HVAC Design for a Biosafety Laboratory

A scientist conducting an experiment using a Biosafety Cabinet

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Man's quest for immortality has promoted research in the field of health and medicine. Research is carried out to develop new drugs to fight diseases. Over a period of time, the disease–causing germs become resistant to a particular drug and hence the need for continuous development work. Such drugs have to be tested and evaluated before they can be prescribed by doctors and scientists who study diseases, drugs and other topics related to human health are called Biomedical scientists.

Piramal Life Sciences has an R&D facility at Goregaon in Mumbai where qualified scientists are working round the clock for the benefit of millions of people.

Recently, I was approached by their engineering team to design an HVAC system for their new Biosafety Lab. Having had the opportunity of working under the guidance of experts from National Institute of Health, USA in the past, I felt confident in accepting the challenge. As you read along, you will realize why I call the task a challenge.

What is a Biosafety Lab?

Many readers will be familiar with the HVAC design of a pharmaceutical plant.

Typically, the important criteria in design of a pharma plant is the level of cleanliness and a zoning plan. The air between two zones is not allowed to mix, so as to prevent cross contamination. Also, to ensure a clean area, the air is filtered through a series of filters, starting from coarse filters to fine and very fine or HEPA filters. The clean room is kept under a positive pressure, which simply means that when a door to the room is opened, the air movement is always "in" to "out" and not vice versa.

A Biosafety Lab is a specialized lab in which research is carried out using DNA, tissues and pathogens (bacteria / viruses). Thus, such a lab could pose a danger to the personnel working in the lab. The scientists could get infected and they may pass on the infection to others they come in contact with. Sounds scary! Doesn't it?

Hence, all the experiments have to be carried out in a controlled and safe environment so that the scientists do not catch an infection. Air management in such labs therefore plays a very critical role and this is where the role of an HVAC engineer comes in.

Guidelines on lab safety have been published by leading institutes like the U.S Department of Health & Human Services, Centres for Disease Control & Prevention and National Institute of Health (U.S).

About the Author

Sangita Jhangiani has over two decades of HVAC experience and is a LEED Accredited Professional. Energy modelling for green buildings using simulation tools is her recently acquired skill. She is a mechanical engineer and a member of ISHRAE, ASHRAE and CII IGBC. She can be contacted at *sangita@enova.co.in*

Classification of Biosafety Labs

Based on the level of safety requirement or the danger posed by the hazardous material being used in the lab, Biosafety Labs are classified as BS level 1, 2 ,3 or 4.

A BSL 1 facility is a comparatively safer lab where the reagents used are not potentially harmful either to the researcher or to the environment. Thus, there is no specific HVAC criteria for these labs, except that the lab is maintained under negative pressure. The experiments are carried out under Chemical Fume hoods.

A BSL 2 Lab deals with moderately hazardous material. A BSL 3 Lab deals with dangerous or exotic reagents which are harmful. A BSL 4 facility is critical where the materials dealt with can cause life threatening diseases.

Important HVAC Design Features for a BSL Facility

Unlike a pharma 'clean' room, a Biosafety Lab is essentially kept under negative pressure. Leakage of air from "out" to "in" is permissible but the reverse is not advisable. This ensures that the pathogens are contained within the Lab area and do not mix with the air outside the room.

A Biosafety Lab is an independent zone with it's own AHU. The chilled water supply could be through the common chiller located in the building.

To design an HVAC system for such an area, the following principles have to be followed:

- The Lab access is never direct to adjoining areas. The access to the area is through a corridor with two self-closing doors. This corridor is commonly called an "air lock". Access is limited to people who are authorized to work in the Lab. People entering the area have to use sterile clothing. The Lab has a gowning area at the entrance and a de-gowning area at the exit. Caps to cover shoes, head, mouth/nose have to be used prior to entering the Lab.

A magnahelic gauge indicating negative pressure inside the animal room

Inside the animal room with a passbox seen on the right

- The Lab usually has a sink to wash hands. All the surfaces are easily cleanable and washable.
- The Lab, as mentioned above, is essentially kept under negative pressure. The pressure differential between the Lab and adjoining areas is normally 15 to 20 Pa
- The temperature to be maintained is 22° C +/- 2° C. Relative humidity to be maintained is 55 % +/- 5 %. Control on temperature and RH is critical for a Lab because a warm humid environment is a well suited environment for microbe growth.
- The Lab air conditioning is a "once thru" system, which means that there is no recirculation of air. The supply and exhaust are 100 % .
- The air change rate is normally between 6 to 15 air changes per hour.
- The processes carried out in the Lab should be known to the HVAC engineer. This will help to factor in the heat rejection by the equipment in the heat load calculations. Just for interest and to familiarize the reader, a few processes used in research are centrifuging, grinding, blending, vigorous shaking/mixing, sonic disruption etc.
- The duct work should be air tight and well sealed to prevent air loss. Both supply and exhaust air are Hepa filtered.
- The exhaust air passes through a virus "burnout" before being discharged into the environment. This kills all germs making the research process safe.
- The air outlets selected should be non-aspirating type. Normal diffusers tend to induce warm air from the ceiling. This forms a current of air that swirls horizontally close to

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the diffuser face causing an upblast.

- An exhaust air outlet is normally kept close to the floor. A proper air flow pattern can ensure expulsion of pathogens from the room.
- Bubble tight dampers (also called zero leakage dampers) should be specified at critical points.

Biosafety Cabinets

The procedures in a BS Lab are carried out in Biosafety Cabinets. A Biosafety Cabinet is a work bench which provides a sealed and controlled environment specially designed for carrying out research work involving pathogens.

The BS Cabinet works under a negative pressure. This ensures that the harmful agents being worked with, are contained within the Cabinet and do not migrate out. Thus, the operation becomes safe and does not cause any harm to the researcher.

Biosafety Cabinets are classified as Class I, Class II or Class III types. More details of each type can be obtained from the ASHRAE *Applications Handbook* chapter 14 for those interested. The ASHRAE website also has a readable version of this document.

The type of Cabinet selected by the research team needs to be known to the HVAC engineer as each type of Cabinet has a specific air exhaust rate. Unless this is known, the HVAC engineer cannot prepare an air balance diagram.

Air Balance for a Zone having a BS Cabinet

As mentioned above, a Biosafety Cabinet exhausts air to the outside. However it may be possible that when the BS unit is not in operation, the exhaust fan for the same may be off, even though the supply air through the zone AHU is on. Instead of a negative pressure, a positive pressure would develop in the room which is not permissible.The HVAC engineer is advised to build a system so that the air from the room gets exhausted through the zone exhaust air fan. This will require design of additional ducts with motorized air tight dampers. The zone fan will need to have a variable frequency drive.

AHU Selection

The overall length of the AHU will be large as the AHU will comprise of Prefilter section downstream of the fan and Fine filters upstream of the fan. The coil should be specially fabricated in two sections of 4 and 6 or more rows deep each. This is because the AHU is a 100 % fresh air AHU and the cooling load on the coil will be high. Adequate space in between coils (minimum of 450 mm) should be provided on either side of the coil to facilitate maintenance and keeping the coil clean. The motor for the AHU should be sized correctly as the total static pressure for the AHU will be high. Pressure drop across a dirty filter should be taken into account while selecting the motor. The AHU should have access doors on either side. Use of Ultra Violet lamps inside the AHU could be considered. While planning the AHU room size, the HVAC engineer should indicate the coil pull-out space. The 'P' trap for the AHU drain must be sized and installed correctly. Moisture carryover can cause contamination issues.

Documentation, Measurement and Verification

Since a Biosafety Lab is a critical facility, documentation plays an important role.

The HVAC engineer must pen down the design brief or intent received from client or end user.This document should include all design parameters e.g location of site, ambient conditions, etc. Room design criteria should include air change rate, supply and exhaust air quantity, differential pressure, details of equipment in the Lab and filtration levels. The HVAC equipment selected should also form part of this document.

The procedures incorporating good practices during installation should be documented. Safety procedures during installation should be adhered to. Cleanliness during installation should be maintained. Waste from site should be removed regularly. Ducts should be pressure tested. Labelling of various installed items should be done properly so that the operator can use the system easily and effectively.

Measurement during the commissioning is mandatory. The measurements should include taking readings to ensure that the equipment performance is as per design intent. The site measurements for temperature, room pressure , room particle count will verify that the system performance meets the design criteria. The measurements should be documented for future reference.

The documentation should also include a copy of the "as built" drawings for future reference and an operating schedule for ease of the end user.

Building Automation System

A research facility or a pharma plant is built over a large area. The task of supervising each zone is tedious. Each and every design parameter is crucial in the facility. In today's electronic era, the task of managing a critical facility is made easy with help of advanced controllers. Sensors, controllers and a graphic interface forms part of a Building Automation System. With the help of a BAS, the plant operator and maintenace manager can control and monitor each zone sitting at his / her desk through a computer.

Various components of the system like Chiller, Pumps, AHU etc can be started or stopped through a BAS. The BAS can control set points of a complex system. For example, room temperature and humidity can be varied within permissible limits. A BAS monitors various parameters set in the system. The BMS can generate alarms in the event of disruption of a parameter. For example, it can give

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the status of a filter. This would assist the maintenance team to arrange for a timely replacement of a HEPA filter A choked filter, or a disruption in room pressure differential would generate an alarm.

It is advisable for the OEM to arrange for training of the owner's Operation and Maintenance team. A correctly operated and maintained system promises a potential for energy saving, which is critical in today's era. The installed capacity in a research facility is large. Hence it is essential to micro manage the functioning of each area to ensure that the intent is met with, without expense of extra energy.

Conclusion

The complexities involved in design of a critical facility makes the project an interesting one. A clear concept of psychrometrics plays an important role in the design of a Lab facility. Students and junior engineers, who intend to make a career in the field of HVAC can learn a lot through the experience of working on a Lab project under the guidance of an expert. The concepts so learnt will help in the design of non–critical commercial applications as well.

The Lab at the Piramal Life Sciences was designed as a BSL 3 Lab and the project has been completed successfully.

Credits

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