HOSPITAL NOTES

Environmental Control Including Ventilation In Hospitals

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Introduction

People can suffer and even die as they are exposed to diseases they did not have when they come to the hospital. Often there are things, we as hospital planners and engineers could have done to prevent that germs from being there in the first place. These disease causing organisms enter the building on air supply, feed on moisture produce, breed in reservoirs installed, and move about on vehicles we maintain. Air contaminants, which includes fungus, mold, bacteria, inorganic, and organic matter, cause many problems from nuisance colds to fatal pneumonia. Legionnaire's disease, got it's name from the 1976 incident in Philadelphia where 34 members of the American Legion attending a convention, died of that previously unnamed pneumonia. After a much investigation, it was determined that the bacteria was distributed by the air-conditioning system.

In this era of antibiotics, prevention of hospital acquired infections is too often seen as unimportant. It is commonly accepted that patients will sometimes suffer infections while in the hospital. "So what! A shot of antibiotic penicillin and that little rash or fever is gone, right?". Not quite true, as, in the United States twenty thousand (20,000) people die every year as a direct result of nosocomial infections. Sixty thousand (60,000) others die where nosocomial infections are a contributing factor. Patients equaling five percent (5%) of the total admissions to US hospitals suffer some sort of hospital acquired infection (1). At an admission rate of 30-40 million people per year that means 1.5-2 million people are being infected in our hospitals every year.

The engineering, architectural or medical communities have put very little emphasis on designing facilities for maximum infection control. Often those who built the facility did so on criteria that was more concerned with cost and aesthetics than reliability, serviceability, or asepsis. It is no longer enough for hospital engineers and planners to blindly accept what they design as the best for patients care.

Controlled Environment

There has been a growing concern in the medical community regarding the hazardous effects of poor indoor air quality on the heath of individuals which leads to increased incidence of health related symptoms like headache, dizziness, eye and throat infection, fatigue, memory loss etc. The terminology 'Indoor Air Quality' refers to the nature of the conditioned (heated/cooled) air that circulates throughout the space (2). This refers not only to the comfort, which is affected by temperature, humidity, odor, but also to the harmful chemical and biological contaminants present in the conditioned space.

The basic differences between controlled environment by air conditioning for hospitals to take care of the above mentioned factors and that for other building types stem from :

1. The need to restrict air movement in and between the various departments.
2. The specific requirements for ventilation and filtration to dilute and remove contamination in the form of odor, air-borne microorganisms and viruses, and hazardous chemical and radioactive substances.

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3. The different temperature and humidity requirements for various areas; and
4. The design sophistication needed to permit accurate control of environmental conditions.

The heating ventilation & airconditioning (HVAC) system & indoor air quality

Studies have shown that patients in controlled environments generally have more rapid physical improvement than those in uncontrolled environment. Patients with thyrotoxicosis do not tolerate hot humid conditions or heat waves very well. A cool, dry environment favours the loss of heat by radiation and evaporation from the skin and may save the life of the patient. On the contrary burn patients need a hot environment and high relative humidity. A ward for severe burn victims needs to have temperature controls that permit adjusting the room temperature up to 32° C dry bulb and the relative humidity up to 95%.

To provide comfort conditions in the hospital HVAC systems are installed. The HVAC system comprises of following major components :-

1. Compressor 2. Condenser 3. Evaporator 4. Pumps & Cooling towers 5. Air Handling Units 6. Air Distribution System (Ducts, Grills/Diffusers).

The recommended design conditions, ventilation, and pressure requirement for comfort and cross contamination control for critical areas are indicated in Table 1 (3).

Table 1

S. No.	Area	Temp ^{0}C	Relative Humidity %	Pressure Relationship w.r.t. Adjacent Area	Ventillation	
					Minimum Air changes of outdoorair per hour	Minimum total air changes per hour
1.	Operation theatres (for 100% fresh air system) (for recirculatory system)	17-27 (adjustable over above range)	45-55	(+)	15 5	15 25
2.	Rcovery rooms	24	45-55		2	6
3.	Nursery full time special care (incubation)	24 24-27	30-60 30-60	(+) (+)	5	12
4.	Nursing	24	50	(±)	2	6
5.	Intensive care units	24	30-60	(+)	2	6
6.	Patient bedrooms	24 or less	30% for winter 50% for summer	(±)	2	4
7.	General areas	24-27	30-60	(±)	2	9
8.	Radiology/surgery	24-27	40-50	(+)	3	15
9.	Diagnostic	24-27	40-50	(±)	2	6

(I) Air intake/exhaust outlet

(A) Air intake

Final air quality depends on the supply. It is critical that you select the location of an air intake for the best available air not the most economical. Intakes must be located to draw in the best quality air. They must be away from vehicle exhaust, plumbing stacks, and any other contaminant source. Birds and vermin like to nest in air intakes. Birds are a major source of Aspergillus, one of the most common cause of infection in immunocompromised patients. Insects provide waste matter that is both a culture medium for pathogens and irritating to humans (4).

Intakes must be located to reduce accessibility to the animals and yet allow for cleaning. They must be screened to keep out small creatures and provide no crevices for nesting. Louvers in outside air intakes should have surface so designed to prevent entry of rainwater.

These intakes should be located as far as practical (on directionally different exposures whenever possible), but not less than 9 m from combustion equipment stack exhaust outlets, ventilation exhaust outlets from the hospital or adjoining buildings, medical-surgical vacuum systems, cooling towers, plumbing vent stacks, smoke control exhaust outlets, and areas that may collect vehicular exhaust and other noxious fumes. The bottom of outdoor air intakes serving central systems should be located as high as practical (3.6 m recommended) but not less than 1.8 m above ground level or if installed above the roof, 0.9m above the roof level.

(B) Exhaust outlets

These exhausts should be located a minimum of 3 m above ground level and away form doors, occupied areas and operable windows. Preferred location for exhaust outlets is at roof level projecting upward or horizontally away form outdoor intakes. Care must be taken in locating highly contaminated exhausts (e.g., from engines, fume hoods, biological safety cabinets, kitchen hoods, and paint booths). Prevailing winds, adjacent buildings, and discharge velocities must be taken into account.

(II) Air handling unit (AHU)

The main constituents of an AHU are Blower with drive mechanism, cooling/heating coils, condensate or drain pans and humidifier etc. As the air passes through various sections, it is susceptible to various kinds of infections.

(A) Heating and cooling coil

Higher efficiency coil and fin designs have been developed that makes air twist and turn. They exchange much more heat, but also trap much more dirt.

While doing their jobs coils extract moisture from the air. Air containing particles pass over the coils depositing some particles into the moisture on the coils. Even in the best systems some contamination will adhere to the coils. In those less than the best, debris will build up and mold and fungus will grow until no air will be able to pass through the coils. This buildup will serve as a reservoir that will release germs into the airstream.

Periodic cleaning is necessary to remove these contaminants. The frequency and methods are dependent on the quality of the incoming air, the design of the coil, and quality of conditioned air desired.

(B) Drain pan

Condensate removed by the coils is removed from the air handler through drain pans. If it is not drained out properly, water-logging takes place in the pan and give rise to bacterial growth. Spray foam insulation on the inside surface of drain pans is becoming common. This is a very unhealthy practice because an even surface and consistent pitch is impossible with a spray foam.

(C) Housings

Two of the most important features of an air handler housing is it's interior finish and accessibility to all interior sections. The interior sections if not resistant to corrosion, not smooth to resist build-up of debris, and prone to absorb moisture shall give rise to infection growth. Any unprotected metal should be primed and painted, preferably with epoxy paint. Any rusted metal should be repaired and the cause of the rust, such as excess moisture, should be corrected.

(D) AHU Insulation

Often AHU plenums are insulated from inside using fiberglass for noise reduction, several studies have shown that fiberglass is unsuited for use in the air stream. It absorbs moisture, has irregular surface that traps dirt, is impossible to clean, and releases inorganic respirable fibers. As a result, bacteria and mold thrive in the fiberglass and may even be transported to the patient on a fiberglass fiber.

(III) Air filteration

To prevent the flow of air containing infectious particulates, air filtration is provided in Air Handling Units which filters particles, pathogens and water droplets carried into the air, either from the coils and humidifiers or through leaks in the low-pressure side of the unit. For critical care areas like operation theaters, ICU, emergency and recovery areas normally three-stage filtration is provided.

Pre-Filters (BS-6540) : These are first stage filters having efficiency 70% down to 10 Microns. These filters are cleanable and washable and installed at inlet of airstream.

Fine filters (BS-6540-part-I) : Second stage filters having efficiency 99% down to 5 Microns. The pressure drop in dirty conditions should not exceed 20mm WG and the initial drop should be between 6.5 to 8.5mm WG. These filters are washable.

Hepa filters: With efficiency 99.97% down to 0.3 Microns used for operating rooms and ICU's. These are special high flow types with more media to handle higher air quality (DOP tested as per federal standard 209). The filtering media is micro fiberglass paper to provide the required filtering efficiency. For specifically critical hospital applications the pressure drop in choked conditions should not exceed 50 mm WG.

(IV) Duct system

The function of the duct is to convey the air between two points viz AHU and room to be conditioned. It also carries the room air back to the air-conditioning apparatus.

Air Conditioners duct system functions as the respiratory system of your hospital. Over the time contaminants like dust, dirt, fibers, dander, smoke particles gets accumulated in the duct system and make it an ideal breeding ground for mold, spores, pollen, bacteria and other microbes (5). Each time the air-conditioner is turned on, these disease causing demons are sprewed out and circulated through interiors affecting the health and comfort of people present.

Duct cleaning has been therefore vital and complex aspect of hospital infection control. To mitigate this problem robotic air duct-cleaning systems have recently been evolved which comprises of the following : -

Duct cleaning system

- Heavy-duty vacuum machine is connected to the duct to collect harmful contaminants and dust etc.
- Compressed air blasts dirt away to vacuum.
- Motorised brush system mechanically clears the duct from inside.
- Once duct system has been cleaned all access holes are sealed.

It has been seen that a clean duct in addition to improving IAQ gives you substantial energy saving also. One such system has been recently used in PGI, Chandigarh to clean duct of Old AC Plant connected to Operation Theaters and results have been quite encouraging.

(V) Conditioned space

In addition to the contribution by HVAC, air stream infection in a conditioned space is also added by local factor viz. wet walls, interior finishes, furniture, tiles, carpets, cleaning and disinfection agents, floor tiles, granite tops, patients and attendants etc. Chemical pollutants, odors and fungi are major health hazards in indoor environment. This causes allergies and sickness of respiratory tracts. High incidence of sickness due to allergies, asthma, fatigue, headache, cold and respiratory disorders are results of poor indoor air quality.

Ozone generators

Ozone generators provide easy to use solution to reduce or eliminate odor, pollutants, VOC and fungi. This is neither a filter nor a deodorant. It does not mask the odor of pollutants. It oxidises the pollutants and structurally alters the chemical compounds. The result of oxidization is carbon dioxide and moisture.

Mounted in AHU plenum it continuously injects controlled and regulated quantity of ozone into the air system. The released ozone combines with the mainstream air in the supply air duct and reaches the space. It is present in the indoor space at the times at low concentration. When it encounters chemical pollutants, it almost instantly oxidize them and keeps the indoor air free of chemical pollutants VOC as interferes with metabolism of cell multiplication of fungi resulting in the reduction of fungi along which is responsible for vide range of indoor related allergies.

Conclusion

The hospital engineer can no longer take an inactive role in the hospital's infection control effort. If hospitals are to make progress in reducing nosocomial infections, everyone will have to take part. There are as many reasons for nosocomial infections as there are infections.

HVAC Engineers have the challenge to improve indoor air quality of healthcare facility without enhancing the cost of installation and energy bills. To aggressively address the issue, joint efforts by medical and engineering professionals are required.

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