International Institute for Sustainable Laboratories®

Best Practices Guide

Principles for Building Automation Systems in Laboratory Facilities

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Introduction

One crucial principle must guide the use of building automation systems in laboratories: if you need something to work, you must make sure it works. Many aspects of lab operations are simply too important to ignore—from the safety and well being of lab workers to the quality and integrity of the research. Thus, if a system is important to an organization, necessary steps must be taken to ensure the system works as designed and intended.

This guide explores best practices to ensure that building automation systems (BAS) in life science and laboratory environments perform correctly and continue to perform that way, including monitoring for safety, performance, pressurization, and ventilation rates.

Key BAS Questions

Three very basic questions set the context for any discussion of building automation systems in life science and laboratory environments:

1. How do HVAC systems use energy in lab environments?
2. When do we accomplish sustainability? (Or: When does sustainability occur?)
3. Where is the building automation system?

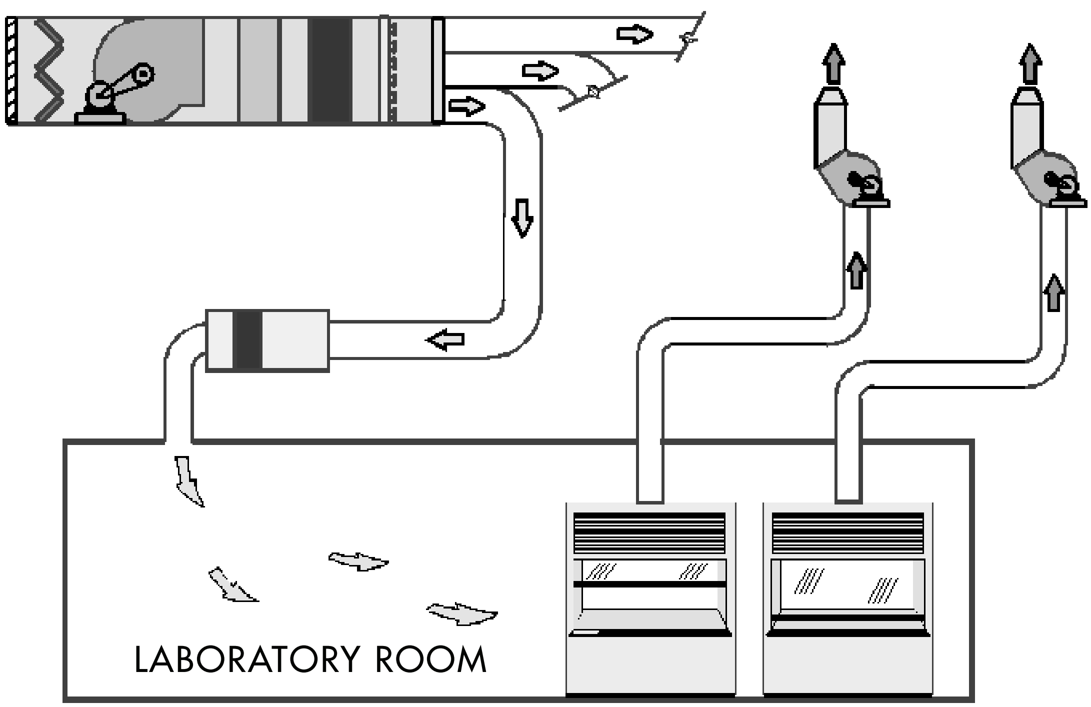

Figure 1. How do HVAC systems use energy in lab environments? Source: Siemens.

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How Do HVAC Systems Use Energy in Labs?

Figure 1 on page 1 shows an air-handling unit (AHU) with fan and coils, which work together with the air terminal to deliver air into a laboratory space. From there, the air is exhausted from the room either through the exhaust devices or the fume hoods.

Air handlers use energy to heat, cool, humidify and dehumidify air supplied to the air terminals. Reheat coils at the lab room use energy to temper the typically cold supply air before introducing it to the space. The fans that move the air also consume energy, though to a lesser extent than the coils.

For both fans and coils, the energy consumed is a strong function of the quantity of air flowing. Thus, when energy conservation is an objective, the first priority should be to use less air, followed by improving the heating and cooling process. This can mean applying heat recovery, or reducing simultaneous heating and cooling. The third priority is moving air more efficiently. (For more on these concepts, see Thompson, 2021; Frenze et al., 2005; and Reilly, et al., 2012.).

When Do We Accomplish Sustainability?

Sustainability remains a important objective for organizations around the globe. Two aspects of sustainability particularly related to buildings are energy usage and a safe and healthy indoor environment. Both of these happen as a building operates day after day and year after year. Design is important; commissioning is crucial. These are necessary enablers, but sustainability actually occurs (or doesn't) in long-term operation.

Where Is the Building Automation System?

The short answer is that the BAS is everywhere—from the sensors that measure airflow, space pressure, contaminants, temperature, and humidity to the fans on the roof of the building. Figure 2 illustrates how complex this system is as it moves air through a life science space.

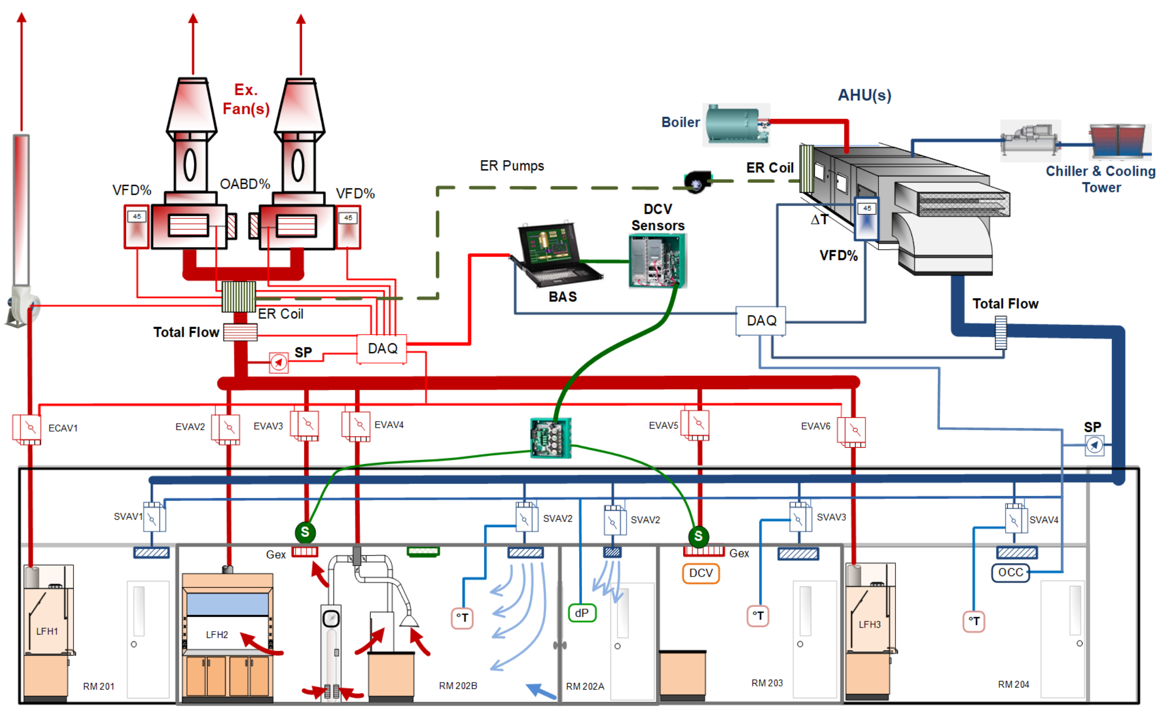

Figure 2. BAS in lab space. Source: Tom Smith, 3Flow.

The BAS has four core jobs:

- Operating the equipment to control ventilation, temperature, humidity, lighting, containment, and pressurization parameters that are required for safe, healthy and efficient operation.
- Setting alarms and alerts for the people who use the building—from the lab workers performing research to the building operators who keep everything functioning.
- Logging data to confirm operations and functionality (in addition to real-time alerts and alarms).
- Connecting building operators with the mechanical systems so they can see what's going on in every part of the system and in every area of the building.

All of these tasks begin with the sensors and their connected information infrastructure to enable key stakeholders to operate the building and—more importantly—monitor its operation for safety and performance.

With this context in mind, here are best practices for BAS in laboratories.

The BAS: Key Information

The BAS is home to nearly all the data needed to monitor for both safety and performance, with three types of stakeholders' needs being met:

- Lab workers: This group interacts with the BAS at the room level (for example, at the fume hood display panel, and at the room unit or lab monitor, via room pressure monitors).
- Facilities staff: This group relies on the BAS' interactive graphics, reports, alarms, and other data to support decisions about operating and managing the system.
- Safety officers: These stakeholders can use BAS records that indicate how the systems function and when systems degrade. Importantly, they will need immediate alerts for any unsafe conditions.

A BAS is complex and involves so much data that manual monitoring is impractical. Consider establishing a monitoring program by first setting up a secure remote connection to the BAS, which can then serve fault detection and diagnostic (FDD) functions, as well as building analytics specifically for use in laboratory and life science environments (Figure 3).

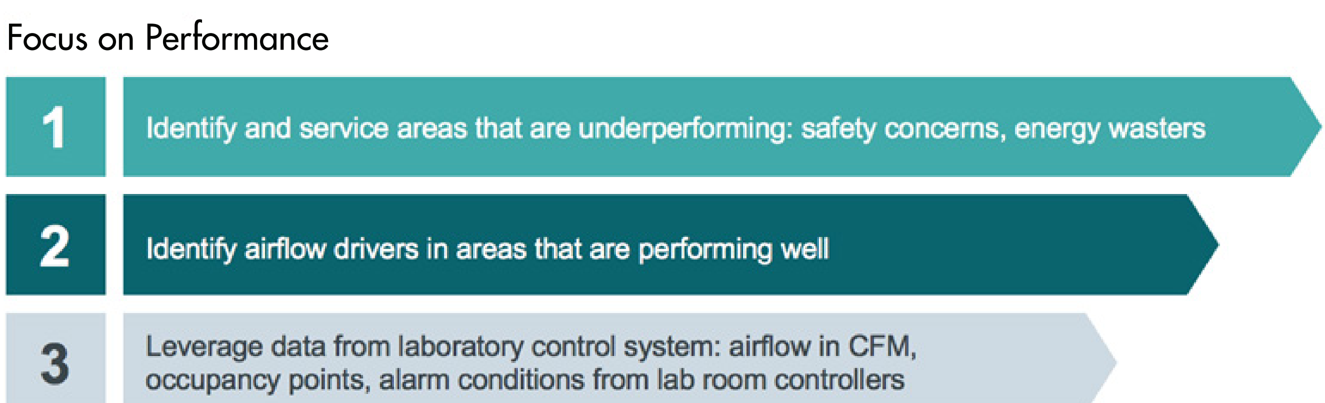

Figure 3: Laboratory performance report package. Source: Siemens.

Analytics are powerful decision-making tools that not only support a lab's safety and performance monitoring program but also can inform operational decisions that affect energy efficiency and sustainability. For example, if the data reveals that you're using most of your energy for ventilation, you can use the analytics to drill down and find the biggest drivers in your specific lab. Fume hoods rightfully get a lot of attention in terms of energy conservation measures, but if they're not the equipment driving the usage, adjusting their settings won't make an impact. Building analytics for labs will effectively provide a menu of options that will actually work in your environment. A good FDD system can also offer key information to guide routine maintenance decisions (Rhoads, 2020).

The right report turns mounds of data into solid support for operating decisions. An airflow driver report tells the amount of airflow caused by each of the HVAC functions: diluting and removing contaminants, controlling temperature, balancing exhaust (Coogan, 2013). This makes it possible to select the conservation measures most applicable to the specific building or area.

If the **fume hoods** are the main driver of lab airflow, further analysis identifies the most effective measures:

- Are the hoods used regularly? Consider decommissioning unused equipment.
- Are the hoods frequently left open? If so, sash management programs or automatic closers make sense.
- Do hoods drive the airflow even when they are closed? Re-evaluate the minimum flow rate in light of current standards.

If a **specified room ventilation rate** drives the airflow, then:

- Evaluate the dilution flow with an up-to-date hazard analysis. Lower rates may be justifiable.
- Set back ventilation during unoccupied periods.
- Apply contaminant sensors to vary the ventilation rate according to actual indoor air quality.

If the need to **cool the room** drives the airflow rate, look for ways to reduce or address the thermal load:

- Reduce electric lighting.
- Relocate heat sources.
- Consider alternate means of cooling.

Pressurization

Room pressurization is a ventilation technology that controls the migration of air contaminants by inducing drafts between spaces. Figure 4 on page 5 shows fume hoods at the back of a lab and the room exhaust and room supply air fans in the ceiling. To create a space with negative pressure—one where the environment contains contaminants within it—the BAS supplies less air to the room than it exhausts. Infiltration makes up the difference, creating an inward airflow at the gaps; this contains pollutants. Positive-pressure spaces function in the opposite manner, keeping contaminants out of the lab space by supplying more air to the room than is exhausted.

People who conduct laboratory ventilation testing often find discrepancies between the assumed or "supposed to" lab ventilation performance vs. the actual performance. Ultimately, though, success in this context is measured not by airflow numbers and pressure valve settings but by the actual control of contaminants.

Three methods of controlling space pressurization are widely known:

- Space pressure feedback: Measure the pressure difference across the room boundary; compare with the selected

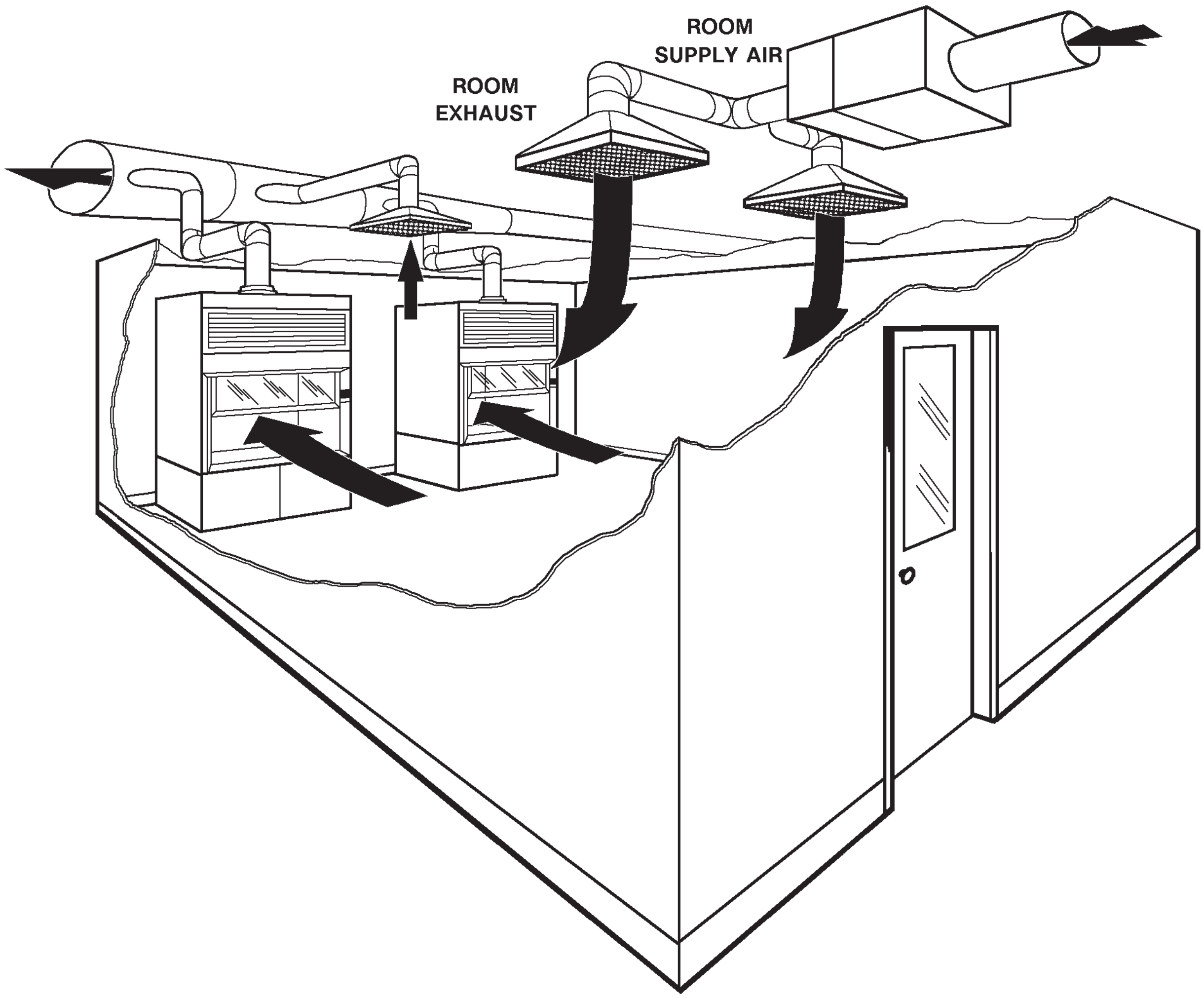

Figure 4. Room pressurization physics, illustrating a lab that is negatively pressurized compared with the space outside of it. Source: Siemens.

setpoint; adjust a supply or exhaust flow damper to reach the desired pressure.

- Differential flow control: Apply an airflow control loop (flow sensor, damper actuator, setpoint, and feedback algorithm) to each supply and exhaust. Coordinate the airflow setpoints to pressurize the room. Select the difference between supply and exhaust to achieve the desired amount of infiltration. Adjust the difference to reliably pressurize the room.
- Cascade control: This method combines the first two. Instead of manually selecting the flow difference, the room pressure control loop adjusts automatically.

The key to selecting a control method is usually an assessment of the room envelope and its airflow leakage area (Figure 5 on page 6). For a tighter, less “leaky” environment, space pressure feedback is most likely the right control method for more reliable pressurization. For spaces with looser construction, differential flow control is usually the

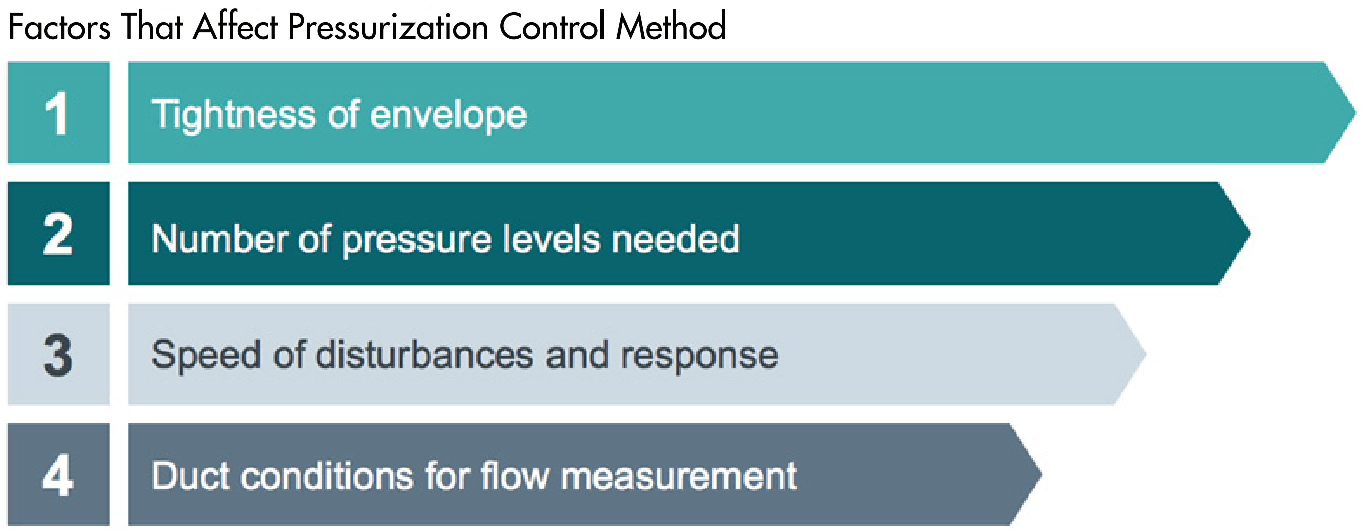

Figure 5: Selecting a control method. Source: Siemens.

better option. In other words, the best practice is to design around the airflow leakage and account for it when selecting a control method. If you're uncertain about the airflow leakage, you can include room pressure sensors in the design, and work with the control system provider to plan a way to change the control method after construction.

Ventilation

Ventilation engineers and safety officers work together to answer a range of questions about laboratory ventilation: How much airflow is required to remove contaminants that are not capture by exhaust devices? How do we set the right lab ventilation rate, typically expressed in air changes per hour?

Answering these questions—and others—may start with a hazard assessment. Often, this leads to the conclusion that a constant ventilation rate does not make sense for a given environment. In other words, airflow rates may need to vary, depending on use and circumstances in the lab. Demand controlled ventilation is any means of varying the airflow rate, based on the changing number of occupants and/or changing ventilation requirements (Sharp, 2021).

Occupancy is a well-established means for setting variable ventilation rates, using the strategy called demand controlled ventilation. In addition to the hazard assessment, consider deploying a comprehensive network of sensors to detect people, contaminant concentrations, and environmental conditions that align with your safety program and goals. Today's newest sensors can also reveal traffic patterns in your lab, alerting managers when people are congregating in areas where they should not. In a post-COVID-19 era, this type of information can prove invaluable for a range of situations beyond setting ventilation rates.

The lab design team will collaborate in a multidisciplinary, four-step process to create an effective demand controlled ventilation program:

- Identify conditions that warrant differing airflow rates. If it's true that, when people leave the space, contamination decreases, this condition can be applied to the BAS.

- Determine safe, appropriate flow rates for the conditions. Select separate rates to use when spaces are occupied and unoccupied.
- Select BAS controls inputs to trigger changes in airflow.
- Design indicators for lab workers and others in the space. They need to know the moment conditions change to help keep them as safe as possible while they work.

As the lab operates, rely on the BAS to confirm that all sensors work correctly: that they are indeed connected to the system and indicating the correct spaces. Carefully verify the dynamic effect on the ventilation rates. In short, once again—if you need it to work, make sure it works.

A final note on ventilation: the safety process for contaminant sensing is not as straightforward as it would seem. Where and how to sense the contaminants of concern are important considerations. Simply populating the space with sensors is not enough to keep everyone automatically safe.

Conclusion: BAS as a Source of Information

In summary, this guide offers a range of best practices for the BAS in lab and life science environments:

- Monitoring for safety and performance: Consider establishing a monitoring program by first setting up a secure remote connection to your BAS, which can be leveraged for fault detection and diagnostics as well as building analytics specifically designed for laboratory and life science environments.
- Pressurization: Design around airflow leakage, and account for it when selecting a control method. If you're uncertain about the airflow leakage characteristics of a space, install room pressure sensors to enable consistent performance monitoring within the BAS.
- Ventilation: Consider deploying a comprehensive network of sensors to detect people, contaminant concentrations, and environmental conditions that align with your safety program and goals. Rely on the BAS to confirm that all sensors work correctly, that they are indeed connected to the system and indicating the correct spaces. Carefully verify the dynamic effect on the ventilation rates.
- Commissioning of failure modes: This is a critical task that is sometimes overlooked or glossed over. All failure scenarios should be fully simulated and tested during commissioning, rather than not being assessed until real failures occur. Include power failures at various points, shutdowns and partial shutdowns due to safeties and mechanical failures, smoke detectors and fire alarms, and so on.

Ultimately, the BAS is more than just a system to control the physical events that happen within the life science environment. It's also a valuable source of information and data, supporting those who seek the safest, most efficient, and most effective lab operations. By integrating and applying a network of sensors, remote analytics, fault detection and diagnostics, and a long-term commissioning strategy (Mathew, 2021), the BAS is key to monitoring operations for safety and performance, pressurizing spaces, and establishing ventilation rates that maximize both efficiency and safety.

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