PRODUCT APPLICATION

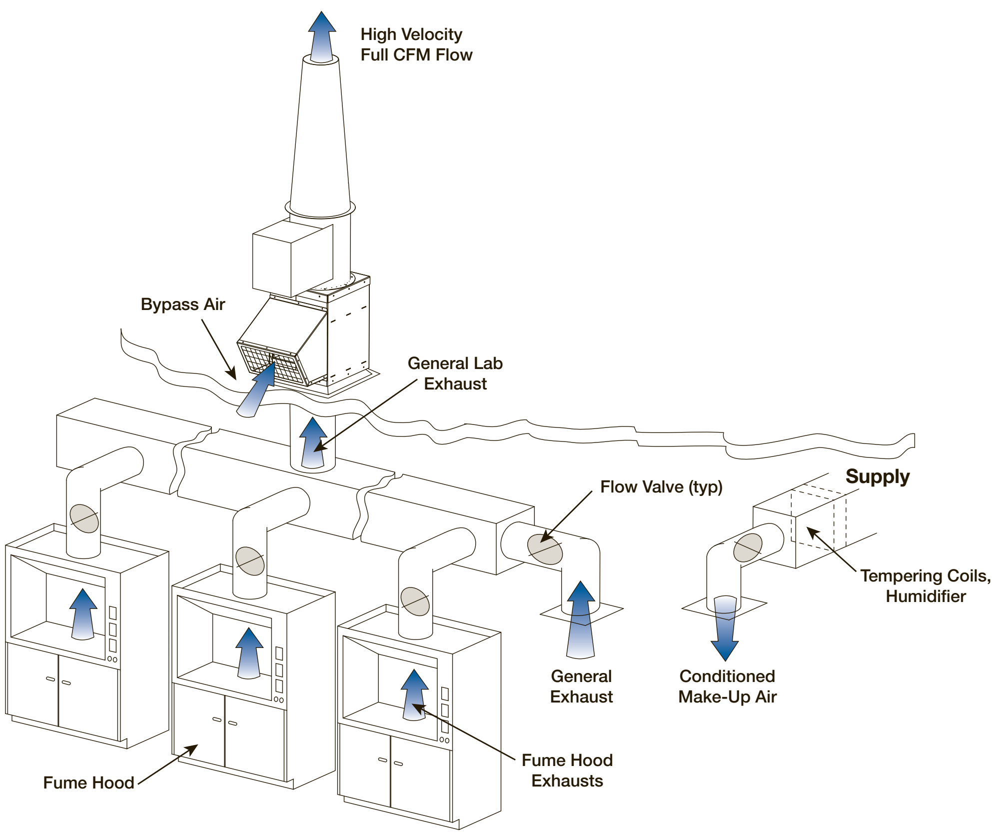
A technical bulletin for engineers, contractors and students in the air movement and control industry

Variable Volume Laboratory Systems, an Overview

On a variable volume laboratory exhaust system, hazardous and/or noxious contaminated air is exhausted through fume hoods, as well as through general exhaust grille(s), using a laboratory exhaust fan system.

One of the goals of the exhaust fan system is to maintain a minimum contaminated air discharge velocity and resultant plume height out of the stack of the roof-mounted exhaust fan system. Therefore, a minimum volumetric flow (CFM) must pass through the fan. As the variable volume controls in the laboratory vary the exhaust flow from the lab to maintain lab pressurization and fume hood face velocity for containment, the quantity of air exhausted from the lab will vary. To maintain the minimum CFM into the exhaust fan, a bypass air damper is provided with the exhaust fan system to add unconditioned air to the mix with the reduced lab exhaust volume. This allows the exhaust fan to maintain the desired discharge velocity exiting the stack.

In a typical system, as shown, conditioned air is supplied to the space to "make up" the air that is exhausted through the fume hoods and the general exhaust grille. This make-up air is typically supplied at a volumetric flow rate slightly less than that which is exhausted. This keeps the laboratory at a negative pressure with respect to adjacent spaces. In the event there is a chemical spill or biological release outside the fume hood, *infiltration into the lab will occur instead of exfiltration out of the lab.*



Controls

Three separate control loops make up the overall control system in a variable volume laboratory:

1. A control loop for each fume hood to control the flow into the hood. This is to ensure capture and containment by the fume hood and to maintain a constant sash opening velocity.
2. A control loop for the bypass air damper on the exhaust fan system. Allowing the proper amount of bypass air into the exhaust fan can be challenging. The most successful strategy is to use a constant static pressure control which maintains a constant static pressure in the exhaust riser by opening and closing the bypass air damper as the lab exhaust volume varies. The location of the static pressure sensor is critical. In many cases, high velocities are present in the exhaust duct that disrupt the static pressure measurement. It is also a common problem to oversize the bypass air damper, believing that a larger bypass damper is better. This is far from the truth and typically results in unsatisfactory system control and performance. The exhaust fan system manufacturer needs to apply damper application knowledge and specialized lab VAV system expertise to properly size and select the bypass air damper.
3. A room ventilation control loop that maintains room pressurization, the minimum number of air changes, and comfort levels within the laboratory.

   Room pressurization. Room pressurization may be positive or negative. Negative is the most common and is generally the case for laboratories with heavy chemistry. However, much research now involves tissue culture, or clean spaces, where the rooms need to be positively pressurized. Regardless of whether the room is positive or negative, the supply airflow tracks the exhaust airflow so the net pressurization is maintained. This is accomplished by maintaining a fixed CFM differential between supply and exhaust air. This control method is referred to as “CFM Tracking” or “Flow Tracking.”

   Minimum number of air changes. An air change is the volume amount of air required to replace the air exhausted in a given space per unit of time. The number of air changes is calculated by dividing the amount of air entering the space per unit of time by the space volume. The minimum air change rate will normally be in the range of 6 to 12 Air Changes per Hour (ACH) or could be higher for some labs during occupied periods and may be lower during periods when the lab is not occupied.

   Comfort levels within the laboratory. The cooling demand for the room may require an increase in the minimum air change rate. As temperatures in the space rise above the cooling set point, the minimum air change rate may be increased to provide additional cooling.

It is easy to conclude that the supply volume into the space either tracks the demands from the fume hood, from the minimum required air change rate, or from the cooling load required in the laboratory. If the minimum air change rate or cooling load alters the supply air volume, the exhaust loop tracks the supply flow increase to maintain the required room pressurization.

The response time of these control systems is critical to maintain containment and safety in the laboratory. The response speed of the fume hood and the lab make-up air loops are the most important. The response of the bypass air damper control loop is less critical and is a function of the number and status of the fume hoods in operation.

Items that drive conditioned air into the lab space are:

1. Fume hood exhaust air volume
2. Air change rate (usually a minimum of 6 to 12 air changes per hour)
3. Cooling ventilation, which typically exceeds the fume hood exhaust demand

An important performance function of the bypass air damper is to significantly reduce the quantity of conditioned exhaust air from the lab space when the sashes on the fume hoods are lowered or closed. The general exhaust from the lab could be used in place of the bypass air damper, however, large quantities of conditioned air would need to be exhausted from the space, wasting energy and increasing operating costs.

Energy Use

Although this varies from geographic location to location, for moderate annual climate conditions, the breakdown of energy usage in a laboratory is approximately:

33% Supply Air Cooling

33% Supply Fan Energy

17% Supply Air Reheating

17% Exhaust Fan Energy

Generally, the cooling component would be higher in areas of the country with high humidity, and the heating components would be higher in areas with lower ambient temperatures.

Given the high cost of conditioning the air in a lab space, it is prudent to decrease the supply into the space whenever possible and to provide make-up air (bypass air) to the exhaust system to maintain minimum volume or stack velocity. Using bypass air preserves the bulk of the savings provided with the variable air volume (VAV) system.

Variable volume flow from laboratories is typically controlled using the bypass damper and plenum as described above. Historically, the use of variable frequency drives (VFD) on lab exhaust fans to modulate lab exhaust flow is typically avoided for two reasons:

1. Slowing the fan down to reduce flow results in a drop in stack discharge velocity, and
2. The decreased flow rate reduces exit momentum resulting in decreased plume rise.

There are a number of schemes to provide reduced exhaust fan energy as loads vary, including staging fans on and off (using multiple equally sized fans on a common plenum), static pressure reset, and by using VFDs. Care should be taken, however, when applying VFDs to laboratory exhaust fan systems. Variable frequency drives should only be applied to laboratory exhaust fans specifically designed and applied to maintain safe, minimum discharge exhaust stack velocities at reduced flow rates.

Manifolded fume hood systems offer the following advantages:

1. Centralized exhaust fan system on the roof.
2. Elimination of one fan per fume hood (fewer fans to be maintained).
3. Increased fume hood reliability (connected to a manifolded fan system).
4. Additional dilution of exhaust from manifolded fume hoods.
5. Additional momentum (greater plume rise) at fan’s discharge (more CFM at discharge velocity).
6. Reliability of the exhaust system is created by the addition of a redundant (standby, or N+1) fan.

Obtaining answers to the following items will assist in the selection, design, and specification of the required lab exhaust system:

- General or specialized fume hoods
- Chemical and/or biological exhausts
- Excessive concentrations
- Exhaust orientation with respect to other campus buildings and HVAC intakes
- Constant or variable volume exhaust
- Heat recovery or HEPA filters
- Economics including operating, maintenance, and replacement costs
- Materials of construction
- Fan/blower type
- Utilizing a "system" design approach
- Architectural considerations
- Acoustic considerations
- VFDs on exhaust fans

Designing a laboratory exhaust system can be a complex process and it may be beneficial to consult with the fan manufacturer that has a team of dedicated technical experts and application engineers to assist with any laboratory exhaust design questions and to select a product that best meets your application.

AMCA Certified Ratings

A manufacturer that participates in AMCA's Certified Ratings Program (CRP) assures the industry that the products and equipment will perform as stated by the manufacturer. The program stipulates the various rules and regulations for presenting cataloging data: AMCA 211 for aerodynamic performance and AMCA 311 for acoustic performance.

P.O. Box 410 • Schofield, WI 54476
Phone: 715.359.6171 • greenheck.com