Ductless Air Handling Unit with Air Conditioning System for Operation Theatre

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KEYWORDS:

Ductless Air handling unit, air cycle, relative humidity, surgical site infection, nosocomial infection, operation theatre, air conditioner, HEPA (High-efficiency particulate arrestance).

ABSTRACT: Operation theatres in a hospital requires effective heating, ventilation and air conditioning systems and design for the patients in order to have desired comfort zone within the space. This paper provides a proper methodology in-order to rediscover how ductless AHU for operation theatres works to provide class II quality of air supply and beneficial it is for patients to avoid chances of surgical site infection. The main objective is to develop a system which adhere all the requirements of the best modular operation theatre according to the standards suggested in ASHRAE guidelines and to take into account challenges that current Air handling unit are facing to provide proper quality of air inside the operation theatre. Surgical site infection is one of the greatest side effects of a major operation. A proper operation theatre with good quality of indoor air quality plays a major role in avoiding the chances of spreading of this post-operative infection. Windows and split air conditioners are major pockets of microbial growth, hence they are not suggested in intense care units or operation theatres, central air conditioners are one of the options but it requires 24 hours of AHU blowers to avoid stagnant air inside operation theatre hence it adds up to operating cost and thus is also not power efficient plus AHU of each operation theatre should be dedicated and should not be linked to another service area as that may lead to Nosocomial infection. This paper helps us to understand the new concept of Ductless AHU with air conditioner which is one of the options to provide efficient air quality.

Patent No :- 319253 Date of filling :- 05/12/2016 Patentee :- Zakir Hussain

INTRODUCTION:

Surgical care is an integral part of health care throughout the world, with an estimated 234

million operations performed annually [1]. However, surgical care is also associated with a considerable risk of complications and death.

A study on the incidence and nature of in-hospital adverse events has shown that 1 in every 150 patients admitted to a hospital dies as a consequence of an adverse event and that almost two thirds of in-hospital events are associated with surgical care [2].

Surgical site infections (SSIs) remain one of the most common causes of serious surgical complications [3]; they account for 14% to 17% of all hospital-acquired infections and 38% of nosocomial infections in surgical patients [4, 5].

Each SSI is associated with approximately 7-10 additional postoperative hospital days and patients with an SSI have a 2-11 times higher risk of death, compared with operative patients without an SSI [6, 7].

The three main sources of Surgical site infection are autoclave sterilization, surface infection and Air borne infection. The thermal conditions of an operation theatre like pressure, humidity, temperature, etc. greatly affect the well being of the patients. Due to the issues faced due to other air handling unit, a dedicated system which does not become accumulated place for the growth of microbes in operation theatre was very important. In this study, the researcher has tried to provide a satisfying solution to all the problem faced to reduce particle count and to increase indoor air quality.

OPERATION THEATRE AIR HANDLING UNIT REQUIREMENT:

There are different recommendations by different institutes providing guidelines for the proper service of operation theatre and they provide ways to avoid the surgical site infection in operation theatre. Some of the guidelines that are provided by different organizations, the conditions provided in researched equipment was done as per the guidelines provided in table 1.

The guidelines provided by NABH refers Air handling in the OT including air Quality that Air is supplied through Terminal HEPA (High-efficiency particulate arrestance) filters in the ceiling. The HEPA can be at AHU level if it not feasible at terminal level inside OT. The minimum size of the filtration area should extend one feet (i.e. 304.8 millimetres) on each side of the OT table to cover the entire OT table and surgical team. The minimum supply air volume to the OT (in cubic feet per minutes CFM) should be compliant with the desired minimum air change. Both guidelines were taken into consideration while research and the amendments were done according to the guidelines provided.

To Obtain a perfect condition inside the Operation theatre factors such as air changes per hour, Air Velocity, positive pressure inside the room, temperature and relative humidity must be taken into consideration. There must be atleast 20 air changes per hour in the experimented room, air velocity must be unidirectional and on table air velocity should be 25-35 FPM (feet per minute) which could be obtained using laminar air flow system, minimum positive pressure recommended is 2.5 Pascal (0.01 inches of water) and humidity 55% for 18-27 degree Celsius temperature.

Temperature	Relative humidity in %	Ventilation	Reference
17-27	45-55	Positive pressurization. Minimum 25 air cycles per hour, with atleast 5 air changes per hour of outer air.	ASHRAE [10].
20-24	30-60	Positive pressurization of at least 2.5 Pa. Primary Supply Diffusers & non-aspirating. Minimum 20 ACH (air changes per hour), with atleast 4 ACH(air changes per hour), of outdoor air	ASHRAE [11].

Table 1 Recommended indoor conditions for operation theatre [9]

Materials and Methods:

The HEPA filters used in the experimented equipment are of 4 types which includes two Nylon washable prefilters of 5 microns, one non-woven bonded activated carbon filter to neutralize volatile organic chemical (VOC) and other gases, 3 micron microvee filter and one mini-plate HEPA filter of 0.1 micron with two types of coatings on it. A mini-plate HEPA filter of 0.1 micron which has a nano-particle coating of Ethanol, Hydrogen peroxide, Silver nitrate, Sodium Hypochlorite, and Keratin is used. Silver nitrate has bactericidal and virucidal property and keratin helps to clear VOC (volatile organic chemical) that is used to remove the unwanted smell from the experimented room and absorbs gases. This type of HEPA filter has an ability to trap the virus and deactivate it with the use of chemical coating on it. The HEPA filter used in this experiment has low pressure drop that allows reduction in energy consumption. It has high dust holding capacity and is made using E10 filtration efficiency which is effective in capturing submicron particle. As the HEPA filter used is made of synthetic material, it has high mechanical stability and durability.

Ultraviolet light helps to Reduce Mold as Fungal contamination via HVAC units is a common issue which cannot be ignored. It spreads infectious diseases, allergic rhinitis and asthma-inducing organisms as well as other diseases. Ultraviolet lights help develop a robust air purification system in operation theatre. They eliminate fungi, germs, bacteria, pathogens and virus growth on cooling coil. It provides improved air quality by killing irritants and combating contaminants that originate in the air-handling units.

Air damper is used to get fresh air inside the operation theatre. Negative ion generator is used to settle positively charged microbes as well as dust particle without any side effects on human body. The body of experimented system is made of ACP sheet, aluminum profile with thermal break and Acoustic material for sound reduction.

METHOD:

Routine monitoring of airflow performance inside the experimental area was monitored through observations and/or measurements of pressure gradient, flow pattern, temperature and humidity.

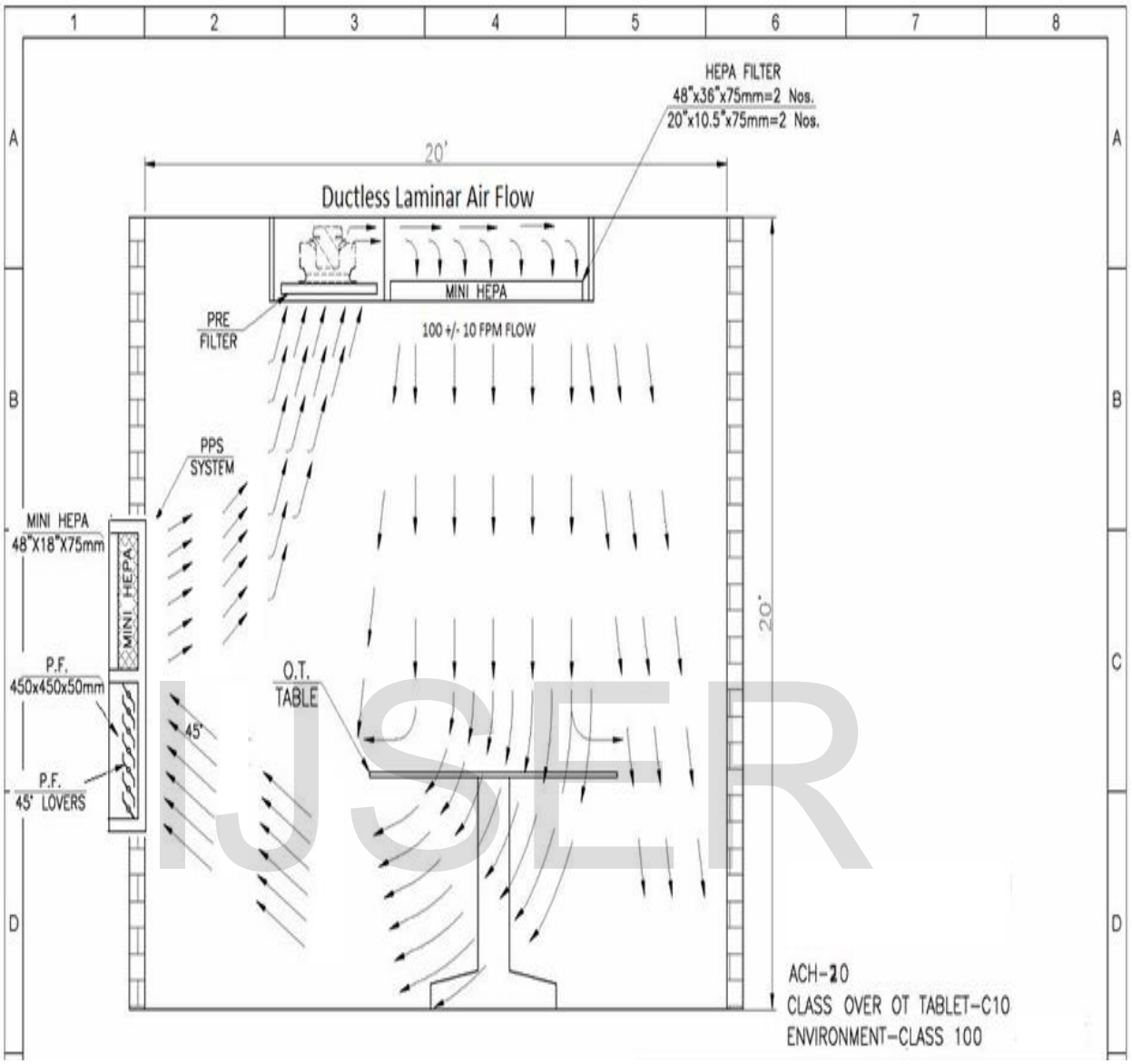

Fig. Layout for Laminar & PPS air flow system

To ensure sterility in the operating theatre, routine bacterial sampling using sterile disposable plastic air samples strips filled with tryptone soy agar (TSA) and Sabouraud agar for total microbial count was performed.

The plates were placed in three positions (i.e. high, low and at the air exhaust). The high position was located by the anesthesia apparatus near the operating table, 2-2.5 m above floor level; the low position was located near the operating table, 0-1m above floor level; and the air exhaust position was in front of either of the exhaust grilles. The plates were incubated at 37 C for two days and 30 C for five days for fungal and bacterial counts. A colony count of less than 30 colony-forming units (CFU)/m3 for the TSA agar and 3 CFU/m3 for the Sabouraud agar is acceptable standard in all operating theatres. This samples were than tested in NABL accredited laboratory

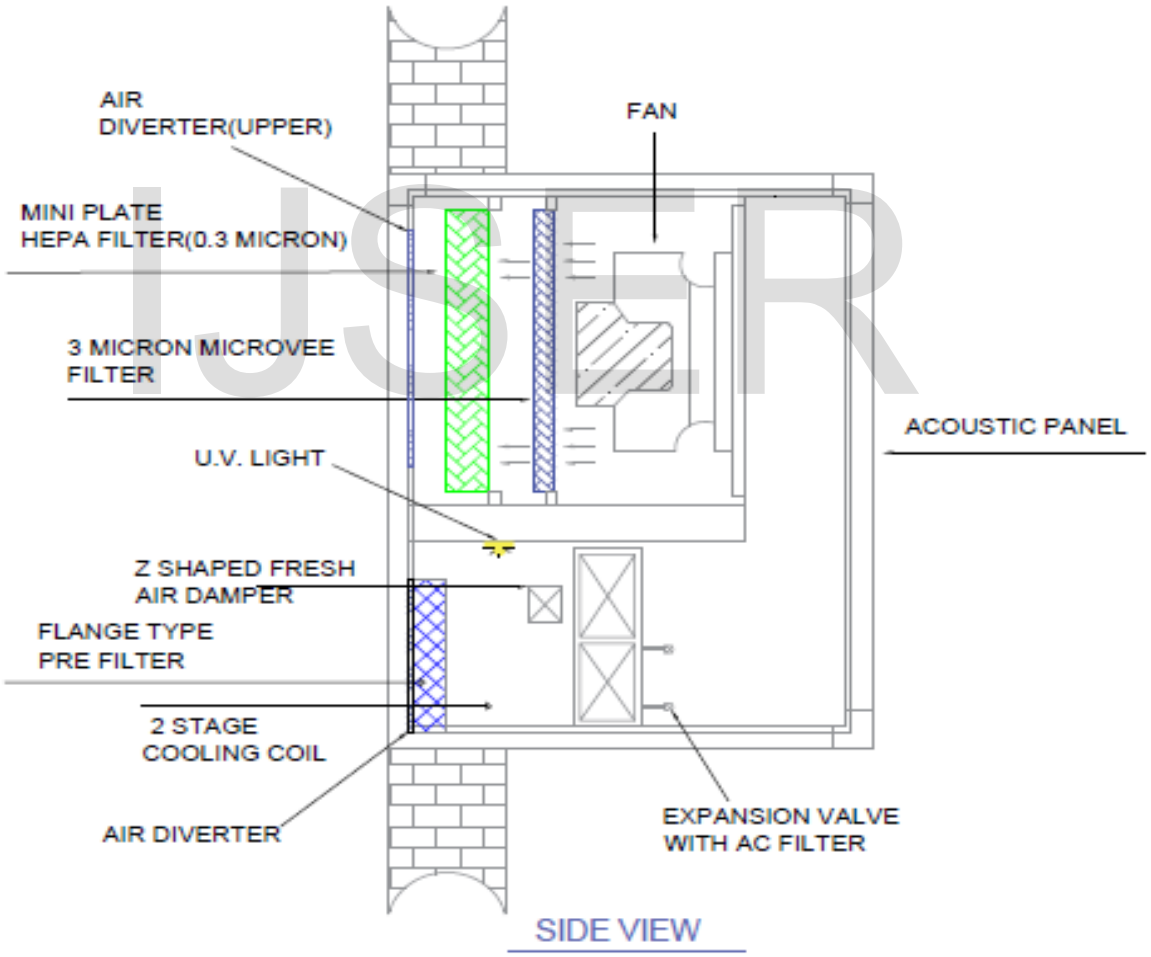

Fig. Block Diagram Representation Of Air Handling Unit

Ductless Air Handling Unit with Air Conditioning unit:

The block diagram representation of air handling unit is as per shown in the diagram, the experimented system is used for both air conditioning and filtration. The two flange type pre filters used is of 5 microns each. The air is sucked through this part with the help of backward fan. This filtered air is passed through ultraviolet light and z-shaped fresh air damper which is a 24VAC power closed, power open motorized air damper designed for a fresh air intake. The air from the fresh air damper is passed through expansion valve for cooling the air which is then passed through 3 micron microvee filter, 0.3 micron mini plate HEPA filter and two different prefilters one of which is used for absorbing fresh air from outside and other is used for taking the fresh air from inside the experimented area. The air diverter is used to separate fresh, clean air from the contaminated air, this helps to create 20 air cycle per hour. Air diverter is used to divert air flow towards the laminar air flow system. The experimented system has digital system installed with many types of sensors in it. The display includes Actual Temperature Display with control, Humidity (Rh) Display with control, Pressure of Air Flow From HEPA Filter, Air Cycle Per Hour (ACH) which helps to know whether the experimented area has enough air cycles and is ready for operation , Multiple Gas Sensor detecting sensors to sense amount CO, i-butane, Propane, Methane, Alcohol, Hydrogen, Smoke present in the experimented area, CO2 sensor used in the system to obtain fresh air, which helps the fresh air damper to open and occupy desired air Quality, Air Particle Quality, HEPA Filter working status, Positive Pressure (Pascal) inside the experimented area.

Results and Discussion

After some months of construction, refitting, repeated performance checking and testing, most system requirements were met successfully. Colony counts of less than 30 CFU/m3 for the TSA agar and less than 3 CFU/m3 for the Sabouraud agar were achieved consistently in the routine checks. the computational flow dynamics simulation method used helps to understand the uni-directional air flow pattern inside the experimented area. The biggest hindrance faced was in checking whether there is any fluctuation in important parameters such as positive pressure, temperature, humidity level, air velocity, particle count, air cycle per hour, etc. which was solved using multiple sensors and a display system that gave exact report to the conditions in experimented area. These are were important parameters while choosing a perfect modular operation theatre.

Conclusion:

The experimented system used proves to be efficient in many ways. As it is not connected to an any other AHU, it proves to be an isolated system which helps to minimize nosocomial infection. The multiple filters used allows to generate class II air quality with the particle count of 10-100 which can be checked using particle counter device. This device helps to obtain 20 air cycle in the experimented area. The perfect condition in the experimented area such as air changes per hour, Air Velocity, positive pressure inside the room, temperature, HEPA filter status, humidity level, particle count, etc. were tested regularly to obtain the final result. Different conditions were monitored carefully and any changes in the exact level was devised and fluctuations in the equipment was done accordingly. It was taken into account the conditions such as atleast 20 air changes per hour, unidirectional air velocity of 25-35 FPM (feet per minute) using laminar air flow system, minimum positive pressure of 2.5 Pascal (0.01 inches of water) and humidity 55% for 18-27 degree Celsius temperature was obtained using experimented equipment. From the study performed, we found out that while designing an air conditioning system for an operation theatre, one should take into consideration the thermal conditions and comfort levels required by the surgeons, medical staff, patients inside the operation theatre. Humidity plays an important role in determining

the air conditioning system. A higher humidity can cause growth of bacteria whereas lower humidity may result in the coagulation of blood. As mentioned above the relative humidity must be of 45-55% in operation theatre. All the conditions are very important in the manufacturing of the air handling unit for an intense care unit. All the parameters mentioned in this paper are interrelated and must be taken acre of while designing an operation theatre, any missing parameter leads to unsatisfactory condition in operation theatre and may therefore lead to postoperative infections which may cause a risk to health of the patient and also the health of the medical of the occupants due to risk of nosocomial infection in the operation theatre this even adds up to the healthcare costs.

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Operating theatre quality and prevention of surgical site infections

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