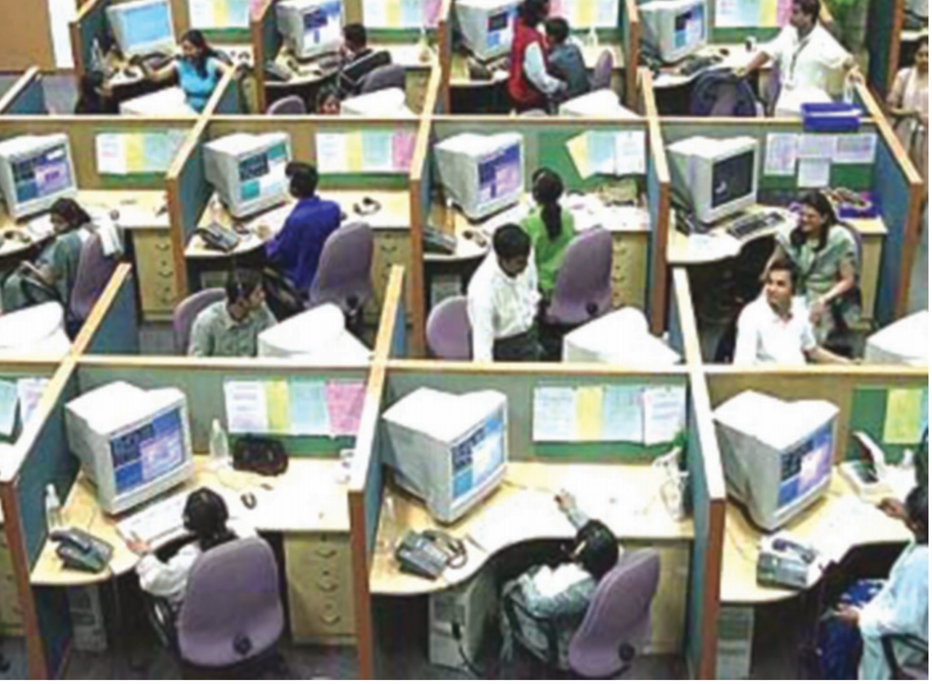

HVAC for the Sunrise Industries

Information Technology and Biotechnology

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It was about 10 years ago that the demand from the software industry for central airconditioning plants surfaced in a big way and thereafter, it has kept growing steadily. There were, to be sure, some hiccups - the recession first, late in the 90's and later again, due to the impact of 9/11. Except for these brief interruptions, the growth of demand for HVAC from the IT industry has been rising spectacularly. Many air conditioning companies are enjoying a mega-boom during the past few years, particularly, in the southern part of the country. This is thus an industry come lately.

Biotechnology, on the other hand, is a very old industry; it may even be regarded as an ancient industry. It represents a developing and expanding service of technology dating back in many cases, thousands of years, to when humans first began unwittingly to use microbes to produce foods and beverages such as bread and beer and to modify plants and animals through progressive selection for desired traits. Bio-technology encompasses many traditional processes such as brewing, baking, wine-making, cheese production, the production of oriental foods such as soy sauce and tempeh, idli making, dosa making etc. In sewage treatment, the use of micro-organisms has been developed, though, somewhat empirically over countless years.

The *new* biotechnology (modern biotechnology) revolution began in the 70's and early 80's.

This revolution has developed basically and largely, as a result of post-war introduction into biology of other scientific disciplines such as physics, chemistry and mathematics with engineering and technology added. It is with this post 70s' biotechnology that we are concerned; in our country, we may as well as call it as post 80's.

It will be thus seen that both the IT and BT sectors have captured the attention of the air conditioning industry only in the last few decades. This is to be compared with the *old* industries like machine tools industry, pharmaceuticals, precision engineering, construction industry, hospitality industry, medicare and watch manufacturing and even later on electronic manufacturing. It is therefore, in this sense that the IT and BT industries are talked about as amongst the "sunrise industries". Although the requirements of these segments (IT & BT) are not similar in any significant sense, the fact is that they belong to the category of sunrise industries, because of their comparatively recent origin. That's why they have both been presented in the same article.

Information Technology

The IT industry comprises several segments:

- Software Centers (where software development is carried out) featuring Work Station Areas.
- Call Centers and Business Process Outsourcing (BPOs).
- Data Centers and Server Rooms.

About the Author

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Software Centers

i. Work Station Areas

The software development area is the most important amongst several auxiliary areas which also require air conditioning in software centers viz., server rooms, UPS, and labs, besides support areas like meeting rooms, discussion rooms, reception and dining. We shall survey the requirements of these various areas in what follows.

The typical requirement of work station areas may be summarized below:

- *Inside Design Conditions*

  Requirement is essentially comfort conditions (typically 23±1°C DB and RH about 60%).

- *Number of Persons*

  Typically 5 to 6 m^2 / person, but it can go upto 9m^2/person.

- *Appliances*

  Typically 150 to 200 W/person, but it can go up to 400 W/ person. Translates to about 40 to 45 W/m^2.

- *Outside Air*

  15 to 20 cfm or even 25 cfm/person

  (The values indicated are in compliance with ASHRAE Std 62 - 2001)

The software development area is the most important area in a software center. It features a work station (commonly called work station areas) duly supported by auxiliary areas.

The focus here is basically on number of persons and the configuration of appliances in each work station (or for each person) - like the number of PCs and printers used. These two parameters viz., the W/person and number of persons fix the heat gains due to appliances and the heat gain due to ventilation air respectively. The usage of floor area is very critical, as the user would like to accommodate as many work stations as possible in the available area and thus maximize production. The designer therefore needs to focus especially on these parameters.

For UPS rooms, the load due to appliances may be substantial. The required cooling capacity therefore needs to be calculated after duly taking such gains into consideration. Dedicated AHUs are provided for UPS rooms.

In spite of this focus on work station loads and ventilation requirements, the total heat gains in work station areas generally work out to about 16 to 18 m^2/ TR. This value is really not very different from commercial air conditioning values.

Typically a plant for work station areas (which includes all auxiliary and support areas also) will consist of the following:

- Air cooled chillers / water cooled chillers.

  Imported chillers are used most of the time.

  Redundancy in chillers is usually achieved by providing one extra chiller over and above 100% capacity. Typically, the configuration is 2+1 or 3+1 chillers. The pros and cons of air cooled chillers and water cooled chillers are well known.

- Chilled water pumpsets.
- AHUs (sized for about 500 - 550 cfm/TR incorporating EU -5 grade filters).
- 2-way modulating control valves.
- Precision air conditioners.
- Heat wheels.

Heat wheels which, recover cooling from the exhaust (room) air to cool the ventilation air are often included in order to reduce the plant capacity.

ii. Ventilation is of Critical Importance

There is special focus on ventilation. Software engineers keep long hours and stay glued to their work stations. Under such conditions, they are especially susceptible to IAQ problems like burning eyes, blocked nose and throat, headache, dizziness, lethargy, fatigue, irritation, wheezing, sinus, congestion, dry skin, skin rash, sensory discomfort from odours and nausea. Of course, not all persons suffer from all these complaints!

This is the reason for special focus on ventilation in the software industry.

iii. Noise Consideration

Particular attention should be paid to restrict noise level to acceptable values. Such sensitive areas include those which are close to AHUs. Noise considerations become particularly critical, especially where high caliber areas like cabins and meeting/ discussion rooms are involved.

Chiller and pump noise could also pose problems, essentially if they are located over a part of the terrace in which other facilities are also accommodated like canteen/dining or if the terrace becomes a venue for social functions. Noise can also give rise to complaints from the neighborhood. Such complaints, if not solved promptly, may lead to serious problems and even lead to intervention of the pollution control authorities.

No particular attention is required for auxiliary areas like reception, discussion rooms, meeting rooms and dining; their requirements will be no different from similar areas in other applications.

iv. Energy Saving Strategies

It is well known that in virtually all software buildings, about 60% of the total building power

continued on page 52

continued from page 50

requirement is from HVAC. Attention to energy saving strategies and value additions are therefore increasingly becoming a must, like for that matter for most applications.

Some of the applicable strategies are:

- *Variable Speed Drive*

Widely applied for CHW pumps and in some plants for cooling tower fans also. Lately centrifugal and screw chillers are also becoming available though not with all manufacturers.

- *Heat Recovery Chillers*

Not available in the usual ranges nor for all kinds of chillers in use.

- *Free Cooling*

To be considered when air conditioning is required during night hours.

- *Thermal Storage*

Applicable, if cooling requirements during night hours is either quite small or does not exist at all.

- *Building Management System (BMS)*

v. Operation & Maintenance for High Performance

Maintenance of the plant is an important factor. If for example, filter maintenance is not carried out according to an established schedule, it could result in reduction of air flow and consequently, poor cooling. Besides, it could give rise to indoor air quality problems.

The importance of operating and maintaining the plant in a deliberate and purposeful manner to extract high performance, from the point of view of energy conservation, cannot be over emphasized.

Another prerequisite for achieving high performance is the ability to initiate and carry out well thought out and planned strategies and by strict adherence to such strategies. Monitoring of the plant health and performance and implementation of the operating strategies are essential. A properly maintained BMS will go a long way to secure targeted high performance.

Call Centers & Business Process Outsourcing (BPOs)

The m^2/person can be less than five. For gains due to appliances however, the figures can reach values as high as 300 W/m^2 (this may be compared with values like 40 to 45 m^2/person for work station areas). The designer has to obtain all necessary information and proceed accordingly. As noted earlier, first-cut figures should be questioned. They should be analyzed and discussed till the information becomes realistic and credible.

Comfort conditions have to be maintained and ventilation should be adequate. The expectations of working conditions from the occupants are usually not as high as in work station areas.

Some call centers work only during night hours. Design should take due account of this feature also. Once the scenario of the working patterns, appliances and occupancy is clear, design can proceed in accordance with good practice. Except for these factors, the air conditioning for call centers will not be different from air conditioning for work station areas.

Data Centers & Server Rooms

i. High (Sensible) Heat Gains

Heat gain in a data center is predominantly sensible. The gains are extremely high - from 300 to 400 W/m^2 to values as high as 2500 W/m^2 data center area. Rise of even this figure, up to as much as 5500 W/m^2 is envisaged. Also these heat gains do not occur uniformly.

ii. Typical Layout

Recent practice, and in some cases current practice also, is to provide PACs on the perimeter facing inwards in a data center. The PACs discharge air into the plenum formed by the raised floor. Air distribution will be through floor diffusers arranged in the panel flooring, the number and size of the diffusers being adjusted to provide high supply air flow rates towards areas of concentrated heat gains.

iii. Intake Conditions of IT Equipment are All-important and Not Ambient (room) Conditions

The conventionally specified inside conditions are 22°±1.1°C DB and 50 ± 5% RH. However, even when these conditions are being maintained, the temperature of components in the racks could exceed the permissible limits, resulting in shut down of the data processing equipment. That's why the ambient conditions do not carry the usual significance.

Usually, the flow rate of the fan of the computer cabinet is higher than the chilled air supply from the perforated tiles (floor diffusers). Accordingly, the fan (of the computer cabinet) draws a mixture of the SA from the diffusers and the ambient air. The temperature of air entering the computer cabinets is a mixture temperature and is inevitably higher than the temperature of air emerging from the diffusers (i.e. approximately same as the temperature of air leaving the cooling coil). Accordingly, lower the temperature of the air leaving the coil and the higher its fraction in the mixture, the lower will be the temperature of air entering the computer cabinet. It is therefore this temperature and not the ambient temperature (like 22 or 20°C ± 1 or 2°C or comfort conditions) that is of significance to ensure that the computer cabinet will keep running. From this point of view, data center cooling can be likened to

continued on page 54

continued from page 52

process cooling rather than comfort cooling or space cooling.

iv. ASHRAE New Guideline for Data Center Cooling

The "New Guideline for Data Center Cooling" published by ASHRAE in 2004, stresses these aspects and specifies recommended envelopes of temperature and relative humidities for air entering the computer cabinet and gives a go-by to room (ambient) conditions. It lists four environmental classes of which Class 1 is the most stringent. For this class, the inlet temperature range recommended (for IT equipment) is 20 to 25°C DB and RH is 40 to 55%. This envelope is however embedded within an allowable envelope, which is larger. It permits a temperature range of 15 to 30°C and an RH range of 20 to 80% with an upper limit of 17°C for the dew point. The manufacturers of IT equipment are required to design their computer components to keep working as long as the inlet conditions (to the equipment) are within the allowable envelope.

The HVAC engineer should aim to produce conditions at the inlet of the cabinets, which will lie within the recommended envelope. The region between the recommended envelope and allowable envelope provides a buffer that results in extending IT equipment-operating life, with all other factors being equal. See *Figure 1*.

The Class 1 conditions - even though they are the most stringent - are more relaxing than 22±1.1°C DB and 50±5% RH recommended earlier in Chapter 17 of the 2003 ASHRAE Hand Book - HVAC Applications, because a wider range of conditions viz., 5°C in DB (as compared to 2.2°C) and 15% RH (as compared to 10%) are permissible. This relaxation should promote energy savings in various ways viz., greater use of economizer cycles, run-around systems, high air discharge temperatures, lower latent dehumidification loads etc.

Consider the following example for benefits derivable by using a run-around system. Assuming ambient (room) conditions as 27°C and 37% RH, (with h = 48.09 kJ/kg) and ADP = 6°C for inlet conditions, cooling capacity 2000 kW (566 TR) and a flow rate of 120,000 l/s, the rough calculations shown below give a glimpse of the scenario :

- Cooling capacity 3960 kW (1120 TR).
- Reheat required (from external source)

= 120,000 x 1.23 x (20 – 6)/ 1000 = 2066 kW

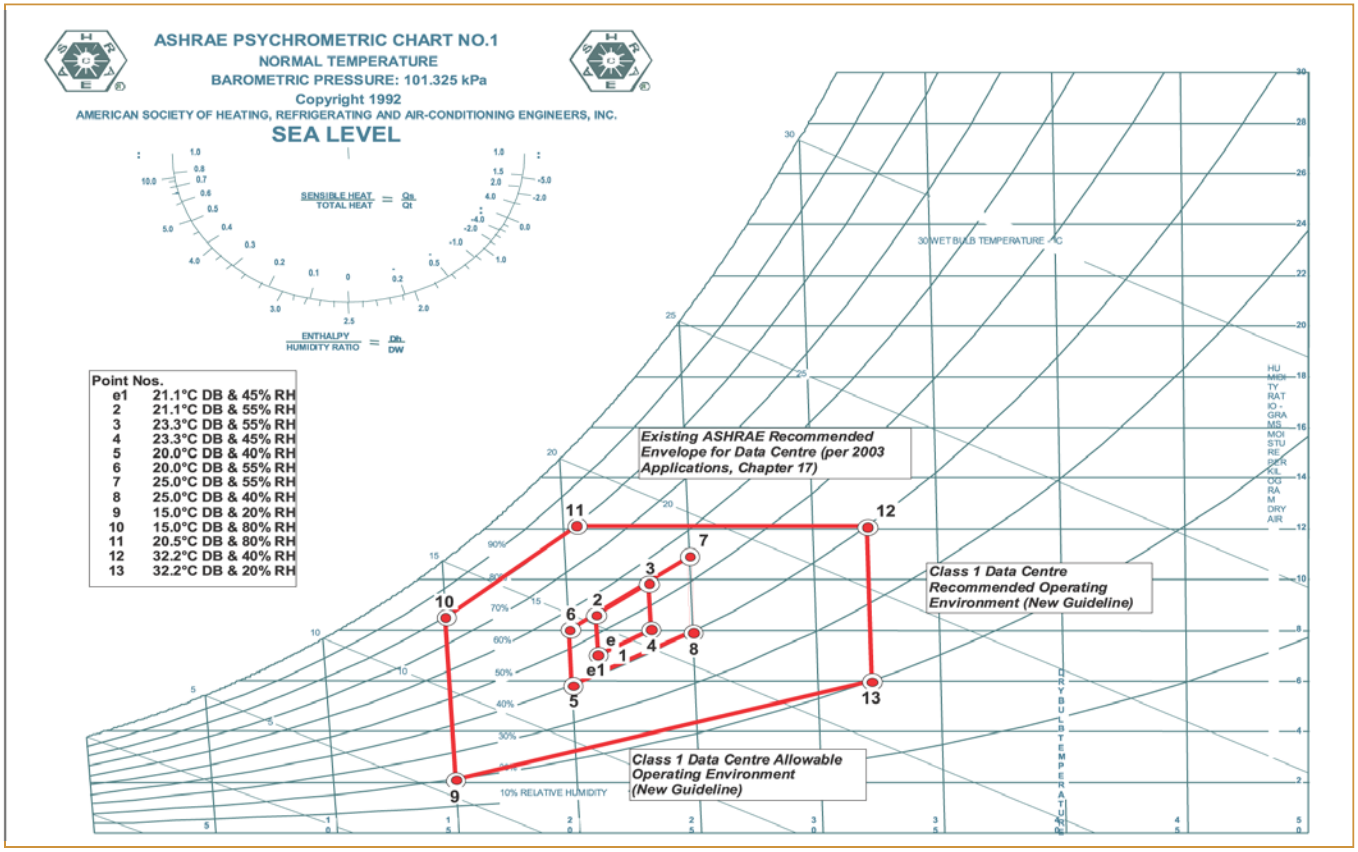

Figure 1: ASHRAE recommended envelopes for data centers

continued on page 56

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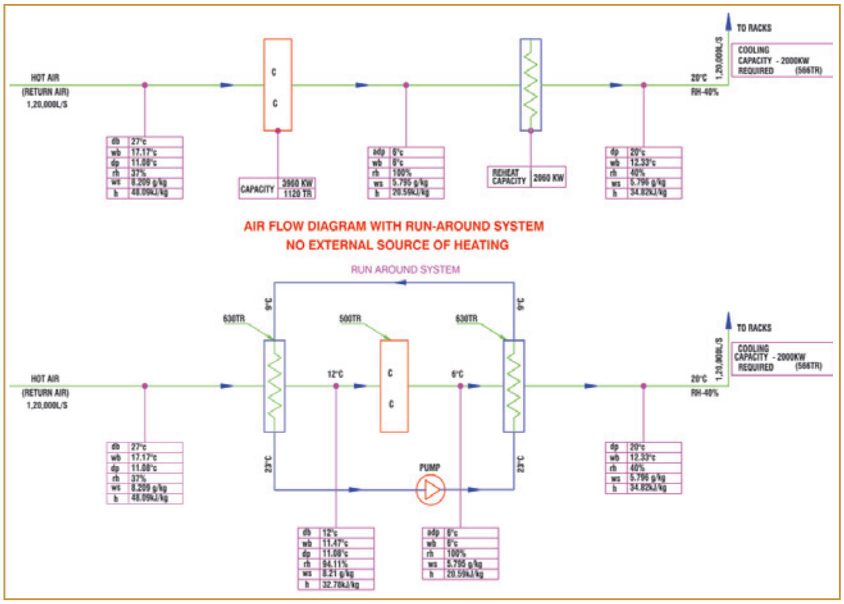

Figure 2. Air flow schematic with reheat from external source.

In case a run-around system is used, the cooling capacity will come down to about 500 TR. The precooling / post cooling capacity of the run-around system will be about 630 TR each. No external source of reheating is required. Please see *Figure 2*.

Thus, while applying the ASHRAE guidelines, it is essential to explore all possible energy saving strategies.

Precise and detailed calculations must be made during design / execution to validate choice of strategy.

v. Air Distribution

It is now clear that a critical consideration in data center environmental design is ensuring that each and every cabinet will get the necessary air flow at the recommended conditions. That brings us to the crucial issue of air distribution.

There are three standard air flow protocols for equipment and air distribution system layouts:

- Front to Top.
- Front to Rear.
- Front to Top and Rear.

The above airflow protocols relate well with a Standard adopted within the telecommunication industry, Telcordia, NEBS, GR-3028-CORE.

In *Figure 3*, the Front to Top Layout is shown.

The arrangement also depicts the lining up of the computer cabinets in rows with the alternative space or gaps being Cold Aisles and Hot Aisles. With these basic arrangements, (airflow protocol and equipment layout) heat release densities up to nearly 5400 W/m^2 have been found to be effectively handled.

Raised Plenum

The following points should be noted in designing the raised floor plenum:

1. The pressure in the plenum should be positive everywhere so that the supply air flows from diffusers to the data processing hall. Its value should be not less than 35 - 40 Pa.

2. To maintain adequate pressure (35 - 40 Pa), the velocities should be kept low (should not exceed 2.83 m/sec).

In the event velocities go higher, the plenum will develop negative pressure. Consequently, the airflow will be from the data process hall to the plenum, which is, of course, not permissible.

Another way of looking at the necessity to avoid high velocity near diffuser locations is that if the velocities are high, air will rush past diffusers rather than turn to enter the data processing hall.

Sl.No.	Description	Work Center	Call Center / BPO	DataCenter
1	m^2 / Person	Typically 6, but can go upto 12	6.0	Not Relevant
2	Watts / Person	150 to 400	200 - 1800	Not Relevant
3	OA [b]	7.5 - 13 l/s per Person	7.5 - 13 l/s per Person	1 ach
4	Appliances - W/m^2	25 - 40	125 - 300	500 - 2500, but can go upto 5000 also
5	Inside Design Conditions	Comfort	Comfort	20 - 25° C DB & 40 - 55% RH at IT Equipment inlet Recomm-ended Envelope for Class-1 Environment [a]

Note

a Permissible Envelope as per ASHRAE - 2003, Thermal Guidelines for Data Centers and other Data Processing Environments.

b. OA requirements based on ASHRAE Standard 62.1 - 2004.

Wide ranges shown for some of the parameters/applications indicate that check figures are not of much help; data have to be obtained painstakingly - from the customers project-to-project.

Table - 1 - Summary of design data

continued on page 58

continued from page 56

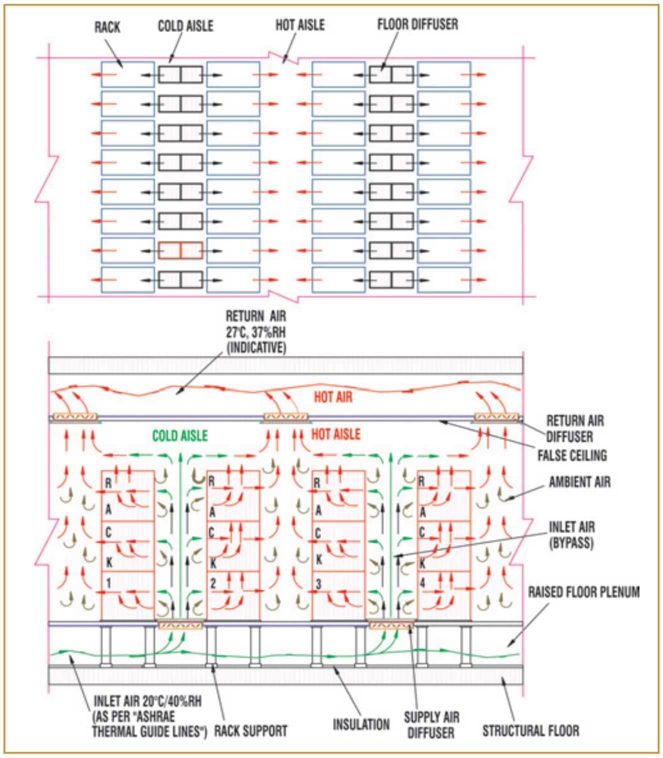

Figure 3: Front to top air flow

3. The depth of the raised floor should therefore be adequate even in sections when obstructions like structural elements and other services restrict available cross sectional area for flow. With a known and assured positive pressure in the plenum, the airflow rates can be regarded as proportional to the diffuser size. Also flow will occur wherever solid tiles are replaced by diffusers.

vi. Review of Design Procedure

Let us now summarize the procedure briefly:

a. Obtain a thermal report (heat and air flow reporting) on the computer cabinet.

b. Review all available information regarding the datacom equipment.

c. Calculate the total cooling requirements.

d. Calculate the air flow rate of the AHU - assuming that the temperature drop across the cooling coil will not be more than the 80% of the temperature rise in the computer cabinet.

The implication is that the AHU airflow rate is higher than the computer cabinet flow rates. This will help to reduce the ambient air component (and increase the chilled supply air component) in the mixture that enters the computer cabinet.

e. Design the air distribution system paying due attention to the various points discussed. Take particular care to see that features which offer flexibility, are duly incorporated.

f. CFD studies of airflow, temperatures and velocities near the computer cabinet inlets and outlets and in the Hot and Cold Aisles is advisable - and infact, may be a requirement.

g. Look for opportunities for applying energy conservations strategies; there could be substantial potential for energy saving.

vii. Emerging Trend

The above discussions relate to the concepts introduced in ASHRAE's "Thermal Guidelines for Data Processing Environments" 2004. As far as this writer is aware there is no HVAC plant for data centers designed and installed in our country in accordance with the Thermal Guidelines. But considering that the Thermal Guidelines are the result of an understanding between the IT equipment manufacturers and the HVAC designers, it appears that, we need to be prepared to apply the concepts in the coming days.

Impact of Location In Builders' Premises

It is also necessary to note an aspect of HVAC work in software buildings, which is not technical in nature. A majority of software centers are located in buildings constructed by developers. The software company takes them on hire/lease from the developers. This occurs at different stages in the construction of the building. Several of the tenants occupy the building after all construction work is completed.

a. Since the building is ready, the tenant has to provide only the services and move in.

b. This is a recipe which turns software applications into fast track projects. Completion periods can be a few months (3 to 4) or even 2-3 weeks depending on the natural size of the plant.

c. Impose constraints on the kind of equipment and system that can be provided. Such restrictions result in shortage of space, lack of adequate height for providing raised floors, false ceiling, lack of space for accommodating equipment etc.

d. This situation gives rise to serious and major constraints into air flow paths as far as choice of equipment and system is concerned which the designer cannot ignore.

Bio-Technology (BT)

One of the definitions of Bio-technology or "Bioprocess Technology" is "the integrated use of biochemistry, microbiology and engineering science in order to achieve technological (industrial) application capabilities of micro organisms, cultured tissue cells and parts there of".

The product formation stages in bioprocess technology are essentially very similar for all products,

continued on page 60

continued from page 58

no matter what organism is selected, what medium is used and what product formed. In all examples, large numbers of cells are grown under defined controlled conditions. The organisms must be cultivated and motivated to form the desired products by means of physical/technical containment system (the bioreactor or the "reactor tanks"), and the correct medium composition and environmental growth regulating parameters such as temperature and aeration. Optimization and proper exploitation of an organism's potential to form distinct products of defined quality and in large amounts, will need a detailed knowledge of the biochemical mechanisms of product formation.

Since the product formation stages are similar, the same apparatus, with modifications, can be used to produce an enzyme or antibiotic, an amino acid or single cell protein. In its simplest form, the bioprocess can be seen as just mixing micro-organisms with a nutrient broth and allowing the components to react, e.g. yeast cells with a sugar solution to give alcohol. More advanced and sophisticated processes operating on a large scale need to control the entire system so that the bioprocess can proceed efficiently and be readily and exactly repeated with the same amount of raw materials and inoculum to produce precisely the same amount of product.

The end of product formation in the reactor tank leads to downstream processing. Downstream processing is primarily concerned with initial separation of the bioreactor broth into a liquid phase and solid phase and subsequent concentration and purification of the product. Processing will normally involve more than one stage. Methods in use or proposed, range from, the conventional to those that few understand, including distillation, centrifuging, filtration, ultra filtration, solvent extraction, adsorption, selective membrane technology, reverse osmosis, molecular sieves, electrophoresis and affinity chromatography.

Final products of the downstream purification stages should have some degree of stability for commercial distribution. Stability is best achieved for most products by using some form of drying. In practice this is achieved by spray-drying, fluidized-bed drying or by freeze-drying. The method of choice is product and cost dependent. Products sold in the dry form include organic acids, amino acids, antibiotics, polysaccharides, enzymes, single cell

Sl. No.	Description	Air Conditioning				Ventilation
1	Class					
a	US Federal Std 209-D	100	10000	100000	Unclassified	Unclassified
b	ISO - 14644 -1	5	7	8		
2	DB - Deg C	←	22 ± 2	→		Not specified
3	RH - %	←	Not to exceed 65%	→		Not specified
4	ACH - per hour	60	30	20	10 (minimum)	10 (minimum)
5	Filters in AHU	50-55% efficiency EU-5 Cleanable Panel Filters	50-55% efficiency EU-5 cleanable Panel Filters	80-90% efficiency EU-7 Bag Filters.	90% Arrestance down to 10 Micron EU-3 Cleanable Panel Filters.	90% Arrestance down to 10 Micron EU-3 Cleanable Panel Filters.
		85-95% efficiency EU-9 Bag Filters.	85-95% efficiency EU-9 Bag Filters.	99.97% efficiency EU-13 HEPA Filters (installed in AHU Plenum) selected for 0.45 m/s face velocity.	50-55% efficiency EU-5 Cleanable Panel Filters.	50-55% efficiency EU-5 Cleanable Panel Filters.
		99.999% efficiency EU-14 Terminal HEPA Filters selected for 0.45 m/s face velocity.	99.999% efficiency EU-14 Terminal HEPA Filters selected for 0.45 m/s face velocity.			

Table 2: Design data for biotechnology

continued on page 62

continued from page 60

protein and many others. Many products cannot be supplied easily in a dried form and must be sold in liquid preparations. Care must be taken to avoid microbial contamination and deterioration and, when the product is proteinaceous, to avoid denaturation.

a. HVAC in BT

Commonly known product formation processes are media preparation, culturing, mixing, compounding, growth, fermentation and downstream processes. Downstream processes, which require air conditioning include media preparation, compounding, growth areas, blending, filling and sealing process. In many cases, clean rooms with various classes of cleanliness are also involved.

In the fermenters, amongst the various utilities required, could be brine and chilled water.

The inside design conditions required in unclassified areas are generally those applicable to comfort. In clean rooms, the specifications applicable to them viz., a dry bulb temperature of 22°C to 23°C and RH of 50 to 60% can apply. Nevertheless, the inside design conditions need to be checked with the owners and their confirmation obtained.

It will be seen from the *Table 2*, however, that there are essentially no special requirements in bio-technology applications as such.

The classes of cleanliness generally involved are Class 10000 and Class 100000 to US Federal Standards F209.

b. Cleanliness Levels: Higher Filter Efficiencies Lead to Lower Airflow Rates

Cleanliness level requirements are often furnished by the customer with reference to other Standards. *Table 3* presents the relation of the various Standards to Federal Standard 209D and to each other.

U.S.A Federal 209D	U.S.A 209E	Britain BS 5295	Australia AS 1386	France AFNOR NFX 44 -101	Germany VDI 2083	ISO
100	M1.5	C	0.035	-	1	3
100	M2.5	D	0.35	-	2	4
1000	M3.5	E or F	3.5	4000	3	5
10000	M4.5	G or H	35	-	4	6
100000	M5.5	J	350	400000	5	7
1000000	M6.5	K	3500	4000000	6	8

Table 3 : Comparison of cleanliness level designated in various standards

It will be noticed incidentally that T*able 1* also shows the number of air changes of total airflow together with an indication of possible filter grades that can be provided.

In *Table 4* the cleanliness levels that were widely adopted earlier are also shown. It will be noticed that the number of ach has since gone down. For example, they used to be 40 to 60 ach for Class 10000. In *Table 2* the corresponding figure is only 30. Likewise, the air changes have declined from 25 - 30 for Class 100000 area.

The reduced airflow rates are acceptable, since filter efficiencies today are higher; also over designing or safe designing prevalant earlier is no longer acceptable as designs are being monitored continuously for minimum first cost as well as operating cost.

c. Graded Pressures and Air Distribution System

Usually the most critical areas from the point of view of cleanliness are the filling and sealing areas. These areas command the highest class of cleanliness in the facility, followed by others, like preparation, auto claving etc. Class 10000 conditions are maintained in filling, sealing and preparation areas with Class 100 or higher levels of cleanliness being made available at the process itself by use of laminar flow hoods. Areas like change room, ante rooms etc. are maintained at class 100000 conditions. In all these areas, the direction of air movement has to be from filling and sealing areas to preparation and auto claving through ante room and change rooms etc. to general areas like packing and circulation areas. Thus the highest pressure prevails in filling and sealing areas with progressively lower pressures being maintained in general areas and intermediate areas. This calls for planning the AHU and the air distribution system to maintain graded pressures.

Normally, the corridors are areas, where the pressures are lowest; even so, they generally need to be at positive pressures with respect to the atmosphere. In some isolation areas - like virology, for example, negative pressures need to be maintained, but flow of air from the corridor directly to virology is not permissible. In such cases, it is necessary to provide an ante room between the corridor and the negative pressure areas. (Please see *Figure 4*). The pressure in the ante room should be higher than in the corridor (it will, of course, be higher than in the negative pressures areas). This can be achieved by keeping the ach of OA in the ante room higher than the ach of OA in the corridor.

ISO Class	As they were	As they are
1	500 - 600	60
2	40 - 60	30
3	25 - 30	20

Table 4: Clean room ACHs as they were and as they are today.

Whenever graded pressures are employed, the

continued on page 64

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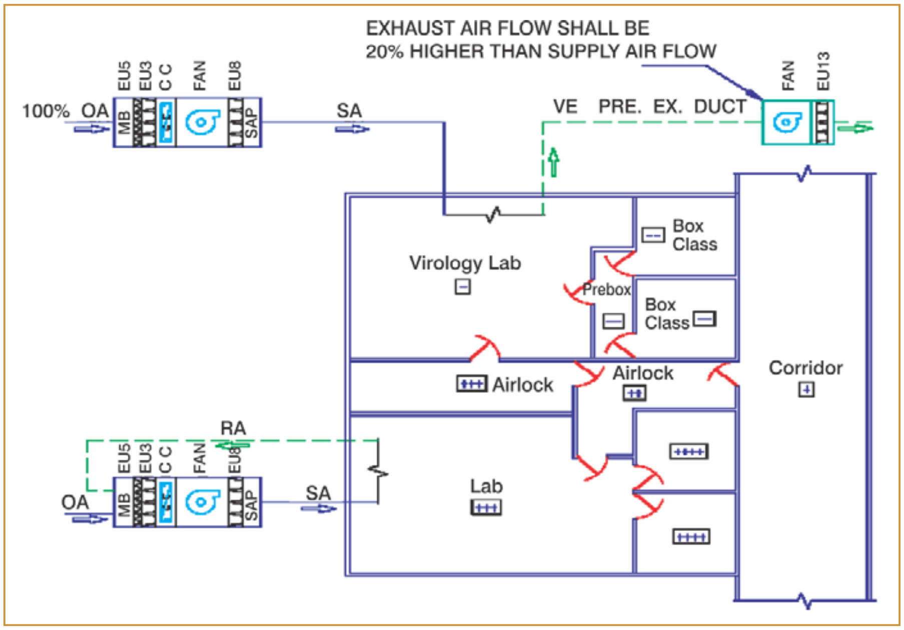

Figure 4: Air distribution arrangement for negative pressure areas

differential pressures between two adjoining pressure grades (not necessarily adjoining areas), are usually maintained at 6.5 - 12.5 Pa. A differential pressure of 6.5 pa could be cutting it too fine from the point of view of pressure controlling; on the other hand, higher differential pressures will mean larger air leakages, which, in turn, will lead to higher energy consumption.

d. Fume Hoods & Biological Safety Cabinets

Biotechnology applications involve the use of fume hoods in large numbers - and usually, not so much in air conditioned areas, as in areas served by ventilation and exhaust systems. Further, fume hoods are to be found mainly in chemistry labs. The biology labs employ biological safety cabinets. In any case, the presence of fume hoods, regardless of where they are located needs to be checked and all relevant data necessary for arriving at plant capacity, design of the air distribution system, exhaust flow rates and the like, should be gathered and brought to bear on the HVAC work.

The following are the primary types of fume hoods and their applications:

Fume Hood

- Standard fume hoods (approximately constant-volume airflow with variable face velocity). A hood that meets basic SEFA (Scientific Equipment and Furniture Association) definition. Sash may be vertical, horizontal or combination.
- **Bypass** (approximately constant-volume airflow with approximately constant face velocity). Standard vertical sash hood modified with openings above and below the sash. The openings are sized to minimize the change in the face velocity, which is generally to 3 or 4 times the full-open velocity, as the sash is lowered.
- **Variable Volume** (constant face velocity). Hood has an opening or bypass designed to provide a prescribed minimum air intake when the sash is closed and an exhaust system designed to vary air flow in accordance with sash openings. Sash may be vertical, horizontal or a combination of both.

Biological Safety Cabinets

A biological safety cabinet protects the researcher and, in some configurations, the research materials as well. Biological safety cabinets are sometimes called safety cabinets, ventilated safety cabinets, laminar flow cabinets and glove boxes. Biological safety cabinets are categorized into six groups.

Class I Similar to chemical fume hood, no research material protection, 100% exhaust through a HEPA filter.

Class II **Type A1**
70% recirculation within the cabinet; 30% exhaust through a HEPA filters; common plenum configuration can be recirculated into the laboratory.

Type B1
30% recirculation within the cabinet; 70% exhaust through a HEPA filters; separate plenum configuration must be exhausted to the outside.

Type B2
100% exhaust through a HEPA filters to the outside.

Type A2
70% recirculation within the cabinet; 30% exhaust through a HEPA filters; common plenum configuration must be exhausted to the outside.

Class III Special applications; 100% exhaust through a HEPA filter to the outside; researcher manipulates material within cabinet through physical barriers (gloves)

Although several classes and type are available, standard fume hoods (approximately constant volume with variable face velocity) are used for most production work.

Biological safety cabinets are applied for containment-like for example in virology noted earlier. Unlike the fume

continued on page 66

continued from page 64

hoods, these cabinets protect the research materials also. Selection amongst the various classes and types of fume hoods and safety cabinets are made by the customer, though the participation of the HVAC engineer is of crucial importance. Information on exhaust flow rates or type of fume hoods, number of fume hoods, dimension, etc., is also furnished to the HVAC engineer by the customer.

e. Air Distribution System

That fume hoods and bio safety cabinets are employed widely should be duly recognized in the design of the air distribution system. Their performance should not be affected adversely by room air movement; it should be within the range of 0.3 to 0.5 m/s. Nothing in the room like an open window or proximity to doors, for example is permissible. Further, in isolation areas, where bio safety cabinets are used, the exhaust airflow rate should be always higher than the supply airflow rate in order to ensure negative pressure in the space served.

The fume hoods and bio safety cabinet require ventilation and exhaust systems complete with the necessary fans, ducting, etc. When dealing with a large number of hoods, there will be a several independent exhaust systems with each system serving a cluster of fume hoods. The fume hoods and bio safety cabinets themselves will be usually procured by the customer himself. The HVAC engineer has to take care of the following:

- Arriving at the number of exhaust systems.
- Selection of (exhaust).
- Location of (exhaust) fans.
- Design and routing of exhaust ducting.
- Control of the system.
- Material of construction for fans.
- Material for ducting.
- Insulation material.
- Routing of ducting.

The control system depends on selection of the operating requirements. Thus, consider, for example, a system in which there are very few hours/day (or in a year) in which all the fume hoods connected to a fan are required to be in operation. The peak flow rates (on the fan and the rest of the system) therefore occur only for a very short duration. During other periods, they will be lower. The fan speeds may be reduced to reflect the reduction in flow rates to achieve energy saving. The decision that needs to be made is whether the fans can be operated at the rated speed all the time or whether the fan motors should be selected for two speed operation or whether VFDs are to be employed.

Air Handling Unit

The AHUs should be to Pharma Standards with respect to design, construction, material used, etc. All the AHUs serving clean rooms - or more generally, all AHUs which are required to operate at high pressures should be leak-tested to BS EN:1886 - Class B Standards It is not necessary that all AHUs are witness-tested. The owners and /or consultants should take a decision in a matter of this kind. In any test, the ultimate requirement is that the results show measured actual leakages lower than the permissible leakage.

Ducting

Choice of material of all sheet metal work should be finalized in consultation with the customer. All ducting or designated parts of it, should be leak tested. Here again, leak testing rigs should be employed to measure the leakages and to make sure that they are within designated permissible limits. The applicable standards are *DW- 143- A Practical Guide to Ductwork Leakage Testing* and *HVAC Air Duct Leakage Test Manual - 1985* or to *SMACNA 85 Standards*.

Insulation

The choice of insulation material has to be made keeping in view the necessity to ensure that it does not shred. All relevant factors involved in selection of material should be discussed with the customer and the choice of material finalized only thereafter.

f. General

As far as appliances, lighting, number of people and ventilation requirements, there are no requirements that are special to biotech applications. It is, of course, necessary to choose the ventilation flow rates required from the point of view of the necessity to take care of exhaust airflow rates and to provide the desired room pressure.

There are no special requirements in respect of other items like chillers, cooling towers, pumpsets, piping, BMS also.

It is, of course, essential that all work conforms to Good Engineering Practice and is executed by competent and experienced agencies.

g. Compliance with Requirements of Regulating & Licensing Bodies

The HVAC System should comply with the following requirements:

- cGMP (Current Good Manufacturing Practice):

In the US, descriptions of cGMP are to be found in regulatory requirements and specification documents such as CFR 210 and 211, ISPE guides and NFPA standards and EUcGMP (European Current Good Manufacture Practice) widely known as the "Orange Guide". The goal of cGMP is to achieve proper and repeatable methods of producing sterile products free

continued on page 68

continued from page 66

from microbial and particulate contamination.

- Requirements of licensing bodies like USFDA, CFR, MCA and TGA.
- Inspection and validation procedures as generally applicable to Pharma (DQ, PQ, IQ, OQ)

Conclusion

Being sunrise industries both IT and BT are set for phenomenal rates of growth. Besides, technical requirements vary and also keep getting more stringent. The HVAC industry needs to be on its toes to meet the challenges.

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