closed.<br>One of the emergency panels didn't get energized.<br>At around noon the panel serving the telecom room and control server was locked out to do emergency re-circuiting. This disabled the remote | |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | | differential setpoints. (page 38 of 57 in [redacted] submittal Rev 4)<br>8. AC-01 and 02 roof make-up air dampers are closed.<br>9. Fume hood face velocity drops to 60 fpm where hoods are powered<br>10. AC-01 supply duct FSD's are open to allow airflow to floor 1 and 2<br>11. All systems resume stable operation<br>12. Note fume hood alarms where present, clear hood alarms<br>13. Building pressurization remains at setpoint for all areas requiring pressurization | access to the front end. [redacted] was unable to log in to find the problem. ~ 12:30pm left the site as there was no more to do pending ALC's analysis of what failed.<br>See hood power connection spreadsheet for confirmation on E-power for controls. Most e power panels were in LOTO for electrical re-circuiting | |
| | 14. After stable operation for some time (min. 30 mins) in E-power mode, de-activate emergency power system by re-enabling main utility power. Emergency power feeds from [redacted] are disabled. | a. Transfer switch changes position again<br>b. E-power alarm is cleared in control system. ATS position monitored.<br>c. Main equipment is temporarily disabled (part of a second, record outage duration with power testing equipment for Div 26) then comes on line again without staggering<br>d. All VAV terminals return to normal operation<br>e. Hoods with power connected return to 100 fpm operation<br>f. Exhaust fan clusters return to normal (dual fan) operation<br>g. Building pressurization remains at setpoint for all areas requiring pressurization | We did not do this as a test on 11/17 Neither [redacted] nor [redacted] on site.<br>. | N |

Re-test [redacted], 2012

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| 2. Emergency Power Operation | 1. Activate emergency power system by using "pull the plug" test – disable main utility power. Emergency power feeds from [redacted] are .enabled. | 1. Transfer switch TSW-2[redacted] changes position<br>2. Alarm generated in control system and ATS position visible in control system.<br>3. Main equipment is temporarily disabled, then re-enabled after short power dip (record outage duration with power testing equipment for Div 26) and re-enabled in 15-second intervals as follows (see sheet 50 of 57 in [redacted] submittal Rev 4):<br>BL-03 (124) and 04 (125) (one fan only)<br>BL-01 (122) and 02 (123) (one fan only)<br>AC-01(18) and 02 (19) 50% design airflow, 50% cooling<br>Other exhaust fans BL- 05 (126), 07 (128), 08 (129), 09 (130), 15 (136) and 16 (137)<br>HW system<br>AC-22, 23, 24, 25 | [redacted]12 at 1:45 PM<br>Verified Ex fans come back on, Door pulls in certain areas > 30 lbs for awhile. On 3rd floor for about 10 seconds, saw something like 70-100 lbs – why higher on 3rd floor than 2nd floor? If anything, should have been higher at 2nd floor – room pressure trends do not indicate values for the third floor that would lead to such door forces, see Figure 90 to Figure 94.<br><br>West hoods back at 100 fpm<br>But Low flow alarms on 11 hoods<br>VAV-015 / Room 108<br>VAV-019 / Room 110<br>VAV-039 / Room 214A<br>VAV-042 / Room 214B<br>VAV-062 / Room 214A<br>VAV-072 / Room 214B<br>VAV-074 / Room 214E<br>VAV-083 / Room 320D<br>VAV-104 / Room 320B<br>VAV-105 / Room 320B<br>FET-320K / Room 320K<br>See Table 1 and Figure 80, Figure 81. | N<br><br>N |
| | | 4. All downstream terminal units served by AC-01 and 02 limit their primary airflow to ½ of design. (verify with status screen or trends) with the exception of terminals 108A (gen exh wide open, supply tracks | Did not see this, looks like std supply volumes. Probably will need to change programming on these to reduce hood alarms | |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | | pressure), 111 (min.airflow) and 111B (shut).<br>5. Exhaust terminals continue to modulate airflow to maintain their respective CFM differential setpoints. (page 38 of 57 in [redacted] submittal Rev 4)<br>6. AC-01 and 02 roof make-up/bypas air dampers remain closed.<br>7. Fume hood face velocity stays at 100 fpm<br>8. AC-01 supply duct FSD's are open to allow airflow to floor 1 and 2<br>9. All systems resume stable operation<br>10. Note fume hood alarms where present, clear hood alarms<br>11. Building pressurization remains at setpoint for all areas requiring pressurization | Yes<br>Yes<br>Yes, drops to low values on East side due to lack of plenum pressure, but west side remains mostly at 100 fpm.<br>Yes<br>Not clearable – one fan running on East side means persistent alarms. See Table 1 at end of this report.<br>No, door pull testing shows that > 30 lbs occurred during test, do not know why – guess is that exhaust terminals went wide open, and when exhaust fans come back, excess air volumes occur before terminals re-balance to setpoints<br>Need explanation from [redacted] on why this occurred. | Y |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 2.After stable operation for some time (min. 30 mins) in E-power mode, de-activate emergency power system by re-enabling main utility power. Emergency power feeds from [redacted] are disabled. | a. Transfer switch changes position again<br>b. E-power alarm is cleared in control system. ATS position monitored.<br>c. Main equipment is temporarily disabled (part of a second, record outage duration with power testing equipment for Div 26) then comes on line again without staggering<br>d. All VAV terminals return to normal operation<br>e. Hoods with power connected return to 100 fpm operation<br>f. Exhaust fan clusters return to normal (dual fan) operation<br>g. Building pressurization remains at setpoint for all areas requiring pressurization | [redacted]/2012 @ 3PM : back on utility power. Note switch back occurs without power down – ATS switches fast enough that neither lights nor equipment show any outage. | Y |

| Floor 2 West | Gen Exh Flow | Flow Stpt | Dmpr (%) | Total Hood Flow |
|---|---|---|---|---|
| VAV-054 TSI 8681 (Rm 222) | 148 | 218 | 24.0 | 836.0 |
| VAV-056 TSI 8681 (Rm 223) | 625 | 612 | 45.0 | 477.0 |
| VAV-063 TSI 8681 (Rm 227) | 65 | 17 | 12.0 | 1007.0 |
| VAV-065 -VAV-069 TSI 8682 (Rm 229) | 36 | 10 | 0.0 | 2819.0 |
| VAV-076 -VAV-077 (Rm 223) | 176 | 175 | 32.1 | |
| VAV-078 -VAV-079 (Rm 234) | 366 | 368 | 42.6 | |
| **Floor 3 Wes** | | | | |
| VAV-087 -VAV-088 (Rm 301) | 229 | 226 | 31.3 | |
| VAV-089, -VAV-090 (Rm 303) | 291 | 290 | 34.6 | |
| VAV-122, 123, 124 (Rm 327A) | 1276 | 1215 | 36.7 | |
| VAV-126 TSI 8682 (Rm 327B) | 337 | 362 | 25.0 | 1769.0 |
| VAV-136 /AV-137 (Rm 327G) | 122 | 122 | 27.0 | |
| VAV-140 TSI 8681 (Rm 327J) | 495 | 431 | 40.0 | 796.0 |
| **Roof** | **Total Exh Flow** | **Total Setpt** | **Max Dmpr** | |
| BL-122 & BL-123 | 11984 | 12076 | 45.0 | |

**Figure 69: West side hood airflows before E-power test**

**Roof**

BL-122 & BL-123 (East Wing Lab Exhaust)

| Floor 1 East | Gen Exh Flow | Flow Stpt | Dmpr (%) | Total Hood Flow |
|---|---|---|---|---|
| VAV-007, VAV-008 (Rm 107) | 67 | 70 | 21.3 | |
| VAV-009, VAV-010 (Rm 107A) | 172 | 167 | 33.5 | |
| VAV-011, VAV-012 (Rm 107C) | 138 | 135 | 22.0 | |
| VAV-013 TSI 8681 (Rm 108) | 796 | 794 | 80.0 | 137.0 |
| VAV-017 TSI 8681 (Rm 110) | 524 | 540 | 52.0 | 751.0 |
| VAV-020, VAV-021 (Rm 111) | 590 | 575 | 64.0 | |
| VAV-022 TSI 8681 (Rm 112) | 175 | 200 | 30.0 | 698.0 |
| VAV-024, VAV-025 (Rm 117) | 205 | 200 | 37.7 | |
| VAV-059, VAV-060 (Rm 108A) | 188 | 190 | 41.6 | |
| VAV-061, VAV-062 (Rm 111B) | 180 | 173 | 41.1 | |
| **Floor 2 East** | | | | |
| VAV-037 TSI 8682 (Rm 214A) | 69 | 0 | 12.0 | 1882.0 |
| VAV-040 TSI 8682 (Rm 214B) | 176 | 183 | 19.0 | 1678.0 |
| VAV-043 TSI 8681 (Rm 214C) | 481 | 478 | 52.0 | 0.0 |
| VAV-045 TSI 8681 (Rm 214E) | 10 | 0 | 0.0 | 879.0 |
| VAV-047, -VAV-048 (Rm 214F) | 92 | 92 | 33.8 | |
| VAV-049, -VAV-050 (Rm 214G) | 210 | 215 | 49.6 | |
| VAV-051 TSI 8681 (Rm 214H) | 241 | 240 | 54.0 | 0.0 |
| VAV-071 TSI 8681 (Rm 214D) | 452 | 139 | 0.0 | 0.0 |
| VAV-075 (Rm 218) | 515 | 510 | 49.7 | |
| **Floor 3 East** | | | | |
| VAV-103 TSI 8682 (Rm 320B) | 696 | 677 | 7.0 | 1794.0 |
| VAV-106 TSI 8681 (Rm 320C) | 171 | 159 | 44.0 | 0.0 |
| VAV-107 TSI 8681 (Rm 320D) | 41 | 75 | 20.0 | 813.0 |
| VAV-108 TSI 8681 (Rm 320E) | 966 | 977 | 40.0 | 944.0 |
| VAV-111 TSI 8681 (Rm 320K) | 14 | 0 | 0.0 | 854.0 |
| VAV-112, -VAV-113 (Rm 320F) | 96 | 99 | 30.8 | |
| VAV-114, -VAV-115 (Rm 320G) | 40 | 40 | 19.5 | |
| VAV-116 TSI 8681 (Rm 320H) | 320 | 0 | 52.0 | 0.0 |

| Roof | Total Exh Flow | Total Setpt | Max Dmpr |
|---|---|---|---|
| BL-122 & BL-123 | 18251 | 17455 | 80.0 |

**Figure 70: East side hood airflows before E-power test**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

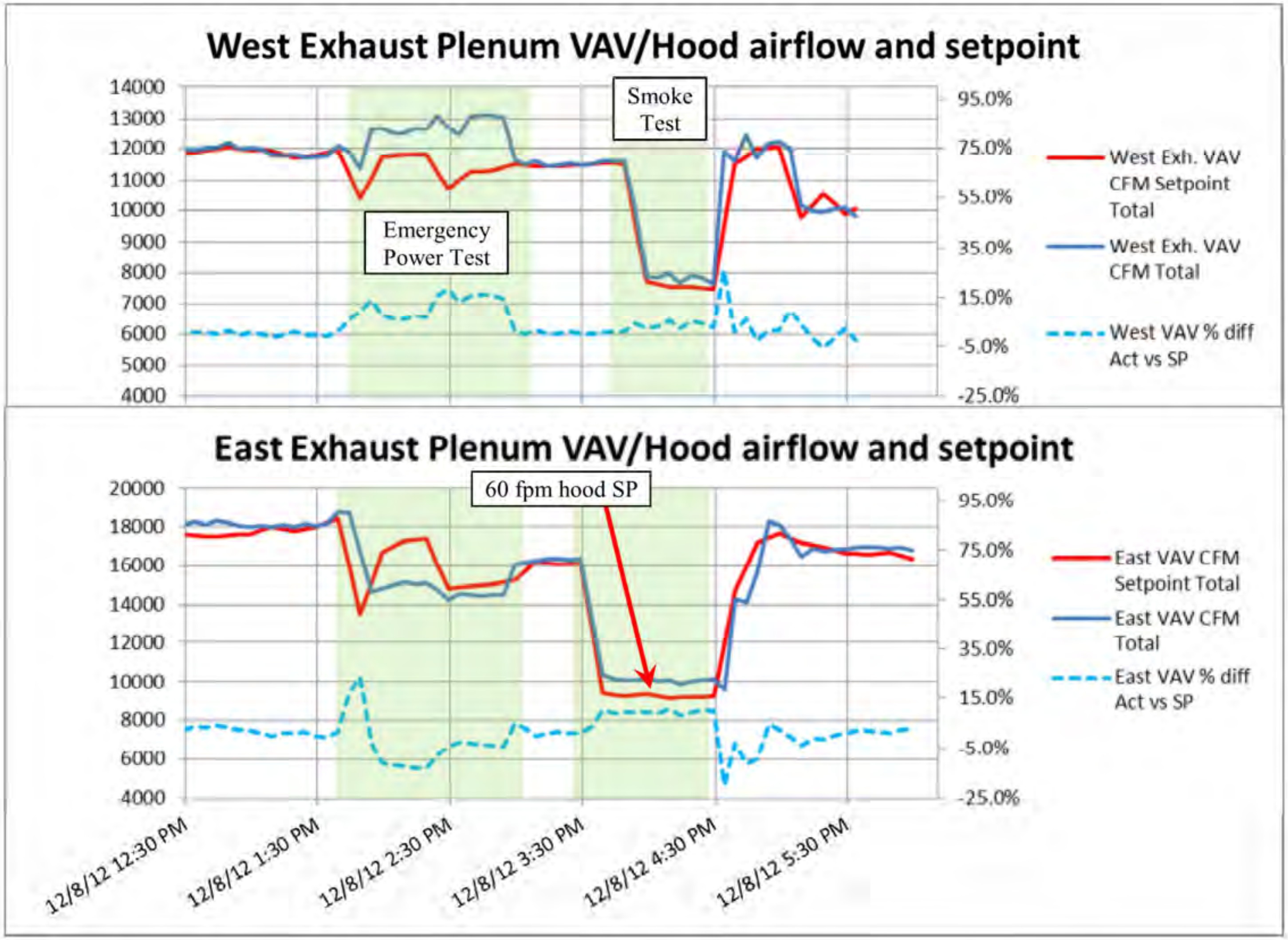



**Figure 71: Exhaust airflows and setpoints during testing on [redacted] West side exhaust exceeds setpoint during E-power test, and East side exhaust falls below setpoint. During smoke test, East side exhaust is ~10% above SP, West side exhaust ~5% above SP. Hood airflow setpoint reduced to 60 fpm in smoke mode. General Supply/Exhaust for non-hood rooms to zero in E-power**

| | | AHU | Schedule | Zone Temp (°F) | Setpt Adj (°F) | Clg Setpt (°F) | Htg Setpt (°F) | DAT (°F) | Dmpr (%) | Flow (cfm) | Flow Setpt (cfm) | HWV (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VAV-001 | AC-020 Interface | Occupied | 70.3 | 0.0 | 74.0 | 70.0 | 74.8 | 100 | -11 | 550 | 94 |
| | VAV-003 | AC-020 Interface | Occupied | 73.1 | 0.0 | 74.0 | 70.0 | 74.7 | 100 | 3 | 450 | 0 |
| | VAV-004 | AC-020 Interface | Occupied | 67.6 | 0.0 | 74.0 | 70.0 | 72.5 | 100 | -2 | 45 | 100 |
| | VAV-005 | AC-020 Interface | Occupied | 70.0 | 0.0 | 74.0 | 70.0 | 84.3 | 100 | -1 | 60 | 100 |
| | VAV-006 | AC-020 Interface | Occupied | 72.3 | 0.0 | 74.0 | 70.0 | 73.7 | 100 | -14 | 450 | 0 |
| | VAV-002 | AC-018 Interface | Occupied | 69.6 | 0.0 | 74.0 | 70.0 | 76.1 | 100 | 647 | 875 | 100 |
| | VAV-007 | AC-018 Interface | Occupied | 71.3 | 0.0 | 74.0 | 70.0 | 66.1 | 35 | 104 | 100 | 0 |
| | VAV-009 | AC-018 Interface | Occupied | 68.1 | 0.0 | 74.0 | 70.0 | 88.1 | 34 | 150 | 150 | 100 |
| | VAV-011 | AC-018 Interface | Occupied | 68.5 | 0.0 | 74.0 | 70.0 | 77.2 | 43 | 148 | 150 | 100 |
| | VAV-059 | AC-018 Interface | Occupied | 70.3 | 0.0 | 74.0 | 70.0 | 84.6 | 44 | 139 | 140 | 84 |
| | VAV-016 | AC-018 Interface | Occupied | 72.3 | 0.0 | 85.0 | 60.0 | | 34 | 74 | 75 | |
| | VAV-013 | AC-018 Interface | Occupied | 72.5 | | 74.0 | 70.0 | | 60 | 619 | 640 | 38 |
| | VAV-017 | AC-018 Interface | Occupied | 66.1 | | 74.0 | 70.0 | | 44 | 982 | 1000 | 100 |
| | VAV-020 | AC-018 Interface | Occupied | 66.6 | 0.0 | 74.0 | 70.0 | 79.4 | 57 | 307 | 310 | 100 |
| | VAV-061 | AC-018 Interface | Occupied | 69.0 | 0.0 | 74.0 | 70.0 | | 29 | 157 | 150 | |
| | V114 | AC-018 Interface | Occupied | 70.8 | 0.0 | 85.0 | 60.0 | 68.2 | 42 | 124 | 125 | 0 |
| | VAV-024 | AC-018 Interface | Occupied | 71.0 | 0.0 | 74.0 | 70.0 | 65.5 | 40 | 148 | 150 | 0 |

**Figure 72: First floor supply airflows during E-power test ([redacted] 2:00 PM). AC-20 is scheduled off, and zones connected to it show zero airflow**

| | AHU | Schedule | Zone Temp (°F) | Setpt Adj (°F) | Clg Setpt (°F) | Htg Setpt (°F) | DAT (°F) | Dmpr (%) | Flow (cfm) | Flow Setpt (cfm) | HWV (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| /AV-025 | AC-020 Interface | Unoccupied | 75.2 | 0.0 | 85.0 | 55.0 | 71.8 | 0 | 0 | 0 | 0 |
| /AV-028 | AC-020 Interface | Unoccupied | 72.4 | 0.0 | 85.0 | 55.0 | 72.5 | 0 | -0 | 0 | 0 |
| /AV-029 | AC-020 Interface | Unoccupied | 66.9 | 0.0 | 85.0 | 55.0 | 71.8 | 0 | -0 | 0 | 0 |
| /AV-030 | AC-020 Interface | Unoccupied | 71.1 | 0.0 | 85.0 | 55.0 | 71.9 | 0 | 1 | 0 | 0 |
| /AV-031 | AC-020 Interface | Unoccupied | 73.4 | 0.0 | 85.0 | 55.0 | 71.4 | 0 | -7 | 0 | 0 |
| /AV-032 | AC-020 Interface | Unoccupied | 73.2 | 0.0 | 85.0 | 55.0 | 72.1 | 0 | 12 | 0 | 0 |
| /AV-033 | AC-020 Interface | Unoccupied | 70.0 | 0.0 | 85.0 | 55.0 | 72.4 | 0 | -2 | 0 | 0 |
| /AV-034 | AC-020 Interface | Unoccupied | 69.9 | 0.0 | 85.0 | 60.0 | | 0 | -1 | 0 | |
| /AV-035 | AC-020 Interface | Unoccupied | 74.0 | 0.0 | 85.0 | 55.0 | 72.4 | 0 | -8 | 0 | 0 |
| /AV-036 | AC-020 Interface | Unoccupied | 73.4 | 0.0 | 85.0 | 55.0 | 71.7 | 0 | -2 | 0 | 0 |
| /AV-027 | AC-019 Interface | Occupied | 71.2 | 0.0 | 74.0 | 70.0 | 68.6 | 27 | 303 | 300 | 0 |
| /AV-054 | AC-019 Interface | Occupied | 72.6 | | 74.0 | 70.0 | | 48 | 867 | 880 | 30 |
| /AV-056 | AC-019 Interface | Occupied | 73.1 | | 74.0 | 70.0 | | 51 | 733 | 750 | 26 |
| /AV-063 | AC-019 Interface | Occupied | 72.8 | | 74.0 | 70.0 | | 29 | 845 | 860 | 28 |
| /AV-065,69 | AC-019 Interface | Occupied | 72.0 | | 74.0 | 70.0 | | 55 | 3362 | 3271 | 54 |
| /AV-076 | AC-019 Interface | Occupied | 68.4 | 0.0 | 74.0 | 70.0 | 85.1 | 28 | 155 | 150 | 100 |
| /AV-078 | AC-019 Interface | Occupied | 65.2 | 0.0 | 74.0 | 70.0 | 65.3 | 40 | 364 | 360 | 100 |
| /AV-082 | AC-019 Interface | Occupied | 71.8 | 0.0 | 74.0 | 70.0 | 66.1 | 100 | 396 | 420 | 0 |
| /AV-026 | AC-018 Interface | Occupied | 68.3 | 0.0 | 74.0 | 70.0 | 86.5 | 100 | -2 | 270 | 100 |
| /AV-037 | AC-018 Interface | Occupied | 73.1 | | 74.0 | 70.0 | | 28 | 1487 | 1560 | 31 |

**Figure 73: Second floor West supply airflows during E-power test ([redacted], 2:00 PM). AC-20 is scheduled off, and zones connected to it show zero airflow**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| | AHU | Schedule | Zone Temp (°F) | Setpt Adj (°F) | Clg Setpt (°F) | Htg Setpt (°F) | DAT (°F) | Dmpr (%) | Flow (cfm) | Flow Setpt (cfm) | HWV (% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -VAV-040 | -AC-018 Interface | Occupied | 72.8 | | 74.0 | 70.0 | | 33 | 1501 | 1560 | 35 |
| -VAV-043 | -AC-018 Interface | Occupied | 70.1 | | 74.0 | 70.0 | | 41 | 253 | 280 | 98 |
| -VAV-071 | -AC-018 Interface | Occupied | 72.6 | | 74.0 | 70.0 | | 33 | 121 | 140 | 30 |
| -VAV-045 | -AC-018 Interface | Occupied | 72.6 | | 74.0 | 70.0 | | 30 | 510 | 541 | 34 |
| -VAV-047 | -AC-018 Interface | Occupied | 71.3 | 0.0 | 74.0 | 70.0 | 66.2 | 39 | 139 | 140 | 0 |
| -VAV-049 | -AC-018 Interface | Occupied | 72.0 | 0.0 | 74.0 | 70.0 | 65.2 | 36 | 145 | 140 | 0 |
| -VAV-051 | -AC-018 Interface | Occupied | 71.7 | | 74.0 | 70.0 | | 40 | 127 | 140 | 54 |
| -VAV-053 | -AC-018 Interface | Occupied | 70.5 | 0.0 | 80.0 | 60.0 | | 29 | 50 | 50 | |

**Figure 74: Second floor East supply airflows during E-power test ([redacted], 2:00 PM).**

| | AHU | Schedule | Zone Temp (°F) | Setpt Adj (°F) | Clg Setpt (°F) | Htg Setpt (°F) | DAT (°F) | Dmpr (%) | Flow (cfm) | Flow Setpt (cfm) | hwv_output (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VAV-087 | AC-019 Interface | Occupied | 69.8 | 0.0 | 74.0 | 70.0 | 87.7 | 100 | 63 | 210 | 100 |
| VAV-085 | AC-019 Interface | Occupied | 69.6 | 0.0 | 74.0 | 70.0 | 89.3 | 100 | 47 | 150 | 100 |
| VAV-086 | AC-019 Interface | Occupied | 71.4 | 0.0 | 74.0 | 70.0 | 70.9 | 100 | -80 | 300 | 0 |
| VAV-089 | AC-019 Interface | Occupied | 68.9 | 0.0 | 74.0 | 70.0 | 84.9 | 100 | -3 | 270 | 100 |
| VAV-091 | AC-020 Interface | Unoccupied | 72.0 | 0.0 | 85.0 | 55.0 | 70.7 | 0 | -0 | 0 | 0 |
| VAV-092 | AC-020 Interface | Unoccupied | 69.2 | 0.0 | 85.0 | 55.0 | 69.4 | 0 | -2 | 0 | 0 |
| VAV-093 | AC-020 Interface | Unoccupied | 67.7 | 0.0 | 85.0 | 55.0 | 69.5 | 0 | 4 | 0 | 0 |
| VAV-094 | AC-020 Interface | Unoccupied | 72.9 | 0.0 | 85.0 | 55.0 | 70.1 | 0 | -7 | 0 | 0 |
| VAV-095 | AC-020 Interface | Unoccupied | 72.7 | 0.0 | 85.0 | 55.0 | 70.6 | 0 | -3 | 0 | 0 |
| VAV-096 | AC-020 Interface | Unoccupied | 70.4 | 0.0 | 85.0 | 55.0 | 70.0 | 0 | 1 | 0 | 0 |
| VAV-097 | AC-020 Interface | Unoccupied | 67.8 | 0.0 | 80.0 | 60.0 | | 0 | -1 | 0 | |
| VAV-098 | AC-020 Interface | Unoccupied | 71.8 | 0.0 | 85.0 | 55.0 | 69.8 | 0 | 1 | 0 | 0 |
| VAV-099 | AC-020 Interface | Unoccupied | 71.5 | 0.0 | 85.0 | 55.0 | 69.5 | 0 | -4 | 0 | 0 |
| VAV-100 | AC-020 Interface | Unoccupied | 69.8 | 0.0 | 85.0 | 55.0 | 70.0 | 0 | -1 | 0 | 0 |
| VAV-122,124 | AC-019 Interface | Occupied | 70.8 | 0.0 | 74.0 | 70.0 | | 28 , 26 | 1261 | 1215 | 0 , 0 |
| VAV-136 | AC-019 Interface | Occupied | 70.3 | 0.0 | 74.0 | 70.0 | 92.3 | 39 | 158 | 160 | 91 |
| VAV-126 | AC-019 Interface | Occupied | 72.2 | | 74.0 | 70.0 | | 97 | 1569 | 1570 | 53 |
| VAV-140 | AC-019 Interface | Occupied | 71.9 | | 74.0 | 70.0 | | 42 | 1091 | 1100 | 51 |

**Figure 75: Third floor West supply airflows during E-power test ([redacted], 1:59 PM). AC-20 is scheduled off, and zones connected to it show zero airflow**

| | AHU | Schedule | Zone Temp (°F) | Setpt Adj (°F) | Clg Setpt (°F) | Htg Setpt (°F) | DAT (°F) | Dmpr (%) | Flow (cfm) | Flow Setpt (cfm) | HWV (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VAV-084 | AC-020 Interface | Unoccupied | 71.1 | 0.0 | 85.0 | 55.0 | 70.5 | 0 | 1 | 0 | 0 |
| VAV-103 | AC-018 Interface | Occupied | 74.4 | | 74.0 | 70.0 | | 16 | 1788 | 1800 | 1 |
| VAV-106 | AC-018 Interface | Occupied | 71.7 | | 74.0 | 70.0 | | 0 | 8 | 150 | 51 |
| VAV-107 | AC-018 Interface | Occupied | 73.1 | | 74.0 | 70.0 | | 37 | 590 | 600 | 29 |
| VAV-108 | AC-018 Interface | Occupied | 72.7 | | 74.0 | 70.0 | | 30 | 1427 | 1500 | 34 |
| VAV-112 | AC-018 Interface | Occupied | 72.0 | 0.0 | 74.0 | 70.0 | 64.7 | 38 | 138 | 140 | 0 |
| VAV-114 | AC-018 Interface | Occupied | 72.3 | 0.0 | 74.0 | 70.0 | 64.1 | 40 | 142 | 140 | 0 |
| VAV-116 | AC-018 Interface | Occupied | 72.8 | | 74.0 | 70.0 | | 49 | 156 | 150 | 34 |
| VAV-111 | AC-018 Interface | Occupied | 72.8 | | 74.0 | 70.0 | | 24 | 296 | 300 | 30 |
| VAV-118 | AC-018 Interface | Occupied | 71.5 | 0.0 | 85.0 | 60.0 | | 25 | 52 | 50 | |
| VAV-119 | AC-020 Interface | Unoccupied | 70.8 | 0.0 | 85.0 | 55.0 | 70.0 | 0 | 5 | 0 | 0 |
| VAV-120 | AC-020 Interface | Unoccupied | 69.1 | 0.0 | 85.0 | 55.0 | 69.3 | 0 | -1 | 0 | 0 |
| VAV-141 | AC-020 Interface | Unoccupied | 67.3 | 0.0 | 85.0 | 55.0 | 69.1 | 0 | 1 | 0 | 0 |

**Figure 76: Third floor East supply airflows during E-power test ([redacted], 1:59 PM). AC-20 is scheduled off, and zones connected to it show zero airflow**

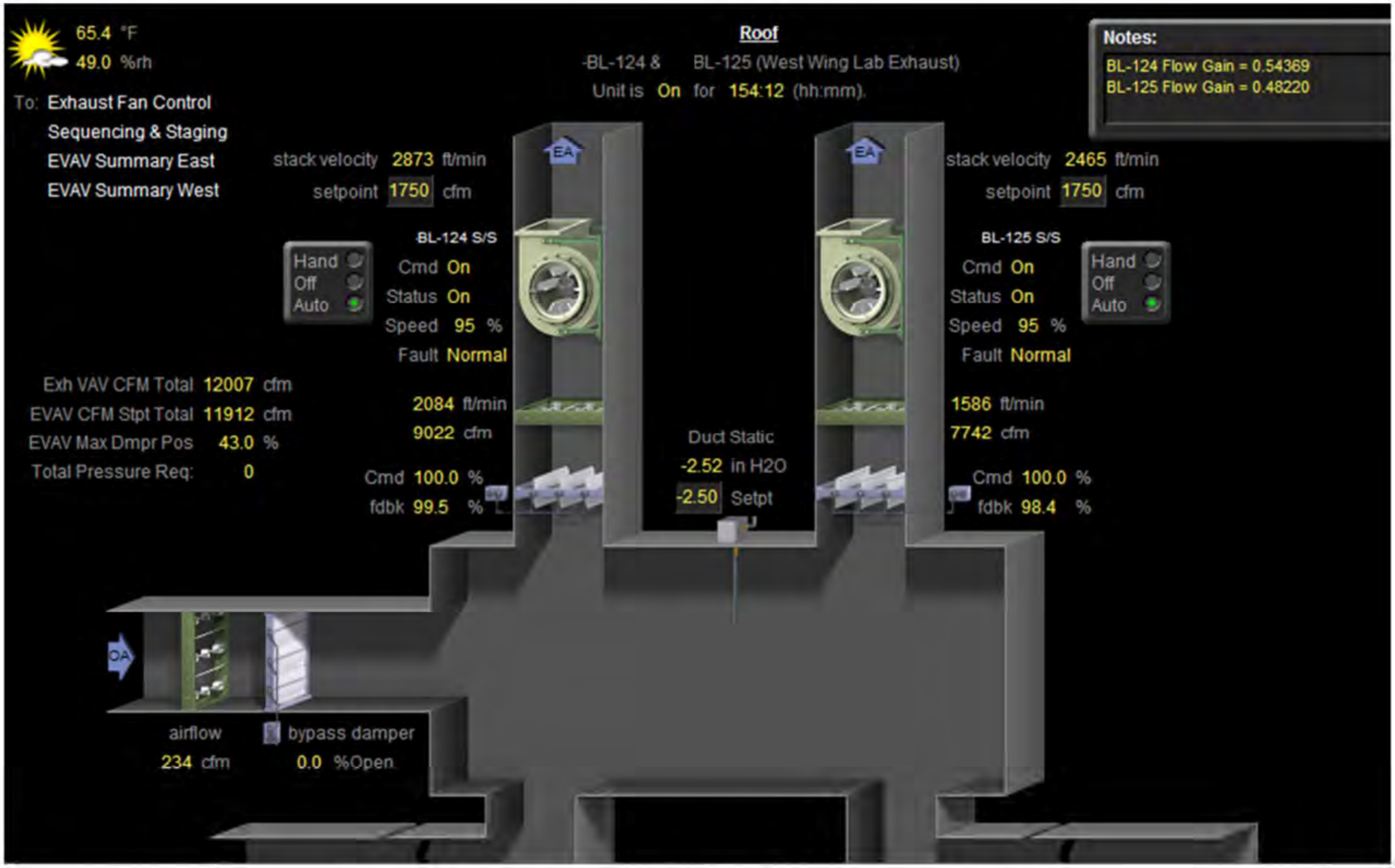



**Figure 77: West side exhaust plenum before switch to E –power, 1:47PM.**

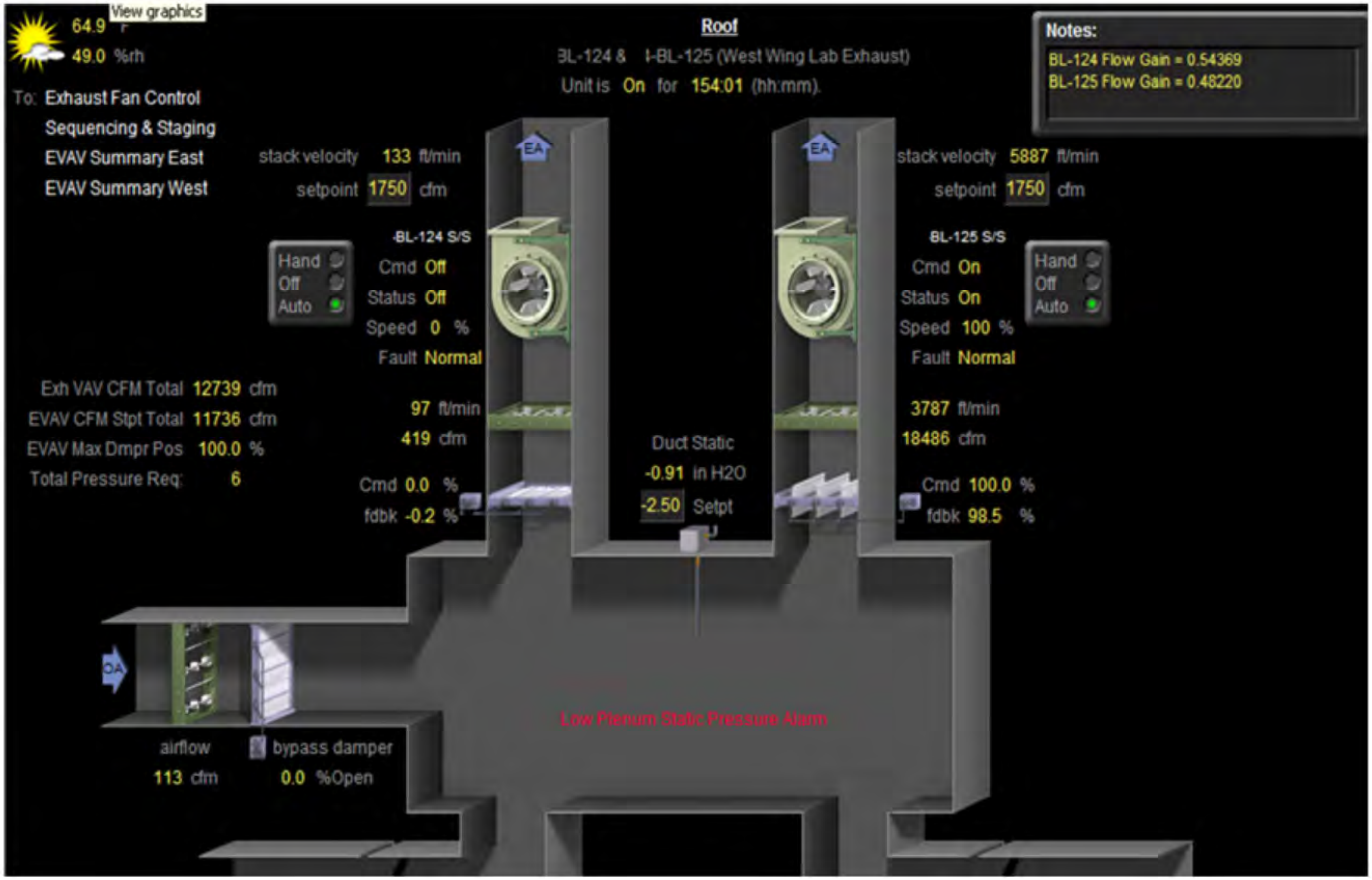



**Figure 78: West side exhaust plenum after switch to E –power, 1:58PM**

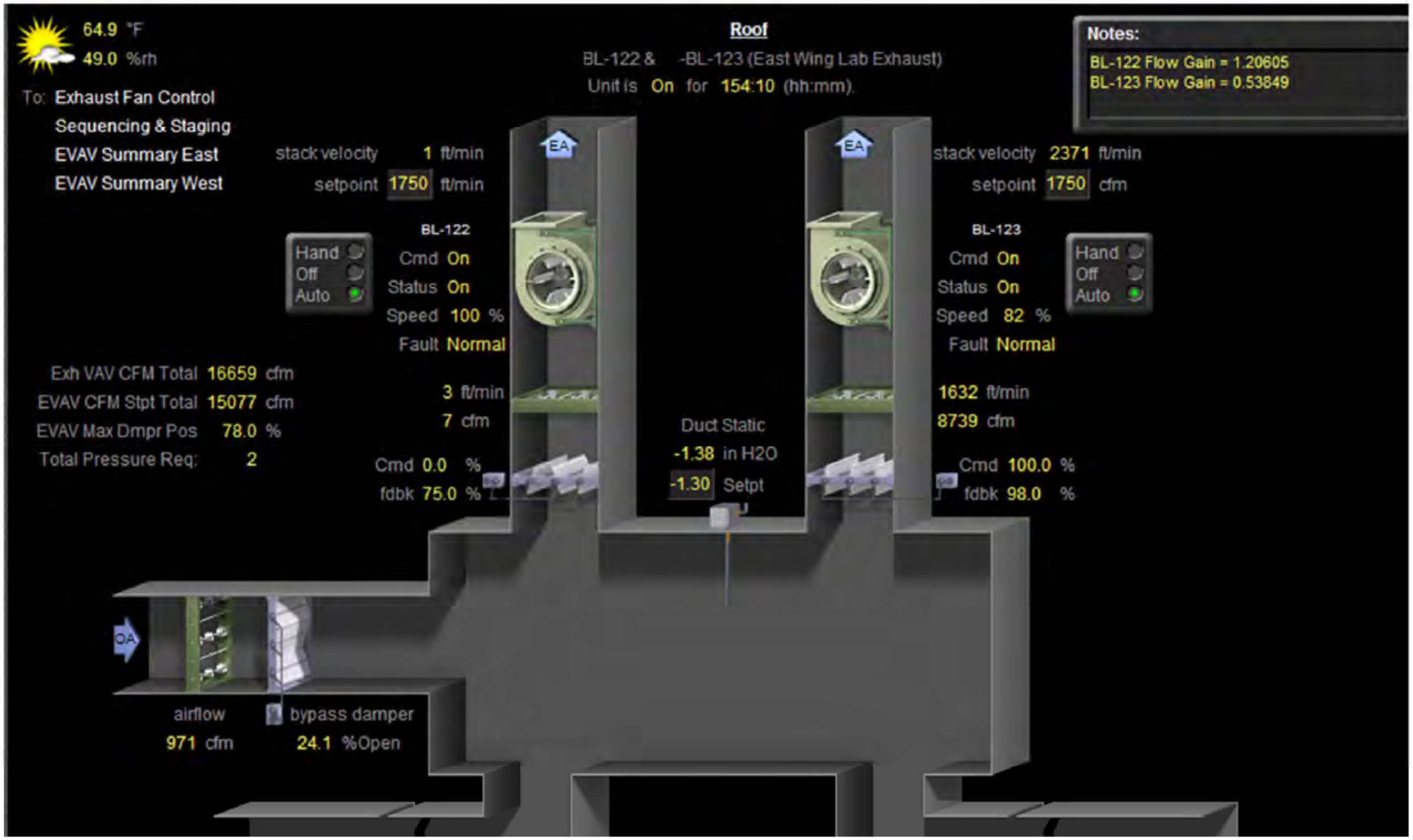



**Figure 79: East side exhaust plenum before switch to E –power, 1:47PM. Note that stack velocity sensor for BL-122 is broken, giving an almost zero reading, causing BL-122 to run at full speed**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

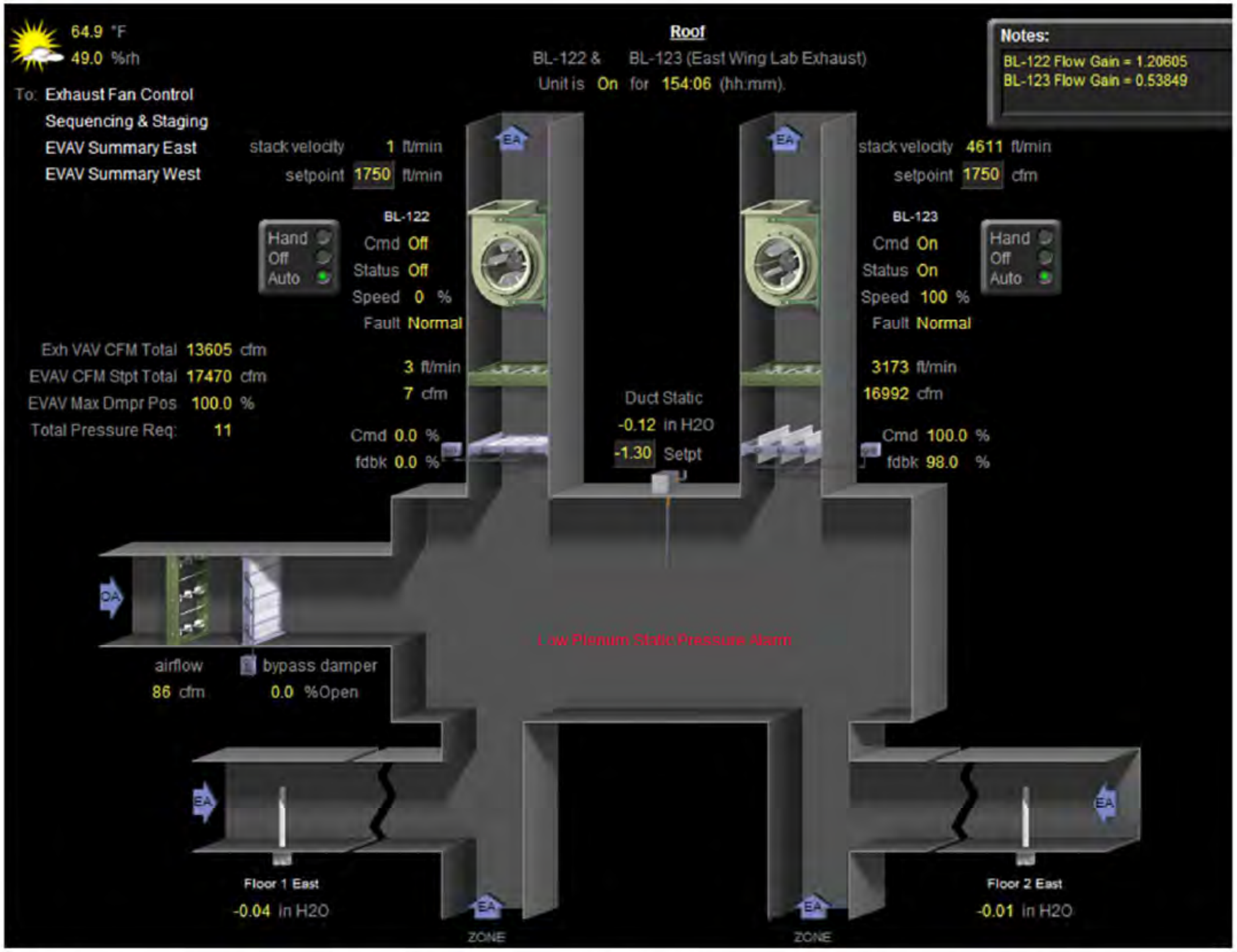



**Figure 80: East side exhaust plenum after switch to E –power, 1:47PM. Note low pressure in branches (-0.12" in plenum and -0.04" / 0.01" in branch lines) leading to 11 hoods on the East side in alarm.**

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

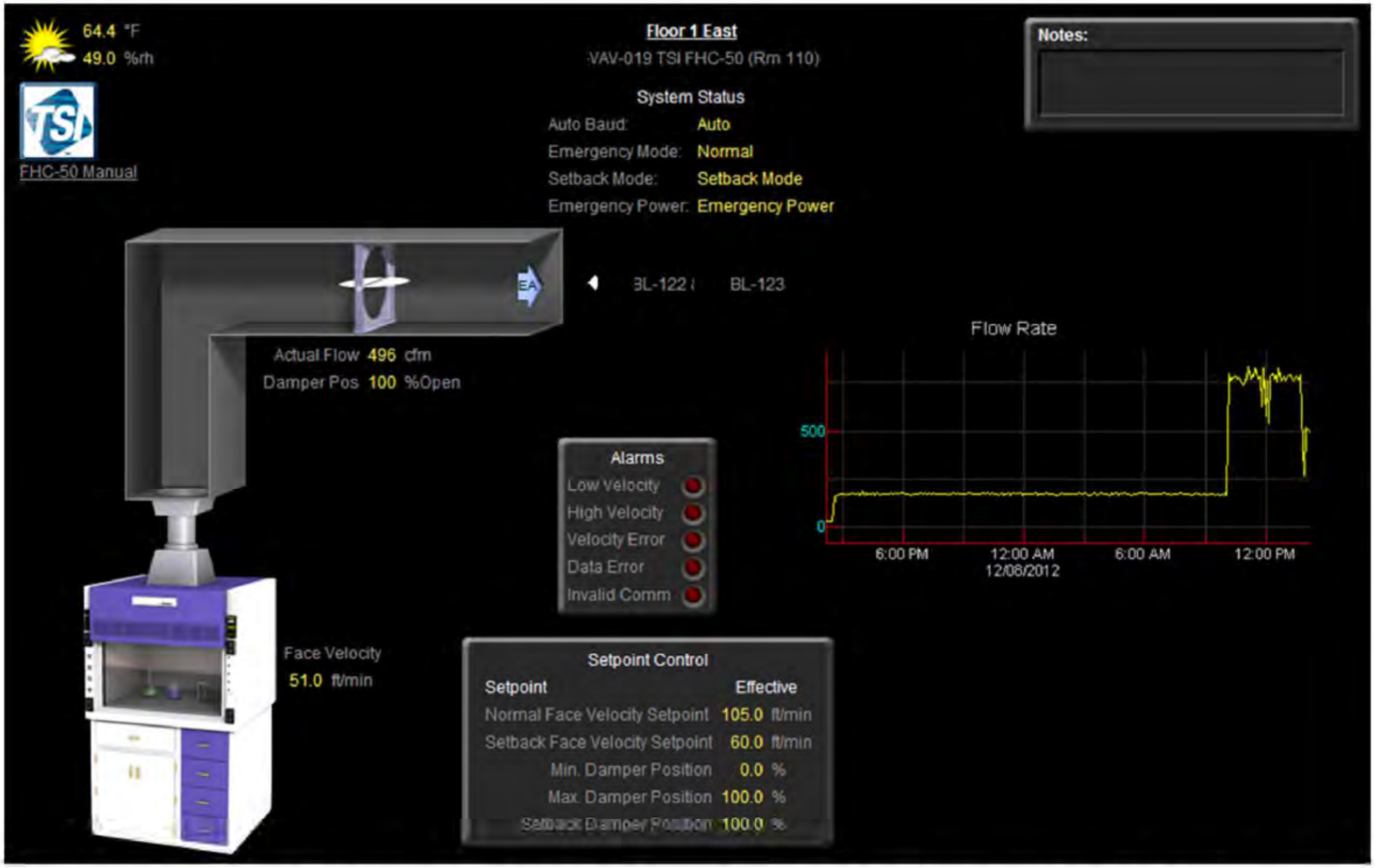



**Figure 81: Example hood with low airflow on East side in E-power mode, Dec. 8 at 2:10PM. Hood is at 51 fpm with fully open exhaust damper. 11 hoods total in low flow alarm.**

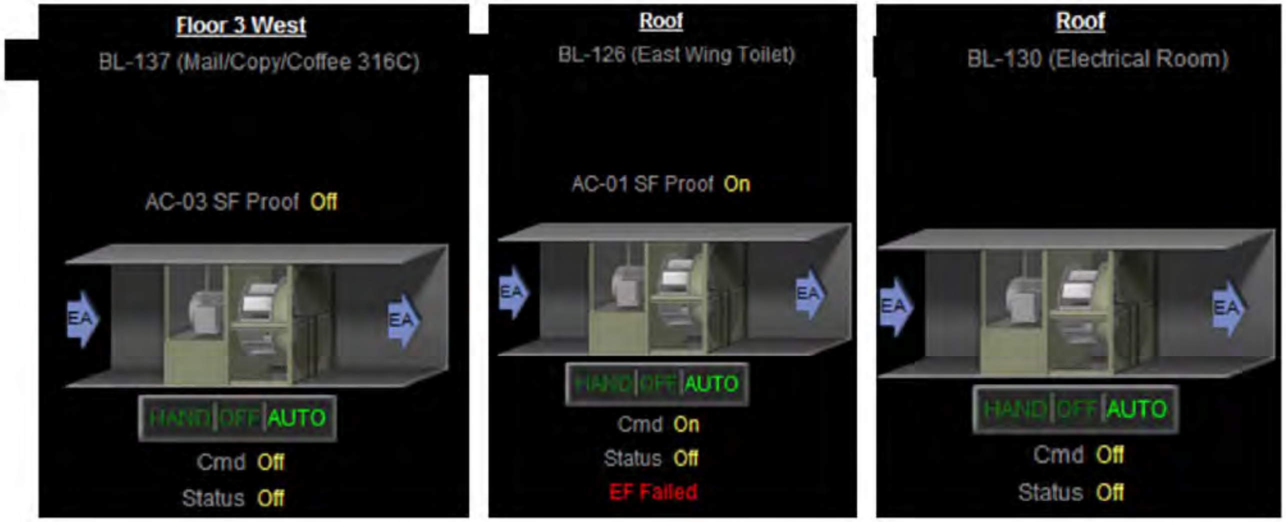



**Figure 82: Miscellaneous small fans in E-power mode, [redacted] at 2:11PM.**

Re-test [redacted], 2013

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| 3.Emergency Power Operation | 1. Activate emergency power system by using "pull the plug" test – disable main utility power. Emergency power feeds from [redacted] are .enabled. | 1. Transfer switch TSW-2[redacted] changes position<br>2. Alarm generated in control system and ATS position visible in control system.<br>3. Main equipment is temporarily disabled, then re-enabled after short power dip (record outage duration with power testing equipment for Div 26) and re-enabled with delays on lab exhaust fans, no delays on other equipment.<br>4. All downstream terminal units served by AC-01 and 02 limit their primary airflow to ½ of design. (verify with status screen or trends) with the exception of terminals 108A (gen exh wide open, supply tracks pressure), 111 (min.airflow) and 111B (shut).<br>5. Exhaust terminals continue to modulate airflow to maintain their respective CFM differential setpoints. (page 38 of 57 in [redacted] submittal Rev 4)<br>6. AC-01 and 02 roof make-up air dampers are closed.<br>7. Fume hood face velocity drops to 60 fpm where hoods are powered<br>8. AC-01 supply duct FSD's are open to allow airflow to floor 1 and 2<br>9. All systems resume stable operation<br>10. Note fume hood alarms where present, clear hood alarms<br>11. Building pressurization remains at setpoint for all areas requiring pressurization. No excessive door pressures witnessed | Date : [redacted], 2013<br>See Figure 83 on page 144 to Figure 85 on page 146.<br>Delays set for equipment:<br>East plenum exhausts BL124-125<br>Delay: 30 seconds<br>Ramp: 1% every second<br><br>West plenum exhausts BL124-125<br>Delay: 30 seconds<br>Ramp: 1% every second<br><br>Makeup units:<br>Delay: 0 seconds, no ramp<br><br>Initial test: 9AM, get to 0.32" on 3rd floor, and roughly 0.4" on second floor<br><br>Double-checked Room 229 doors ([redacted], with pull gauge) and 327A [redacted] without gauge, but felt like 8-10lbs, no problem opening)<br><br>Re-do test at 9:38AM with delays for Ex.fans set to 0.6% every second (for full range ramp up over 1.5 minutes)<br><br>Third floor door opened manually with door pull gauge to verify pressure results against door pull gauge results – matches, at about 28 lbs. | Y<br><br>Y<br><br>Y |

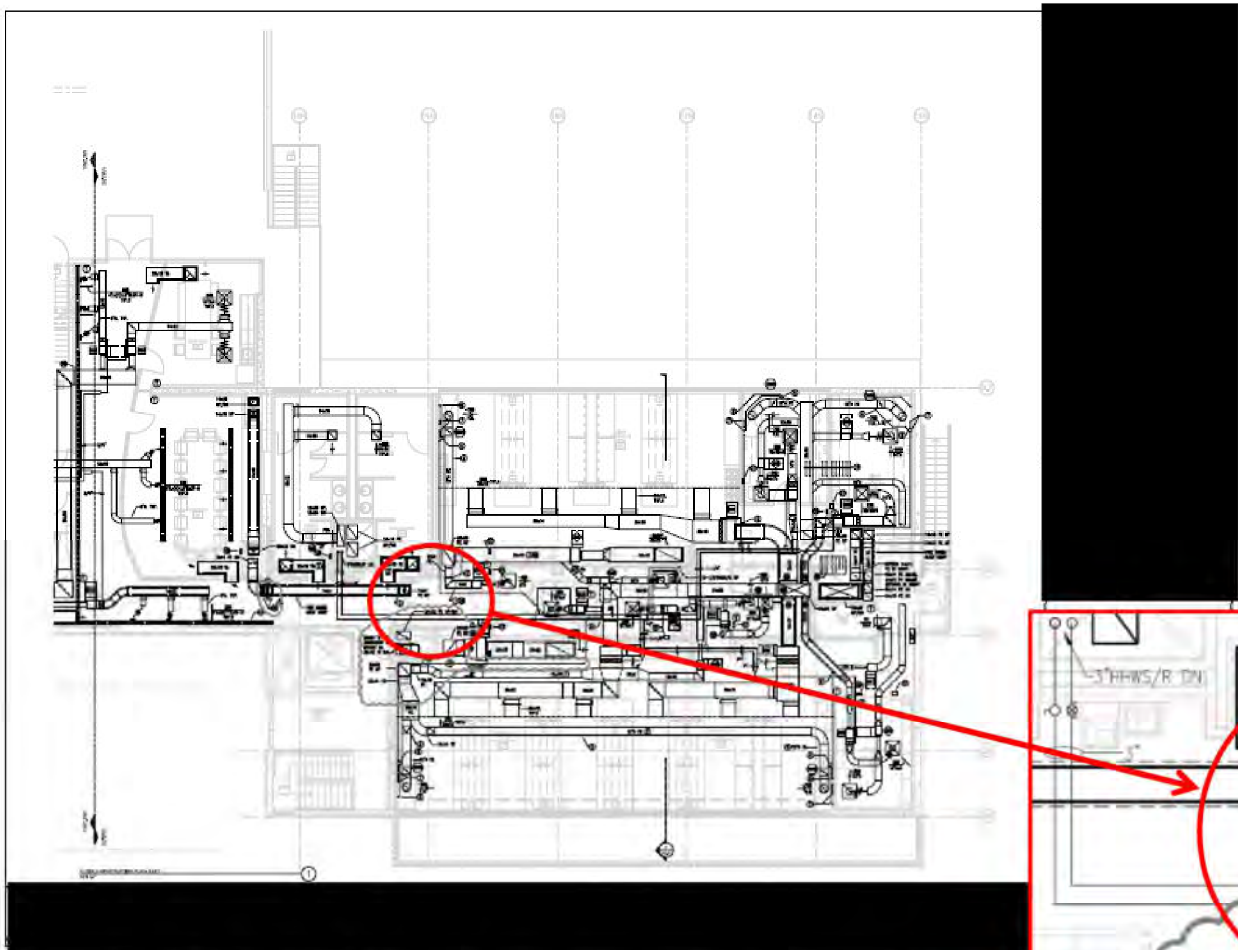
| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | | | Pressures in 3rd floor down to max.0.28" and 2nd floor down to 0.3"<br><br>Third test 9:58AM<br>Back door 214 exterior is about 40lbs, not surprising since mechanical door closure force is 20 lbs. So exterior door currently failed.<br><br>Conclude that reducing air pressures to 10lbs equivalent is not the right solution, would make ramp rates too slow and hood alarms too long. One exit not sufficient, 2 exits required per NFPA45.<br><br>Door currently triggered by fire alarm through hard wired relays, no connection through ALC.<br><br>12C FRAM read error on Hood (room 320A SW hood). Punchlist item for correction.<br><br>Last test 10:45AM, passes (max. pressures 0.35" wg, no exiting issues). Door 214 opens during smoke mode. (See also test section below) | <br><br><br>N<br><br><br><br><br><br><br><br><br><br><br><br><br>See notes<br><br><br>Y |

| Control Function | Test | Expected Response | Observed Response | Pass? |
|---|---|---|---|---|
| | 2. After stable operation for some time (min. 30 mins) in E-power mode, de-activate emergency power system by re-enabling main utility power. Emergency power feeds from [redacted] are disabled. | h. Transfer switch changes position again<br>i. E-power alarm is cleared in control system. ATS position monitored.<br>j. Main equipment is temporarily disabled (part of a second, record outage duration with power testing equipment for Div 26) then comes on line again without staggering<br>k. All VAV terminals return to normal operation<br>l. Hoods with power connected return to 100 fpm operation<br>m. Exhaust fan clusters return to normal (dual fan) operation<br>n. Building pressurization remains at setpoint for all areas requiring pressurization | Yes, return to normal operation during 3 out of 4 tests.<br><br>One set of alarms present on AC-3[redacted]: breaker for control power panel tripped at 10:39AM.<br><br>[redacted]resets at 12:14PM Control power paenl only failed once during 4 tests, suspect breaker is set just a little too aggressively. Review settings with electrician. This failure seen as comm. failure to AC-20 in ALC controls front end.<br><br>One boiler remains in alarm after E-power and switchover.<br><br>Blower BL-124 goes into alarm but comes back upon ATS switch back to utility power (9:13AM after test 1, 10:08AM after test 3, 10:58AM after test 4). Not clear why this. | Y<br><br><br>N See notes below<br><br><br><br><br>N See notes below<br><br>See notes below |

Additional Notes: [redacted]AC-20 control power panel has tripped in the past. This panel does not handle large power consumption. Its operation should not influence other essential components of the building (lab and safety related). Nevertheless, the failure should be investigated. Worst case under current scenario is that comfort complaints lead to investigation and manual reset of the panel.

Blower BL-124 operation can be seen in Figure 86 on page 147 to Figure 89 on page 149. The fan fails several times on returning to utility power (after tests 1, 3 and 4). The fan runs again automatically on the next transition of power, but it should be investigated why it tripped to begin with. It may be that the return to utility power (as the ATS switches back) is almost seamless but not quite, and that a short spike in power is created which is sufficient to take BL-124 offline.

The SW Hood in room 320 (exhaust terminal [redacted]VAV-104) shows an alarm at the hood controller "12C FRAM read error", but the 100 fpm face velocity is maintained. The O&M manual indicates this means all settings for the controller have been lost.



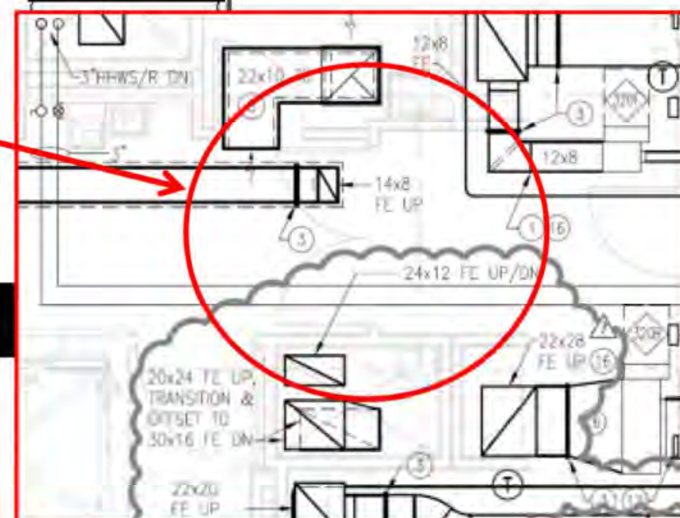



**Figure 83: 2013[redacted] Location of pressure gauges at double corridor doors to Labs 214 and 320 for measuring door pressures for exiting during switch to emergency power mode.**


**Figure 84: 2013-[redacted] Measurement setup at double doors to corridor at Labs 214 and 320. Initial setup with single gauge (left), then ultimate test setup with dual gauges (for 0-0.25" and 0-5" ranges simultaneously) at right. Both rooms set up similarly before commencing first test at 8:50AM.**

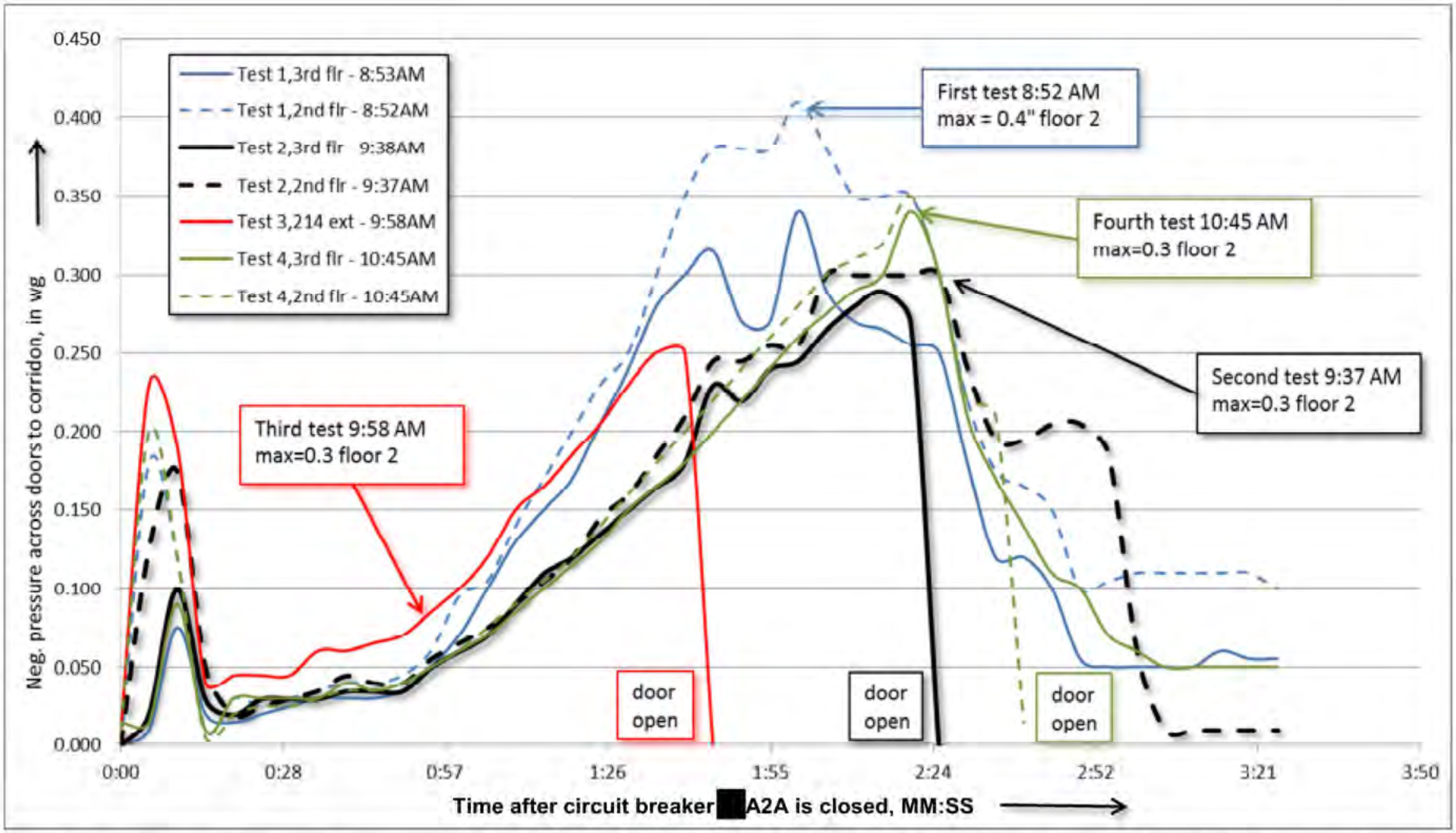



**Figure 85:[redacted], 2013 - Door pressures at 2nd and 3rd floor hallway double doors during 3 consecutive tests (Test 1, 2 and 4) and pressures at door 214B (exterior door, test 3). Measured with magnehelic gauges and videotaped, trends taken from videos in 5 second intervals**

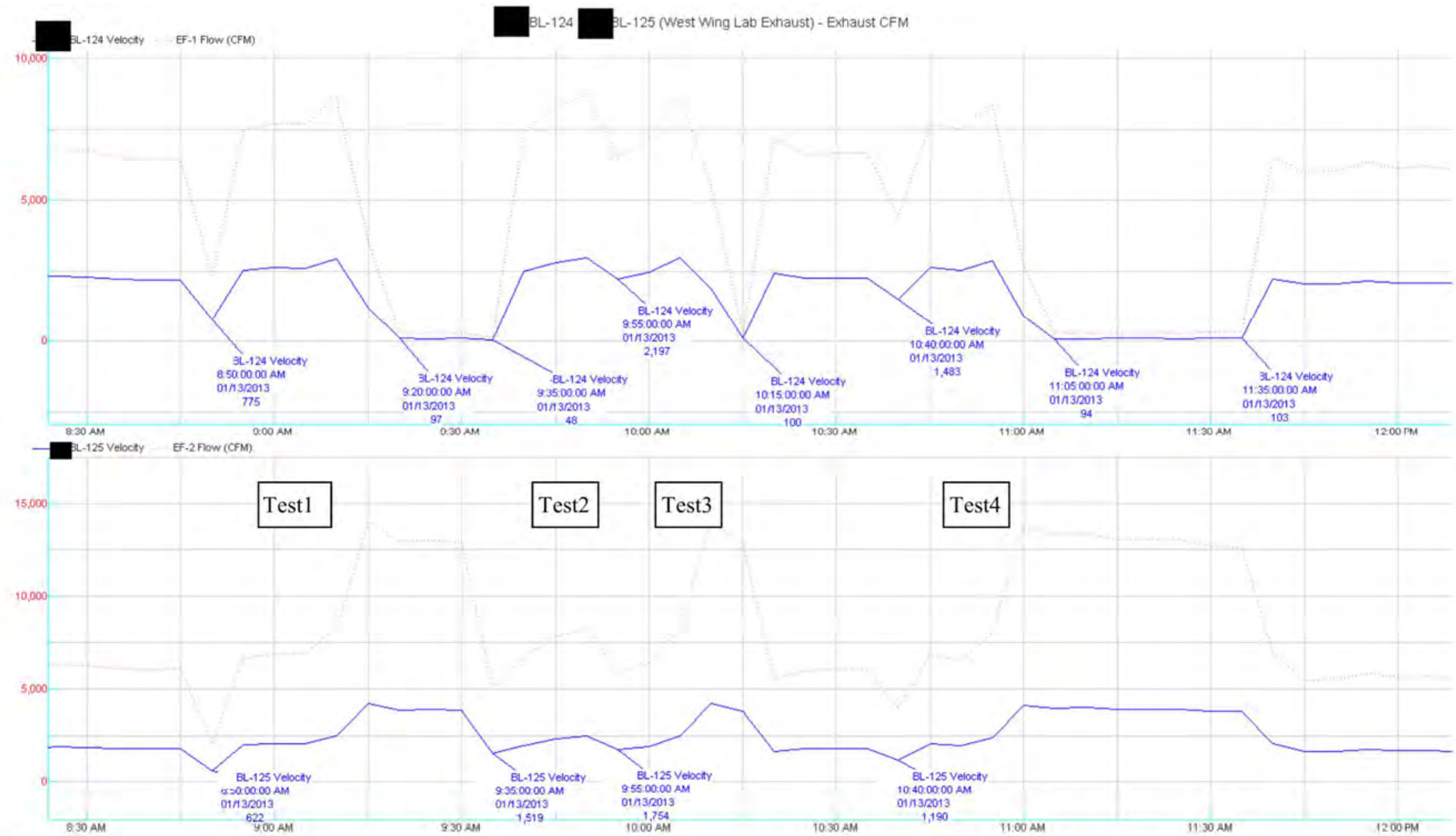



**Figure 86: [redacted], 2013 –Exhaust fan velocities and airflows on West exhaust plenum**

**Figure 87:West side exhaust fan status during 4 tests to E-power and back**

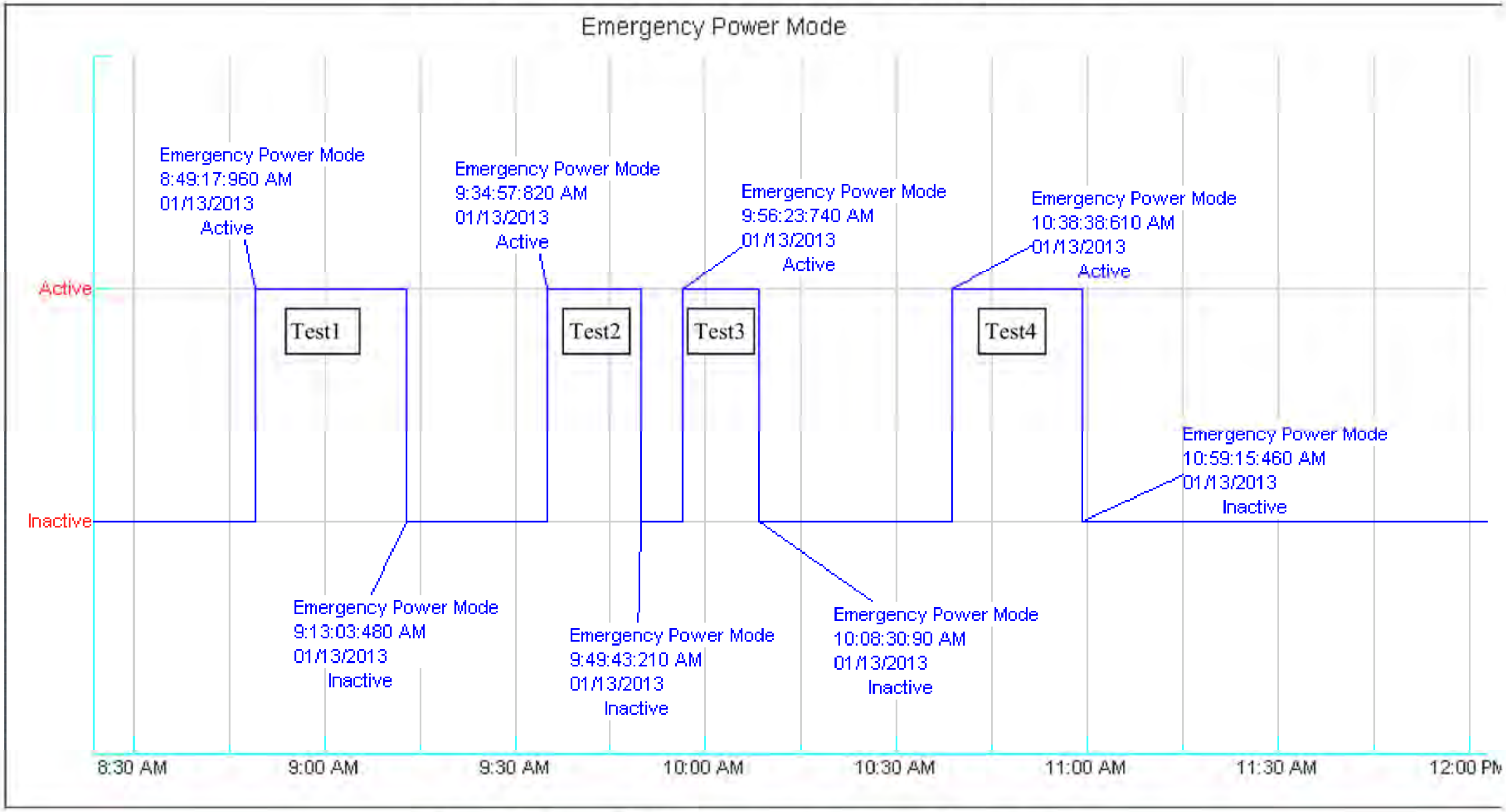



**Figure 88:[redacted], 2013 –Emergency power status during testing**

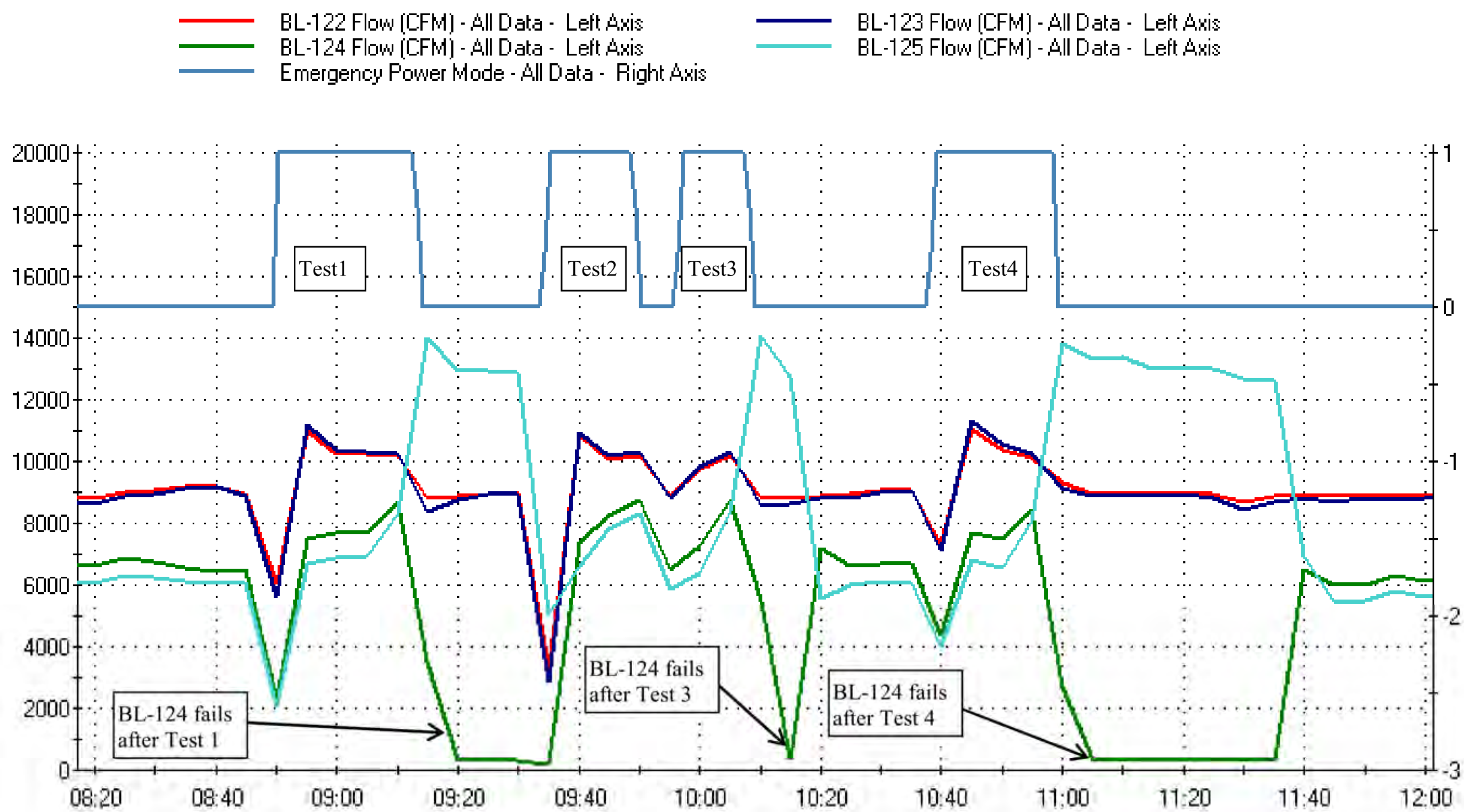



**Figure 89:[redacted], 2013 –Exhaust fan velocities and airflows on West exhaust plenum overlaid against emergency power status.**

Part 9 COMBINED EMERGENCY POWER AND SMOKE MODE TESTS

| | | | | |
|---|---|---|---|---|
| A. Emergency Power Operation | 1. Activate emergency power system by using "pull the plug" test – disable main utility power. Emergency power feeds from [redacted] are .enabled. | a. Transfer switch TSW-2[redacted] changes position<br>b. Alarm generated in control system and ATS position visible in control system.<br>c. Main equipment is temporarily disabled, then re-enabled after short power dip (record outage duration with power testing equipment for Div 26) and re-enabled with delays on lab exhaust fans, no delays on other equipment.<br>d. All downstream terminal units served by AC-01 and 02 limit their primary airflow to ½ of design. (verify with status screen or trends) with the exception of terminals 108A (gen exh wide open, supply tracks pressure), 111 (min.airflow) and 111B (shut).<br>e. Exhaust terminals continue to modulate airflow to maintain their respective CFM differential setpoints.<br>f. AC-01 and 02 roof make-up air dampers are closed.<br>g. All chemical fume hood sashes go to a fully closed position.<br>h. AC-01 supply duct FSD's are open to allow airflow to floor 1 and 2<br>i. All systems resume stable operation<br>j. Note fume hood alarms where present, clear hood alarms<br>k. Building pressurization remains at setpoint for all areas requiring pressurization | Date : [redacted], 2013<br>Time: 10:45AM<br><br>See last day of E-power testing for room pressures, section 8 above, for multiple switches to E-power mode and back (4 total).<br><br>See also previous tests [redacted].<br><br>Last switch to E-power is on [redacted] at 10:45AM, not all variables at left are checked again but E-power tests passed successfully (for everything but room pressure at 2 doorways) on [redacted], 2012. | Y |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

| | | | | |
|---|---|---|---|---|
| B. Smoke mode in emergency power mode<br><br>AC-01 | 2. Activate smoke detector signal in AC-02 (either by actual smoke bomb, preferred, or by fire control system software override) | Preparation / test notes | After successful test of pressures in West wing under all scenarios, will not re-test for combined smoke/E-power on West wing.<br><br>East Wing AC-18 taken down as part of combined test.<br><br>Worst case = go to E-power first (smoke mode means 60 fpm across hoods, so is less stringent for air pressure).<br><br>Date : [redacted], 2013<br>Time: 10:45AM<br>Goto E-power. Once in E-power, wait approx.2 minutes for system to reach max. negative pressure, then go to smoke mode for AC-18/AC-1 by manually smoking the unit. | |
| | | a. AC-01 shuts down. | Yes, unit shuts down | Y |
| | | b. AC-02 and 03 continue to run. | Yes | Y |
| | | c. AC-01 Roof make-up air damper opens | No, damper does not open | N |
| | | d. General exhaust terminals in rooms served by AC-01 close fully | Not verified again (see prev.tests) | |
| | | e. All chemical fume hood velocities in areas served by AC-01 go to 60fpm. | No, face velocities stay at 100 fpm | N<br>See notes below |
| | | f. AC-01 supply duct FSD's are open to allow airflow to floor 1 and 2 | | |
| | | g. Exhaust systems respond to lower exhaust volume by ramping down. | Exhaust systems tuned to ramp up slowly | Y |
| | | h. All systems resume stable operation | Correct, No excessive door pressures during combination E-power/smoke alarm, even though | |

| | | | | |
|---|---|---|---|---|
| | | i. Note fume hood alarms where present, clear hood alarms<br>j. All rooms maintain pressurization at setpoint.<br>k. Maintain this mode for 15 min. at least to ensure results are captured in trends. | hoods stayed at 100 fpm. Include measurement of 3rd floor exterior door about 28 lbs<br><br>Note that 1st floor East hoods – Rock lab and Room 112 sash also closes by itself. | |
| | 3. After stable operation for some time (min. 15 mins) in smoke mode, clear alarms | a. AC-02 resumes operation<br>b. Makeup air damper closes<br>c. Fume hood sashes re-open to normal position<br>d. Exhaust fans speed up<br>e. All VAV terminals return to normal operation<br>f. All room pressures maintained at setpoint | Yes, AC-1 / [redacted] AC-18 returns to normal operation.<br>No damper operation since ALC did not receive fire alarm (see above) | Y |
| C. Return from Emergency power | 4. After stable operation for some time (min. 30 mins) in E-power mode, de-activate emergency power system by re-enabling main utility power. Emergency power feeds from [redacted] are disabled. | a. Transfer switch changes position again<br>b. E-power alarm is cleared in control system. ATS position monitored.<br>c. Main equipment is temporarily disabled (part of a second, record outage duration with power testing equipment for Div 26) then comes on line again without staggering<br>d. All VAV terminals return to normal operation<br>e. Hood sash positions return to normal positions<br>f. Exhaust fan clusters return to normal (dual fan) operation<br>g. Building pressurization remains at setpoint for all areas requiring pressurization | Yes, return to normal operation all systems around 11:30AM. | Y |

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

Additional Notes

ALC did not receive smoke alarm, although unit was physically smoked by [redacted] and local panel went into alarm, door to 214 opened, and [redacted] called a truck to dispatch.

Suspect that module / panel which transfers fire alarm signal to ALC was not on E-power and therefore, ALC did not open bypass dampers on roof, and TSI did not receive signal to reduce face velocities to 60fpm. Nevertheless, no door opening issues other than door 214B. So overall, tests for exiting pass, and the fact that fume hoods did not drop in velocity actually improve operations in terms of operator safety. Nevertheless, recommend finding out why alarm was not relayed. Discussion on site with [redacted] and [redacted] resolves that making 100 fpm the official failure mode (now that it is proven this presents no issues for exiting) is not feasible because by the time a bulletin is issued by [redacted], field changer orders are issued and programming changes are implemented, a re-test will be required, and this will not be feasible in the occupied building.

Hood sash closures still appear to be incompletely addressed to match Bulletin 71 on ground floor – some hoods still closed under motorized sash power.

TECHNICIAN NAME: [redacted] TEST DATE(S) [redacted]

Additional Notes

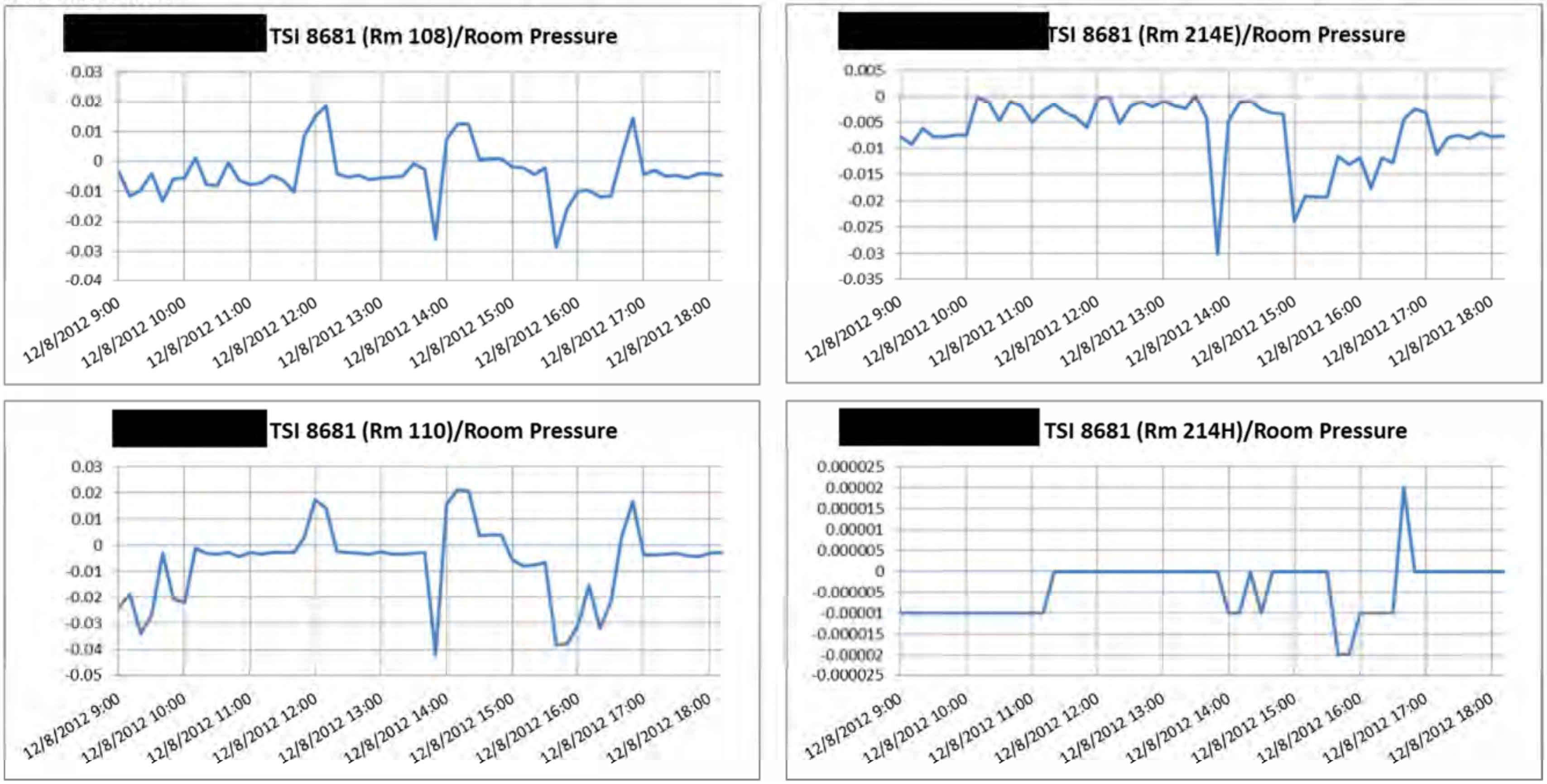



**Figure 90: Room pressures on [redacted], 2012 during E-power (1:45 PM to 3PM)- and smoke testing (3:30PM to 4:15PM)**

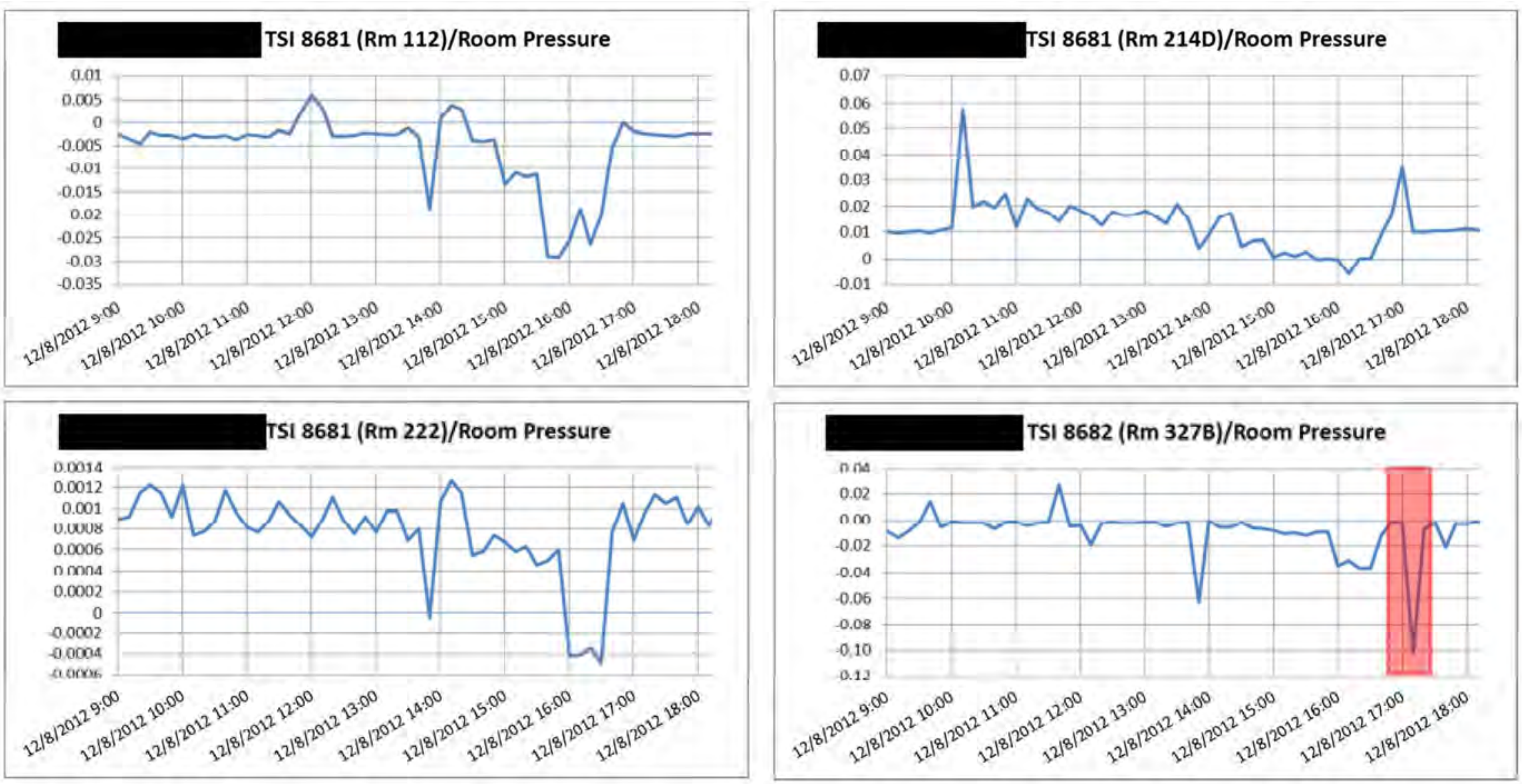



**Figure 91: Room pressures on [redacted], 2012 during E-power (1:45 PM to 3PM)- and smoke testing (3:30PM to 4:15PM). Room pressures below a tenth of an inch noted in red, possible factor in excessive door forces, at two tenths of an inch very likely factor in excessive door forces.**

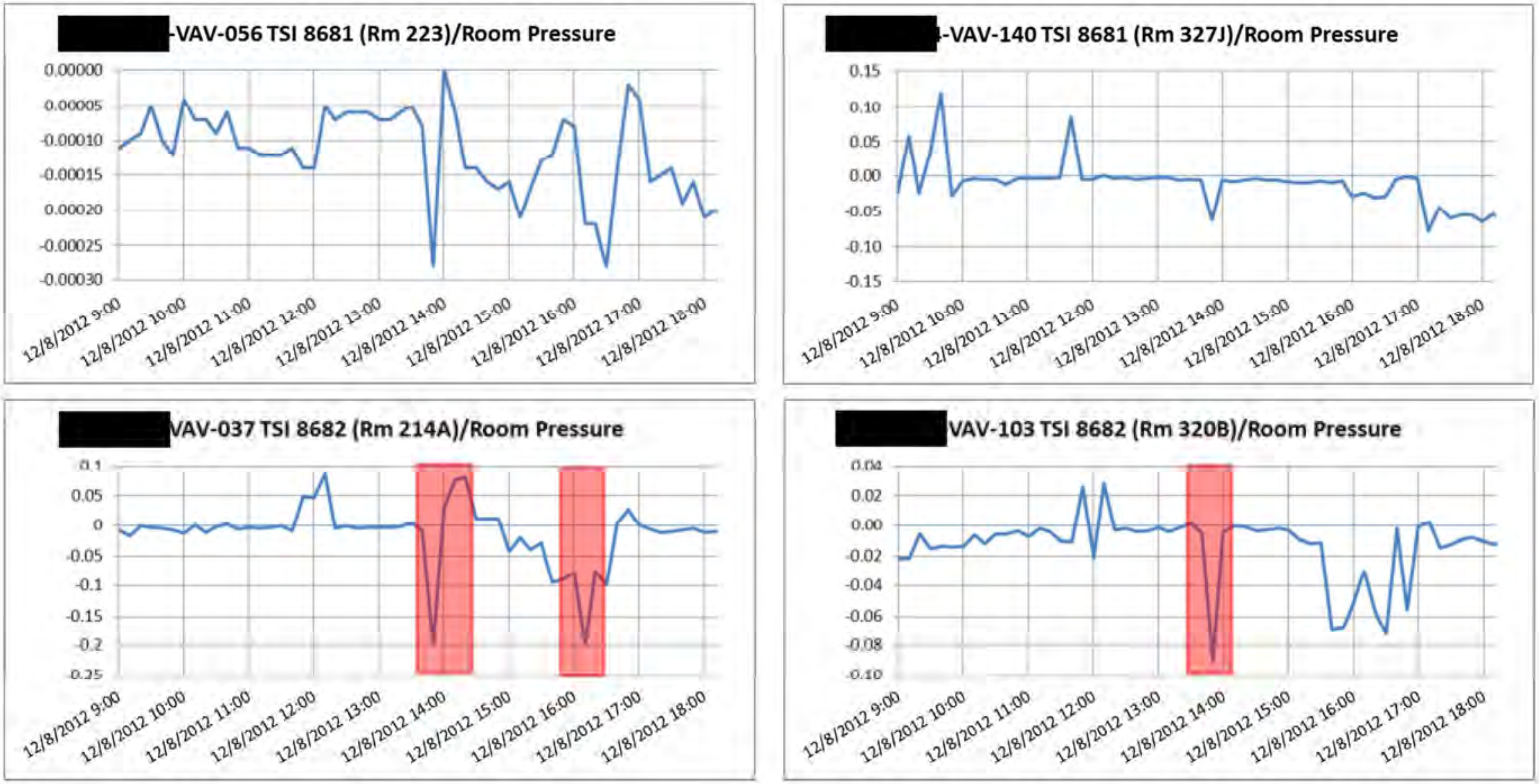



**Figure 92: Room pressures on [redacted], 2012 during E-power (1:45 PM to 3PM)- and smoke testing (3:30PM to 4:15PM). Room pressures below a tenth of an inch noted in red, possible factor in excessive door forces, at two tenths of an inch very likely factor in excessive door forces.**

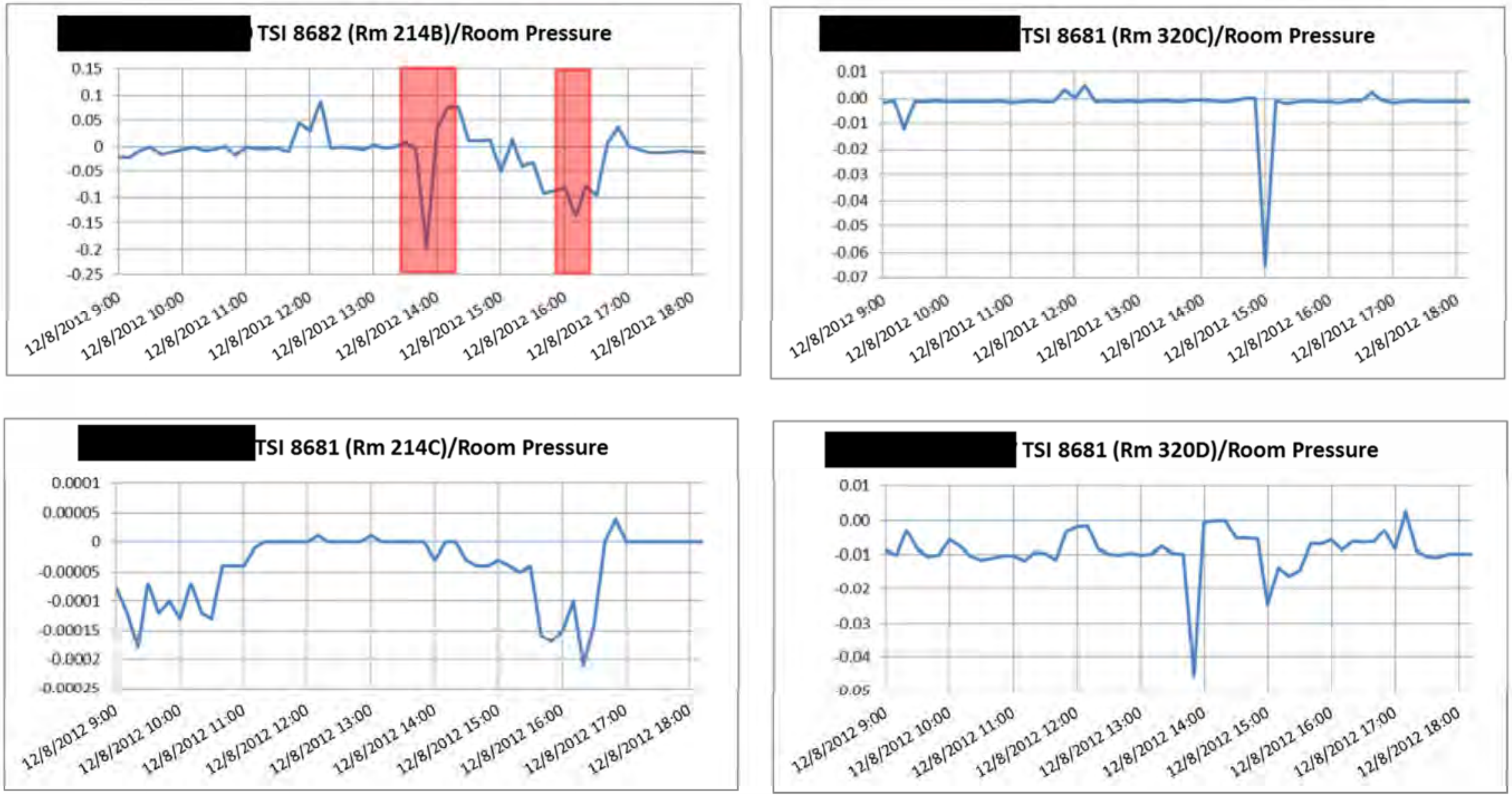
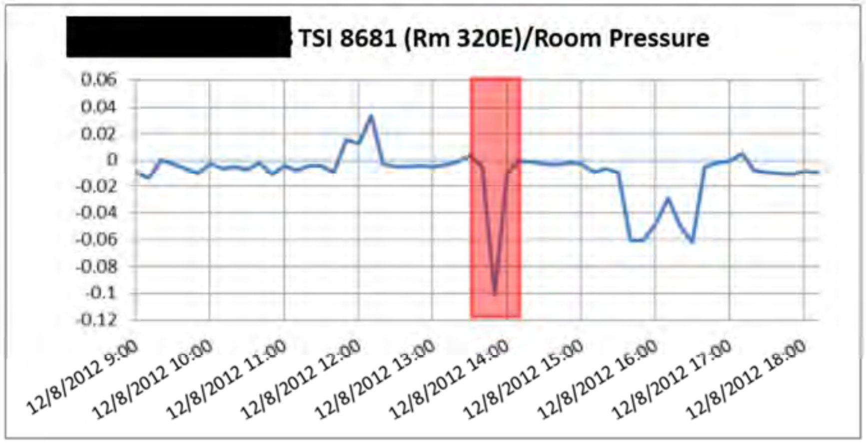
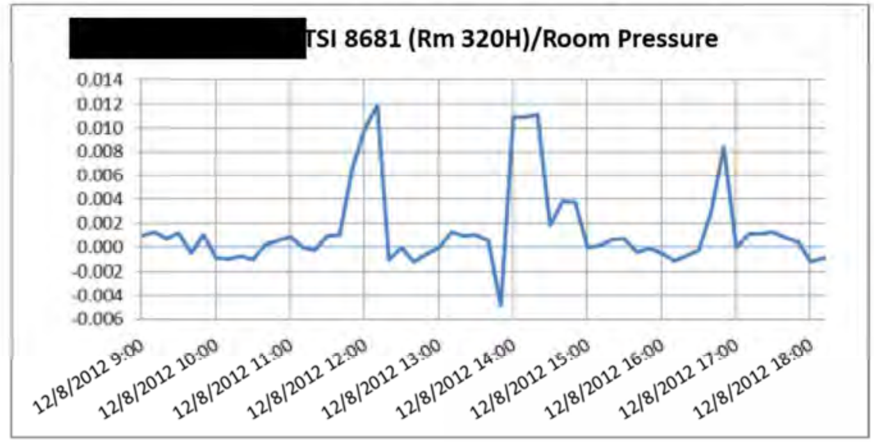



**Figure 93: Room pressures on [redacted], 2012 during E-power (1:45 PM to 3PM)- and smoke testing (3:30PM to 4:15PM). Room pressures below a tenth of an inch noted in red, possible factor in excessive door forces, at two tenths of an inch very likely factor in excessive door forces.**



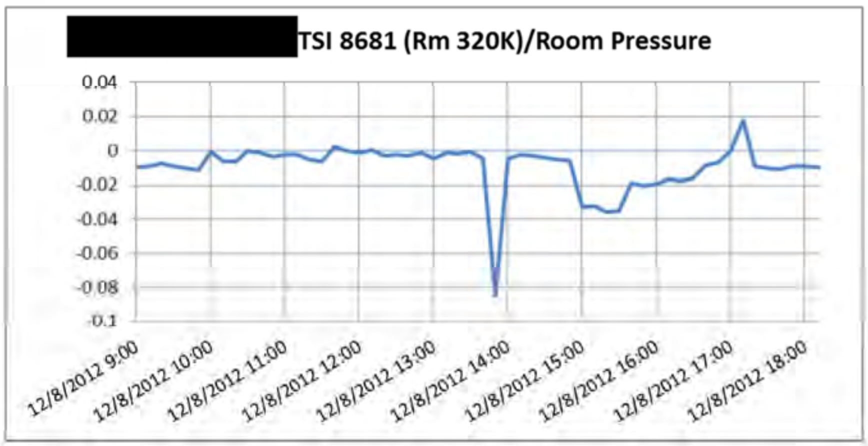




**Figure 94: Room pressures on [redacted] 2012 during E-power (1:45 PM to 3PM)- and smoke testing (3:30PM to 4:15PM). Room pressures below a tenth of an inch noted in red, possible factor in excessive door forces, at two tenths of an inch very likely factor in excessive door forces.**

## 11. Example Trend Review

See below for example of completed trend review

July 14, 2008

XXXXXXXXXX
XXXXXXXXXX
XXXXXXXXXX
XXXXXXXXXX

Subject: XXXXXX Trend Review addendum 1

Dear XXXXX:

Please see the results below of our trend review for the Building at XXXXXXX.

We realize that this report comes after the expiration of the warranty period on the construction of this building; we received trend data on June 18th and have not had the opportunity to review this building earlier.

There are a number of flaws in the operation of the building that should be corrected regardless of the age of the project, such as rapid compressor cycling.

We hope the report will product useful results in the field and are at your disposal to meet with yourself and XXXX to provide comments or explanations.

The graphs were produced using a free tool called the "Universal Translator" or UT, available for download from www.utonline.org, with training videos at http://tedownloads.com/UT/training.shtml

We have posted the export files for the UT on our ftp site so you can review data independently. Access is as follows (all entries case sensitive):

Username: XXXXXXX
Password: XXXXXXX

Sincerely,

# Table of Contents

## Part 1 - Executive Summary

1.01. Overall performance

A. The building is maintained at comfortable levels, but is not operating efficiently.

B. AC-1 and AC-2 do not have correctly functioning economizers.

C. AC-1 and HF-1 are working against each other, causing large reheat penalties.

D. Main AC unit compressors are seriously short cycling, which will affect life span.

E. Rooftop unit fan speed and zone terminal reaction speed should be slowed down to prevent excessively large swings in pressures, airflows and unit operation during unoccupied periods. Most control loops in general are tuned too tightly, causing excessively fast reaction speeds and cycling.

F. Heating fans do not control to setpoint and are excessively hot during Summer, but also during Winter.

G. VAV setpoints look incorrect, and a number of VAV terminals operate “in reverse”, providing more cooling and airflow during occupied periods than during occupied periods.

H. Action summary:

1. **ACTION**: Slow AC unit compressor cycling. See §2.04.F.1.e on page 22.

2. **ACTION**: Reduce minimum outside air intake position on AC-1, AC-2 and provide modulating temperature control on economizer for cold weather. See §2.04.B.4 on page 10.

3. **ACTION**: Slow down fan ramp speed. See §2.04.F.1.d on page 22.

4. **ACTION:** Slow down heating fan supply air temperature control loop, see §2.04.F.2.b on page 27.

5. **ACTION:** HF-2 temperature control ignores setpoint, see §2.04.F.2.c on page 27.

6. **ACTION:** Connect Fancoil unit room sensors for FC 5-3 and 5-5, see §2.05.B on page 28.

7. **ACTION:** VAV setpoints are incorrectly configured and ignored. See §2.06.B on page 28.

8. **ACTION:** VAV setup/setback control causes rapid cycling in rooftop units. Slow down reactions at zone level. See §2.06.G.2 on page 32.

## Part 2 - Detailed Review

2.01. Description of Project

XXXXXXXXX building is a XXX-story structure without basement, served by (2) rooftop dual duct systems. Each system consists of a separate package unit for cooling and a furnace for heating. The floors are served by dual duct terminals and single duct terminals as follows:

| Floor | Nr of Dual Duct Terminals (Heat/Cool) | Nr of Single Duct Terminals (Cooling only) | Trends submitted Dual Duct Terminals | Trends Submitted Single Duct Terminals |
|---|---|---|---|---|
| 1 | XX | XX | 6 | 0 |
| 2 | XX | XX | 7 | 0 |
| 3 | XX | XX | 4 | 0 |

**Table 1: Submitted trend data for VAV terminals**

Note that, for the performance of systems review, no single duct (cooling only) terminals were reviewed. This is significant because the use of cooling-only air terminals can sometimes lead to cold spaces, when minimum required airflow provides more cooling than the internal loads require.

2.02. Project Targets

The aims of this retrofit project were:

- Providing DDC control to the zone level for the upper two floors

- A reduction of overall energy use

- Improved ability to monitor and control the building

2.03. Trend Review Period

A. The charts below show the two periods during which trends were reviewed, and the coincident weather conditions.

B. The Winter period for review extends from December 1, 2007 to February 10, 2008, or 10 weeks.

C. The Summer period for review extends from May 1, 2008 to June 12, 2008, or 6 weeks.

D. All charts used in the report titled "Summer" or "Winter" extend across these two periods. Weekly charts are time-averaged by hour across either 6 or 10 weeks.

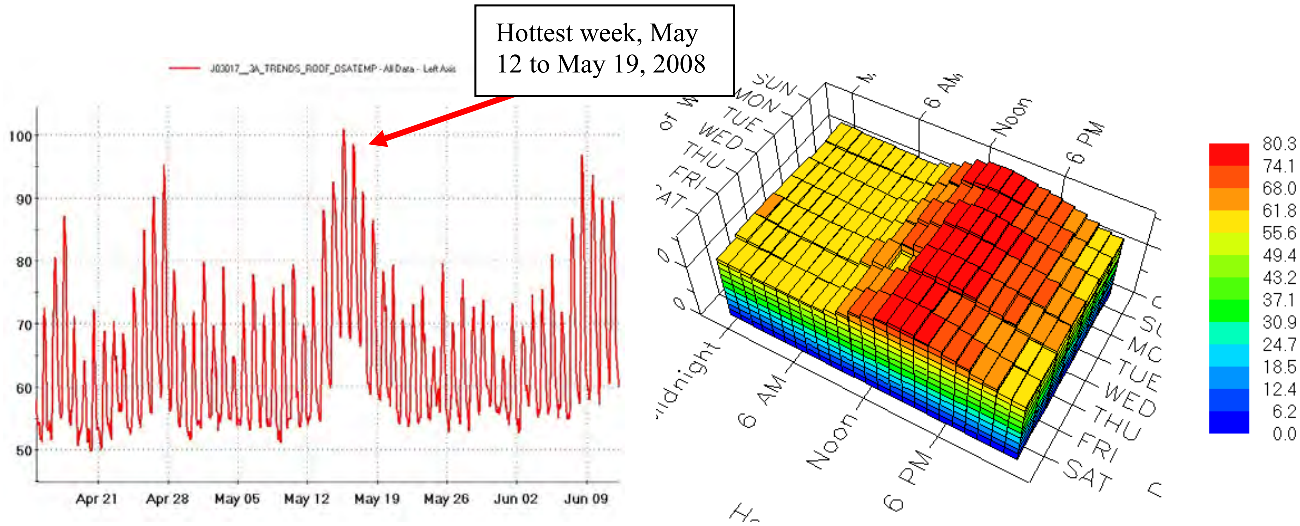



**Figure 1: Outside air temperature during April to June 2008**

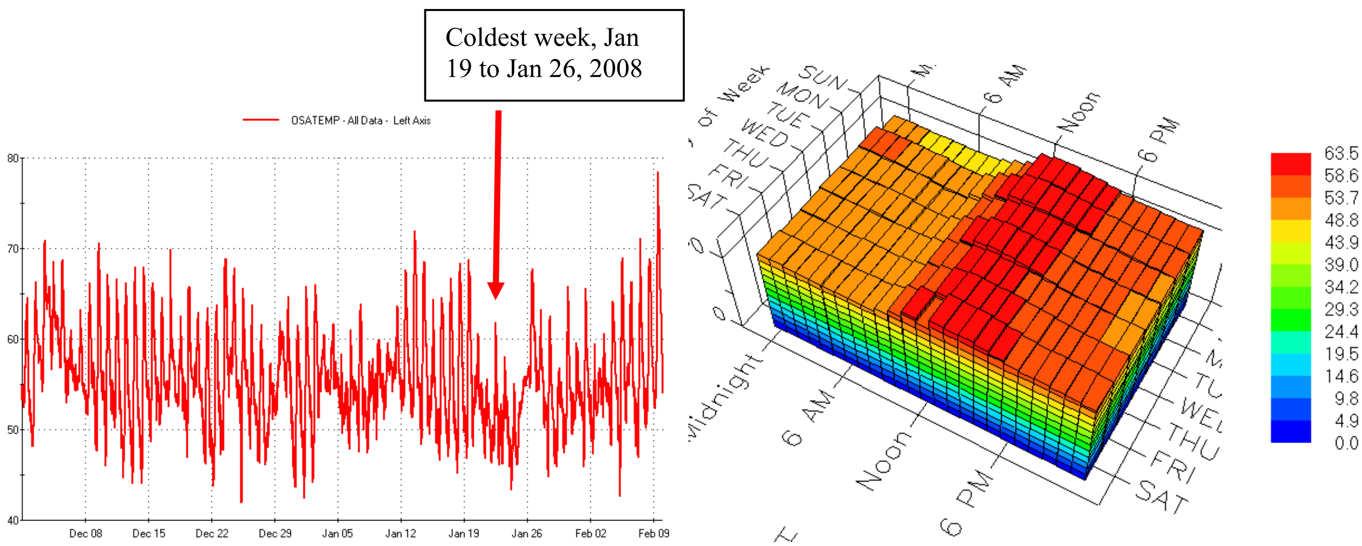



**Figure 2: Outside air temperature during Dec 2007 to Feb 2008, time series (left) and weekly chart (right)**

2.04. AC and HF unit Operation

A. Scheduling

1. The graphs below show scheduling for the periods of Winter (Dec 1, 2007 through Feb 10, 2008) and Summer (May 1, 2008 through June 12, 2008). Note that the graphs are time-averaged on an hourly basis, so that a "fan status" value of 0.5 means the fan was on for 30 minutes and off for 30 minutes on average.

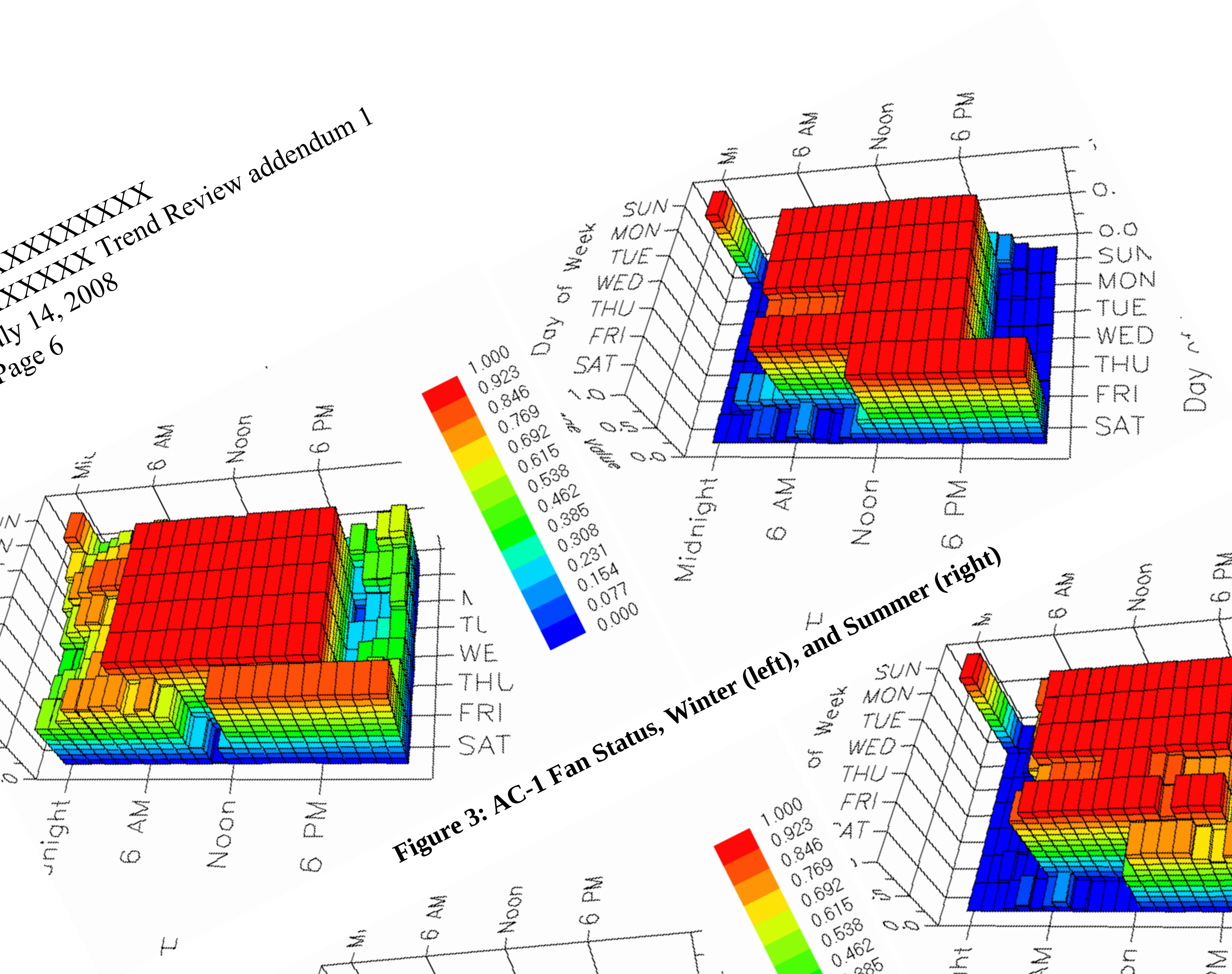



**Figure 3: AC-1 Fan Status, Winter (left), and Summer (right)**

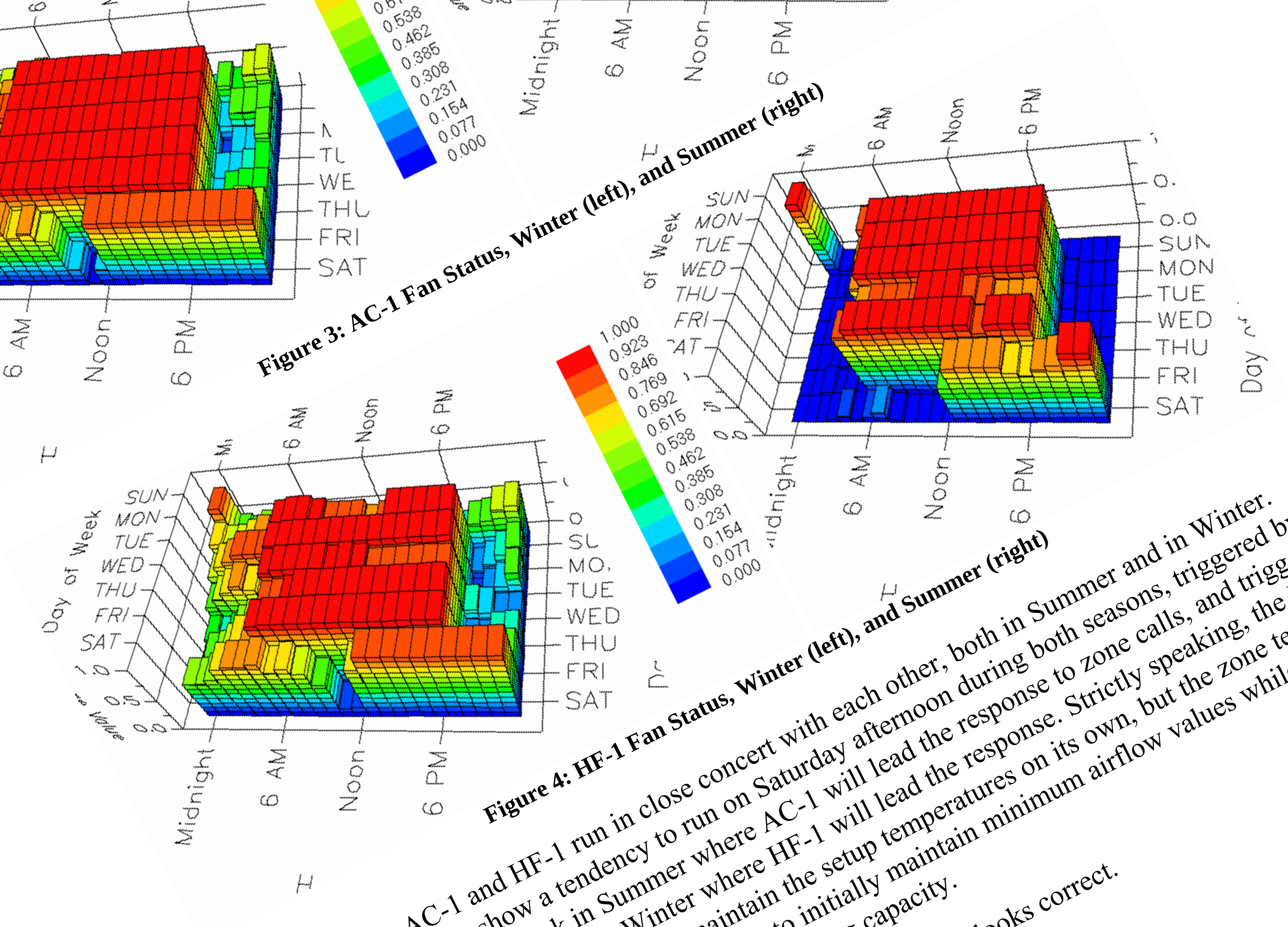



**Figure 4: HF-1 Fan Status, Winter (left), and Summer (right)**

2. AC-1 and HF-1 run in close concert with each other, both in Summer and in Winter. They show a tendency to run on Saturday afternoon during both seasons, triggered by zone setback in Summer where AC-1 will lead the response to zone calls, and triggered by zone setup in Winter where HF-1 will lead the response. Strictly speaking, the HF-1 unit would be able to maintain the setup temperatures on its own, but the zone terminal logic runs cold deck airflow to initially maintain minimum airflow values while using hot deck airflow to trim for heating capacity.

3. As such, the scheduling for AC-1 and HF-1 looks correct.

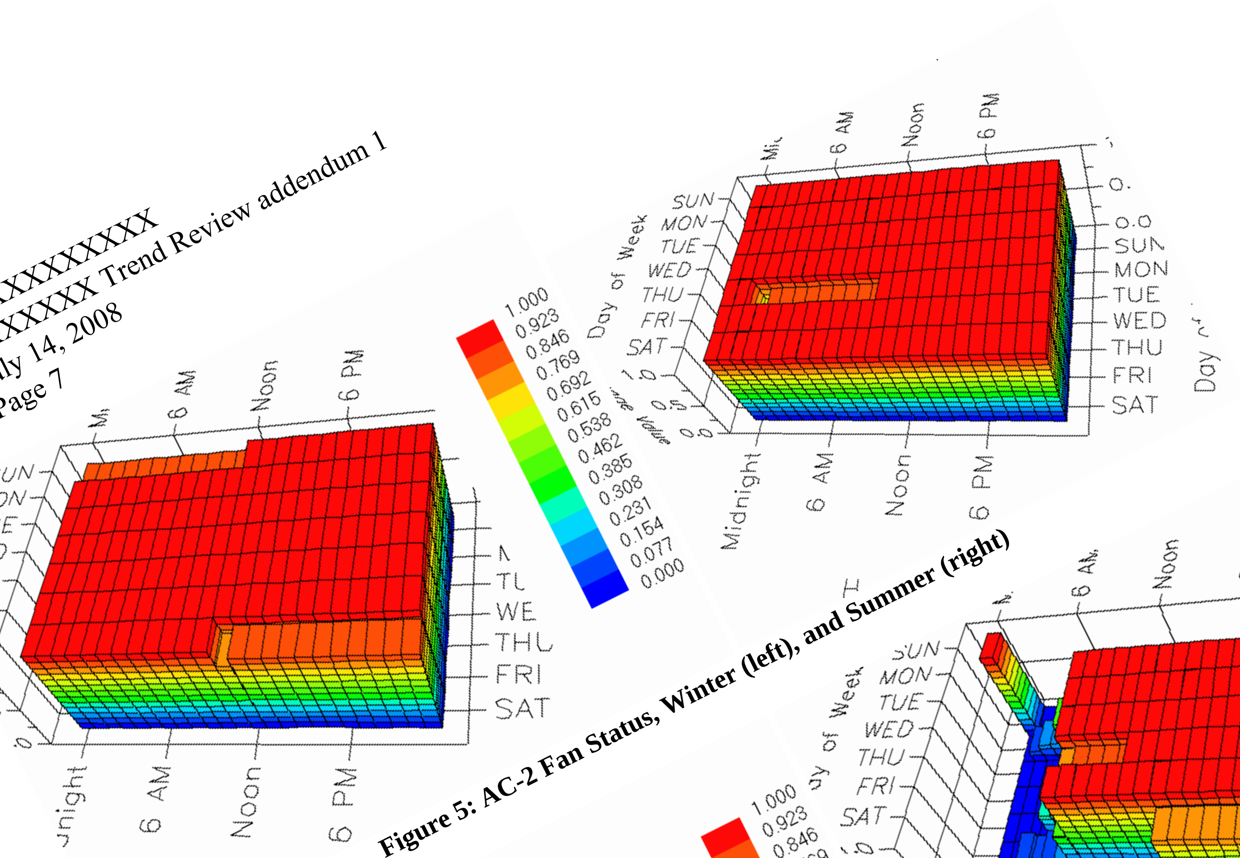



**Figure 5: AC-2 Fan Status, Winter (left), and Summer (right)**

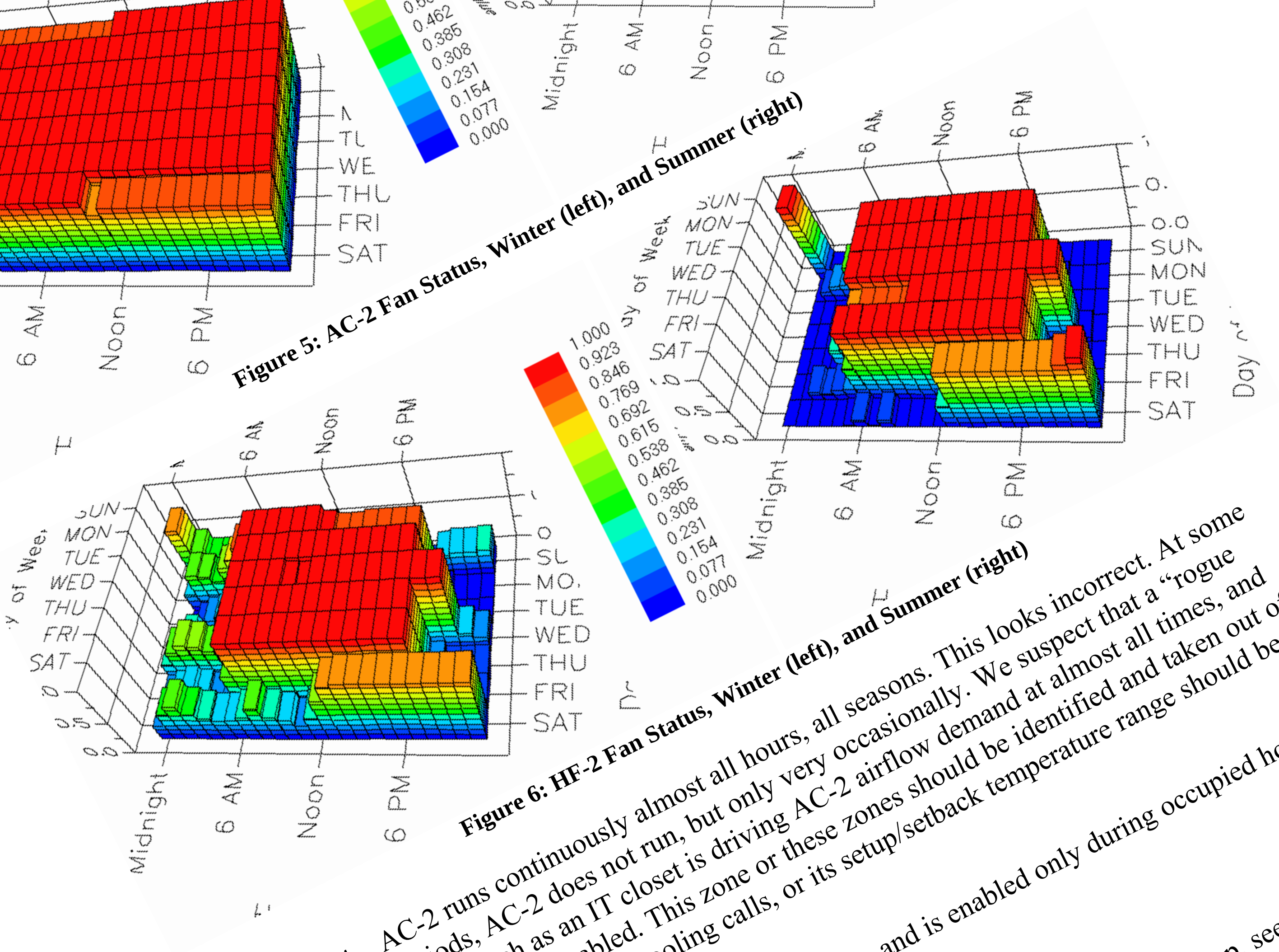



**Figure 6: HF-2 Fan Status, Winter (left), and Summer (right)**

4. AC-2 runs continuously almost all hours, all seasons. This looks incorrect. At some periods, AC-2 does not run, but only very occasionally. We suspect that a “rogue zone” such as an IT closet is driving AC-2 airflow demand at almost all times, and keeps AC-2 enabled. This zone or these zones should be identified and taken out of the list that is used for cooling calls, or its setup/setback temperature range should be widened significantly.

5. HF-2 does not follow the same logic, and is enabled only during occupied hours or when zone setup appears correct.

B. Economizer operation

1. Both AC-1 and AC-2 have economizers that are incorrectly set up, see the eco graphs on the following pages. These consist of a scatter chart showing outsi temperature against ideal (blue) and actual (red) mixed air temperature.

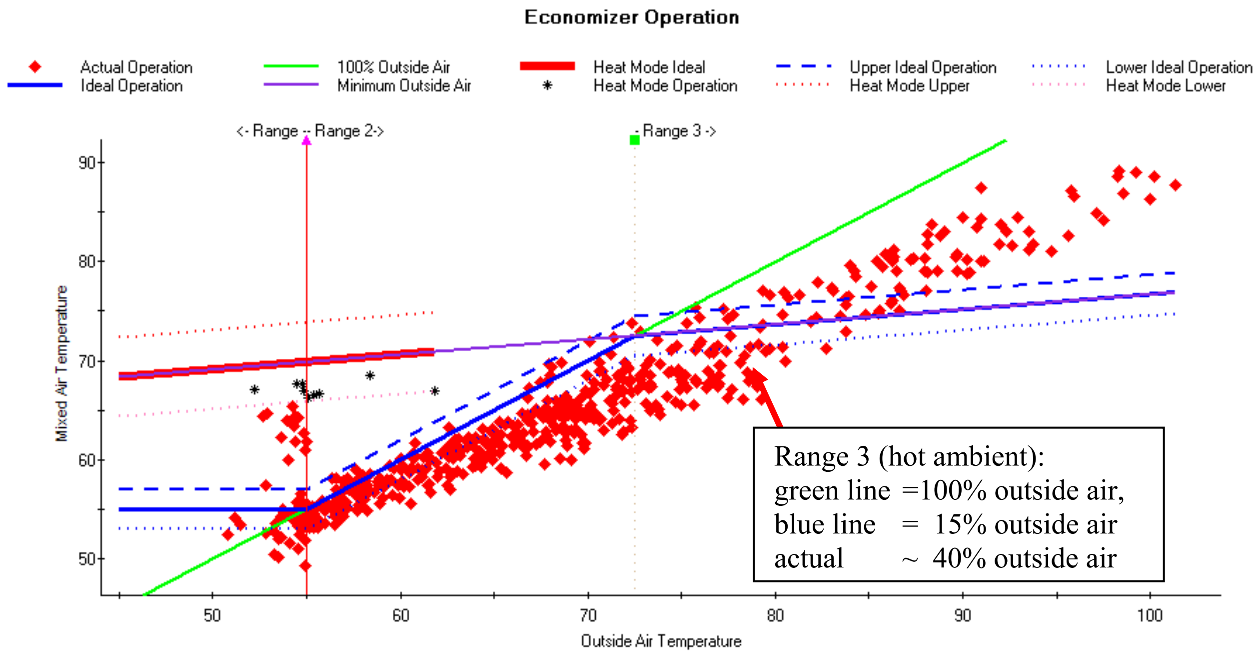



**Figure 7: AC-1 Economizer operation, Summer, Approx. 40% min. Outside Air**

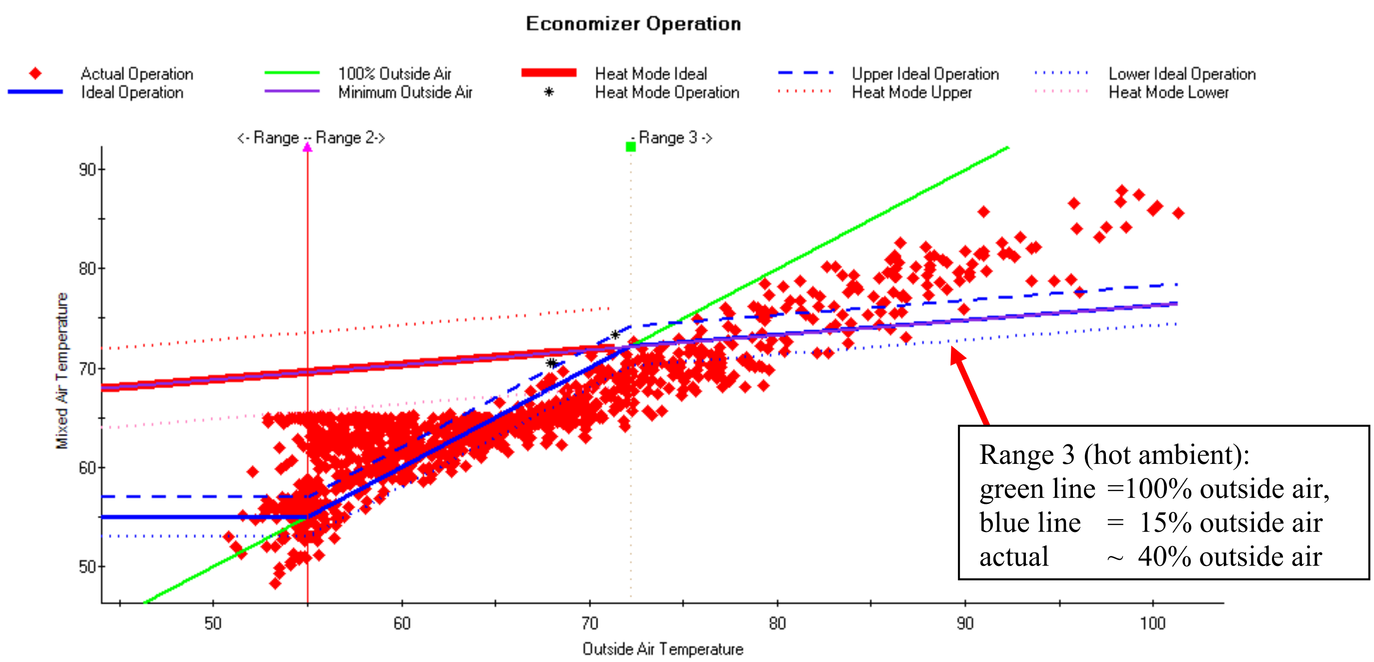



**Figure 8: AC-2 Economizer operation, Summer, Approx. 40% min. Outside Air**

2. Each unit appears to have a very high percentage of minimum outside air in summer (around 40%), which indicates that the minimum damper positions were not calibrated during startup.

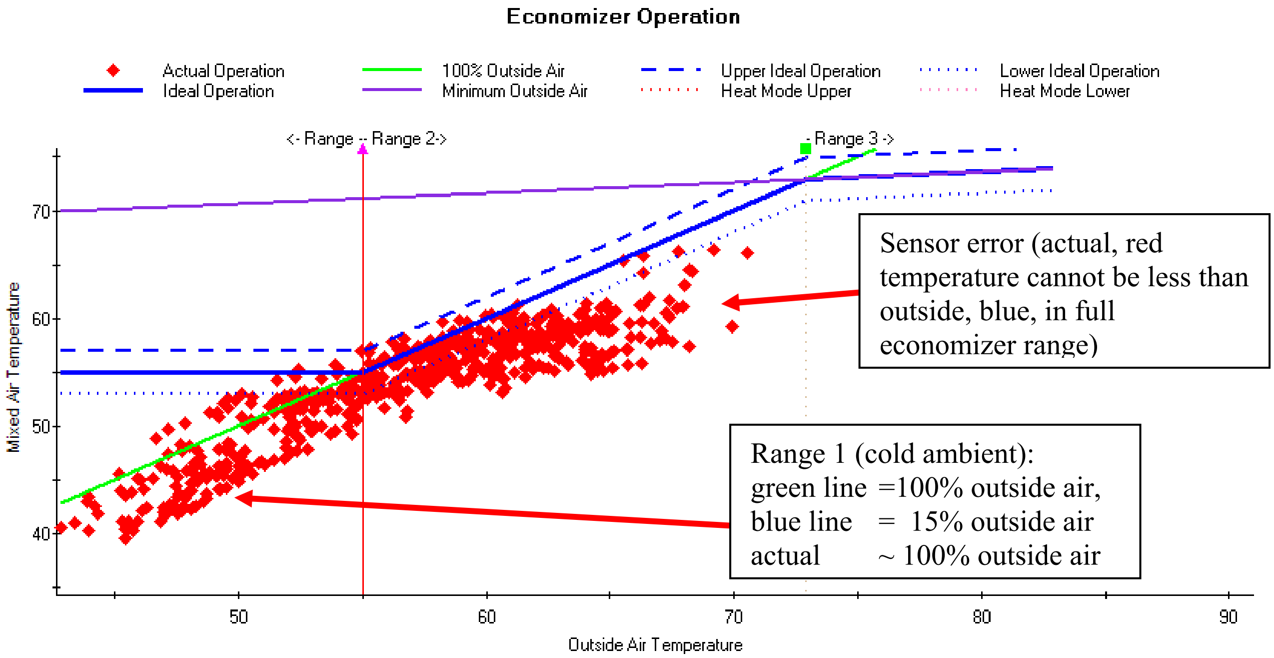



**Figure 9: AC-1 Economizer operation, Winter**

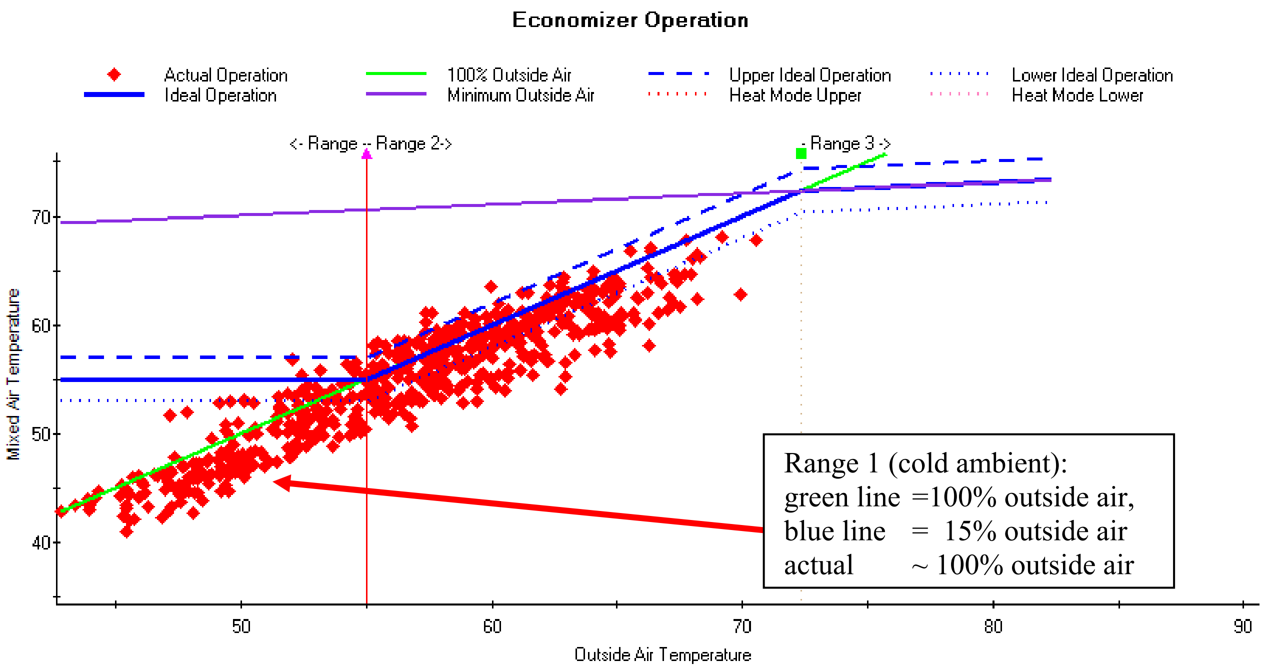



**Figure 10: AC-2 Economizer operation, Winter**

3. Each unit also appears not to modulate the economizer damper for temperature control during very cold weather. Instead, the units remain in 100% outside air mode. As a result, 45°F air is brought into the building and has to be reheated at a significant energy penalty.

4. The economizer operation for both units should be corrected as follows:

    a. Reduce minimum outside air intake position by providing balancing as described in California T24, see pages 4-18 to 4-25 (18 to 25 of 116) in chapter 4 of http://www.energy.ca.gov/title24/2005standards/nonresidential_manual.html

    b. Since there is no dedicated outdoor air damper or airflow measurement in the mechanical systems at XXXX, we suggest using the 2-point balancing method described in the T24 user manual on page 4-19. Note that a single, fixed minimum setpoint for the outside air damper does not meet code.

    c. The low temperature portion of the economizer cycle should respond by closing the economizer damper to provide no less than the supply air temperature reset temperature for the AC unit. Supplying 45°F air is incorrect, since the building will never require such cold air during winter. Instead, the economizer has to close to maintain supply air temperature at setpoint, and (during very cold weather, which is unlikely to occur in California) to close to minimum outside air fraction.

    d. AC-1 shows pronounced sensor error in winter. This is shown in Figure 9, where the scatter chart of mixed air temperature points is skewed toward the right in range 2, away from the blue line showing ideal operation of 100% economizer. This indicates a mixed air temperature below outside air temperature, which is physically impossible for a unit in this range. Return air temperature in this range is above outside air temperature, and so mixed air temperature is at best equal to outside air temperature in a perfect economizer, or somewhat higher than outside air with a leaking return air damper. What is curious is that the distance between the scatter of actual values, and the line of outside air (blue) in this region is not constant, indicating a non-uniform sensor error. This is most likely to an error in the outside air temperature sensor due to solar radiation, to the tune of about 6°F on average, with as much as 10°F offset.

    e. Correcting the outside air temperature by 6°F on average moves both AC-1 and AC-2 to a picture that shows the economizer practically 100% open for hot weather as well as cold weather, see graphs below.

    f. Note that, in all of the economizer examples shown, actual temperatures were filtered for occupied periods (fan running) to avoid false readings during unoccupied periods.

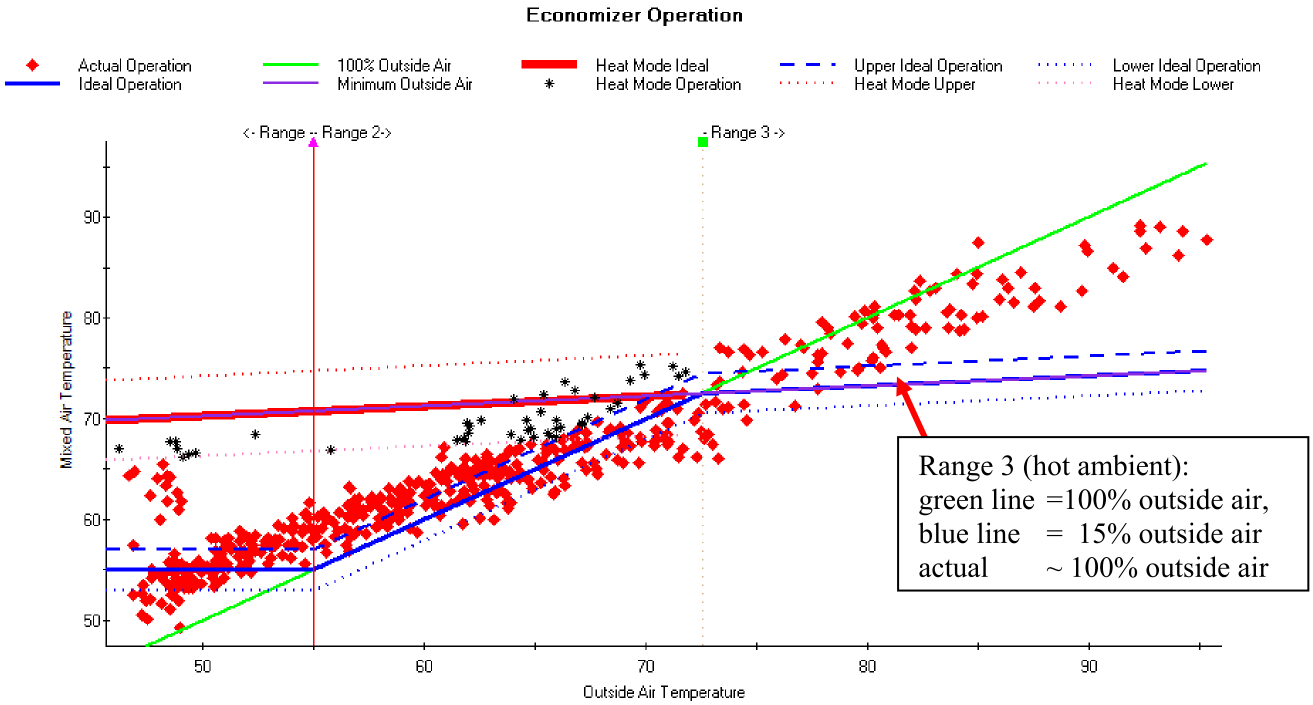



**Figure 11: AC-1 Economizer operation, Summer, adjusted outside air temperature**

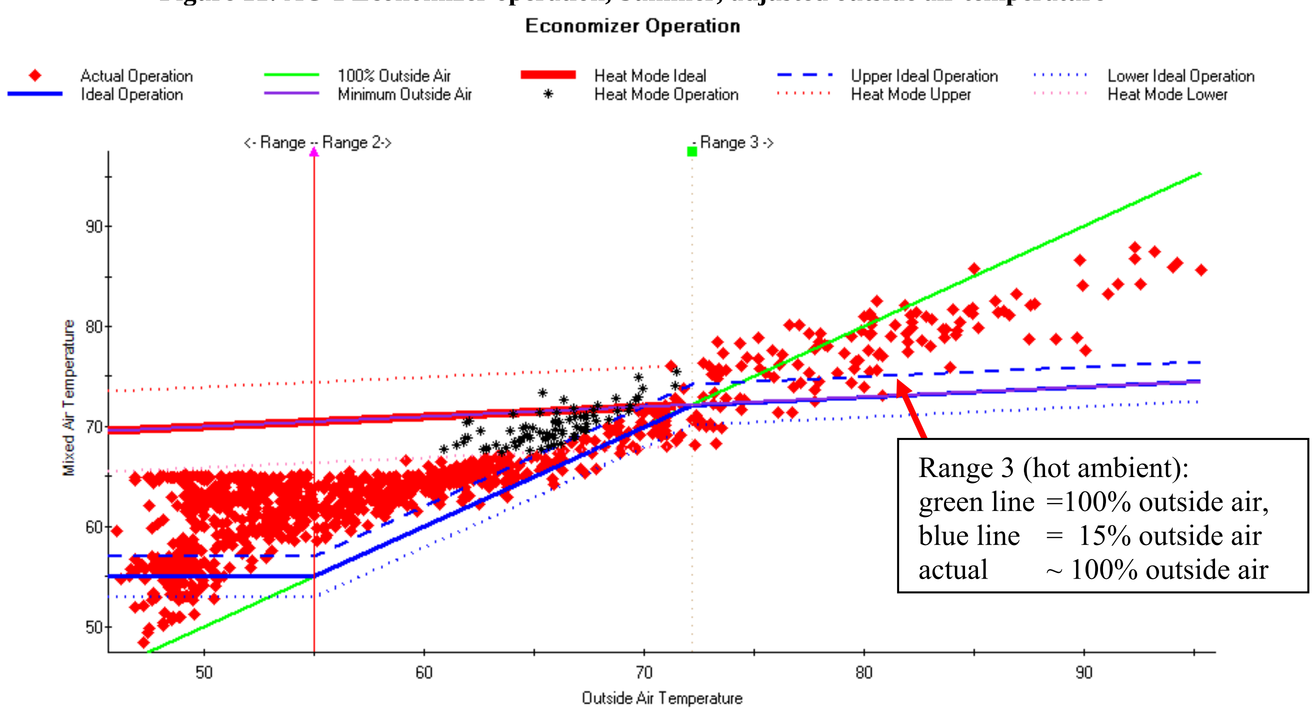



**Figure 12: AC-2 Economizer operation, Summer, adjusted outside air temperature**

C. AC and HF unit Capacity

1. Both AC units appear to have sufficient capacity to meet design criteria. There is a week in the trend range (May 12 to May 19) that is clearly above design, peaking at

around 100°F. During this period, both AC-1 and AC-2 run with all compressor stages enabled and supply fans at full speed.

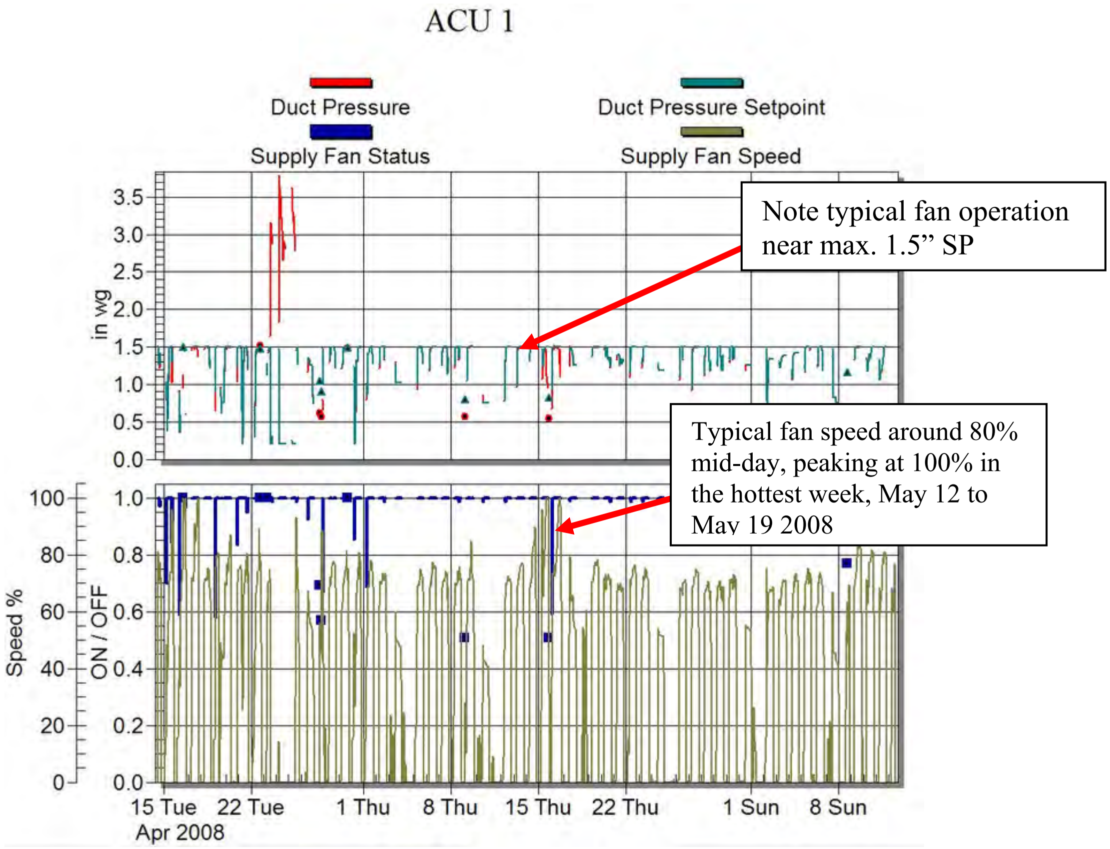



**Figure 13: AC-1 performance from April to first week of June**

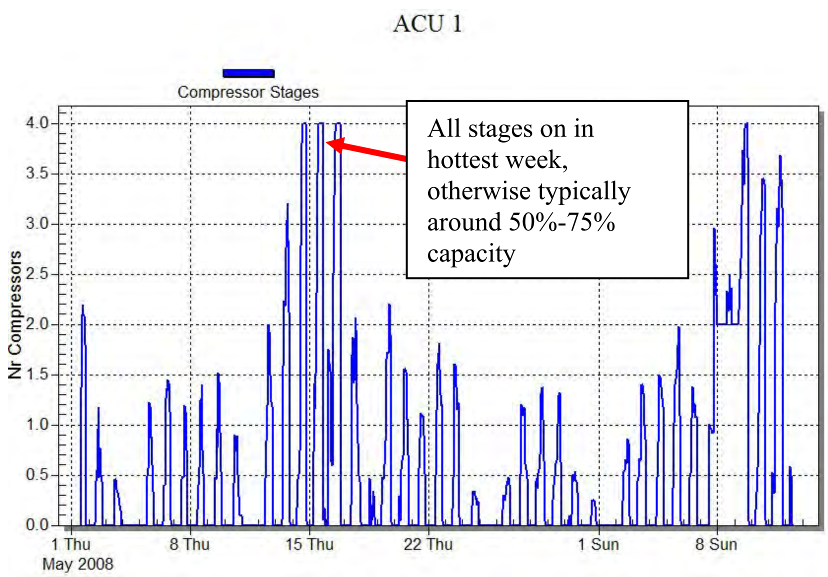



**Figure 14: AC-1 compressor 6 weeks from May to first week of June**

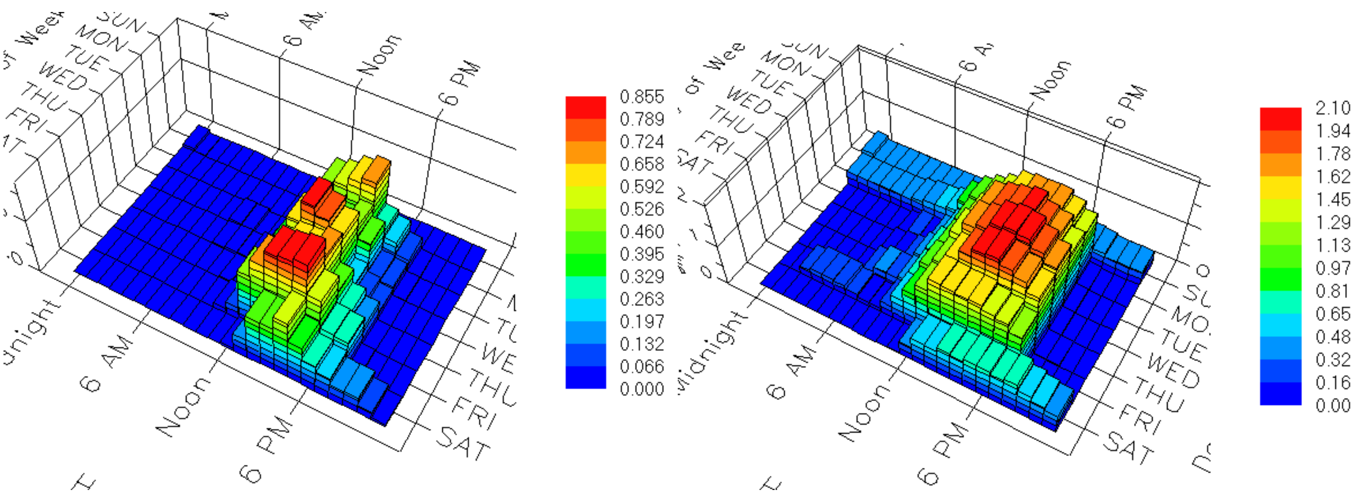



**Figure 15: AC-1 compressor status, hourly average Winter (left) and Summer (right)**

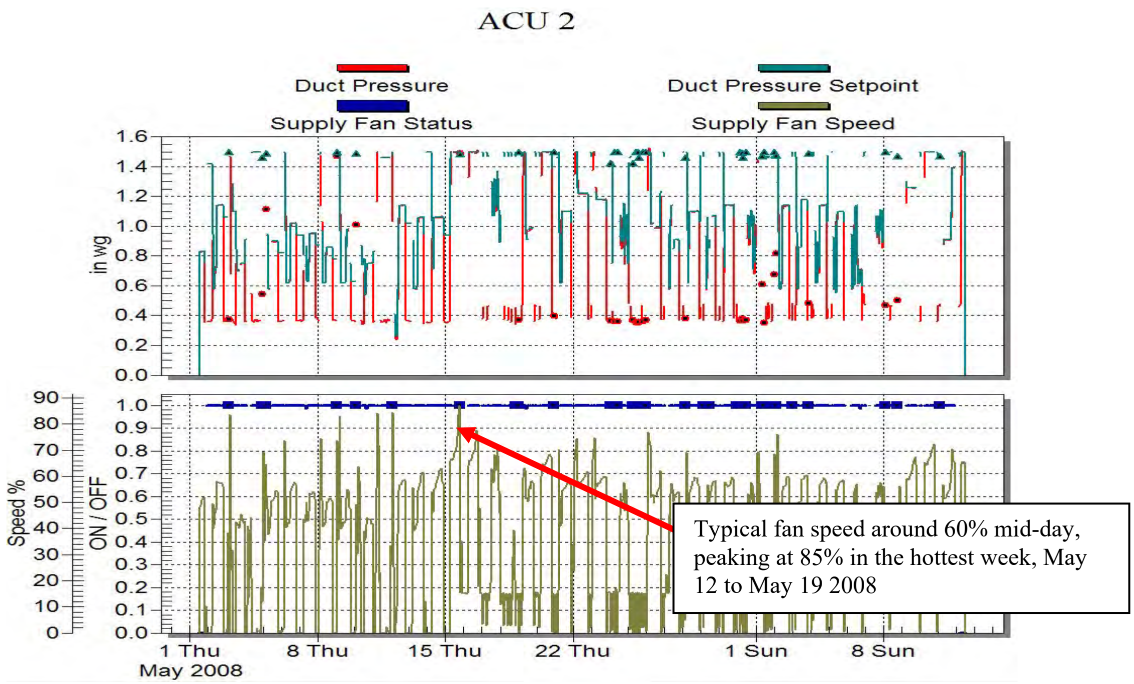



**Figure 16: AC-2 fan performance from May through June 2008**

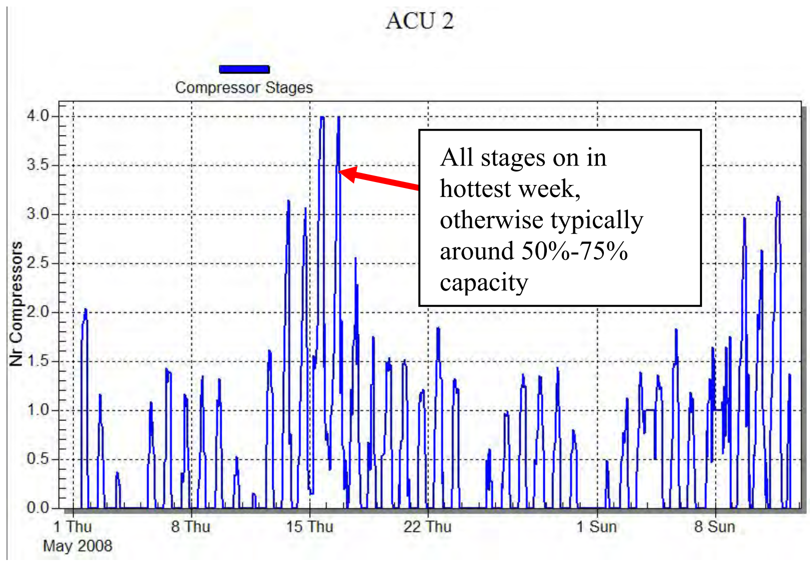



**Figure 17: AC-2 compressor 6 weeks from May to first week of June**

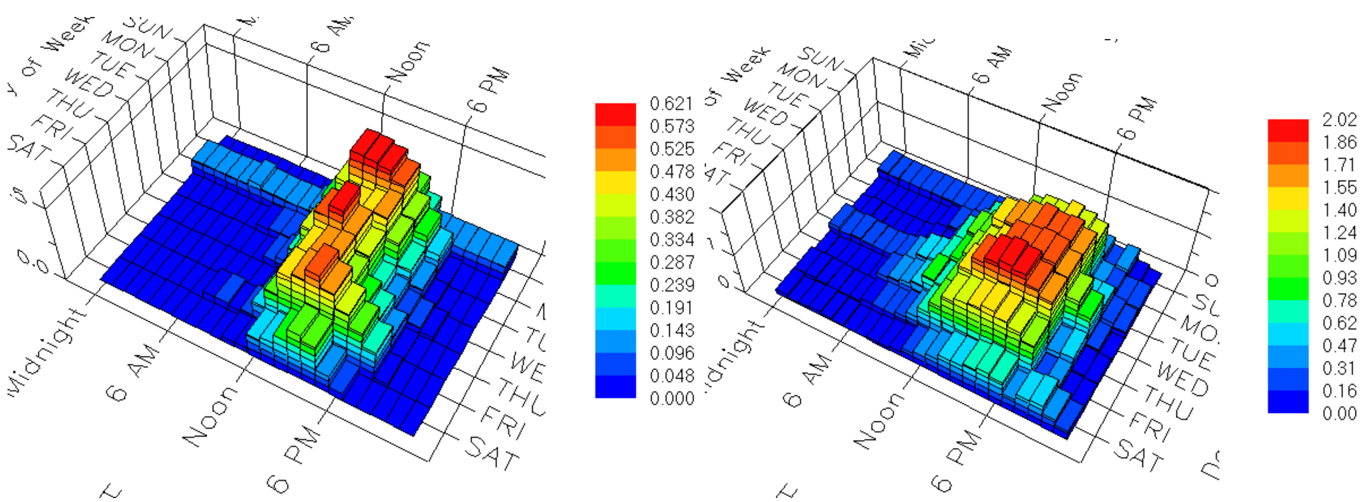



**Figure 18: AC-2 compressor status, hourly average Winter (left) and Summer (right)**

D. Pressure reset

1. The figures below show fan pressure and fan speed for all rooftop units across both Winter and Summer seasons.

2. AC-1 runs runs right around the maximum pressure defined in the reset schedule, 1.5”wg during most of the occupied period. This indicates that the mechanism which is put in place for pressure reset works, but for some reason is not very effective on AC-1. More on this topic follows the review of HF-1.

3. HF-1 operation appears to be the reason for the constant high pressure on AC 1: the cooling system AC 1 and heating system HF 1 appear to be fighting – HF1 is running at almost full speed the entire week, even during the warmest time in the trend period (May-June 2008).

**AC-1 / HF-1 operation, Summer**

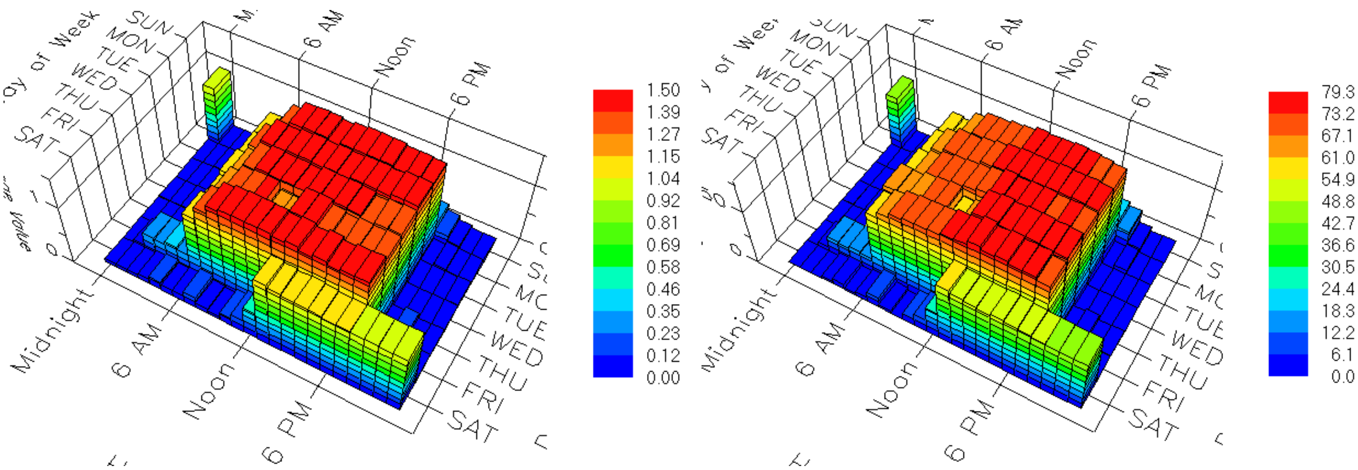



**Figure 19: AC-1 Fan pressure (left) and speed (right) time averaged over 6 weeks from May 5 to June 6 2008**

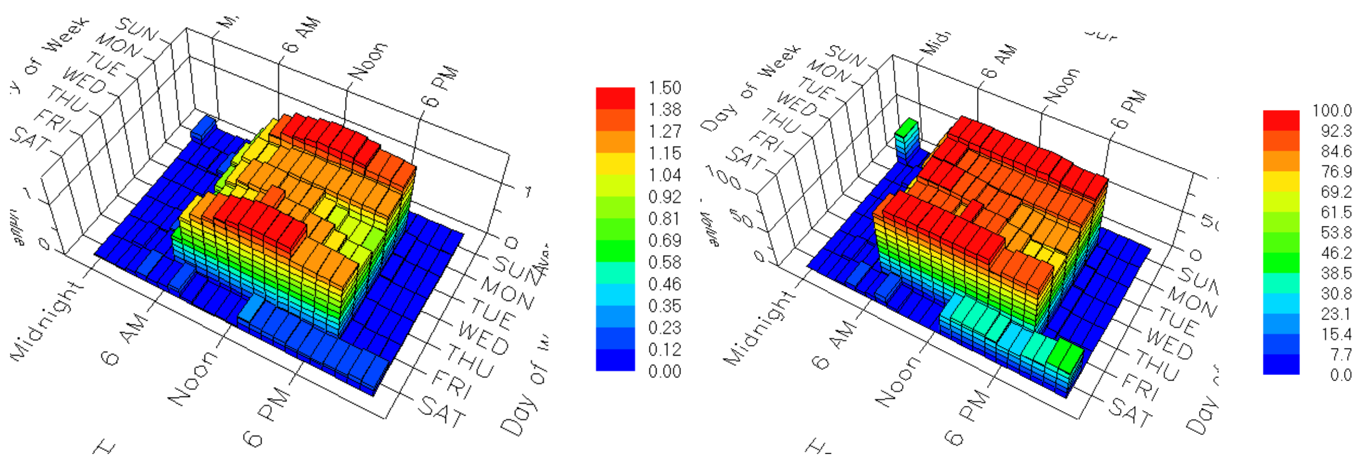



**Figure 20: HF-1 Fan pressure (left) and speed (right), time averaged over 6 weeks from May 5 to June 6 2008**

4. We suspect that the tuning of loops or setting of air volumes may be to blame. If VAV terminals, connected to AC1 / HF1, have supply air minimums that are too high, the sequence of operations will mix in hot air to temper the cold air streams in moderate periods. But for high air volumes, this simply means incurring large reheat penalties, such as a clearly visible on AC1/HF1. While the static reset mechanism itself may work, it is defeated by zones calling for more air volume at all times.

5. The high fan speeds, coupled with high static pressure, mean that there is significant airflow – if only one or two zones were calling for air, the supply pressure could be maintained with far lower fan speeds.

**AC-2 / HF-2 operation, Summer**

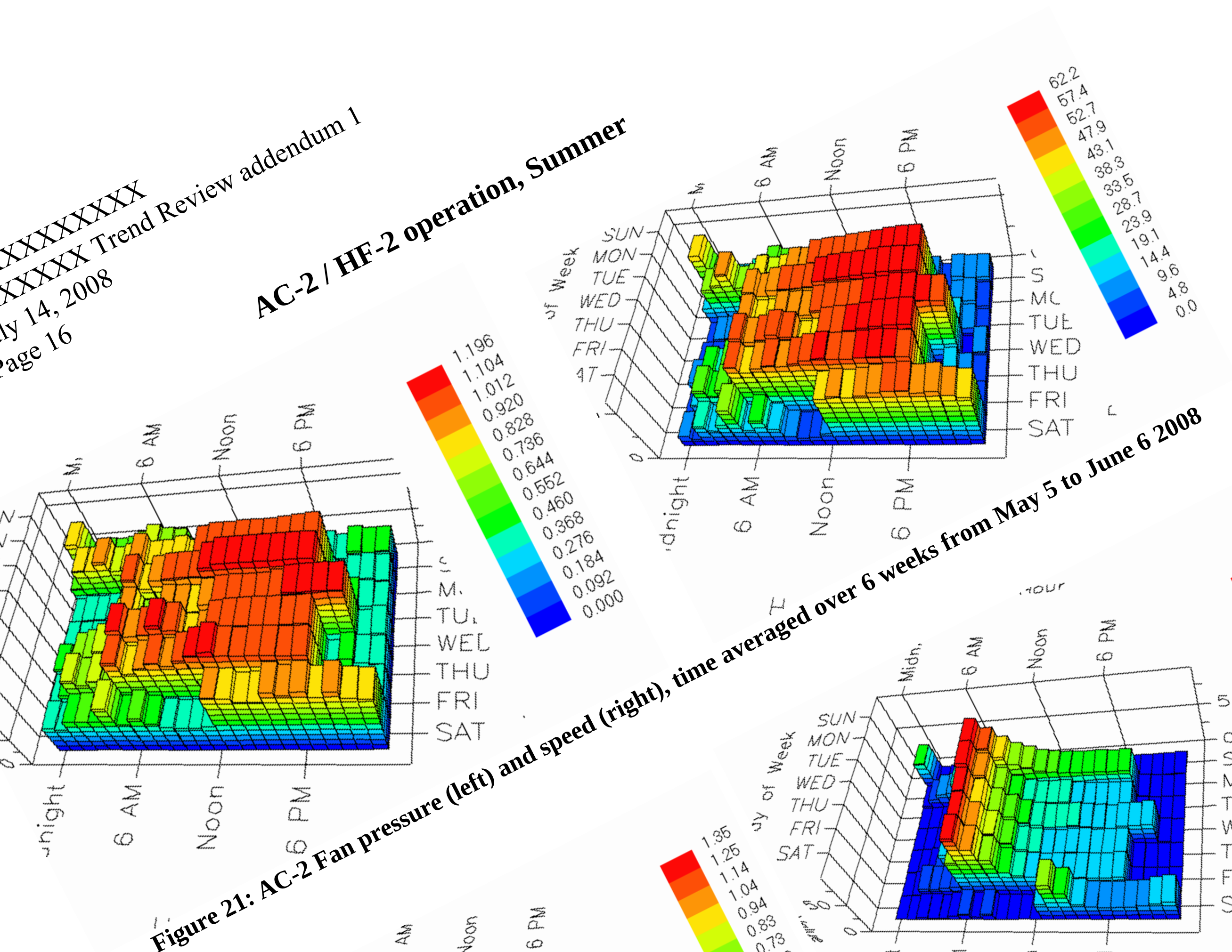



**Figure 21: AC-2 Fan pressure (left) and speed (right), time averaged over 6 weeks from May 5 to June 6 2008**

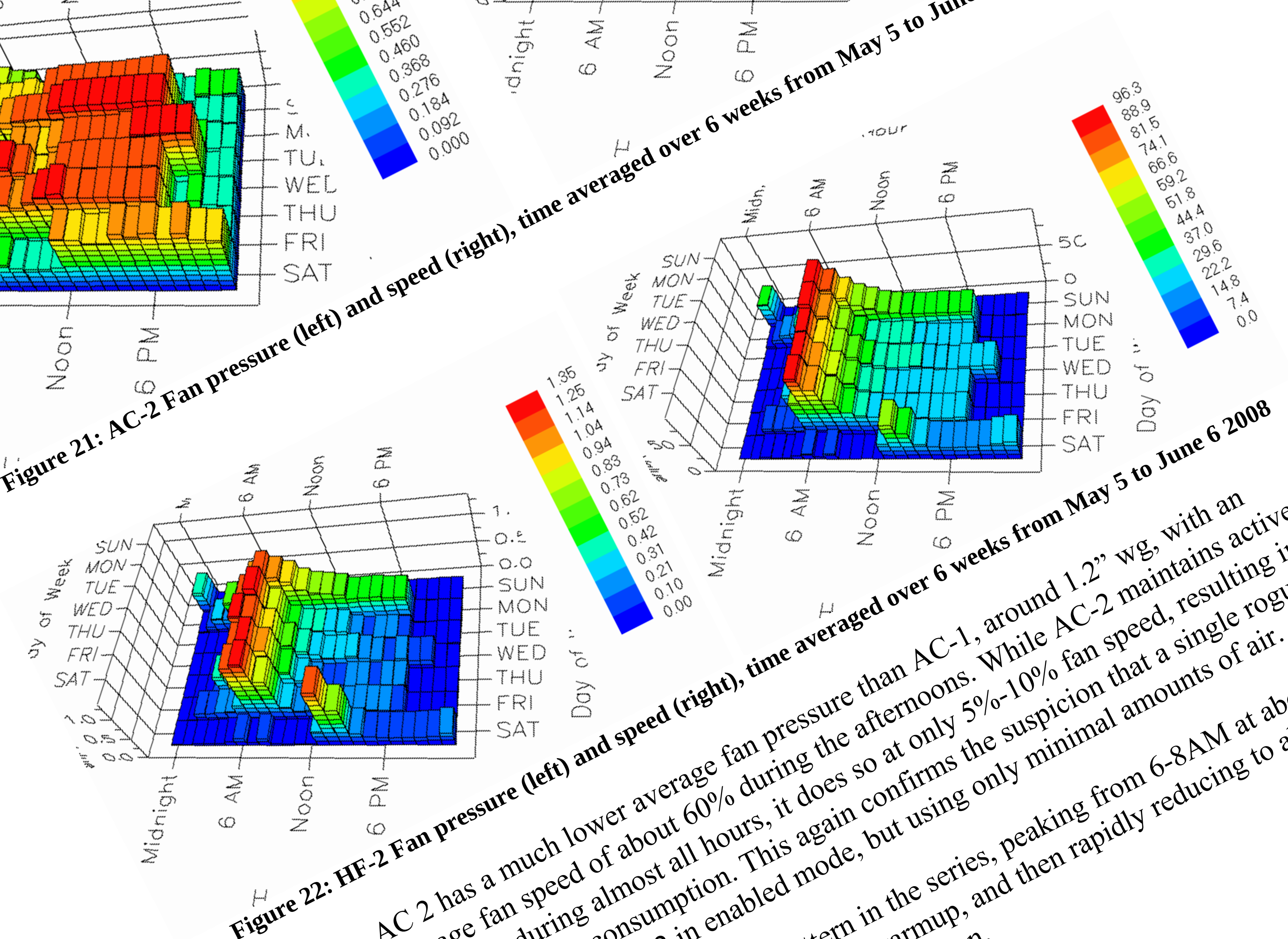



**Figure 22: HF-2 Fan pressure (left) and speed (right), time averaged over 6 weeks from May 5 to June 6 2008**

6. AC 2 has a much lower average fan pressure than AC-1, around 1.2" wg, with an average fan speed of about 60% during the afternoons. While AC-2 maintains active fan status during almost all hours, it does so at only 5%-10% fan speed, resulting in minimal power consumption. This again confirms the suspicion that a single rogue zone is keeping AC-2 in enabled mode, but using only minimal amounts of air.

7. HF 2 shows the only "good" pattern in the series, peaking from 6-8AM at about 1.35" duct static at full speed for morning warmup, and then rapidly reducing to about 0.3… static pressure at 20% fan speed around noon.

## AC-1 / HF-1 operation, Winter

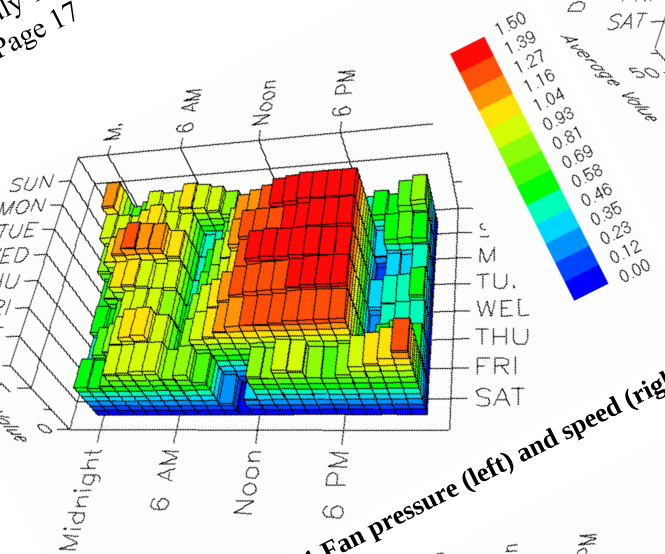
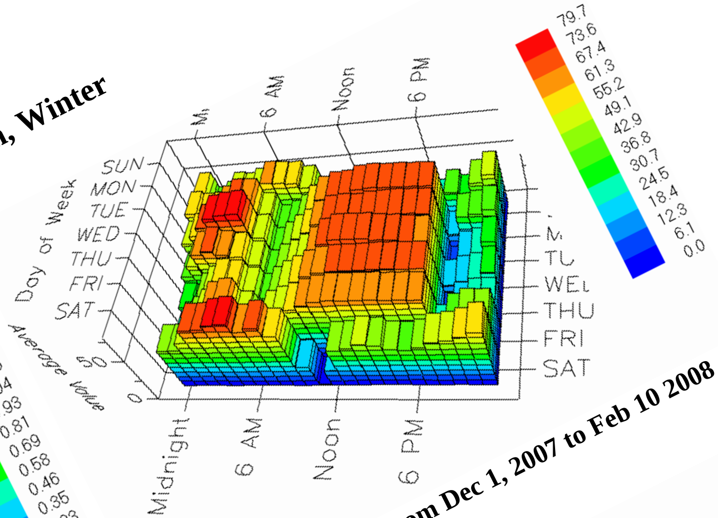



**Figure 23: AC-1 Fan pressure (left) and speed (right) time avg over 10 weeks from Dec 1, 2007 to Feb 10 2008**

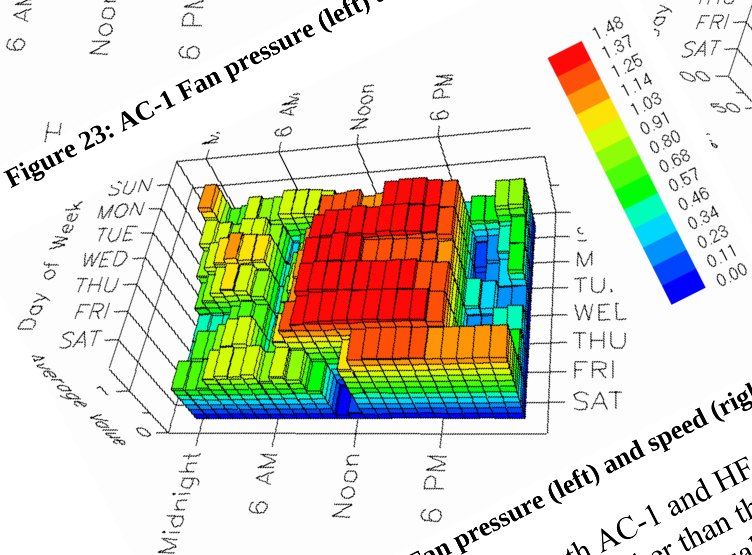
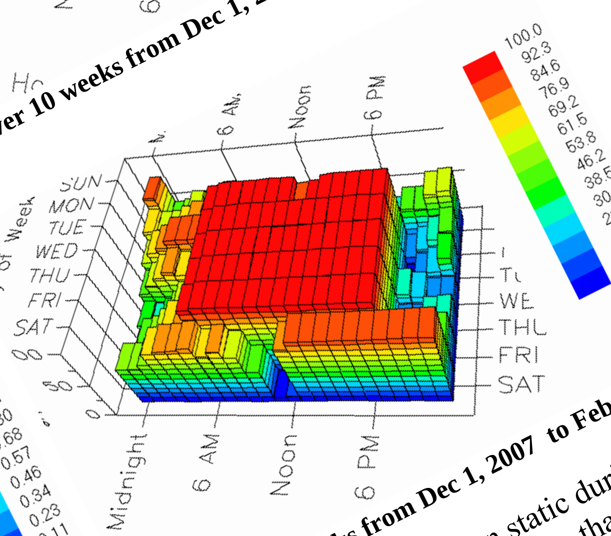



**Figure 24: HF-1 Fan pressure (left) and speed (right), time avg over 10 weeks from Dec 1, 2007 to Feb 10 2008**

8. Once again, both AC-1 and HF-1 show high fan speed and high fan static during all occupied periods other than the mornings, where AC-1 does reset to less than 80% fan speed. Note that AC-1 actually peaks at 5AM on Tuesdays, reaching 80% fan speed on average, but reaching 100% on Jan 22 and exceeding 90% on December 25 to January 8 at 5AM. These are the coldest days of the year, so it is not likely that AC-1 needs to be running at full speed to satisfy warmup requests from spaces at 5AM.

9. From the VAV terminals that were submitted, we are unable to draw conclusions abo the rogue zone ID. Not all terminal data was submitted, and while airflow values we submitted in some cases, air flow setpoints for terminals were not submitted.

10. We would suggest checking all airflow settings for zones connected to AC1/HF few key drivers or "rogue zones" may be responsible for the behavior of both HF1, and leading to large wasted fan power expenditures.

## AC-2 / HF-2 operation, Winter

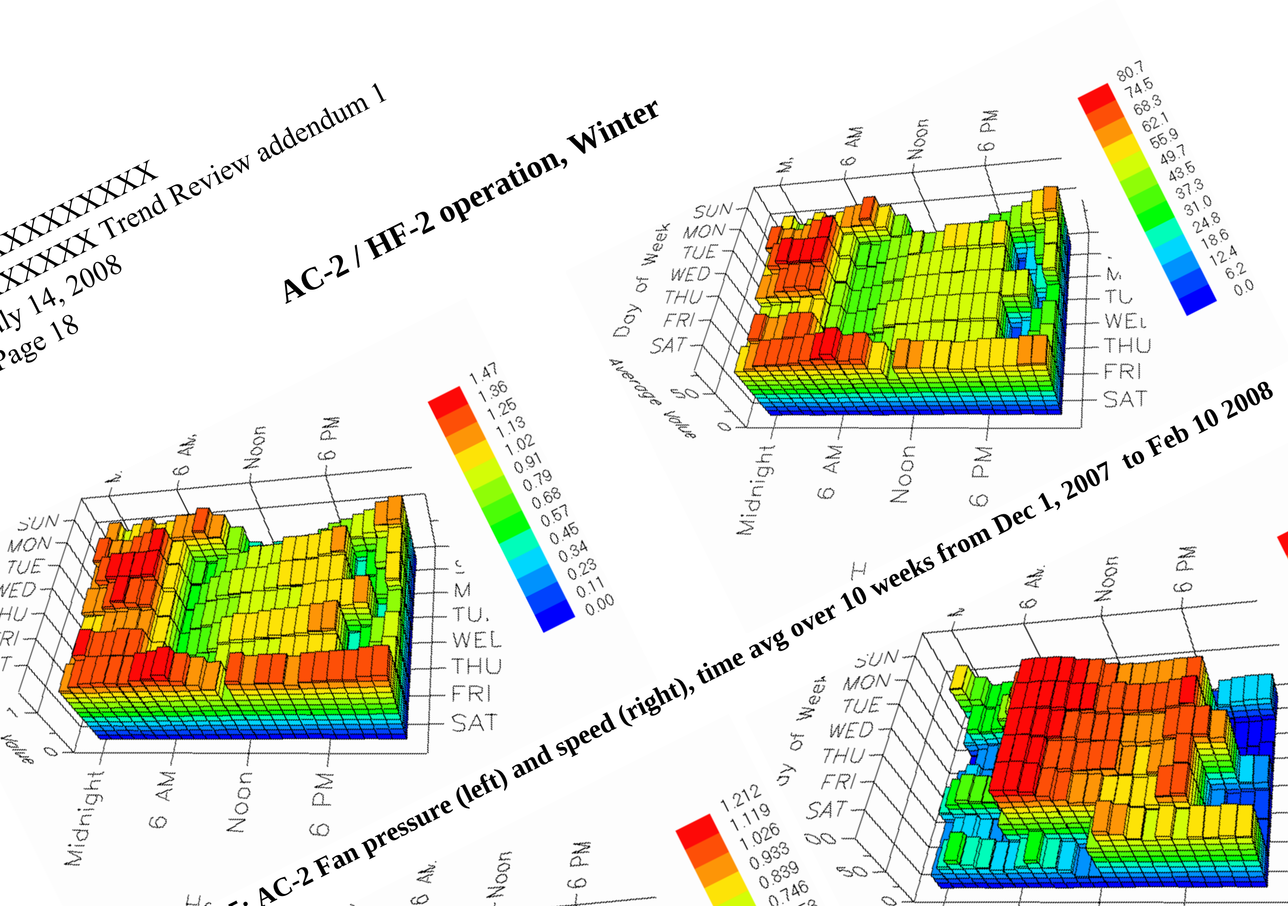



**Figure 25: AC-2 Fan pressure (left) and speed (right), time avg over 10 weeks from Dec 1, 2007 to Feb 10 2008**

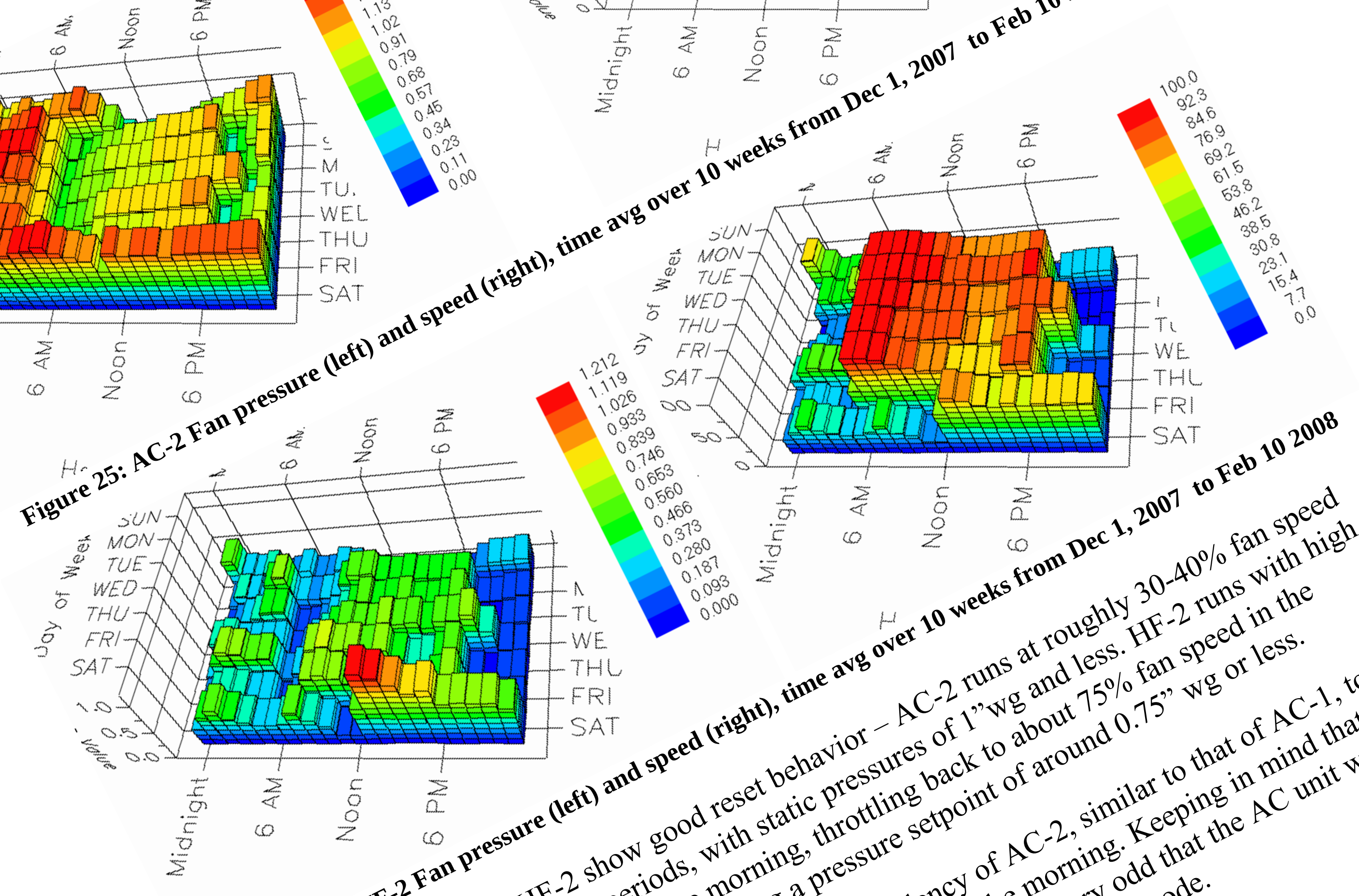



**Figure 26: HF-2 Fan pressure (left) and speed (right), time avg over 10 weeks from Dec 1, 2007 to Feb 10 2008**

11. AC-2 and HF-2 show good reset behavior – AC-2 runs at roughly 30-40% fan speed during occupied periods, with static pressures of 1"wg and less. HF-2 runs with high fan speed (100%) in the morning, throttling back to about 75% fan speed in the afternoons, while maintaining a pressure setpoint of around 0.75" wg or less.

12. What is not easily explained is the tendency of AC-2, similar to that of AC-1, to run at high speed and high static pressure early in the morning. Keeping in mind that the graphs above are for the Winter season, it seems very odd that the AC unit would produce so much fan power to warm up zones in setup mode.

E. Temperature reset

1. As with pressure reset, the supply air temperature reset mechanism appears to b programmed correctly, but is insufficiently tuned to be effective.

2. Both units show a fairly constant supply air temperature of 53°-55°F during the 6 weeks from May to June of 2008, which in itself is not surprising.

3. AC-1 shows a reset to warmer temperatures of around 58°-60° during winter, so this unit is fairly well set up when it comes to supply air temperature reset.

4. AC-2 in contrast remains at about 53°-55° during all occopied periods. Since the figures below are filtered for fan status, it can also be seen that the AC-2 supply fan runs almost continuously, both in summer an in winter.

**AC supply temperatures, both seasons**

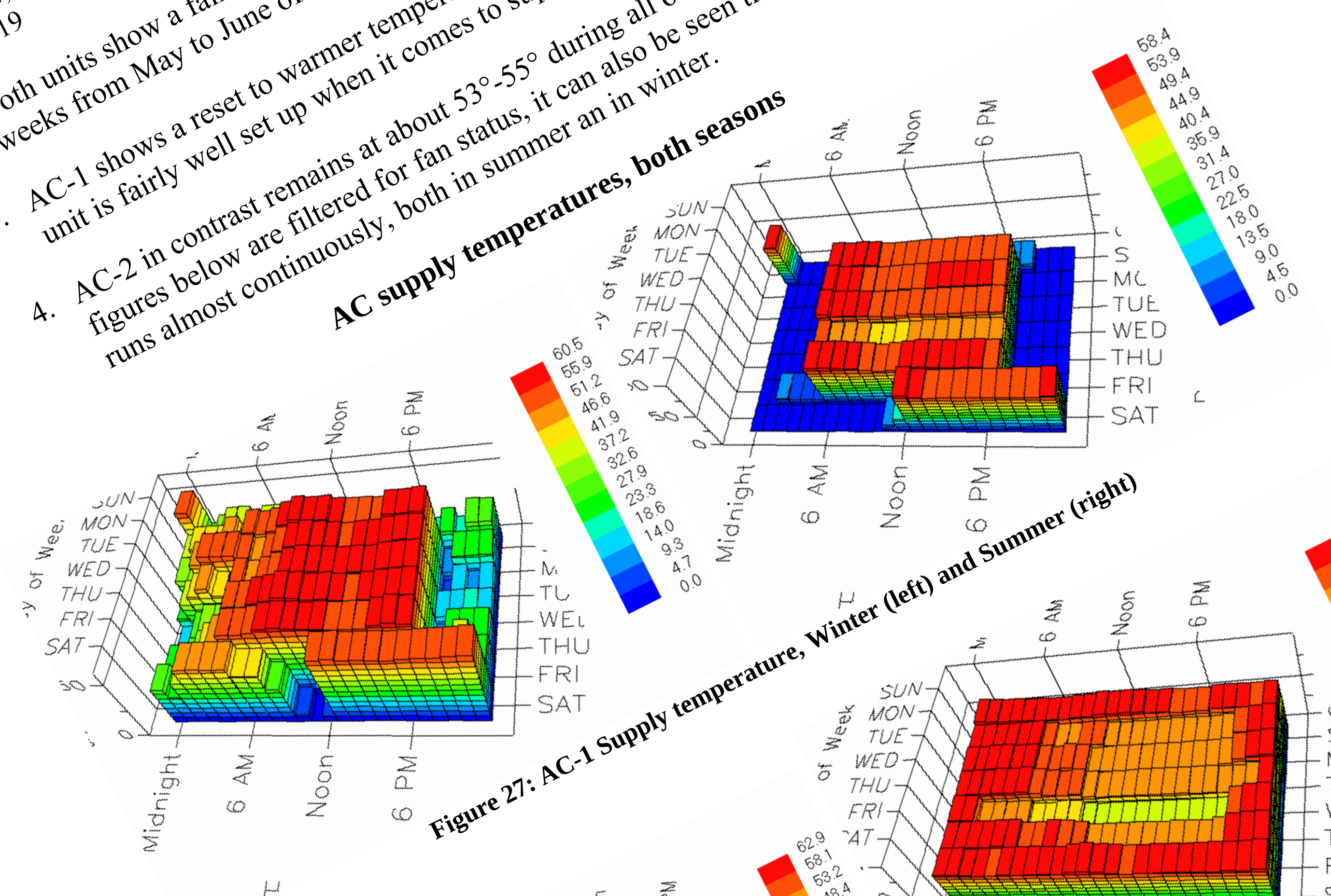



**Figure 27: AC-1 Supply temperature, Winter (left) and Summer (right)**

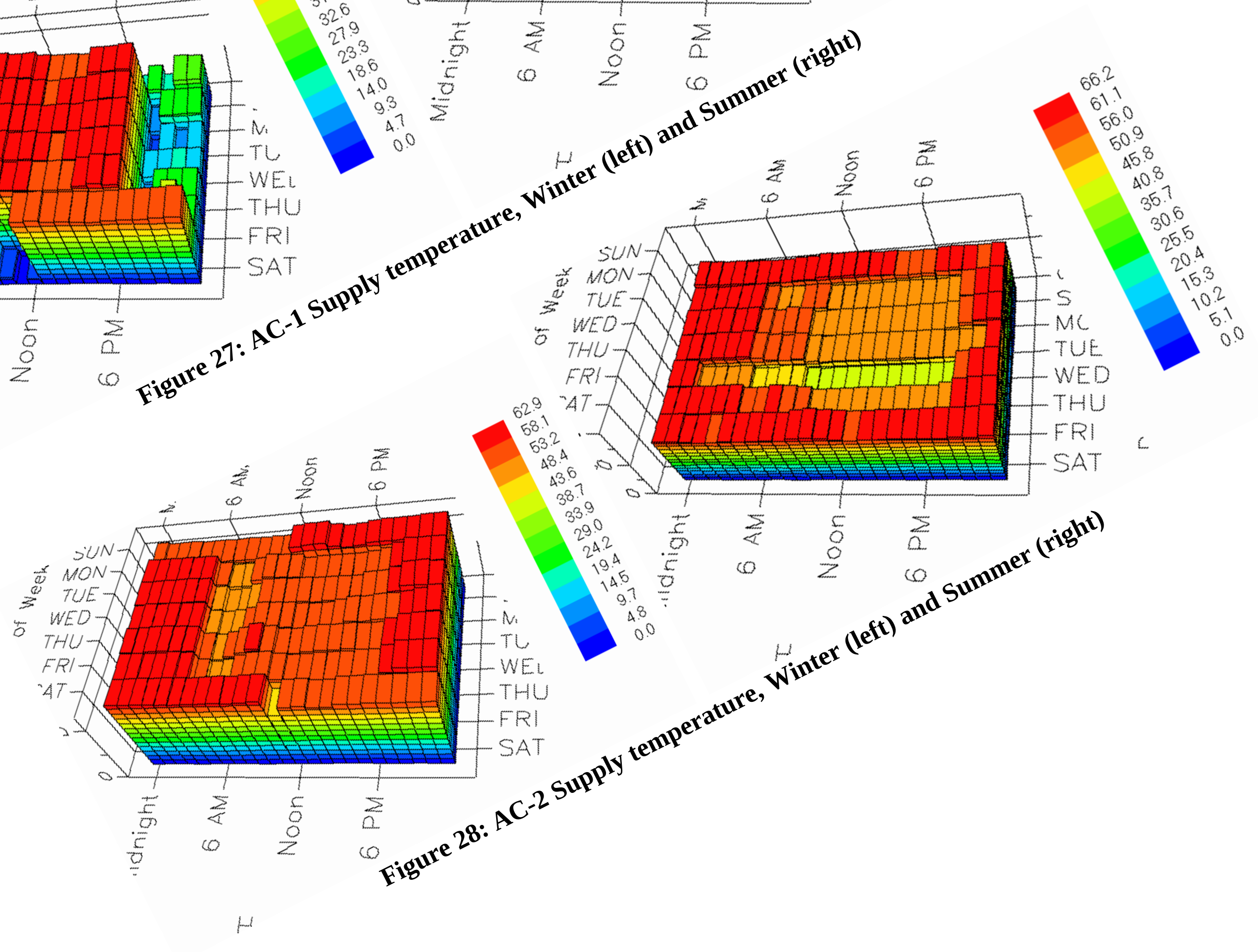



**Figure 28: AC-2 Supply temperature, Winter (left) and Summer (right)**

**HF-1 supply temperatures and gas valve capacity**

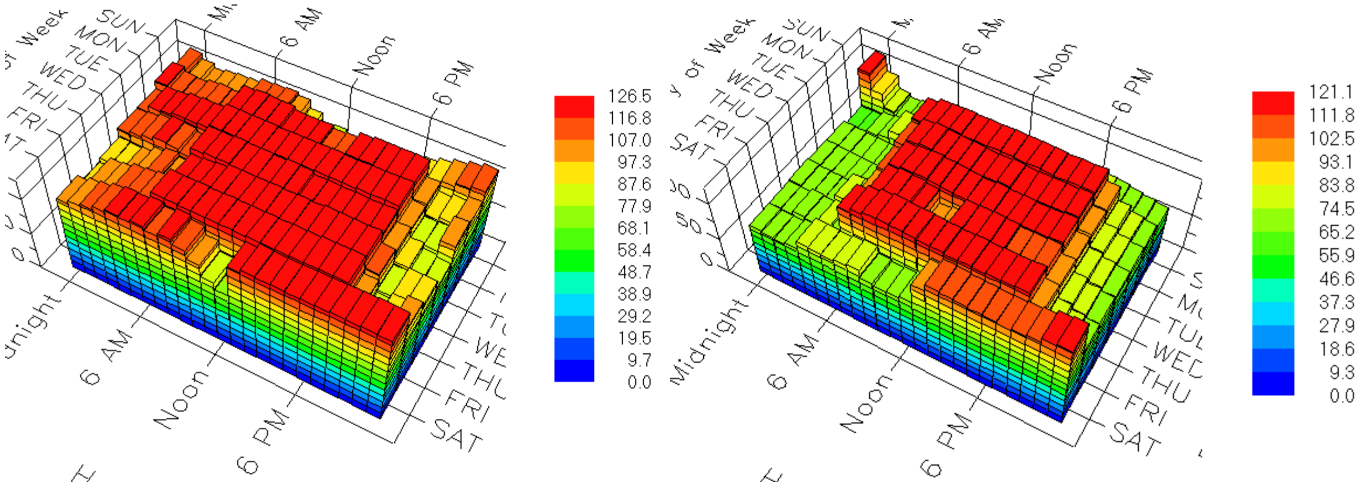



**Figure 29: HF-1 Supply temperature, Winter (left) and Summer (right)**

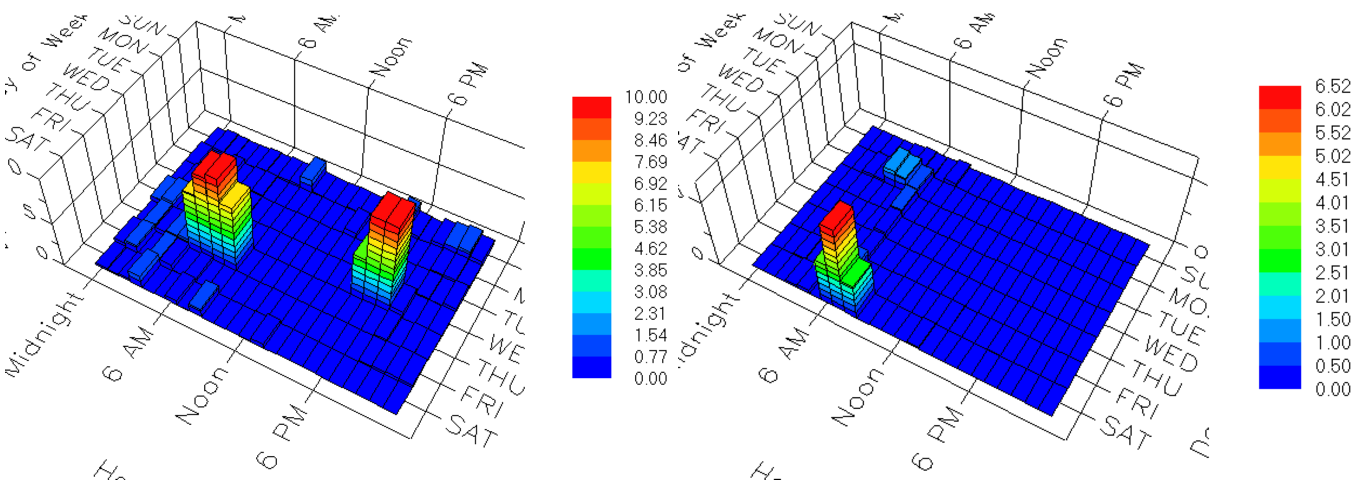



**Figure 30: HF-1 Gas valve % open, Winter (left) and Summer (right)**

5. While minimal gas valve activity is to be expected during May-June, HF-1 supply temperature indicates a steady supply temperature of around 115° during all occupied Summer hours, and 125°F during occupied Winter hours. It is not clear how this supply temperature is maintained while HF-1 fan is running at almost full speed during occupied hours (see Figure 24).

6. While the time-averaged (by hour) weekly graph of HF-1 gas valve activity shows almost no activity at all, the time series (by minute) graph shows short, intermittent spikes to 100% open gas valve, with additional short bursts of about 10% open. These spikes last from 5 to 15 minutes. We suspect that the signal valve for the HF-1 gas valve are incorrect, and may refer to the second stage gas valve only.

**HF-2 supply temperatures and gas valve capacity**

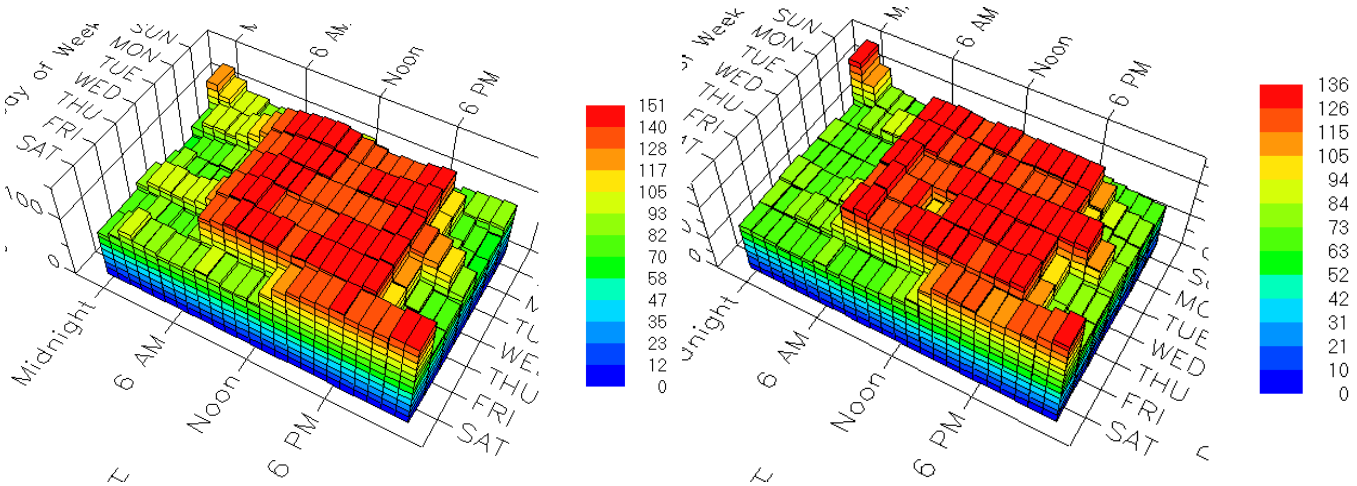



**Figure 31: HF-2 Supply temperature, Winter (left) and Summer (right)**

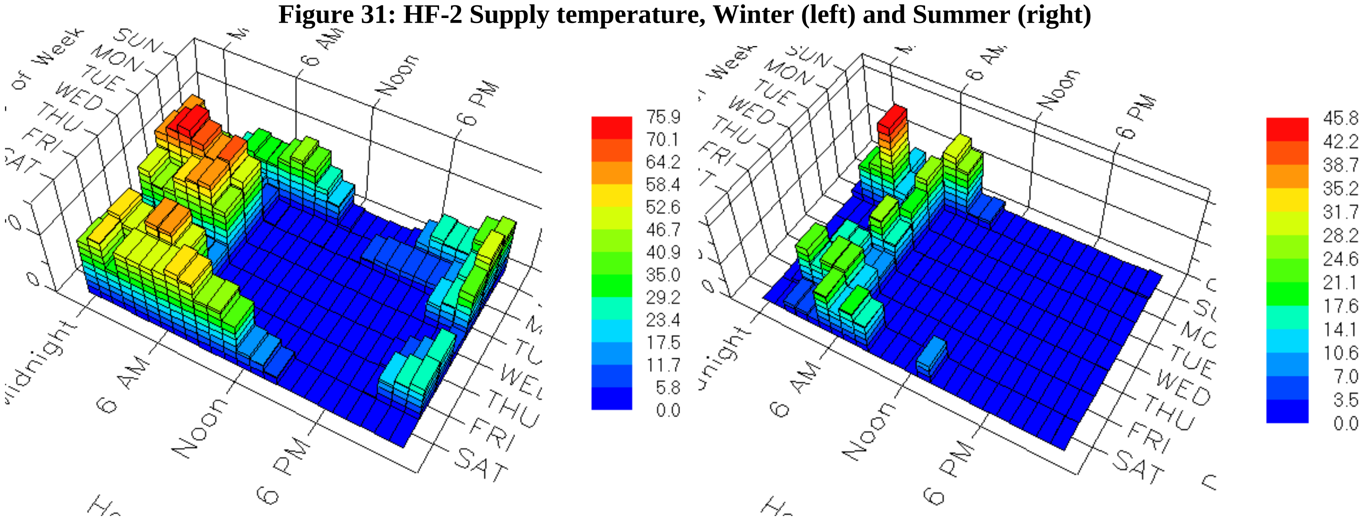



**Figure 32: HF-2 Gas valve, % open, Winter (left) and Summer (right)**

7. Much the same effect as for HF-1 can be witnessed on HF-2: other than during unoccupied hours, the gas valve appears to remain closed in HF-2, while maintaining 150°F during the winter and 130°F in the Summer.

8. We again doubt the accuracy of the gas valve trend, since it appears physically impossible for a unit to maintain 150°F in the Winter without use of the gas burner section. Instead, "gas valve" may refer to the second stage of each burner.

F. Tuning and Stability

1. AC units

a. AC-1 shows cycling at various times, typically at night or during the weekends. This is likely due to the cycling of VAV zones as they become enabled to keep unoccupied rooms at (unoccupied) setpoints.

b. As can be seen in the detailed figures for VAV zones, this cycling occurs at very rapid intervals and keeps building conditions within design parameters; however, the rapid cycling is unintended and cascades up to the AC units, which are not equipped to deal with 15-minute cycles.

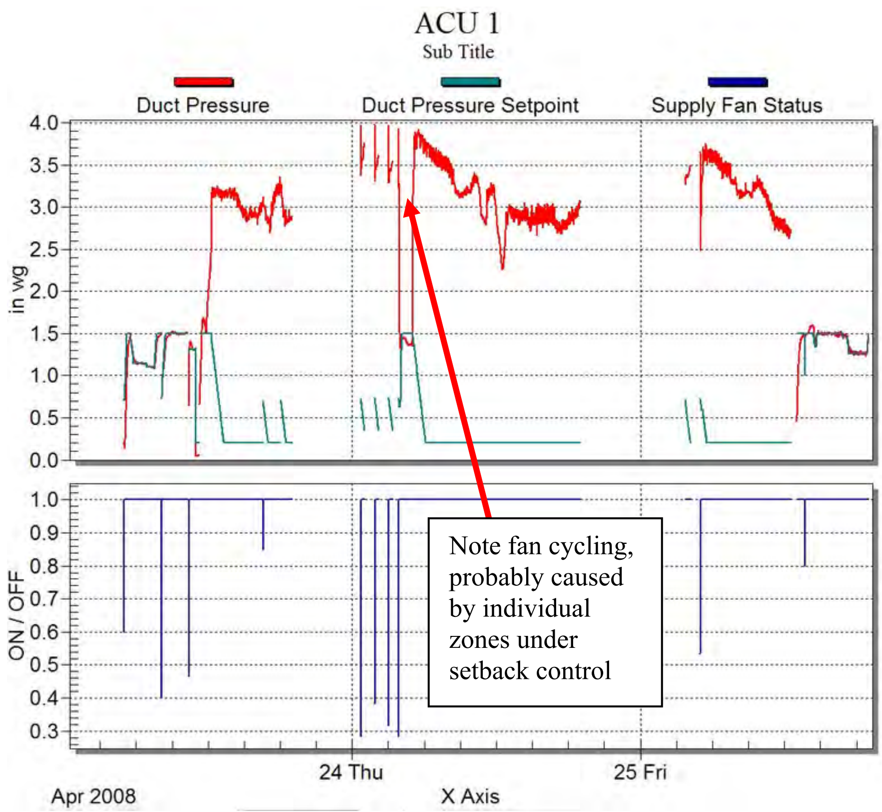



**Figure 33: Fan cycling for ACU 1**

c. The cycling of the fan motors should not necessarily affect the life span of the fans, since they are equipped with variable speed drives so the inrush currents are not likely to overheat the motor windings.

d. Starting the unit quickly, with only a few zones calling for cooling, ramps up the duct supply pressure at times. In the example above, duct static pressure rises to 4" wg several times on the morning of Thu, April 24. We suggest slowing down the fan ramp speed to prevent damage to ductwork or the unit as a result of over-pressure.

e. The compressors in contrast are not protected with variable speed drives. The hourly trends show the expected image of compressors staging up throughout the day, as seen below. However, the actual cycling, as recorded in 1-minute trends, reveals that the compressors are cycling at 3-5 minute intervals.

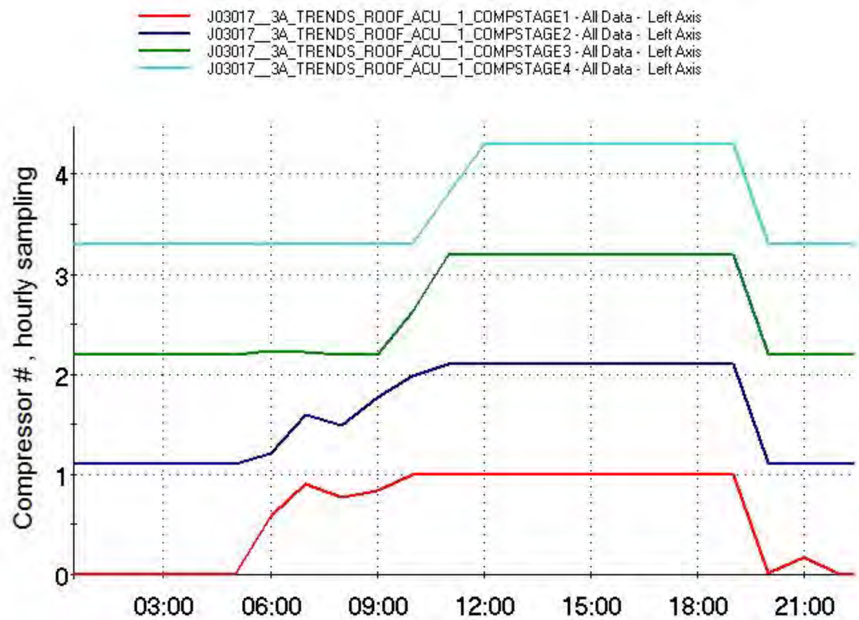



**Figure 34: AC-1 compressor cycling on hottest day (May 15), hourly samples**

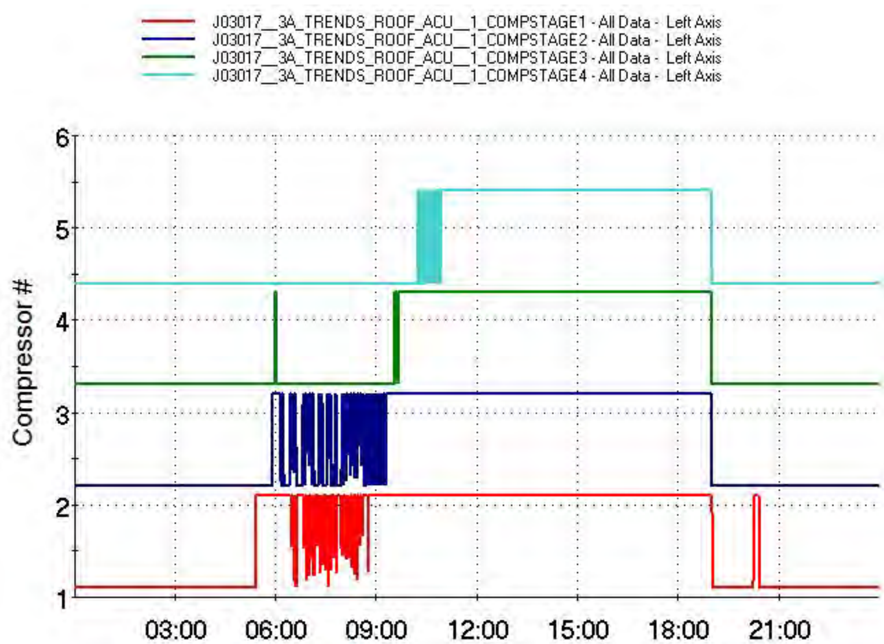



**Figure 35: AC-1 compressor cycling on hottest day (May 15), 1-minute samples**

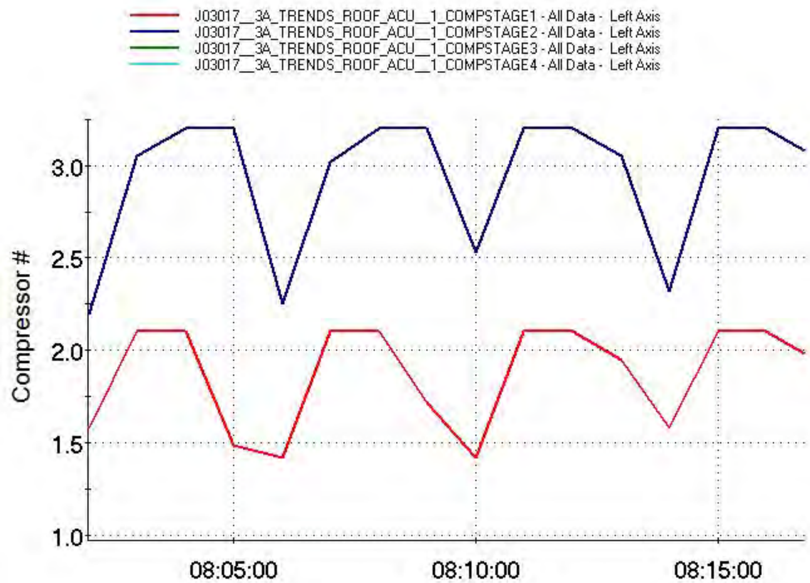



**Figure 36: AC-1 compressor cycling on hottest day (May 15), 1-minute samples**

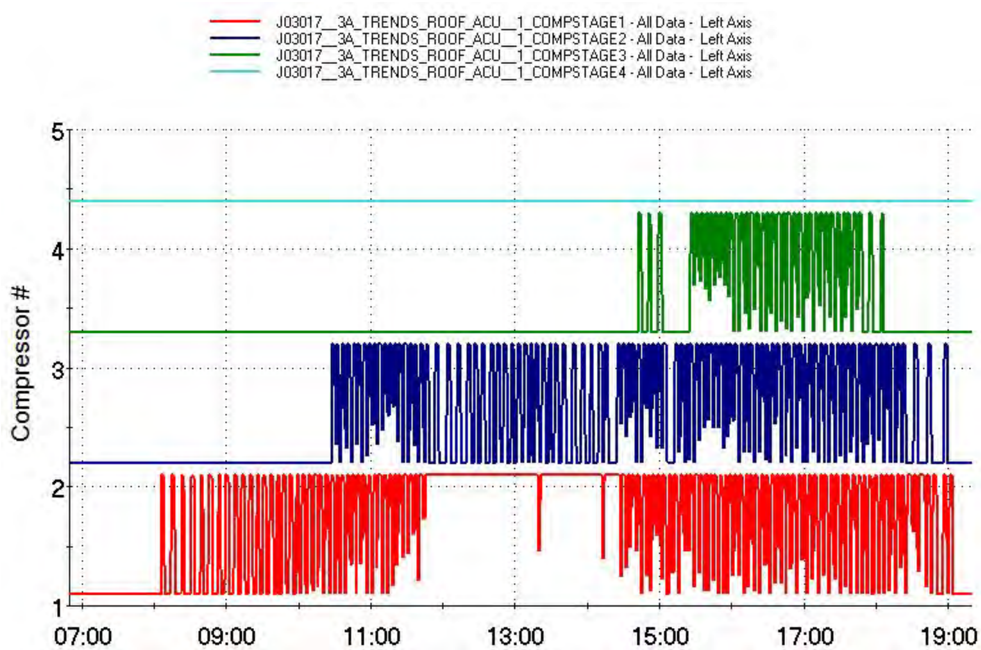



**Figure 37: AC-1 compressor cycling on typical day (June 5), 1-minute samples**

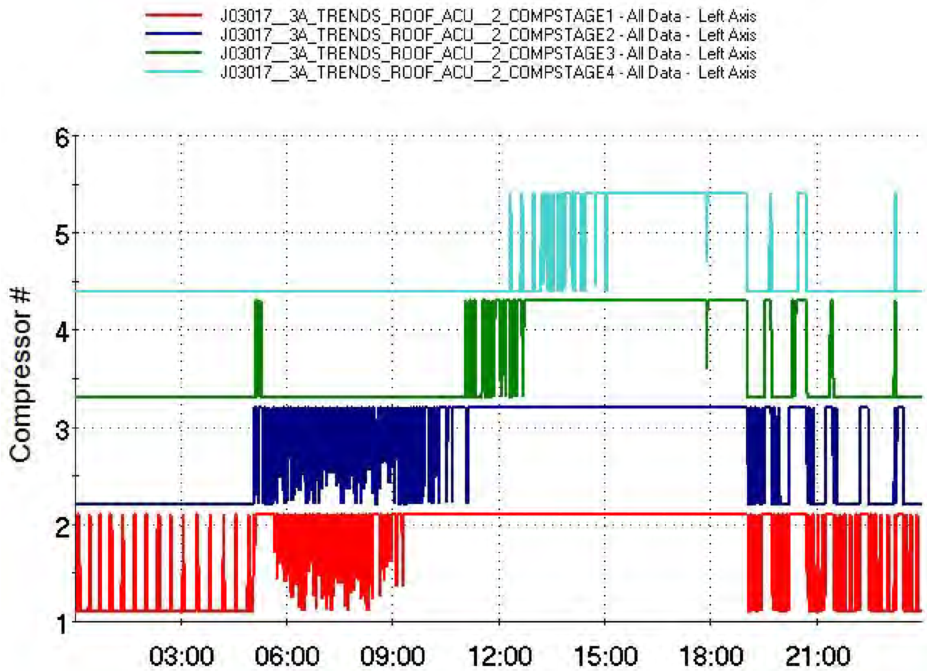



**Figure 38: AC-2 compressor cycling on hottest day (May 15), 1-minute samples**

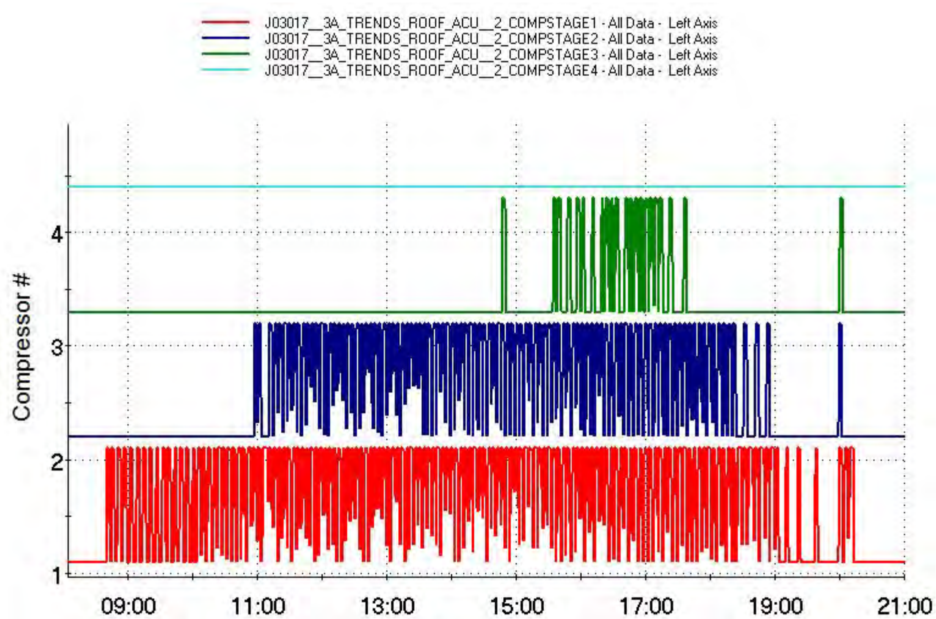



**Figure 39: AC-2 compressor cycling on typical day (June 5), 1-minute samples**

f. It is unclear whether the compressors have maintained operation for this long while actually operating at 5-minute cycle times, or whether there is an issue with the way the trend data is organized. It seems unlikely the compressor motors would have been able to withstand the repeated inrush currents for this long without damage. The original trend data is in a change-of-value (COV) format, and actually shows the values -1 and 0. A sample for the hottest day follows below.

| TSTAMP | VALUE | STATUS |
|---|---|---|
| 6/5/2008 5:30:35 PM | -1 | 0 |
| 6/5/2008 5:33:27 PM | 0 | 0 |
| 6/5/2008 5:34:57 PM | -1 | 0 |
| 6/5/2008 5:37:53 PM | 0 | 0 |
| 6/5/2008 5:39:23 PM | -1 | 0 |
| 6/5/2008 5:42:33 PM | 0 | 0 |
| 6/5/2008 5:44:05 PM | -1 | 0 |
| 6/5/2008 5:46:57 PM | 0 | 0 |
| 6/5/2008 5:48:39 PM | -1 | 0 |
| 6/5/2008 5:51:41 PM | 0 | 0 |
| 6/5/2008 5:53:07 PM | -1 | 0 |
| 6/5/2008 5:55:59 PM | 0 | 0 |
| 6/5/2008 5:58:01 PM | -1 | 0 |

**Figure 40: AC-1 compressor source trend data**

g. We would recommend a field inspection of the AC units. If the compressors are behaving as indicated in the trends, the rapid cycling should be easily observable. The graph below of AC-1 supply air temperature appears to confirm that compressors are in fact cycling, resulting in roughly 20°F swings in supply temperature.

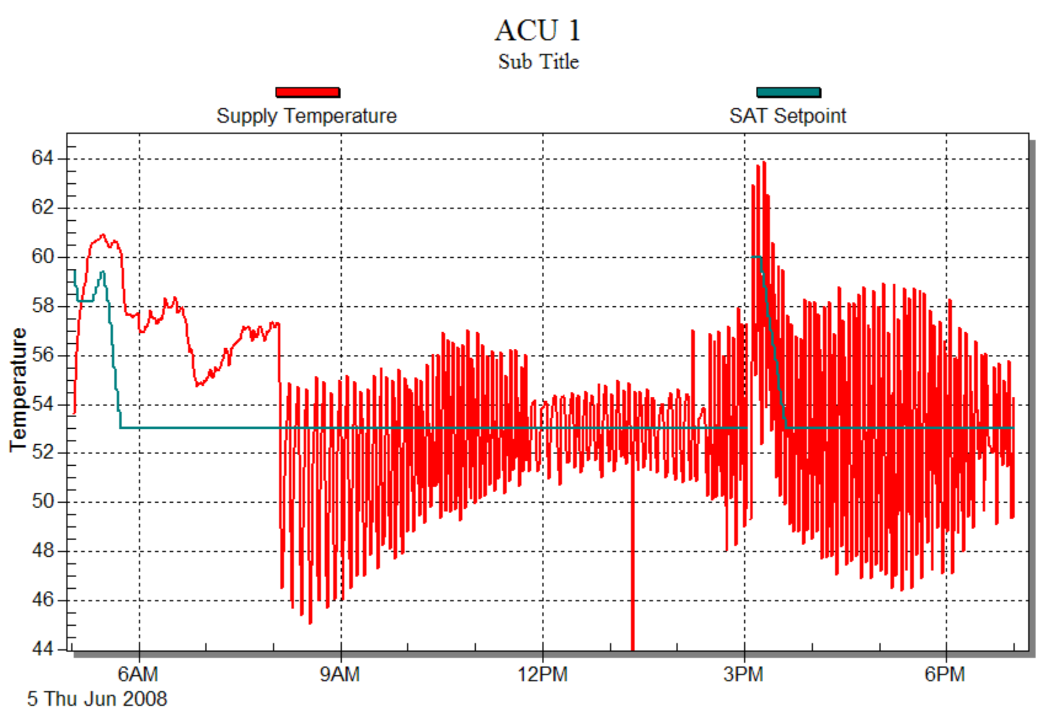



**Figure 41: AC-1 supply temperature on June 5, 2008**

2. HF units

a. Heating fans HF-1 and HF-2 appear to have little or no gas valve movement, see also Figure 30 on page 20 and Figure 32 on page 21.

b. This doubtful pattern is refuted by a closer look at supply temperatures: both HF-1 and HF-2 show rapid cycling of supply temperatures in Summer, which is almost certainly a result of cycling on the low stage of the burner. The discharge temperature control loop should be slowed down.

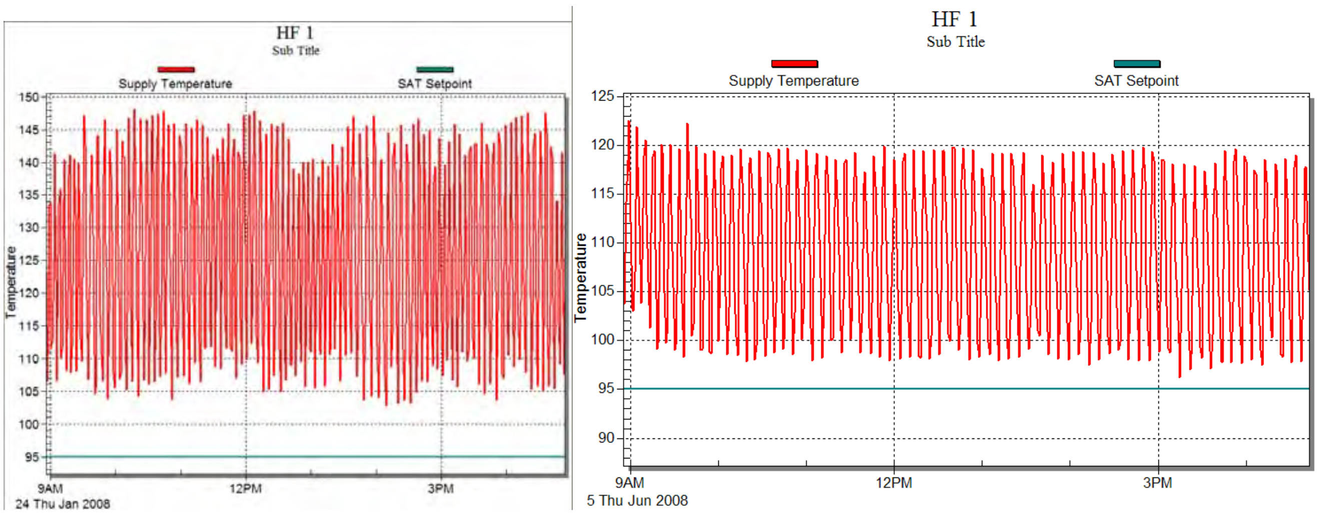



**Figure 42: HF-1 supply temperatures on Jan 24 and on June 5, 2008**

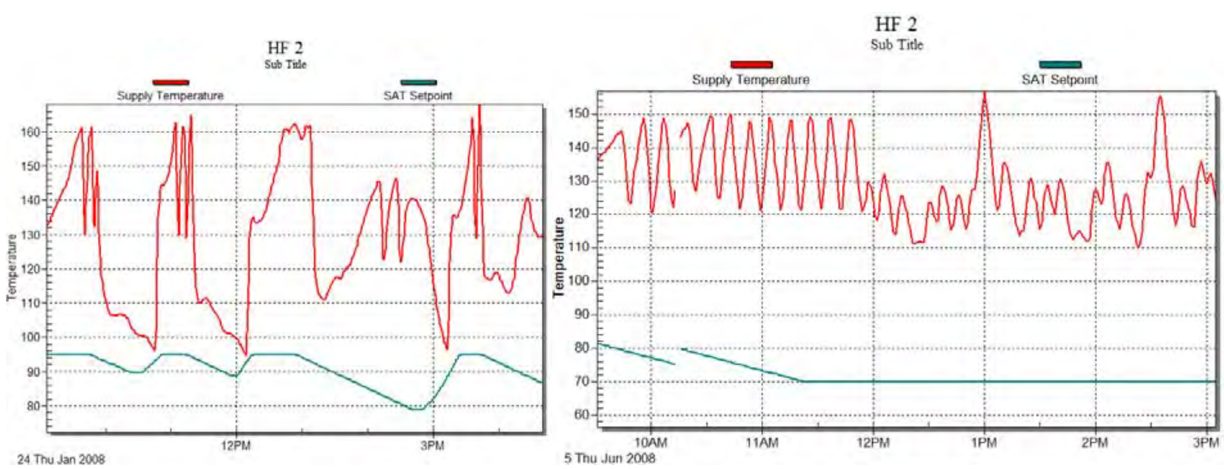



**Figure 43: HF-2 supply temperatures on Jan 24 and on June 5, 2008**

c. Stranger still is the fact that both units maintain a supply temperature far above the setpoint. The control system correctly reset the supply temperature to 70°F in Summer, a fact which is apparently ignored by the routine that actually maintains supply temperature around 120°-130°F.

2.05. Fancoil operations

A. The following fancoil units were submitted as part of the trend database:

1. FCU 5-1, 5-2, 5-3, 5-4, 5-5

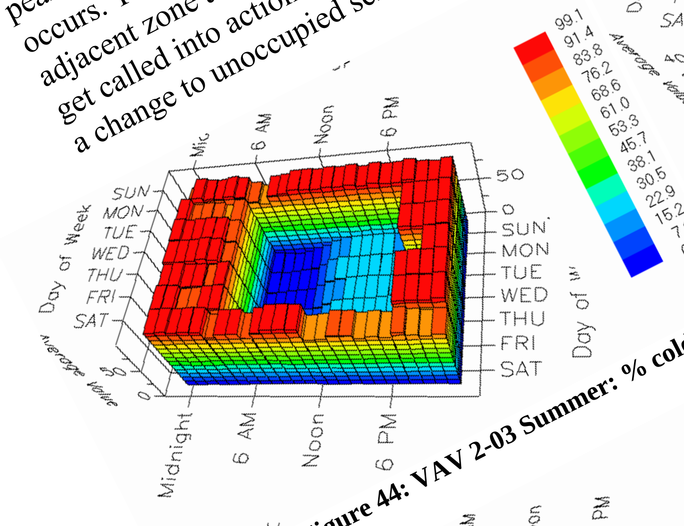
Room temperature trends for rooms served by FCU 5-3 and FCU 5-5 are not connected – their readings return zero degrees at all times.

C. Fancoils cycle while maintaining supply air temperature. FCU 5-2 cycles in hourly intervals, FCU 5-1 cycles in half-hour increments, and FCU 5-4 cycles in 15-minute intervals, indicating that FCU 5-4 is oversized, and to a lesser degree, so is FCU 5-1. It is not clear what spaces are served by these units, but lowering the setpoint for the oversized units will reduce cycling somewhat, and prolong compressor life.

2.06. VAV operation

A. Room temperatures are generally well maintained, although some zones have deadbands set too tightly, resulting in almost 24/7 airflow to maintain tight control.

B. Airflows show numerous examples of a kind of "inverse" zone control: when the zone is occupied, airflow is low or almost zero, and when zones become unoccupied, airflow peaks and remains high throughout the unoccupied period. It's not entirely clear why this occurs. The best we can guess is that zones with this behavior are actually served by other, adjacent zone airflows during occupied hours, resulting in a satisfied thermostat, and only get called into action when the adjacent zone VAV terminal dampers have closed thanks to a change to unoccupied schedule. An example of such control is shown below:



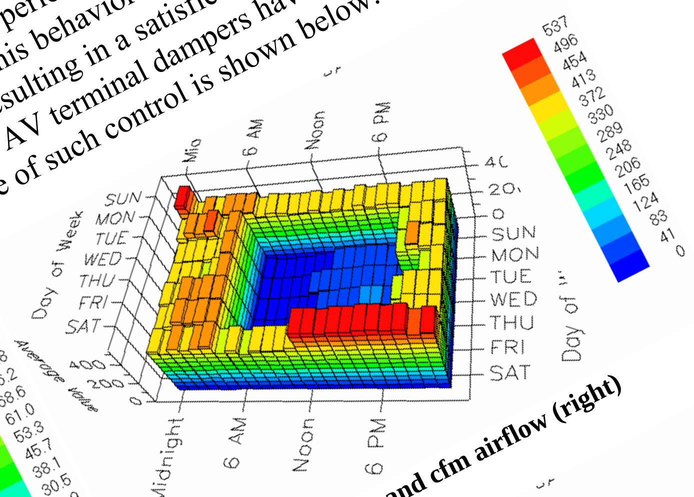
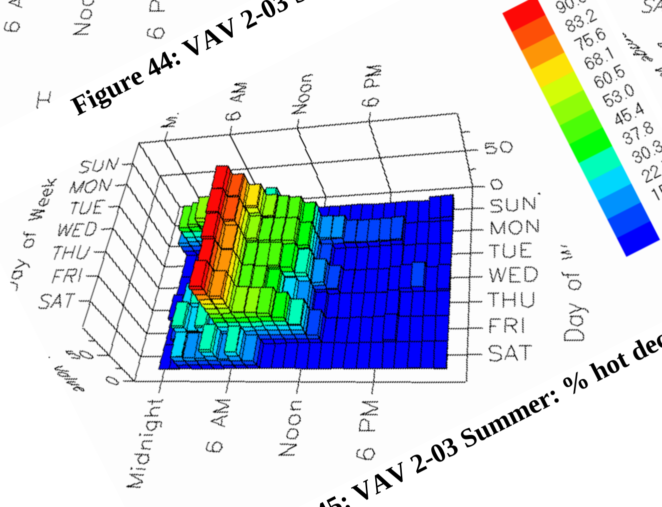




**Figure 44: VAV 2-03 Summer: % cold deck damper position (left) and cfm airflow (right)**



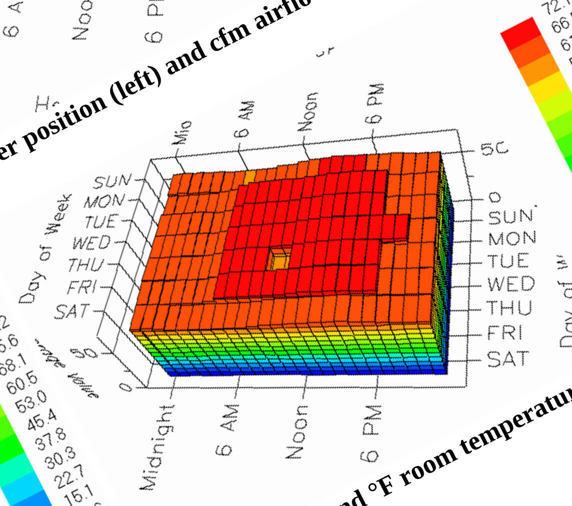




**Figure 45: VAV 2-03 Summer: % hot deck damper position (left) and °F room temperatu**

C. Not only does the example of VAV 2-03 above show high airflows at night, temperatures are also lower at night than they are during the day, in conflict with what would be expected from normal occupied / unoccupied control, which would let temperatures drift up to about 78°F or so at night. Mis-applied setpoints are probably to blame for this behavior, although the controls should automatically lock out unoccupied setpoints with a tighter control range than the occupied setpoints, making such user error impossible.

D. Adherence to setpoints: for some reason, the trended “room temperature setpoint” signal for most rooms is at 90°F during occupied periods, and at 70°F during unoccupied hours. See a typical example below. The settings of this setpoint signal are ignored in all VAV zones.

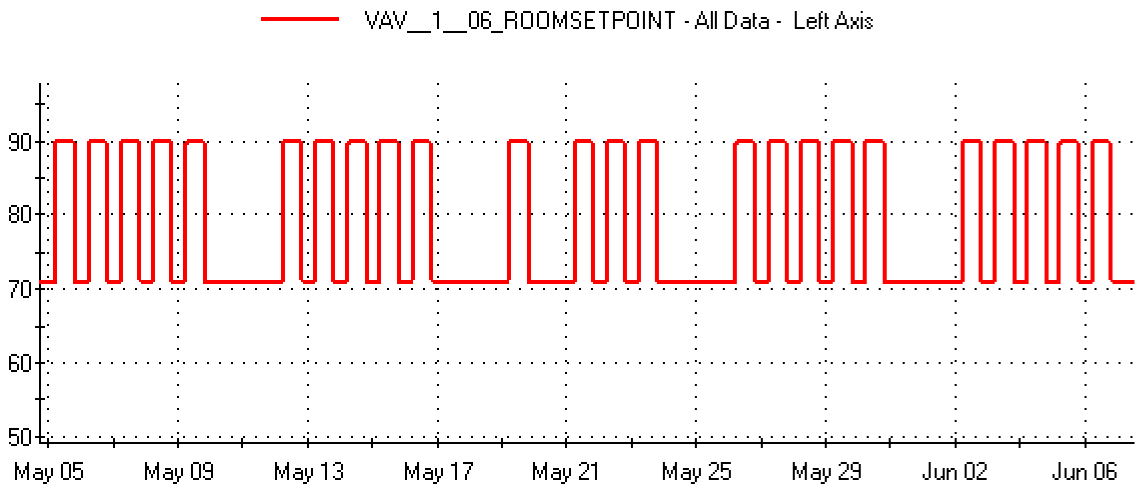



**Figure 46: VAV 1-06 Summer: Room temperature setpoint**

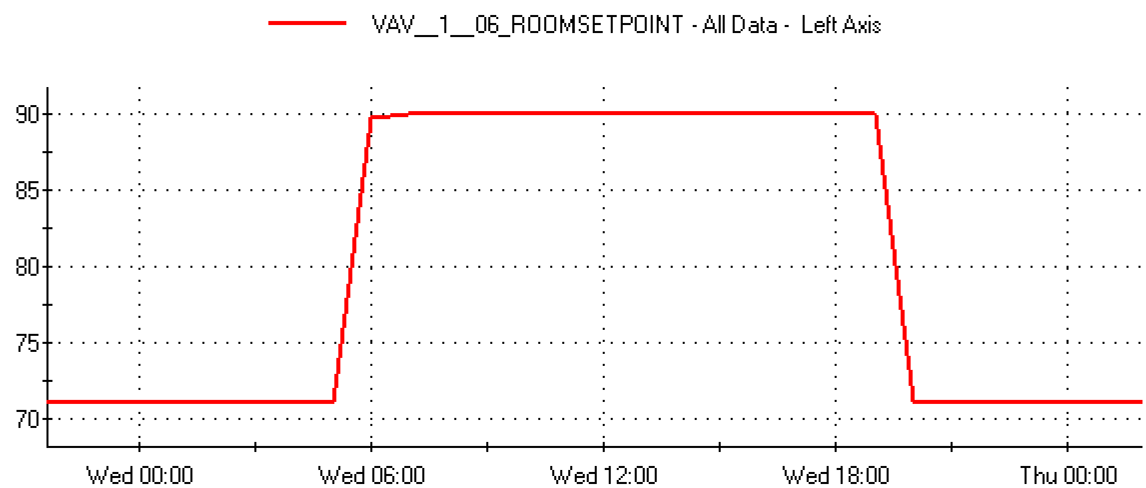



**Figure 47: VAV 1-06 Summer: Room temperature setpoint on May 14**

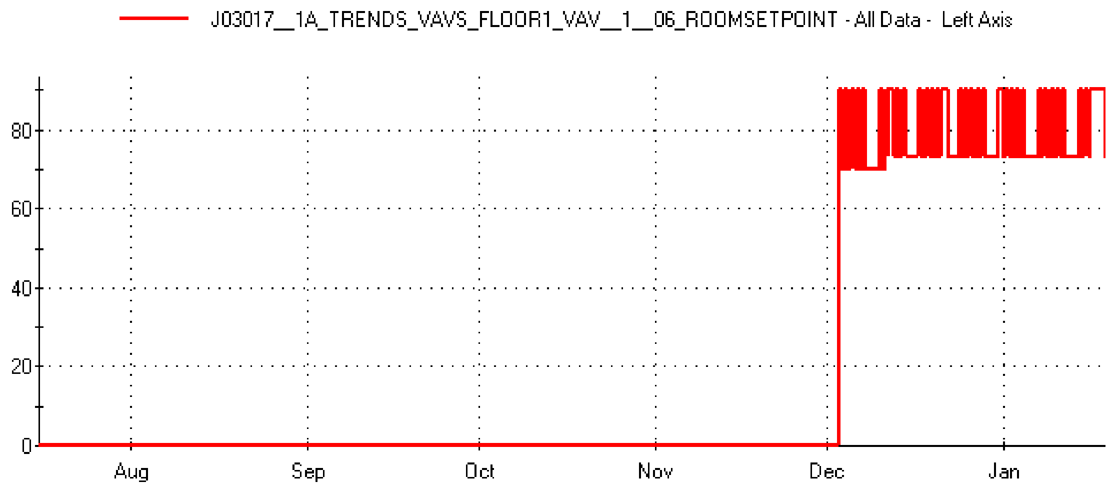



**Figure 48: VAV 1-06 Winter 2007: Room temperature setpoint**

E. As the above graph shows, room temperature setpoints were set at zero before December of 2007. After this point, they take on the 90°F occupied / 70°F unoccupied pattern.

| VAV Tag | Temp. occ | Temp. unocc | CD damper | HD Damper | CD airflow, occ cfm | CD airflow, unocc cfm | Comments |
|---|---|---|---|---|---|---|---|
| 1-02 | 68°-73° | Same | Open 24/7, oversized zone, max. open 30% | Open only while occupied | >350 | ~ 120 | This could be a rogue zone driving AC-2 (not clear if connected to AC-2) |
| 1-03 | 70°-72° | 76°-78° | Open only while occ. max. 50% | Closed | 375-1,100 | 0 | |
| 1-06 | 67°-71° | 70°-76° | Open only while occ. max. 60% | Open only while occ. max. 2% | 375-1,200 | 0 | |
| 1-08 | 70°-71° | Same | Open only while occ. oversized, max. 30% | Open only while occ. max. 100% | 300-450 | 0 | Setpoints too tight, reheat penalty |
| 1-10 | 67°-68° | 66°-71° | Open 24/7, oversized zone, max. open 30% | Open only while occ. max. 50% | N/A | N/A | Setpoints too tight, reheat penalty |
| 1-12 | 69°-70° | 63°-72° | Closed when occupied, open when unoccupied, max 30% | N/A | N/A | N/A | "inverse" control – zone is cooled by surrounding zones until unoccupied. Suspect bad sensor placement. Possible rogue zone for AC-2 |

| VAV Tag | Temp. occ | Temp. unocc | CD damper | HD Damper | CD airflow, occ cfm | CD airflow, unocc cfm | Comments |
|---|---|---|---|---|---|---|---|
| 2-03 | 69°-73° | 62°-66° | Closed when occupied, open when unoccupied, max 100% | Normal (mostly warmup) behavior, max.100% | ~100 | ~ 400-550 | "inverse" control – zone is cooled by surrounding zones until unoccupied. Suspect bad sensor placement. Possible rogue zone for AC-2 |
| 2-06 | N/A | N/A | N/A | Normal (mostly warmup) behavior, max.100% | N/A | N/A | Insufficient data |
| 2-07 | 67°-72° | 63°-81° | Closed when occupied, open when unoccupied, max 100% | N/A | ~120 | ~200-1,200 | "inverse" control – zone is cooled by surrounding zones until unoccupied. Suspect bad sensor placement. Possible rogue zone for AC-2 |
| 2-11 | 70°-74° | 67°-74° | Open when occupied, but more when unoccupied | Normal (mostly warmup) behavior, max.100% | ~65 | ~150-400 | "inverse" zone control |
| 2-16 | 67°-72° | 66°-76° | Normal behavior, oversized, max 30% | Normal (mostly warmup) behavior, max.100% | ~60-400 | 0 | Good control |
| 2-19 | 68°-72° | 67°-81° | Normal behavior, oversized, max 55% | Normal (mostly warmup) behavior, max.35% | ~100-550 | 0 | Good control |
| 2-23 | 68°-73° | 65°-80° | Normal behavior | Normal (mostly warmup) behavior, max.70% | ~60-500 | 0 | Good control |
| 3-04 | 69°-74° | 61°-81° | Normal behavior but with lots of setback during unocc. | Normal (mostly warmup) behavior, max.100% | ~65 | Up to 700 | 1st half of the day has almost no airflow, so in between normal control and "inverse" behavior |

| VAV Tag | Temp. occ | Temp. unocc | CD damper | HD Damper | CD airflow, occ cfm | CD airflow, unocc cfm | Comments |
|---|---|---|---|---|---|---|---|
| 3-07 | 68°-70° | 65°-81° | Same as 3-04 | Same as 3-04 | ~65 | Up to 500 | 1st half of the day has almost no airflow, so in between normal control and "inverse" behavior |
| 3-11 | 68°-77° | 62°-81° | Normal behavior, oversized, max. ~20% | Normal (mostly warmup) behavior, max.100% | ~55 | ~100-500 | Normal behavior during occupied hours but high increases in airflow when unoccupied |
| 3-14 | N/A | N/A | Normal behavior | Normal behavior | ~55 | ~200-300 | Normal behavior |

**Table 2: VAV operational results**

F. The table above shows results for the submitted VAV terminals. These results are not exact since they vary over time, but give some overall impression of zone behavior.

G. Stability

1. During occupied periods, stability is usually fairly good.

2. During unoccupied periods, setback or setup activity results in sudden spikes in pressure and airflow that should be reduced by tuning loops much slower. An added issue with the sudden overshoot reaction of VAV terminals is the fact that it usually only takes a few minutes to bring a zone back within unoccupied setpoints, creating sudden operating spikes in AC units and HF units, which start/stop in rapid, short intervals. An example is shown below

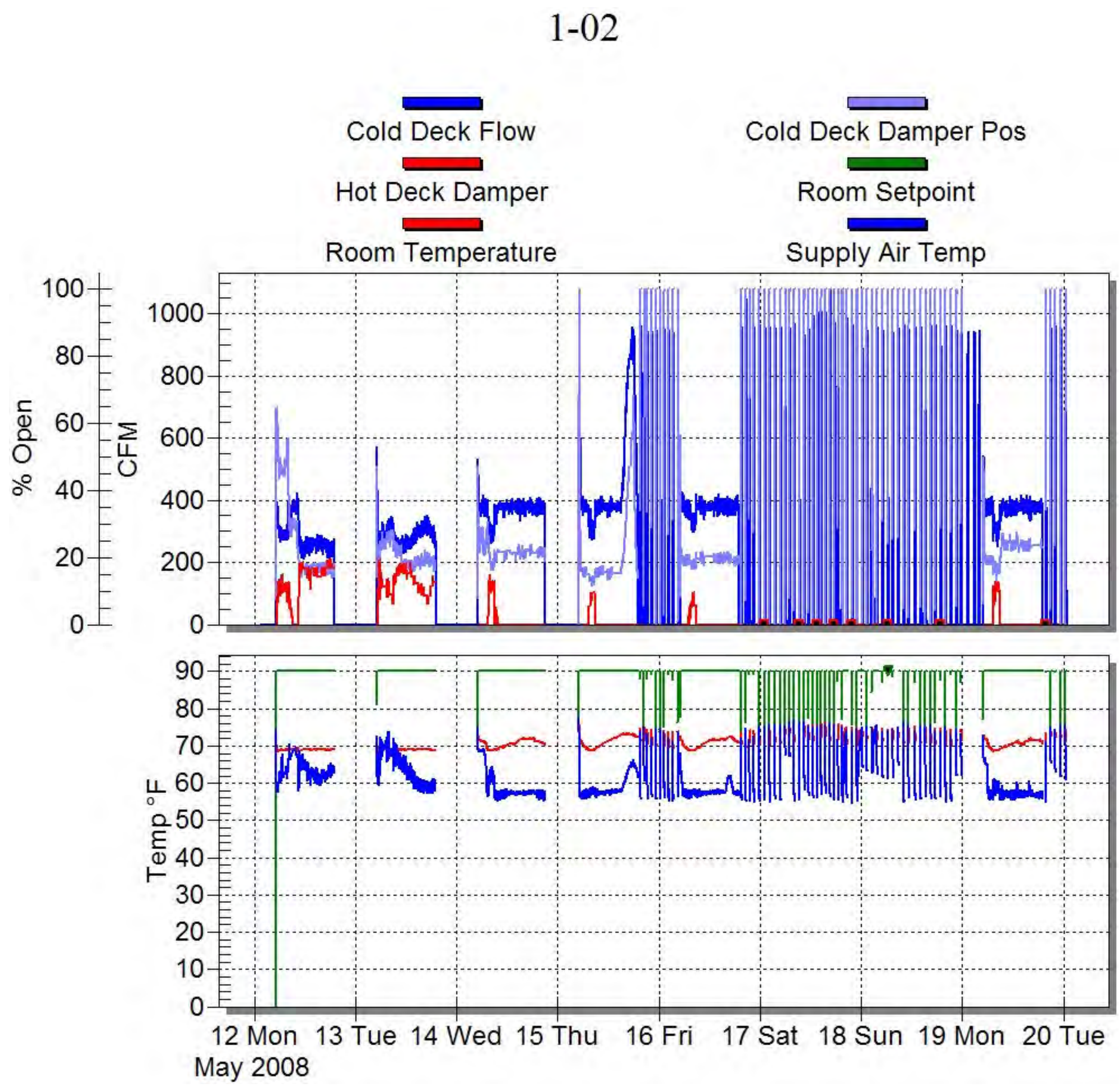



**Figure 49: VAV 1-02 Summer: Room temperature setpoint**

# 1-02

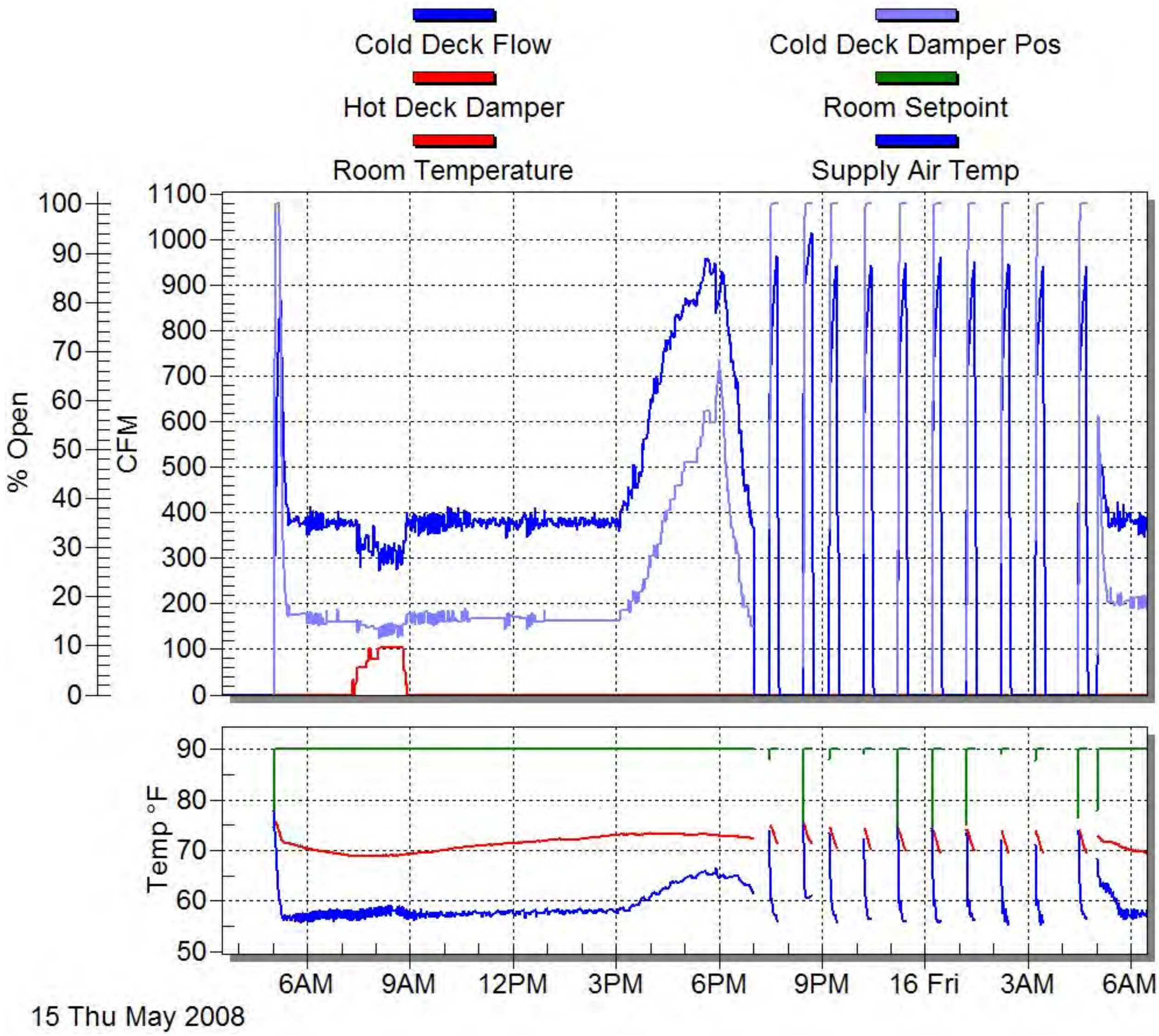



**Figure 50: VAV 1-02 Summer: Room temperature setpoint, single day**

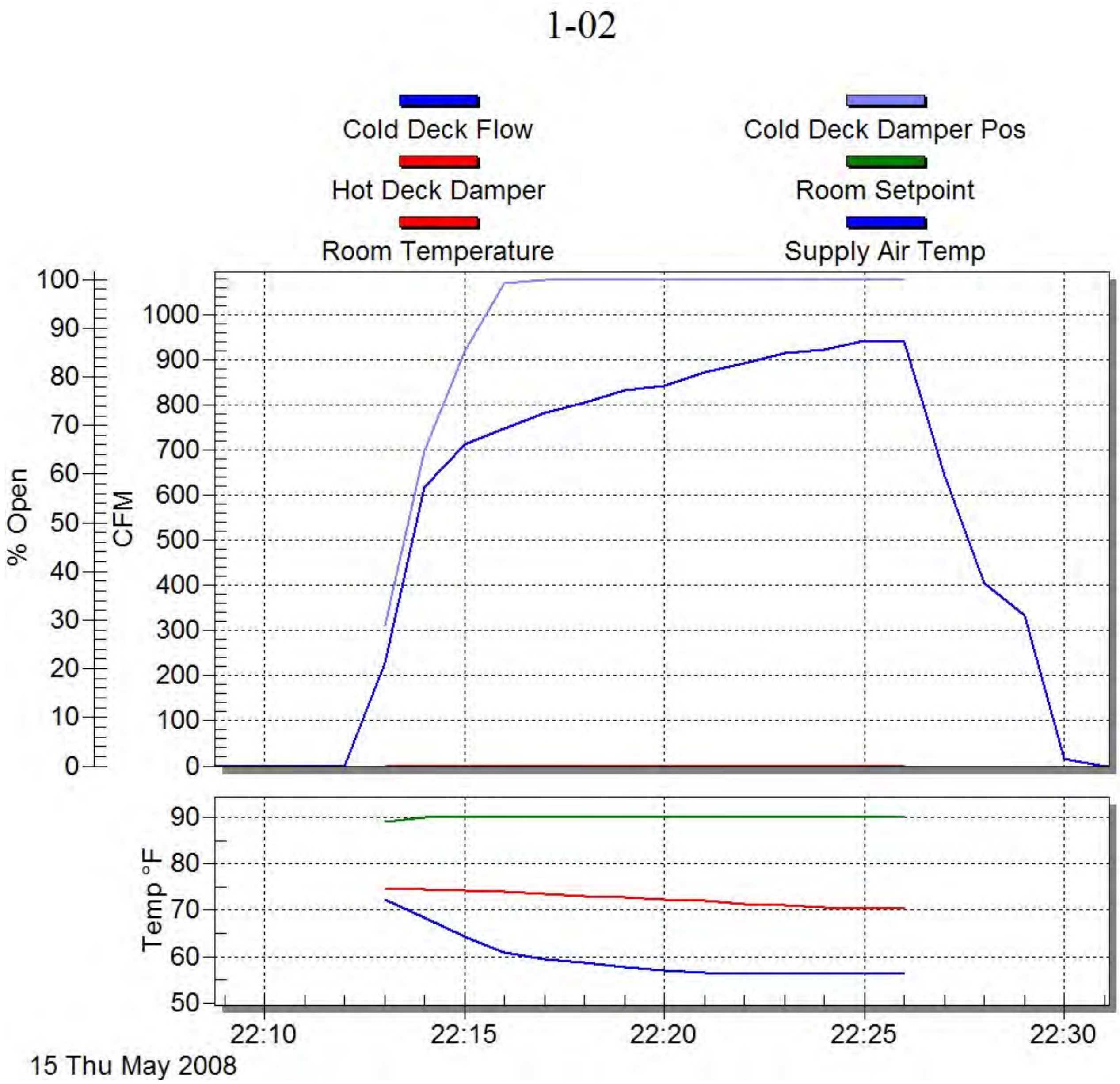



**Figure 51: VAV 1-02 Summer: Room temperature setpoint, single cycle detail**