Hospital Air- conditioning

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***Abstract*— The important aspect about air conditioning of OTs is that the patient and the operating personnel are susceptible to surgical site infection (SSI).The balance between thermal comfort and air quality in healthcare facilities to optimize the Indoor Air Quality (IAQ) is the main aim of this paper. The present paper will present this balance from the viewpoint of the air conditioning design. It was found that the design of the HVAC airside systems plays an important role for achieving the optimum air quality beside the optimum comfort level. This paper highlights the importance of the proper airside design on the IAQ. The present paper introduces some recommendations for airside designs to facilitate the development of optimum HVAC systems. This paper also stresses on the factors that improve the thermal comfort and air quality for the already existed systems (for maintenance procedure) and sets out with describing the HVAC requirements as per NABH recommendations and comparing them with ASHRAE requirements.**

Keywords—*CFD, ACPH, Hospitals operating Theatres (OTs), Air Sterilization System, Air flow pattern*

I. INTRODUCTION

Operation theatre is a very sensitive area, where doctors perform different type of surgeries. As we know that an opening in the body is vulnerable to infections hence utmost, care is taken in the pre- preparation thorough scrub up, autoclaving, fumigation and other methods to ensure that over all maximum sterility level is achieved in the operating room. It is commonly observed that today’s operation theatres are clean and well equipped with instruments, machines and latest air conditioners etc. which reflects the attitude of the doctors to provide best facility to the patients. But one area where doctors need to pay attention, very seriously somehow seems left unseen and that is air management of the operation theatre which is of paramount importance. It’s obvious as surgeons operate in the air medium, and this air has contaminants like microorganisms, pathogens and other impurities.

Fumigation takes care of the airborne pathogens; but in actual practice it doesn’t because maximum fumes are thrown out of the theatre before the procedure through the exhaust. The simple logic is when the exhaust starts throwing the fumes out of the OT, through the doors crevices and slits, the contaminated air from outside starts entering into the theatre which in turn starts contaminating the OT Environment. Therefore after taking all the above precautions. There still remain chances of infection to patients through the air media.

There is an urgent need of every theatre for an efficient air management system which sullies pure & germ free air on & around the patient table area & also builds positive pressure inside the OT, whereby not allowing the outside airto seep inside the theatre but continuously bring fresh and pure air inside the OT., also builds positive pressure and supplies germ free soft air flow vertically on and around the operating table area continuously. Proper air conditioning is helpful in the prevention and treatment of diseases.

Sterilization refers to any process that effectively kills or eliminates transmissible agents (such as fungi, bacteria, viruses etc.) from a surface, equipment, article of food or medication or biological culture medium. Sterilization can be achieved through application of heat, chemicals, irradiation, high pressure or filtration. Air sterilization system refers to sterilizing air and provides purified and fresh air. The Air Sterilization System works on the principle of positive pressure system. When switched on, it supplies pure and germ free air and around the patient’s table area.

II. ENVIRONMENTAL CONTROL

- Temperature & Relative Humidity Control

Codes and guidelines specify temperature range criteria in some hospital areas as a measure for infection control as well as comfort. Local temperature distributions greatly affect occupant comfort and perception of the environment. Temperature should be controlled by change of supply temperature without any airflow control; the temperature difference between warm and cool regions should be minimized to decrease airflow drift. Efficient air distribution is needed to create homogenous domain without large difference in the temperature distribution. The laminar airflow concept developed for industrial clean room use has attracted the interest of some medical authorities. There are advocates of both vertical and horizontal laminar airflow systems. For high-contaminated areas, the local velocity should be greater than or at least equal to 0.2 m/s. For patient rooms 0.1 m/s is sufficient in the occupied area. The unidirectional laminar airflow pattern is commonly attained at a velocity of 0.45 ± 0.10 m/s.

- Air Change and Filtration

Three basic filtration stages are usually incorporated namely: Primary filter, second stage filter (the high efficiency particulate bag filter) and a third stage filter which is the high efficiency particulate filter located at the air supply outlets. Air Change per Hour (ACPH) plays in important role to provide a free contamination place. The patient rooms are served by (2 ACPH – 6 ACPH) in usual. Some critical rooms could be served by value up to 12 ACH. The critical rooms, such as the surgical operating theatres, are supplied by (15 ACPH – 25 ACPH) in usual. There are some guidelines, which advise the value of 60 ACPH for the critical areas.

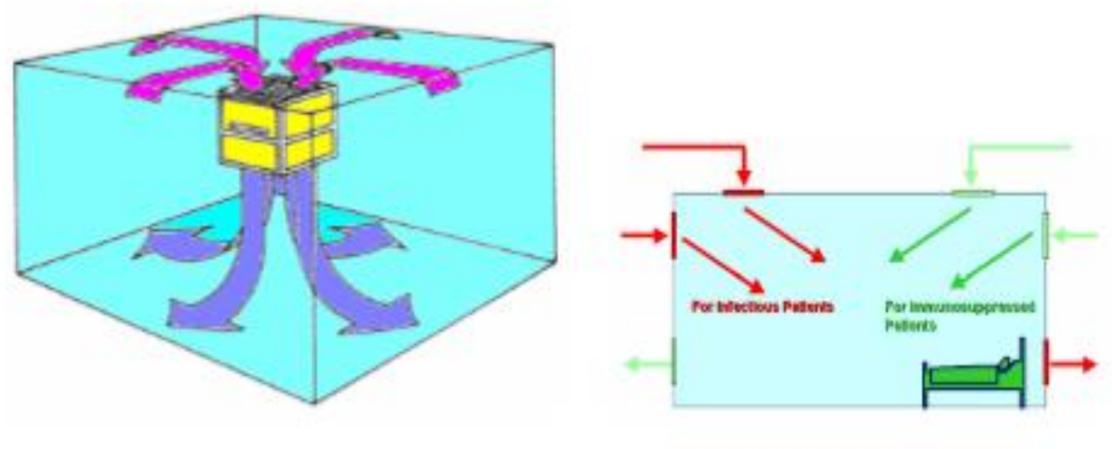

Fig. 1 Air flow movement in room

The negative pressure is obtained by supplying less air to the area than is exhausted from it. This induces a flow of air into the area around the perimeters of doors and prevents an outward airflow. The operating room offers an example of an opposite condition. This room, which requires air that is free of contamination, must be positively pressurized relative to adjoining rooms or corridors to prevent any airflow from these relatively highly contaminated areas. In general, outlets supplying air to sensitive ultraclean areas and highly contaminated areas should be located on the ceiling or on sidewalls closing to ceiling, figure 1, with perimeter or several exhaust inlets near the floor. The bottoms of return or exhaust openings should be at least 0.075 m above the floor.

III. GENERAL DESIGN OF OPERATING ROOM

Sources of infection are multiples like;

- The patient, self-infection into body from the patient's skin flakes and other particles on the body;
- The operating room staff, from skin flakes, expired air, hair, etc;
- The surgical instruments, wadding, etc. used in the procedure;
- The equipments used in a room;
- Air supplied to room;
- Infiltration air;
- Clothing worn by operation room staff

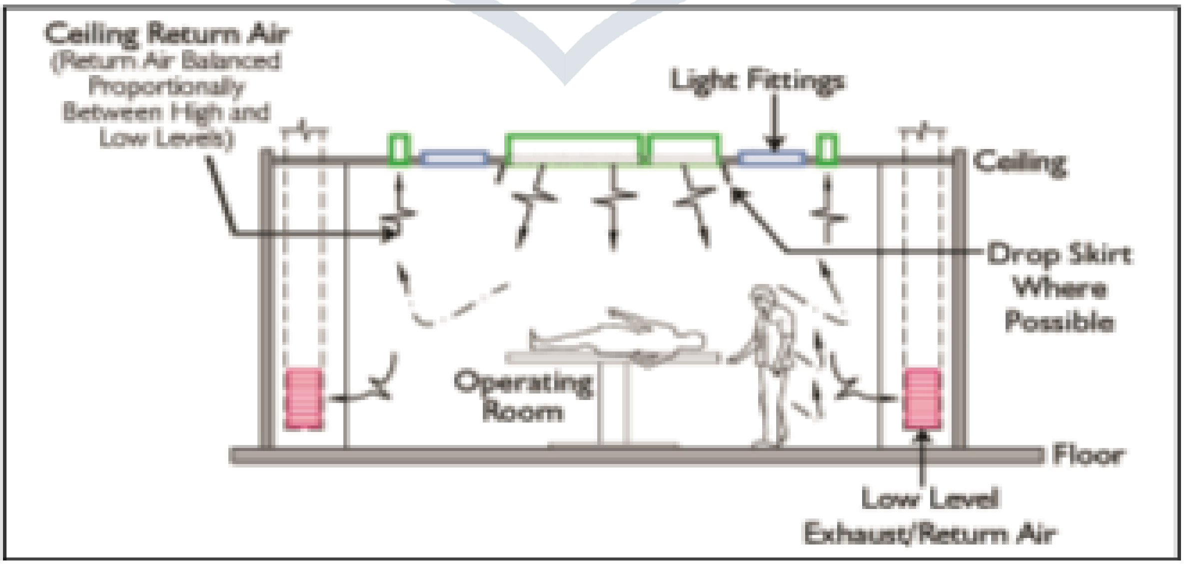

Fig. 2 Operating room: sectional view of air distribution system

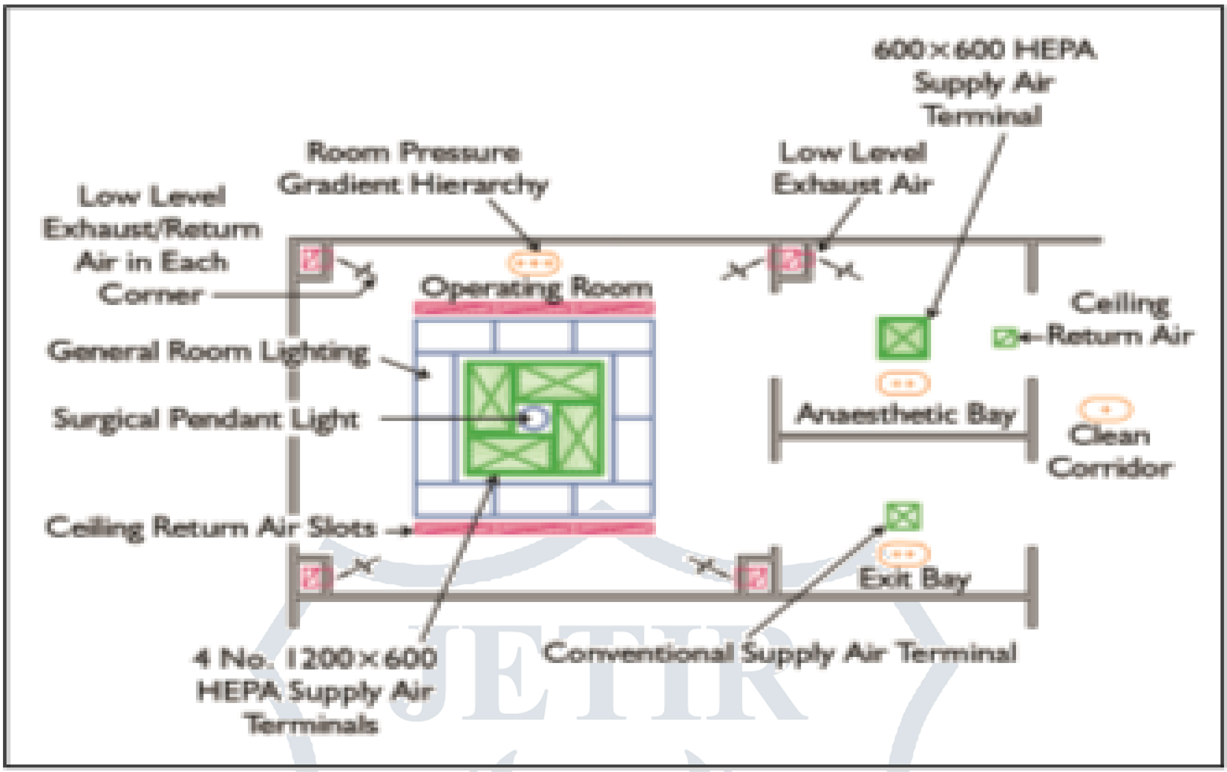

Fig. 3 Operating room-plan view of air distribution system

The favored solutions appeared to be generally either a full laminar flow or a modified version using a smaller area of filters and lower airflow. From many researches, it was decided that the preferred solution was an adopted simple and small scale laminar flow style of system. The basics of the arrangement being the use of four 1200 mm by 600 mm (4 ft by 2 ft) HEPA filter units ceiling mounted directly above the operating table.

Basic arrangement being:

The HEPA units are arranged to provide a square donut, with the center of the donut left for mounting lights or light/pendant combinations;

- Exhausts are located at low levels;
- Return air as a combination of low level and ceiling mounted, with a 50/50 split between low and high level return air. The low level exhaust and return acts as collectors of particulates, with ceiling return air provided to return warm air at the ceiling. The use of linear slot grilles was with the intent to create a more even spread of air intake to prevent producing disturbing currents and to also act as a barrier to entrainment air by drawing in air before it could cause a recirculating pattern.
- A short drop skirt (Figure 1) as an option also was included as this was considered to potentially improve overall performance by effectively lowering the discharge point and reducing the possible effects of infiltration into the discharge airstream. This is an arrangement often used in full laminar flow systems installed to operating rooms; and
- Airflow rate set at 1700 L/s (3,600 cfm), air-change rate was not referenced, as 20 air changes per hour would always be exceeded with anticipated operating rooms sizes. Figures 2 and 3 show the basic arrangement for this system. It was decided that an obvious high confidence existed in the air quality from the HEPA filter bank and the ability to provide suitable temperature control. However, the higher air quantity above that required for normal sensible temperature and humidity control requires special consideration at the air-handling unit, depending on the prevailing local climate.

Three key factors were considered to require further investigation to achieve the necessary confidence to implement the design into the guidelines. These were:

- Room air was not entrained into the clean airstream, which may increase particulate occurrence at wound site;
- Air velocity at wound site would not exceed 0.2 m/s (39 fpm). Air velocity at wound site based on research data suggested this should not exceed 0.2 m/s (39 fpm), so as to ensure excessive drying at the wound did not occur; and
- Airflow pattern that directed first air (direct from HEPA filters) to the patient and spilled away from patient. The requirement of spill away from the patient is to provide protection from particulates from the operating room staff. To investigate these key factors, CFD was chosen as the most appropriate tool.

Based on these CFD modeling results, the decision was made for this design to be included in the infection guidelines. Figure 4 shows the airflow pattern and velocity output analysis from the CFD modeling.

The experience gained from the design, construction and operation of these facilities has revealed the following:

- The guideline airflow rate of 1700 L/s (3,600 cfm) was found to generate excessive noise. Reduction to not less than 1500 L/s (3,180 cfm) has proven to solve the noise problem;

- Simple smoke testing with smoke pencils at commissioning using 1500 L/s indicated performance in terms of airflow pattern comparable to the CFD modeling results;
- The detailed fitment of the four HEPA filter modules and center support light/pendant requires careful consideration and detail design. This is due to the individual;
- Components requiring mounting structure and the mounting unit for a combination surgical light and services pendant can result in an area with clustered mounting units and support framing all sharing a common zone;
- Skirts to the filter group have rarely been used as surgical lights, and services pendent units have made the use of skirts difficult or impossible in many cases;
- Airflow velocity grids (measuring total airflow rate) commonly are used in supply air duct to enable airflow rate to be maintained constant as filters load, which also operates to maintain pressure regimes for infection control between operating room and other areas;
- Local recirculation fans have not been used due to difficulties with noise and maintenance access. The experience with operating room laminar flow units in Queensland was not good in terms of acoustic performance, with strong surgeon complaints of unacceptable noise levels;
- The source of the excessive noise was from local recirculation fans for the laminar flow filter units. The access to the recirculation fans for maintenance required trade staff entering the operating room or operating suite area, which was considered undesirable for hygiene reasons.

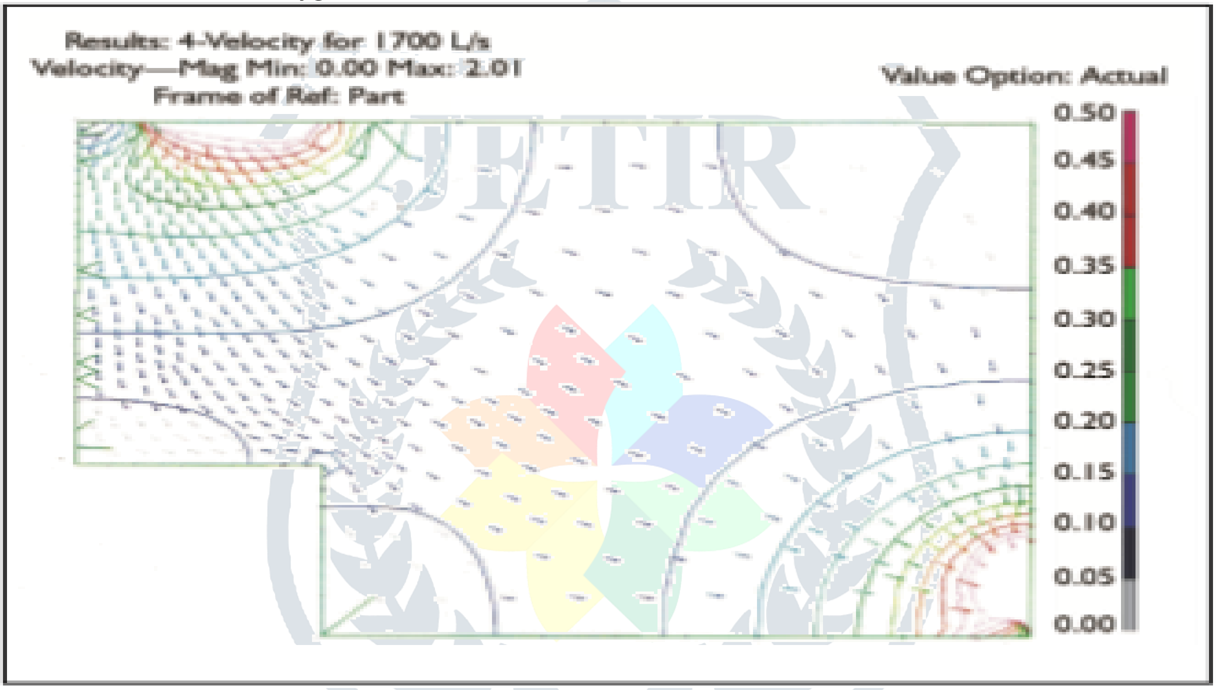

Fig.4 CFD analysis output visualization of air flow pattern and velocity

IV. HVAC REQUIREMENTS

NABH recognizes two distinct types of OTs;

Super- speciality OTs: Operations related to neurosciences, Orthopedics (Joint replacement), Cardiothoracic and Transplant Surgery (Renal, Liver etc.) are carried out here, and the patients are at high level of risk.

General OTs: Operations related to Ophthalmology and other basic surgical disciplines are carried out.

Super- speciality OTs

The NABH guidelines lay down very specific recommendations as given in table 1.there are few observations here:

i. Temperature of 21± 3 0C is recommended, which is a range from 18 ^{0}C to 24^{0}C. In actual practice, depending upon the type of operation, the surgeon may want to have the set temperature as 18 ^{0}C or as high as 24^{0}C. The HVAC designer will be well advised to consider designing a system capability to achieve 18 ^{0}C at 55% RH right up to 24 ^{0}C at 55% RH.

ii. Room overpressure of 15 Pa is much higher then the recommendation of 8 Pa as per CDC. The OT tends to be a little noiser with 15 Pa, as it results in higher exfiltration velocities through door cracks. However, considering the fact that there will be a minimum of 5 ACH of fresh air make up, it is conveniently possible to achieve 15 Pa with fairly good quality OT doors.

iii. Laminar flow velocity of supply air, recommended as 90 to 120 fpm over the supply air grill as per NABH can be 50 to 100 fpm as per ASHRAE. Excessive air velocity over incisions causes faster drying and can be detrimental to operations.

iv. The filtration requirements as per ASHRAE are MERV7 as backup, MERV8 is plenum and MERV17 is terminal location for supply air, and this is line with NBSH recommendation.

v. for OTs located in dry regions, the HVAC designer should incorporate humidifiers. The humidification process should not become a source of contamination.

Table 1: NABH guidelines for super-speciality OTs

Sr. No	Parameter	Data
1	Room size	Around 2ft×20 ft×10ft height till false ceiling
2	Occupancy	5 to 8 persons
3	Equipment load	5 to 7 kW
4	Total ACPH	Minimum 30 ACPH; More air changes may be required if the air conditioning load so demands
5	Fresh air make-up	Minimum 5ACPH
6	Inside temperature and humidity	Temperature should be maintained at 21± 3^0C inside OT all the time with corresponding relative humidity between 40 to 60%, though 55% is considered the ideal RH
7	OT room overpressure w.r.t. adjoining areas	This needs to be maintained to prevent infiltration of outside air into OT; the minimum positive pressure recommended is 15 Pa
8	Terminal air supply	Air to be supplied through terminal HEPA filters in the ceiling; minimum size of filter area to be 8 ft×6 ft to cover the entire OT Table and the surgical team
9	Terminal supply air flow velocity	Airflow needs to be unidirectional and downwards on OT table; Air velocity recommended is 90-120 fpm at grill/ diffuser level
10	Air filtration	There must be two sets of washable flange type pre filters of capacity 10 microns and 5 microns with aluminum/ SS 304 frame with the AHU; necessary service panel to be provided for servicing the filters, motors and blowers; HEPA filters of efficiency 99.97% down to 0.3 microns or higher to be provided in OT and not in AHU
11	Return air	Return air to be picked up and taken out through exhaust grill located near floor (approximately 6 inches above floor level)
12	Air cleanliness class	Air quality at supply i.e. at grill level should be class 100/ ISO 14644 Class 5 (at rest condition) Class 100 means the are no more than 100 particles of 0.5 micron and above in a 1 cubic feet sample

Table 2: NABH guidelines for General OTs

Sr. No	Parameter	Data
1	Room size	Around 2ft×20 ft×10ft height till false ceiling
2	Occupancy	5 to 8 persons
3	Equipment load	5 to 7 Kw
4	Total ACPH	Minimum 25 ACPH; More air changes may be required if the air conditioning load so demands
5	Fresh air make-up	Minimum 4ACPH
6	Inside temperature and humidity	Temperature should be maintained at 21± 3^0C inside OT all the time with corresponding relative humidity between 40 to 60%, though 55% is considered the ideal RH
7	OT room overpressure w.r.t. adjoining areas	This needs to be maintained to prevent infiltration of outside air into OT; the minimum positive pressure recommended is 15 Pa
8	Terminal air supply	Air to be supplied through terminal HEPA filters in the ceiling; minimum size of filter area to be 6 ft×4 ft to cover the entire OT Table and the surgical team
9	Terminal supply air flow velocity	Airflow needs to be unidirectional and downwards on OT table; Air velocities not specified- they should be adequate to keep particulate and bacteria load away from the OT table
10	Air filtration	There must be two sets of washable flange type pre filters of capacity 10 microns and 5 microns with aluminum/ SS 304 frame with the AHU; necessary service panel to be provided for servicing the filters, motors and blowers; HEPA filters of efficiency 99.97% down to 0.3 microns or higher to be provided in OT and not in AHU
11	Return air	Return air to be picked up and taken out through exhaust grill located near floor (approximately 6 inches above floor level)
12	Air cleanliness class	Air quality at supply i.e. at grill level should be class 1000/ ISO 14644 Class 6 (at rest condition) Class 100 means there are no more than 1000 particles of 0.5 micron and above in a 1 cubic feet sample

V. DESIGNING HVAC SYSTEM FOR OTS

Psychrometrics

The HVAC designer, considering 18^0C and 55% RH as the set point on the minimum side, will have to reckon with a dew point of 8.84^0C. The apparatus Dew Point (ADP) could be in the range of 7.5^0C. Chilled water from the central AC system is likely to be at 8^0C or above at the inlet of the chilled water cooling coils, which can at the best pull down the supply air temperature to 13 to 14^0C.

To get the supply air temperature down to 7.5^0c will require supplementary cooling with a DX cooling system or a brine system operating at, say, 2^0C at the inlet to the cooling coils. Another aspect that needs to be considered is the dehumidified air quantity and total air quality. T is quite possible that the total air quantity works out to, say, 4000 cfm and dehumidified air, say, 3000cfm. In order to achieve the temperature and RH in the OT, the extra air needs to be bypassed. Bypassing air can result in a particularly problematic situation for the HVAC engineer. This is on account of the fresh air that will get bypassed along with the unconditioned room return air. The fresh air, if hot and humid, will land up in the OT and disturb the RH there. The way out of this piquant situation is to supply treated fresh air which is tempered to around13^0C using chilled water. Whilst this can be conveniently done if there is a separate treated fresh air AHU serving a cluster of OT AHUs, it can also be done quite practically using a chilled water cooling coil and plenum (with blower) for the fresh air intake.

Another important consideration is the control system for part load operation. Under part load conditions, it is still imperative to achieve the design ADP of round 7.5^0C. This would mean that the DX plant is always operative using a supply temperature sensor and the chilled water cooling coil regulates the room temperature using a room temperature sensor.

AHU Running Hours and Implications

The OT AHUs have to be running on a 24×7 basis, except during maintenance. The AHU fan speed can be lowered by using VFD, and the OT room temperature elevated during non-usage hours to conserve energy. When lowering fan speed, it is imperative that the positive pressure gradient of the OT room is not disturbed.

As a result of operating the OT air-conditioning at low temperatures, the exterior surfaces of the OT partition walls and the floor above and below could sweat. The HVAC designer should examine these eventualities and recommend insulation as necessary.

Fresh Air Make-up

The quality of the outdoor air delivered to the operation theatre affects the quality of air inside the OT. The orthopedics OTs of KEM Hospital in Mumbai had to be shut down for three days in February last year after the discovery of dead pigeons in the air intake duct. This had let to infestation of maggots. Air intakes are accumulation sites for dirt and debris, including rotting botanical materials like leaves. Which are growth sites for fungi such as Aspergillus Fumigatus .

Air intakes should not be located near equipment exhausts vehicular traffic and cooling towers. As per ASHRAE standard 62.1, outdoor air intakes needs to be located at least 25ft from plume discharges and upwind (prevailing wind) of cooling towers, evaporative condensers, and fluid coolers. In addition, outdoor air intakes need to be located at least 15 ft away from intakes or basins of cooling towers, evaporative condensers and fluid coolers. The air intakes need to be well above the ground level to avoid contamination from wet leaves, sanding water or piled leaves. In the case of roof- mounted air intakes, it is similarly advisable to take the intake about 4ft above the roof level.

It is imperative to provide proper access to maintenance personnel to clean to air intakes.

Condensate Drain pans

The condensate drain pan in the AHU needs to quickly remove the condensate water from the AHU. If water stagnates then this accumulates over it and a thick bio of bacteria, fungi and protozoa grow on the metal surfaces. the drain has to be flush with the bottom of the pan. The pan should be made ideally of smooth stainless steel and spilt in two directions so that the possibility of water stagnation is eliminated.

Ultraviolet Germicidal Irradiation (UVGI)

UVGI is being used to limit the growth of micro-organisms in AHUs, UV light, especially around 265 nano meters damages the DNA of micro-organisms. UVGI from the lamps in AHUs inactivate micro-organisms. UVGI from the lamps in AHUs inactive micro- organisms present in the airstream and on surfaces such as cooling coils and drain pans. Vegetative bacteria including mycobacteria and viruses are very susceptible to UVGI, whereas fungal and bacterial spores are least susceptible.

The residence time of the microbe under UVGI illumination, as well as the intensity of the irradiation, are important factors for the inactivation of microorganisms. Low airflow conditions (less than 400 fpm) and appropriate intensity ensure that a substantial amount of vegetative bacterial and fungal spores are inactivated.

The placement of the UV lamps affects its efficacy. UV systems may be installed either upstream (return side) or downstream (supply side) of the evaporator coil. Either installation will keep the evaporator coil clean. The UV lamps have to be turned towards the cooling coils and away from filters. Filter media decay in UV light. The lamps have to remain ON at all times, even when the AHU is switched OFF, expect during maintenance.

Healthcare facilities using UV lamps in AHUs have reported that the drain pans and cooling coils remain in prime condition for years after installation. While using UV lamps, safety considerations are paramount. Safety cut outs are essential to prevent accidental turning on of the lamps when maintenance work is being carried out inside the AHU. Regular maintenance of UVGI systems is required and usually consists of keeping the bulbs free of dust and replacing old bulbs as necessary after their life, determined by hours of operation by the manufacturer, is over.

Guidelines For Filters

1. The filter media shall be warranted by the manufacturer to have an average efficiency of not less than 95 per cent when tested by the dioctyl phthalate (DOP) smoke method, or 99 per cent when tested by the National Bureau of Standards dust spot method. The filter shall be located downstream to all other air conditioning and air handling equipment.
2. The filter frame shall be durable, carefully dimensioned, and shall pro- vide an air-tight fit within the en- closing ductwork. All joints between filter segments and the enclosing duct- work shall be gasket or sealed to provide a positive seal against air leakage.
3. For protection of the required filter, a pre-filter of at least 30 per cent efficiency (DOP test) shall be located upstream to all other air conditioning and air handling equipment.
4. The filter bank shall be supported to eliminate any distortion under normal maintenance or operating conditions. 5. Adequate space shall be provided to permit ease of maintenance of filter system.
6. A suitable differential-pressure gauge shall be installed across each filter bed. The gauge shall be marked to show the normal pressure drop at which the fan capability will require that the filters be replaced.

Installation, Commissioning and Validation of the HVAC System

Cleanliness is the dominant consideration during the installation process. The ducts should have their open sides closed with PVC sheets so that dust does not ingress. Installation of ducts at site should be undertaken only after all the masonry work is completed, a point often ignored due to exigencies of time.

The AHU and the laminar flow module too should be installed with cleanliness in mind. One should seriously consider the possibility of bringing in the AHU in assembled condition to site. The supply air ducts of OT HVAC system are subjected to as high a positive pressure and the return duct are subjected to negative pressure as low as possible. The ducts should be tested for air leakage with duct pressure testing equipment. Duct pressure testing will ensure that energy loss due to air leakage is minimized and in the case of return air ducts, the chances of ingress of contaminated outside air into the ducts is minimized. Testing can be done as per the relevant SMACNA standard for duct tasting.

After installation, an 'air blow down' process should be undertaken and documented before loading the HEPA filters. Before the AHU is stared, the OT should be cleaned and mopped dry. AHU should be run on pre-filter for 24 hours or more to dislodge the coarse dust in the ducts. After mopping and cleaning of the OT again, the post filter should be loaded. After running on post-filter for at least 24 hours and after ensuring that there is no traffic of installation personnel in the OT. The HEPA filters are to be loaded. After air balancing and adjusting the psychrometric process to achieve the air quantity, temperature, humidity and over pressure, the OT is ready for HEPA filter Dispersed Oil Particulate (DOP)/ Poly Alpha Olefin (PAO) challenge test and particulate counting. This process of determining that the designing parameters are met is called the 'validation processes'. OT validation process is to be carried out at least once a year or after change of HEPA filters.

VI. Energy Conservation

Square foot for square, healthcare facilities constitutes the highest energy consuming industry.

Reality Check

Energy has been conventionally conserved by harnessing natural light and ventilation. However, this is not entirely feasible in a modern operating room. Artificial lighting is quite necessary. And therefore, most conservation measures would hinge on the HVAC loads. It may interest some to know that the HVAC load for an operating room of 600 sq ft can go up to 20 TR. Relate this with the conventional 1.5 TR AC unit for an office cabin- one can make do with 5 to 6 TR- and the difference becomes glaring. Conservation here can be achieved by way of both architectural and engineering designs.

Architectural Design

In the event the ORs are located on the top floor with the slab exposed to sunlight, provision of both over deck and under deck insulation helps. Windows are usually and preferably avoided, but if required, these should be switch panes with blinds inside to cut the glare and heat transfer.

Temperature and RH

Surgeon work in layers of surgical garb. And despite the newer OR light emitting next to no heat, the surgeon needs to be comfortable. Therefore the temperature is typically set at 20±1^{0}C.Therefore some surgeons who prefer the temperatures even cooler at 18^{0}C. This, by itself, is not difficult; the drop of every degree below 20^{0}C, though, costs disproportionately higher. The challenge lies in yet maintaining the humidity below 55%. Unless RH is contained within55%, with the temperature set lower, one could witness condensation with water dripping fromgrilles, louvers, on the walls and some very uncomfortable and vexed surgeons, not to speak of proliferation of molds and organisms. This containment has conventionally been achieved with hot water or strip heaters. Dry/ solid desiccants help reduce the latent loads, but we need a system that removes both sensible and latent loads.

Else with the heating required for dehumidification followed by extra energy to cool, the system is both expensive and energy inefficient. One can only imagine the energy expended in cooling, heating, heating and then cooling again. An alternative is available in liquid desiccant systems. This system deploys lithium bromide solution, dispenses with the heating requirement and, therefore, is energy efficient. Cooling coils are required to condense air born water vapour. And over time, these wet coils spew organisms and throw them in the airflow. UV lights have been mooted, but the limited exposure poses questions abot the efficacy of this option. Liquid lithium bromide kills pathogens that come into contact with it and therefore offers an additional bargain.

The Fad of 100% Fresh Air

The high operating cost of a 100% fresh air unit is mitigated by way of a green heat recovery wheel (HRM). HEPA filters effectively help us to arrest particulate matter and no filters are yet available with a porosity of 200 milli- microns, the size of a virus. And thus, it is fine to not insist on 100% fresh air, but to go with 20% fresh air as is also recommended by ASHRAE, and dispense with the HRW.

VII. CONCLUSION

Air conditioning of OTs is a matter of great responsibility for HVAC engineer. It is important that the relevant codes are adhered to and the temperature and humidity needs of the surgeon and OT staff are understood. Since the system will run round the clock, year after year, energy efficient equipment should be used together with energy saving options during non- OT usage hours.

Special care w.r.t cleanliness has to be practiced at the installation stage itself. Periodic validation of system is necessity.

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