



HVAC Systems for R&D Laboratories

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One of the hottest words in the Indian pharma industry today is research. From being no better than a copying department at one time – whose main job was to reverse engineer successful international drugs – this function is all set to become the critical success factor in the pharma business.

The Indian pharma industry is reorienting itself in coming to terms with research being the key driver of growth in the future. Companies are strengthening their R&D base and several have started generating large revenues from their existing R&D activity in the international market. Some names that one often reads about are Dr. Reddy's Laboratories, Ranbaxy and Glenmark Pharma. On the other hand global companies such as Pfizer and Merck are now treating R&D activity as their core business, divesting their manufacturing units and entering into contract manufacturing tie ups in low cost locations. They are also establishing captive R&D centres in India to take advantage of our large pool of scientists and low costs.

The variety of such opportunities available has encouraged Indian and foreign companies to establish new R&D laboratories to do contract research and others to provide both contract research and manufacturing services. The purpose of this article is to shed some light on the design aspects of air conditioning and ventilation/ exhaust systems required for such labs.

It is fair to assume that mechanical engineers who routinely participate in the design of comfort HVAC systems for office buildings, IT centers and hotels are not familiar with the HVAC design of laboratory facilities that could contain potentially hazardous chemicals that may cause health hazards to employees of such labs. The following excerpts from

the OSHA (Occupational Health and Safety Administration) standard of USA illustrate this important perspective:

- The best way to prevent exposure to airborne substances is to prevent their escape into the working atmosphere by the use of hoods and other ventilation devices.
- The laboratory ventilation system should provide a source of air for breathing and for input to local ventilation devices; it should not be relied on for protection from toxic substances released in the laboratory
- As a rule of thumb, use a hood or other local ventilation device when working with any appreciably volatile substance.
- Ensure that laboratory air is continually replaced, preventing

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increase of air concentrations of toxic substances during the work day.

- Direct air flow into the laboratory from non laboratory areas (negative pressure) and out to the exterior of the building.

- A laboratory fume hood with 2.5 linear feet of hood space per person should be provided for every two workers if they spend most of their time working with chemicals. If this is not possible, work with substances of unknown toxicity should be avoided or other types of local ventilation devices should be provided.

The Lab

A typical pharma research lab consists of a long corridor that in turn opens into the main lab area. Here there are several work counters – fume hoods, reagent shelves, open cabinets, where the actual experiments are carried out. The



Photo 1: Corridor leading to the main laboratory.

corridor is at all times maintained at a positive pressure compared to the lab so that the fumes emanating from the experiments are not allowed to escape to the

corridor but remain restricted to the lab area. The air from the corridor flows into the lab through the lab door undercut or through a louver on the door or through grid devices or offsets. The offset quantities for a standard single door and double doors are 240 cmh and 480 cmh respectively. Photo 1 shows the view of the corridor leading to the lab for a large R&D lab.

The Laboratory Fume Hood

The Scientific Apparatus Makers Association (SAMA) defines a laboratory fume hood as a “ventilated enclosed work space intended to capture, contain and exhaust fumes, vapors and particulate matter generated inside the enclosure. It consists of side, back and top enclosure panels, a work surface or a counter top, an access opening called sash and an exhaust plenum equipped with a baffle system for the regulation of air distribution system. The entrance to the work area has an air-foil design, meant to direct the air towards the exhaust outlet. The glass sash may be horizontally operable, vertically operable or horizontally and vertically operable. The horizontally and vertically operable sash conserves energy by virtue of the smaller face area. Sash-stops are provided to prevent the

sash from opening beyond a certain limit. Typically maximum sash openings are 500 mm or 650 mm. The front face houses the fume hood monitor that displays parameters such as face velocity, air pressure etc. The other components include base cabinets (for storage) and lights for better visibility during experiments.

Fume hoods are designed for a face velocity of 0.5 m/sec. Figure 1 shows a schematic of a simple fume hood and its various parts.

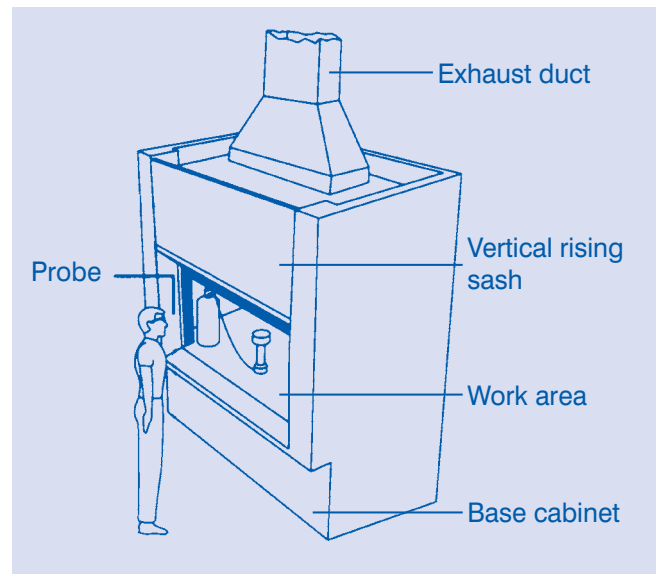


Figure 1 : A typical fume hood.

There are a large number of such fume hoods in a laboratory and their exhausts are connected together to a common exhaust system, where the exhaust air is treated with special scrubbers before finally venting out to the atmosphere (or diverting it for heat recovery).

The dimensions of hoods are decided based on requirements of individual owners, so as to allow enough space for personnel access and experimental apparatus.

Other Exhaust Equipment

Apart from fume hoods, labs also house other local exhaust units such as elephant trunks, cabinets and ventilated reagent shelves. These are passive, constant flow devices. Elephant trunks are spot exhaust devices made of flexible tubing that is connected to the building exhaust and used to vent out both heat and chemical vapors. Ventilating cabinets as well as reagent shelves are balance enclosures used to isolate vapors during weighing operation by connecting them to the building exhaust. Refer Photos 2 and 3 to get an idea of what they look like.

Types of Fume Hoods

Though the function of a fume hood is fairly simple, i.e. to isolate and drive away fumes towards the exhaust

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Photo 2 : Elephant trunks in a laboratory

system, several varieties exist. They can be broadly differentiated as follows:

By Construction

Depending on the nature and magnitude of the experiments required to be carried out, fume hoods can be of various types-table-top, low-level, walk-in, canopy or ductless. Photos 4, 5 and 6 show pictures of some of the types mentioned.



Photo 3 : Ventilated cabinet for carrying out weighing operations.

They are constructed from a variety of materials and covered with an appropriate lining material to give a white or light-coloured interior finish.

Perchloric acid and radio isotope fume hoods are special hoods that handle experiments with dangerous chemicals or radioactive elements, and hence require very special construction. Details of these are not discussed in this article.

By Method of Operation

Constant Volume (CV) – These operate on the constant volume principal, i.e. each hood will have a constant exhaust rate. In case the sash is closed or only partially open, the balance air is bypassed to the exhaust

system. This is a simple design but involves high capital and life cycle costs, since the equipment has to be sized to full load and energy is wasted in blowing out air, even when not required. Eyelid dampers are usually provided for initial adjustment. Figure 2 depicts the schematic airflow of a constant volume laboratory.

Variable Air Volume (VAV) - A VAV fume hood control system is designed to vary the hoods' exhaust rate to maintain a constant average face velocity across the sash opening at all times. Room pressurization is maintained by adjusting the makeup air at a slightly lower rate than the exhaust. Minimum ventilation requirements and proper temperature control may require the use of a general exhaust to overcome the added supply of air.

A fume hood exhaust valve gets actuated based on the signal from the sash sensor or from the velocity sensor of the fume hood so as to maintain a constant face velocity. Based on the exhaust air quantity across the fume hood, the room air supply is adjusted. The supply air quantity has to be such that it provides the minimum required air changes in the room or is equal to the total exhaust from the lab. There will be a condition when all the fume hoods are closed and still the minimum air circulation rate as well as room temperature have to be maintained. During these periods the exhaust of air from the room will be from the general exhaust ducts. During non-occupancy periods, the room temperature may be increased

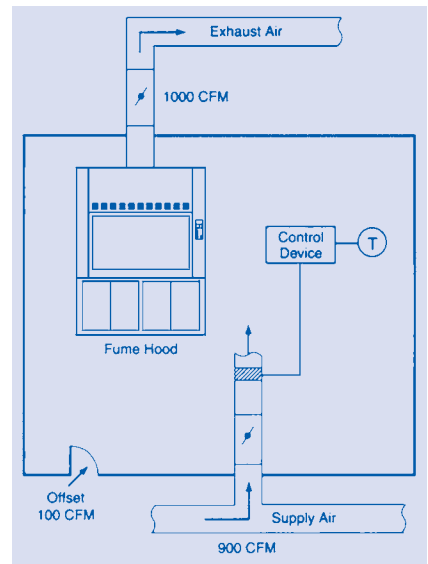


Figure 2 : A constant flow laboratory.



Photo 4 : Table top fume hood.



Photo 5 : Low level fume hood.



Photo 6 : Walk-in fume hood.

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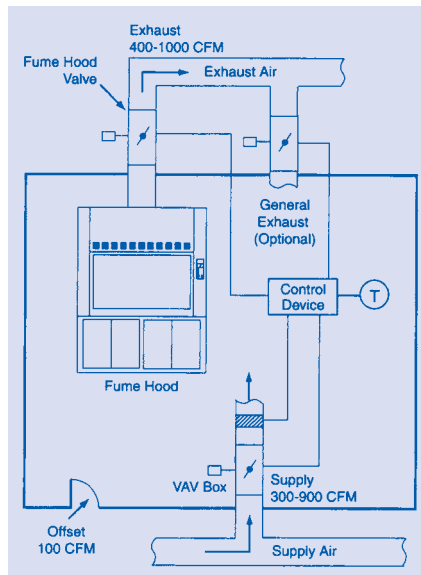


Figure 3 : A variable flow laboratory

resulting in energy conservation. Three sets of valves – fume hood exhaust, general exhaust and supply air exhaust are used. Exhaust valves work in tandem with the supply air and general exhaust valves. The supply air valves are controlled by the duct pressure and room temperature sensors. All these valves work to-

gether to maintain proper room pressures. These are either butterfly valves or venturi valves and it is very necessary that they have fast response times so that fume hood containment and room pressure regime is not disturbed. Please refer Figure 3 for a schematic of such a system.

The obvious advantages of a VAV system are:

- significant energy savings that result when the sashes are closed,
- assured safety due to maintaining proper face velocity at all times,
- increase in lab flexibility due to the VAV control's ability to accommodate system changes,
- low sound levels at reduced flows.

Objectives of Laboratory Air Flow Systems

Having taken an overview of the equipment available for effective exhaust of fumes, it will be worthwhile to revisit the main objectives that we need to keep in mind while planning the air flow systems for such labs:

- Operator safety: This is without doubt the prime concern and the focus should be on capturing and containing fumes.
- Room pressurization: For this the air flow direction has to be maintained at all times, i.e. supply air should always flow from the corridor to the lab area. The fume hood should be able to suck up air fast and thus push the fumes to the exhaust.
- Ventilation: The prescribed fresh air changes have to always flow into the lab.
- Comfort: Indoor temperature and RH has to be maintained to provide a comfortable environment to the lab occupants.

Determining Optimum Velocity Levels

Velocity is one of the main factors in effective containment of fumes. Over the years, several technical bodies including ASHRAE have conducted tests, trying out various velocities across fume hoods in an effort to judge the optimum range where isolation is best achieved. Common industry guidelines now range from 60 fpm to 120 fpm as the acceptable range. In many modern facilities, 100 fpm is accepted as the standard for safe operation.

Optimizing HVAC Design – Understanding Diversity

In its simplest definition, diversity is designing a system for less capacity than the sum of peak demands. Understanding the factors that affect diversity of fume hoods usage can give designers the confidence to size the HVAC system for predicted use instead of total possible use. These factors are:

- Presence (or absence) of an operator – Studies show that the actual time that an operator is present at the hood is a small percentage of the total hours in a day, sometimes less than an hour!
- Knowing how users treat sashes- Users may or may not close the sash after use. As a result, large quantities of air are often drawn into the hood, even when there are no fumes and no operator!
- Random use of fume hoods – It is highly unlikely that all fume hoods would be in use at all times.

Equipped with this knowledge and the number of fume hoods, most users use statistical tools to calculate the diversity that they can safely assume in their labs.

Fume Hood Air Flow Design

For working out the maximum air quantity across the fume hood multiply the internal width with the proposed height to which the sash has to be lifted during the experiments and the sash velocity. The minimum air flow required when the sash is closed will be generally furnished by the fume hood manufacturer.

While there will be multiple fume hoods inside a laboratory, all will not work at a time and even if they are, all will not be opened up to the full sash opening, there by resulting in a diversity. By the diversity the number of fume hoods working and in idle conditions are identified. The diversity has to be carefully discussed with the users.

The total air quantity inside a lab will be worked out by adding up the air flow through the working fume hoods, idle fume hoods and constant volume exhaust devices such as elephant trunks, ventilated reagent shelves and cabinets. The suggested air quantities through elephant trunks, cabinets and ventilated reagent shelves are 180 cmh, 70 cmh and 70 cmh respectively.

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Getting Started

We now discuss step-wise the process of HVAC system design.

Data Collection

This is the all-important first step that will determine the success of your entire design. Try to acquire each and every detail before going to the drawing board. These include:

- Ambient weather conditions as well as inside temperature and RH requirements for various zones
- Air pressure for various zones with respect to adjacent areas
- Duration of operation for each area
- Cleanliness level required for each area
- Fume hoods – types, sizes and diversity of operation
- Local exhaust such as elephant trunks, reagent shelves and cabinets
- Fresh air requirement – Such labs are mostly once-through systems. If not, get the ventilation requirement clarified.

Compiling data and basic calculations

Room-wise cooling loads are calculated based on the above data and the detailed drawings and the calculations tabulated in excel format. The next step is the sizing of chilling plant as well as the air side equipment.

High-side equipment sizing

The chiller and other high side equipment are selected in much the same way as for any other project, with a minor difference.

Such projects typically have very high ventilation rate and more often than not, a once through system is desired. Hence, a thorough study needs to be made on whether the exhaust heat can be recovered in some way. Various types of heat recovery methods such as heat wheel, run around coils and heat pipe systems are available. Run around coils and heat pipe systems are suggested for applications wherein there is no purge back of exhaust air back into the supply air stream. Run around coil using water is the simplest form of the heat recovery system suggested for an R & D lab with 100% outside air.

Based on what system is opted for, the corresponding savings in plant tonnage need to be calculated and confirmation sought from the vendor of the heat recovery device. The actual chilling plant capacity will then get reduced to this extent and so will the corresponding pumps, cooling towers and other paraphernalia. In case of a VAV exhaust system, there will be secondary chilled water pumping system and VFDs on pumps.

Sizing and selecting air side equipment

A fume hood summary sheet is prepared showing the

type, dimensions, air quantities, diversity and details such as electrical, plumbing and gases. Based on the inside temperature, pressure, duration of operation and cleanliness, areas are segregated into multiple zones with dedicated air-handling units. A typical schematic showing details of fume hoods as well as local exhaust devices is prepared.

For round the clock operation it is preferred to have standby air-handling units or two air-handling units each having a capacity of 50% with standby motors. This will prevent total failure of the air conditioning system at any point of time.

Air Handling Units

They are of double skin construction with 50mm thick insulation and thermal break structure suitable for 100% outside air. The sections include return air damper, return air filters, return air fan with variable speed drive, (run around) coil, exhaust air damper, fresh air damper, pre filter, cooling coil with motorized 2-way chilled water valve, supply air fan with variable speed drive, fine filter section and supply air damper. The exhaust section including the fan has to be epoxy coated to protect it from the chemical laden air. Manometers or pressure measuring ports and viewing glass panels are suggested for various sections. A standby motor for the supply and exhaust blowers is preferred in case there is no redundant air-handling unit. The fans are interlocked in such a way that for the negative pressure areas, the supply fan cannot function without the operation of the exhaust air fan. Interlock is suggested to be done with a flow sensor which will not permit the supply fan to run in case of the belt failure of the exhaust fan. For VAV exhaust systems, AHU motors have to be provided with variable speed drives. Refer *Figure 4* for a schematic of a typical sectional drawing of an AHU for lab applications.

Ducting System

The exhaust ducts can be GI with epoxy coating on the inside. Alternatively a polypropylene FRP duct can be used for the exhaust. Air distribution has to be through perforated diffusers to have reduced draft. There should be no supply air terminals near the fume hoods. Fire dampers are mandatory for the supply and return air ducts. The ducts are thermally insulated. In case of a VAV fume hood exhaust system, multiple VAV units with fast-acting controls have to be installed in the duct system.

Pressure Regime

The laboratories discussed above, i.e pharma and chemical labs are maintained at a negative pressure compared to adjacent areas.

An air-flow schematic showing the supply, exhaust air flow and offset for each zone has to be prepared. A pressure regime drawing showing the pressure levels to

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be maintained in each zone with arrows showing the air movement is also required. Figures 5 and 6 depict typical pressure regime and air-flow schematics.

Building Automation System

A user friendly and simple Building Automation System (BAS) is an asset and a huge help in monitoring & controlling as well as trouble shooting.

Chillers, pump sets, variable frequency drives variable air volume units, fume hood control systems can be integrated to the BAS. The fume hoods however, have an independent automation system connected to the laboratory management system.

Installation and commissioning

With the design, schematics, equipment sizing done, it is time to depute a reliable HVAC contractor to carry out the installation as per specification and using the best quality material and equipment.

Validation

After the system is installed, pre-commissioning, commissioning and performance testing activities are to be conducted. The system has to be validated by comparing with the design parameters. A proper handing over document comprising of operation and maintenance manual, highlighting the standard operating procedures (SOP), as-built drawings, test readings, with service escalation charts are to be submitted. Usually, an independent agency does the system validation. In practice however, the entire process may not be as easy as it sounds, mainly because this is not a mere comfort job.

It is extremely important that during actual testing, all pressure gradients and fume hood velocities are as specified. A difference between design and actual values is proof that the exhaust system is improper and is not

successful in containment of fumes.

It could be a long drawn and painful process for the contractor to identify the error in the installation and then rectify it. Even a minor thing such as duct leakage (beyond expected values) can cause this pressure imbalance, costing him time and money.

Noise Control in Laboratories

The exhaust equipment in the laboratory can be a source of considerable noise owing to elements such as the various fume hoods, fans, motorized dampers etc. It is advisable to implement noise control measures in the early design stages. Some suggestions are:

- Size exhaust ductwork to allow for the addition of future fume hoods. Capped connections should also be included in the design to allow for future use.
- The sizing of the exhaust VAV boxes has a direct impact on noise generated in the ductwork. Sound manuals provided by VAV manufacturers should be used.
- Install vibration isolators under plenums and use weatherproof flexible connections when connecting ductwork to plenums.
- Direct driven fans may be easier to maintain but are difficult to adjust for noise control.

Practical Hints

- Since most of these labs are 100% fresh air applications, restrict the inside temperature to just about comfort level, because every degree reduction in temperature will take a toll on the refrigeration capacity required. Some experts recommend as high as 26°C. The RH can be around 60%.
- The exhaust (or return air) path is lengthy and is strewn with several high-pressure drop components such as hoods, ducts, heat recovery wheel (or heat pipe or run-

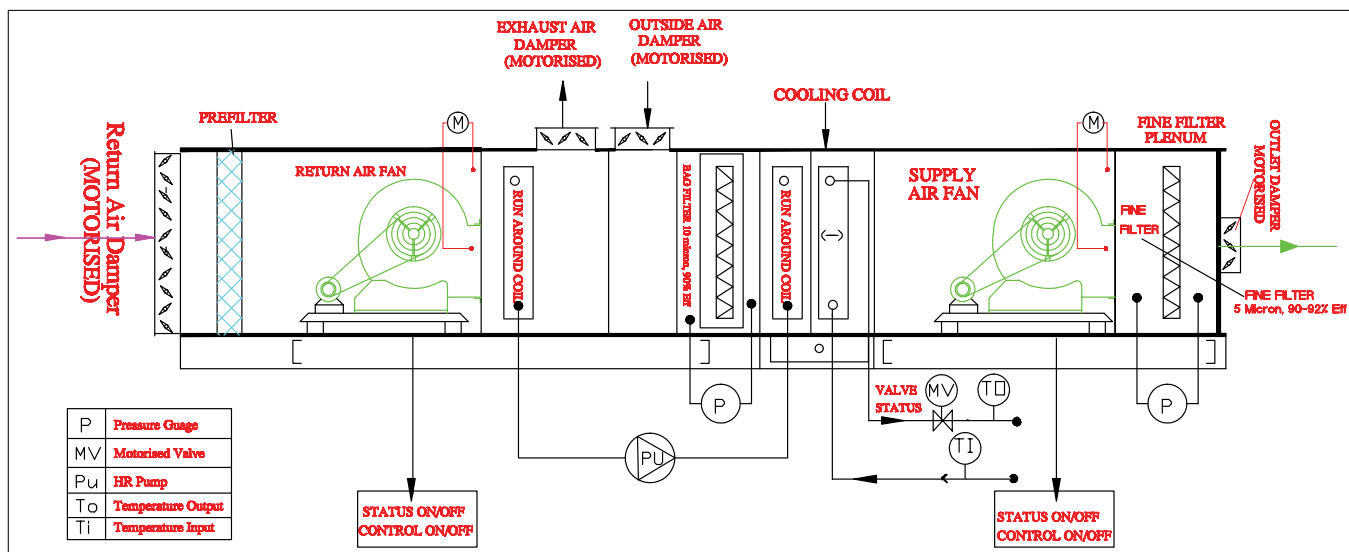


Figure 4 : AHU schematic.

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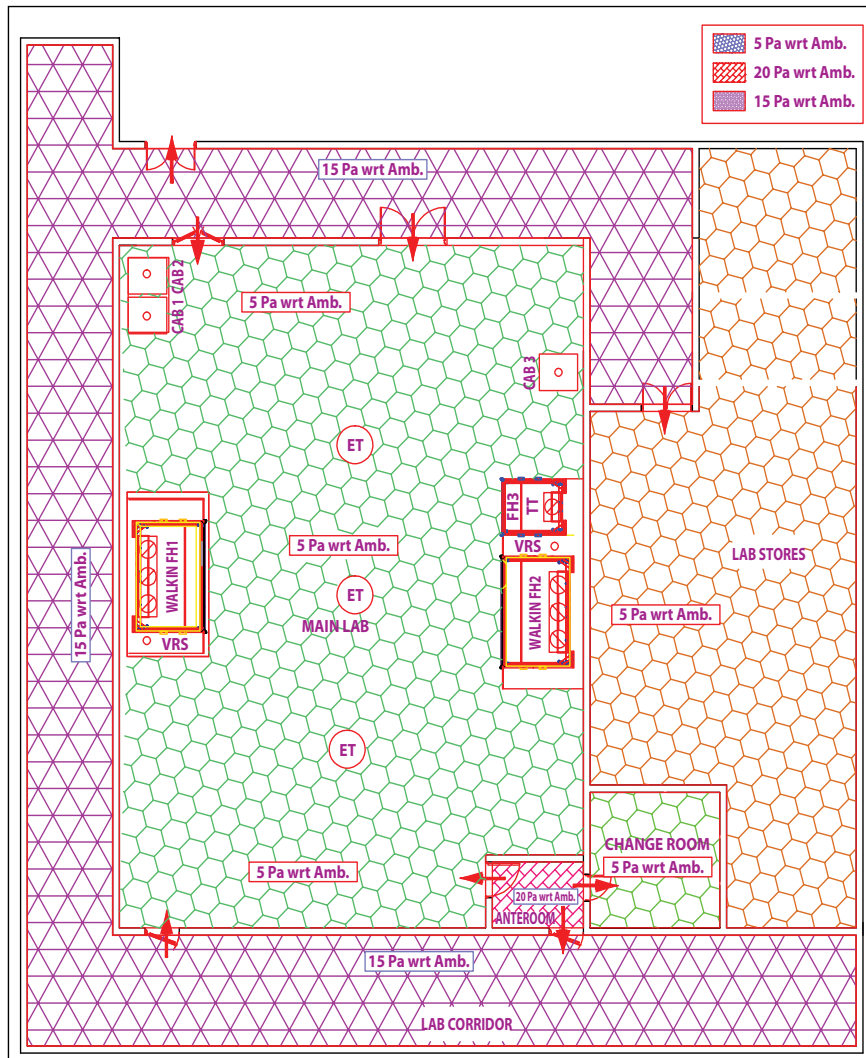


Figure 5 : Pressure regime schematic.

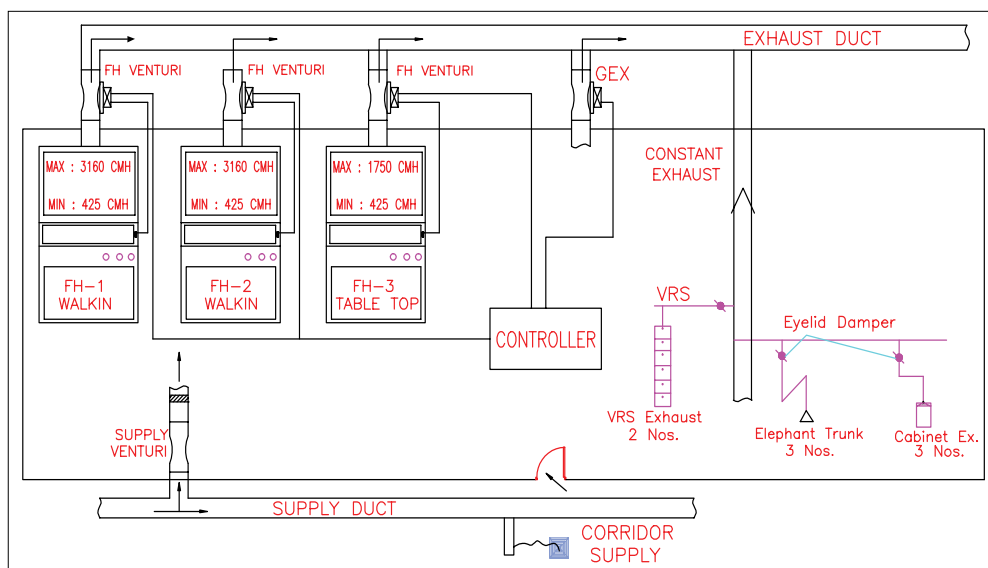


Figure 6 : Air flow diagram.

around coil). Hence the sizing should be carefully done, to avoid insufficiency of airflow.

- For a correct control feedback, the pressure sensors/ switches should be located at the point of maximum deviation.

- Leakage in exhaust ducts leads to short circuiting, rendering the system ineffective. Hence the ductwork should be leak tested and rectified, if required.

- Branches of ducts should have smooth turnings and guided vanes. The junction of two opposite air streams should be designed to avoid bull heading.

In Summary

The pharma industry in our country shows a lot of promise and is expected to become a USD 20 billion industry by 2010. R & D laboratories are mushrooming all over. The HVAC industry has a role to play by designing and installing safe and energy efficient exhaust systems for them. One has to consider all aspects such as first cost, operating cost, maintenance cost, safety, containment, easy augmentation etc. while deciding on the equipment.

User education is also equally necessary to be able to translate the energy savings on paper in to practice. A good example

would be to educate users on sash management, i.e. to urge them to close sashes when not in use. Only then can a VAV system work effectively and generate savings in operating costs.

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