A SunCam online continuing education course

Variable Air Volume (VAV) For Laboratories

by

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Overview:

Variable Air Volume (VAV) systems have been used for many years in commercial HVAC systems *for a variety of reasons. Energy savings in HVAC systems is where the future of good engineering needs to focus. This is also true in facilities where large amounts of outside air are needed to replace exhaust air such as in laboratory facilities. VAV systems have been used in laboratory exhaust and supply systems for years also. This is mainly done for energy savings and not so much for comfort. Applying VAV to labs is a challenge to the engineering due to the need to maintain pressurization control in the lab spaces and the need to exhaust the air from the building in a safe manner where the fume hood exhaust is forced away from the building and surrounding buildings so as not to be re-entrained into outside air intakes.*

In general, peak full load analysis and HVAC system equipment and component selection is fairly straight forward and simple to "design". The challenge in "engineering" is understanding how to optimize a system from every aspect of energy savings, functional performance and comfort during the majority of the time that the system is in a "part load" condition. The understanding of part-load operation is what separates "engineering" from "design" in the HVAC industry. In order to "right size" an HVAC system for a lab it is essential to not only understand the full load conditions; but to also understand how the system and components of the system will respond to part load conditions. PE's who seal the contract documents for laboratory buildings have serious liability for themselves and their firms and must be aware of current technologies in order to protect themselves and their clients.

A challenge of a VAV system in a lab is maintaining the proper pressurization of the lab space when the fume hoods are opened and closed and/or doors to the lab space are opened or closed. These dynamic varying conditions can cause a lab space to swing from positive to negative or negative to positive if the VAV components in the supply and exhaust air ducts are not selected properly.

However, another one of the engineering challenges is to design the system economically and not arbitrarily fall into a trap of specifying products that are more expensive than needed to accomplish the functional requirements of a lab space. In addition, the benchmark has been raised in the fan industry with respect to economical fan applications that must take into account not only performance but also have the required discharge plume even when a lab building is in low utilization mode of operation.

Air distribution ceiling diffuser devices that can provide proper air velocities in the lab at low and high volumes without impacting the hood performance must be part of the HVAC system design consideration. Air supply and exhaust VAV devices must not only be responsive to the needs of the fume hood with respect to response time and accuracy but also with respect to material of construction compatible with the air passing through them. All of these criteria are achievable with VAV systems; however, there is a need to be aware of current products on the market to do it in a manner which balances functionality, maintainability, adaptability, energy use, room pressure control and first cost and operating cost criteria objectives.

Types of Laboratories:

There are many types of laboratories in a variety of building types: Animal Research, Pharmaceutical, Industry Research, Academic, Government and Private Sector Laboratories to name a few. There is likely an opportunity to look at VAV in any type of laboratory facility in one way or another; either at a building level or on a local room level. This course won't attempt to elaborate on VAV opportunities in each lab facility type. However, it is recommended the HVAC engineer be part of the design team early on in the design process for both new and retrofit laboratory projects to discuss VAV system opportunities before the architect, "lab consultant" and lab users get too far into the design process.

Hoods:

This course will not get too deep into all of the various hood types. There are plenty of other resources for understanding hood types and functions. Suffice it to say that some hoods are constant volume and some are by design variable volume. Even constant volume hoods which can be on/off in operation can be part of a building VAV system when these hoods are part of a manifolded VAV fan system. The hood airflow performance, like all other laboratory decisions, needs to take into account the required functional requirements of the hood and laboratory first and foremost. If the functional requirements can allow for VAV airflow then indeed VAV airflow should be considered if the payback or life-cycle analysis of the investment into the controls and HVAC components required show this to be a good decision.

VAV Terminal Devices:

There are a lot of considerations when determining which type of VAV terminal devices are appropriate. It again depends on the functional requirement of the laboratory. In some laboratories it is acceptable to use standard VAV boxes like in any commercial office space except that the laboratory application will generally require either a fiber free type of insulation or a double wall VAV box with metal on the inside of the box. In some applications a stainless steel VAV box may be required on the exhaust air stream for the hood but not for the general exhaust from the laboratory. Another option is to use a modulating concentric type damper with air flow measuring capability. These can be a good intermediate option between standard VAV boxes and "air valves".

Venturi Valve & Room Controller (Photo Courtesy of Triatek - www.triatek.com)

The highest level of control and also the most expensive level of control is to use an "air valve". Air valves are highly engineered products with linear control, high accuracy and low pressure loss. Manufacturers of these products generally have hood and room pressure controllers also.

Part of the key to determining which product is truly needed is to understand the response time and accuracy of control that the VAV terminal devices need to adhere to in order to maintain the required pressurization in the space.

Supply Air:

Supply air diffuser selections in a laboratory space are critical to ensure that the supply air does not disturb the performance of the hoods within the space. There are many manufacturers of many types of air devices. Depending on the air velocity requirements within the space and the quantity of air within the space it may or may not be necessary to utilize some of the more expensive air diffusers on the market.

Some labs may be able to get by with very inexpensive air devices; however, the engineer needs to clearly specify the material of construction and functional performance at both peak and part load performance to ensure the air devices will perform appropriately over the entire range of airflow in a VAV system. This will require tighter specifications to clearly communicate that any “or equal” bidders understand that the “or equal” means equal in **performance** and not just in architectural appearance. This is true in any building application and unfortunately the air device industry has been taken to a low cost commodity mentality focused on first cost and not performance.

ASHRAE needs to focus more research time on air device performance testing in part-load conditions if codes are serious about enforcing ASHRAE Standards 55, 62 and 90.1. Manufacturers of air devices need to step up their game in documenting air device performance at low flow conditions also in both cooling and heating modes.

Another exciting concept for air distribution within laboratories is the use of fabric air distribution diffusers. Fabric has been used for air distribution in laboratories in cases to deliver higher airflow volumes with lower localized draft and noise that may deter proper performance for sensitive laboratory hoods or other equipment. Additionally, fabric air distribution diffusers can also can be effectively used in VAV systems and can be utilized in retrofit projects where the original specified metal air devices have did not provide the necessary performance when labs were renovated and greater airflow, less draft or less noise was needed.

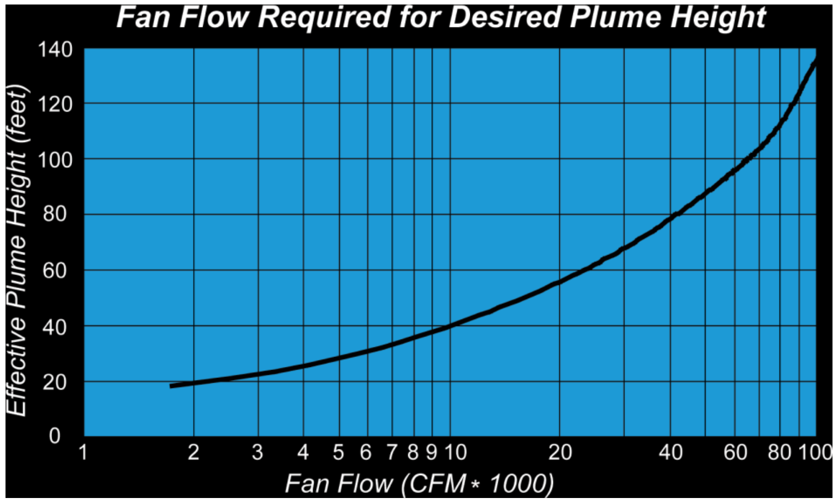
Fabric Air Distribution In Laboratory (“LabSox” Photo Courtesy of DuctSox Corporation)

Room Pressurization Transfer Air:

Even in a VAV system there is a need to have transfer air from a corridor or adjacent space into a laboratory. This transfer air needs to be controlled based on the pressure relationship, positive or negative, of the laboratory space to the adjacent space. The path of the transfer air can be via duct or door transfer grilles depending on the sensitivity of the space with respect to noise, air filtration and other factors. The amount of transfer air is dependent on the degree of positive or negative pressurization within the space. Depending on the use of the laboratory space, the transfer duct, if used, may need to be of special material or isolated in special ways.

According to some sources, typical safety concerns are satisfied with a negative differential in the range of 0.01 to 0.02 inches W.G. A slight air flow can be noticed through an open doorway with a pressure differential of 0.01 inches W.G. The engineer should work with the architect to ensure the room construction and doors are as tight as possible to help minimize the amount of transfer air needed to maintain the required differential pressure in the lab space. When a door is open to a lab room that has no vestibule anti-room then the speed of response of the general exhaust and supply air VAV terminal units may be more important depending on the sensitivity of the lab space with respect to always maintaining the pressurization differential.

Exhaust Air:



In general the exhaust air system capacity and air velocity must transport all hazardous airborne substances away from the origin and discharge them sufficiently high above the facility. These may include substances of one or more or a combination of chemical fumes, vapors, airborne biological substances and various particulate and radioactive elements. The diagram above indicates the use of a “high plume” exhaust fan as opposed to a physical stack.

High plume exhaust fans have grown in popularity mainly due to the desire not to have tall physical stacks; however, the engineer needs to evaluate both for safety considerations when wind conditions are taken into account. There may be times when an air plume by a fan takes a considerable amount of energy and a physical stack is the better more economical choice for the project. This decision should be an engineering performance not an architectural appearance decision due to the liability on the engineer and owner of the facility.

In selecting an exhaust system, the engineer must also consider first costs, life-cycle costs, maintainability, space requirements, expansion possibilities, redundancy and component reliability.

Laboratories typically use either dedicated or centralized exhaust system configurations. In a dedicated exhaust system, each fume hood has its own exhaust fan and ducts. In a centralized system, multiple fume hoods are connected to common manifolded exhaust ductwork. Either type can be VAV.

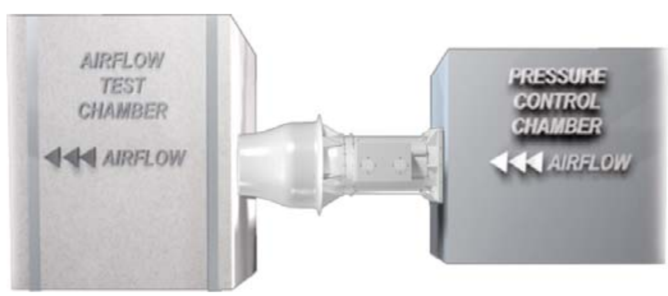
Exhaust Fans:

One of the most important decisions in a VAV lab application is the fan selection and control of those fans. There are many more choices on the market today than ever before. Engineers need to not fall back on what was once considered acceptable because newer proven technologies and products can provide safer installations for their clients. More fan manufacturers have developed fans for various laboratory applications so that engineers have more choices.

Although there is popularity in using induced draft high plume type fans, the engineer needs to realize that these are not needed in all applications and should not be talked into these fans by sales reps with a motive to sell or get proprietary specs on a job. In many lab applications, such as high school chemistry labs, there is generally no need to use expensive high plume induced draft fans; however, as with any engineering decision the application needs to be analyzed.

One fairly recent good news in the industry (and "kudos" to AMCA) is that there is the new AMCA Standard 260-07 "*Laboratory Methods of Testing Induced Flow Fans for Rating"* which gives credibility to tested performance data published by fan manufacturers. This provides a greater degree of assurance that the end user gets what they are paying for and also provides a greater degree of liability protection for the engineer and the facility owner when dealing with contaminated exhaust air streams. This standard was developed with input from all major fan manufacturers who are AMCA members.

AMCA Standard 260 Setup #1



AMCA Standard 260 Setup #2

The AMCA Standard 260 Setup #1 tests the fan inlet air capacity whereas the AMCA Standard 260 Setup #2 tests and quantifies the outlet capacity at the discharge of the windband which includes the fan and induced air volumes. Without this new AMCA testing in the old days there was no AMCA independent validation of the manufacturer's marketing literature claims. Newer technology designs are being validated by this

AMCA test standard to ensure the owner is indeed getting what they pay for and can add another level of liability protection for the engineer specifying these types of fans. The key to specifying high plume exhaust fans is to specify the outlet velocity of the wind band not the nozzle velocity of the fan. Nozzle velocities can vary depending on the efficiency of the product design. A higher nozzle velocity does not necessarily result in the highest wind band velocity.

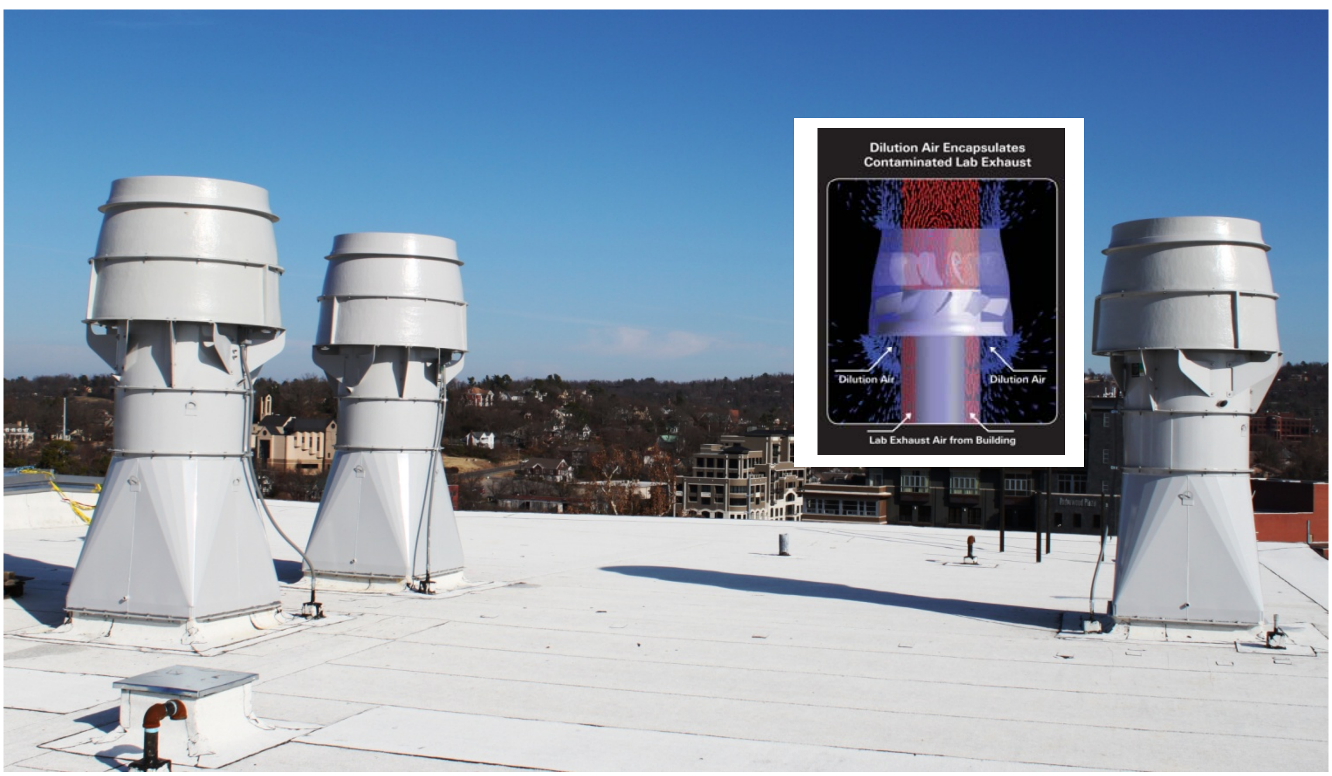
"VariPlume" AMCA 260 Certified Induced Draft Fan (Photo Courtesy of Loren Cook)

Engineers need to consider fan types, full and part-load performance, maintainability, dilution of exhaust air from the fans, energy recovery, redundancy, exhaust air discharge methods with stacks or "high plume" exhaust streams, cross wind velocity impact on the exhaust air from the stacks or the impact of wind on the "high plume" of exhaust air. Engineers can utilize industry guidelines on analyzing the impact on the exhaust air due to winds around the building or they can hire expert wind consulting companies to model their applications. In today's increasingly stringent demands on indoor and environmental air quality it may be worth the investment to hire experts in the field of wind tunnel modeling to share the liability of making the decision of fan types and discharge methods of laboratory exhaust streams.

State-of-The-Art:

There are many people, professional organizations, code entities and government research projects that are continually looking at the safest ways to build laboratory facilities with the least amount of energy use while ensuring safety for the users and the surrounding environment adjacent to the laboratory buildings. This includes looking at hoods, controls, air transport methods and fans. One such example of this is the recent development and implementation of the new AMCA Standard 260 noted above which ensures that fan manufacturers of induced drafts fans do indeed perform as the marketing materials claim. Most of the major fan manufacturers are embracing this standard which was a consensus standard by all of the AMCA fan members. There can be increased liability on the engineer and facility owner if non-AMCA certified fans are used when there are multiple AMCA certified fans on the market to ensure the fans are tested and certified to ensure the published performance meets this state-of-the-art standard.

There is one product that allows very low turndown of a VAV laboratory system's main exhaust fan while not requiring this primary exhaust air fan to expend the energy needed to get the "high plume" desired above the building at high cross winds. A booster fan is used in this state-of-the-art method which uses a separate power to develop the plume while allowing the building exhaust fan to turn-down to low levels. The booster fan allows the primary lab exhaust fan to be much less horsepower since it no longer needs to be the main force provider for the plume.



"PowerPlume" Induced Draft High Plume (Photo Courtesy of Loren Cook)

Maintenance and Operation:

Even the most sophisticated, energy-efficient laboratory HVAC VAV system can become ineffective if the system is not properly installed, maintained and operated by the laboratory users. Education of the entire design and user team is essential to ensure that the energy savings projected in the design are realized in real applications. It is recommended that the IO&M manuals of product equipment be reviewed early in a design process and also as part of the facility commissioning process before system types and product selections are made.

Fans, filters and ductwork maintenance are all part of the design considerations that should be taken into account to ensure laboratory exhaust systems are engineered correctly. Obviously exhaust plume management is the primary objective. This starts with the hood sizing and selection and then the filtration system needs to be considered. There are pros and cons to both direct and belt drive fans including accessibility and maintainability and access to the fan parts.

Codes and Standards:

Various agencies and organizations have developed codes and standards affecting the design of research laboratories. These codes and standards are minimum requirements. Below is a listing of some codes and standards but this is not an exhaustive list. It is always recommended to consult with the Authority Having Jurisdiction for governing codes. It is also recommended to consult with the building owner's insurance agency to check what their insurance coverage requires. Many insurance agencies may require complete compliance with building codes which include consideration of seismic bracing of the lab exhaust system and fans and also adherence to wind forces on the exhaust fans on the roof of such facilities.

- AMCA Standard 260-07, "Laboratory Methods of Testing Induced Flow Fans for Rating"
- ANSI/AIHA—American National Standard Z9.5 for Laboratory Ventilation
- ANSI/ISEA Z358.1—Emergency Eyewash and Shower Equipment
- Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC) standards

- Department of Health and Human Services, Centers for Disease Control and Prevention and National Institutes of Health—Biosafety in Microbiological and Biomedical Laboratories (BMBL) 5th Edition. December 2009.
- Department of Veterans Affairs Research Laboratory Design Guide
- General Services Administration (GSA): Facilities Standards for the Public Buildings Service, P100
- National Institutes of Health (NIH): Design Policy and Guidelines
- National Institutes of Health (NIH): Guidelines for the Laboratory Use of Chemical Carcinogens, Pub. No. 81-2385
- NFPA 30—Flammable and Combustible Liquids Code
- NFPA 45—Fire Protection for Laboratories using Chemical
- OSHA 29 CFR 1910.1450: OSHA—Occupational Exposures to Hazardous Chemicals in Laboratories

