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"Review Performance Analysis of the Ventilation System for the Hospital Operating Room"

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ABSTRACT : *Protecting operating theatres from pollutants, bacteria, viruses, harmful gases and infection is one of the most important ventilation functions in operating theatres. So, when design the ventilation for any operating theatres, it is necessary to match the requirement of codes and standers therefore the ventilation inside the operating rooms does the most important function of it which is to sweep the contaminants and dispose of them as soon as the contaminants enter the operating room. the main objective of this article is to review the previous researches in order to reach to the best ventilation in the operating rooms, this review will focus in the ventilation by using laminar air flow diffuser because most of previews research reach to using laminar air flow diffusers is the best way to achieve high performance of the ventilations inside the operating room. Also, Standers will review to know the limits of requirement inside the operating room and make a comparison between these standees.*
KEYWORDS:*ventilation, operating room, laminar airflow diffuser, standers.*

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I. INTRODUCTION

This article will help future researchers who interested in this topic to reach for best what previous researches reach for it, they will be able to studying the airflow distribution and its properties in the operating room. Using CFD as a tool to simulate the physical model as a numerical model in order to reduce the time and cost of measurement. Calculation of thermal comfort parameters including velocity, temperature and relative humidity of the room and effect on the quality of the air inside. The investigation of room air movement properties can be carried out by any of two main methods, Experimental or numerical as well as their combination.Experimental investigation, generally yield more reliable information about the physical process, when accurately full-scale measurements are performed and can also be done on small-scale model. However, there is no doubt that the experimental investigation is the only method for investigating a new basic phenomenon, and then the computational investigation should follow. Even then, sufficient validation of the computational results should be carried out by the way of comparisons with experimental data

II. LAMINAR AIRFLOW DIFFUSERS (LAF)

The function of laminar airflow diffuser is supplying a uniform airflow(unidirectional) with low velocity which make the motion of air without any circulations or turbulent disruptions between layers of flow that help the environment of the room to be high level of cleanliness which were innovated to control airborne particles and contaminations in the surgical operating theatre as shown in Fig. 1.

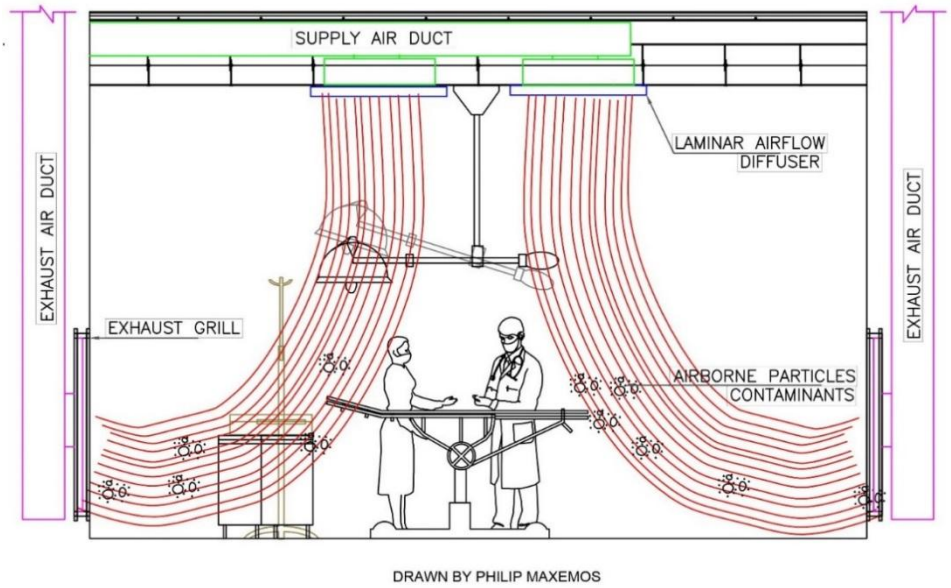


Fig. 1. Shows an operating room using air laminar diffuser, air pattern of flow and how the laminar flow can control the airborne particles of contaminants

There are many researchers reached to using laminar airflow system, is the best way to lead the distributions of ventilation for best performance, which the ability of the laminar airflow can reduce and sweep the contaminants especially vertical laminar air flow so we will review most importing previous research next section.

M. Alsved et al. 2018 [1] they used two airflow ventilation types, vertical laminar flow and mixed airflow as shown in Fig.2.

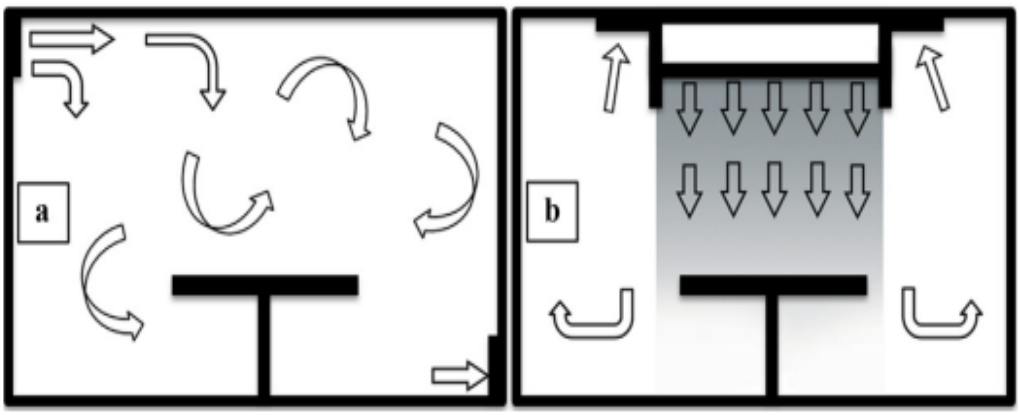


Fig. 2. shows flow principles (a: mixed airflow) (b: vertical laminar flow,[1]

Fig. 2: shows the flow principles of the two ventilation systems for surgical operation room: (a) mixing flow; (b) laminar flow. The result of their work lead to that laminar air flow reject bacteria more efficiently from the air than mixing airflow, chiefly near to the wound or near to the instrument surgical table. And using localized site of turbulent airflow and less speed recirculation areas, this possibly increase the hazard of infection that what reached to it Sanjeev B Thool and ShobhaLata Sinha, 2014[2]

Also, there is another research that reach to laminar air flow is the best options for Cesare M. Joppoloet al. 2016 [3] which they Controverted exists between engineers' staff and clinicians' staff over the beneficial effects of Unidirectional Air Flow (laminar flow) adoption in the air ventilation system in the operating room in order to further minimize airborne partial Surgical Site Infections (SSIs). they presented the results obtained cross an environmental monitoring campaign on 31 surgical theaters, 18 operating rooms equipped within unidirectional flow systems and 13 operating rooms adopted a mixing turbulent flow air ventilation system. Results had appeared how operating table equipped within unidirectional flow diffusion system had generally

less inert and viable airborne particles pollutions in the operating table than those with mixed flow, and therefore a lower hazed of SSIs.

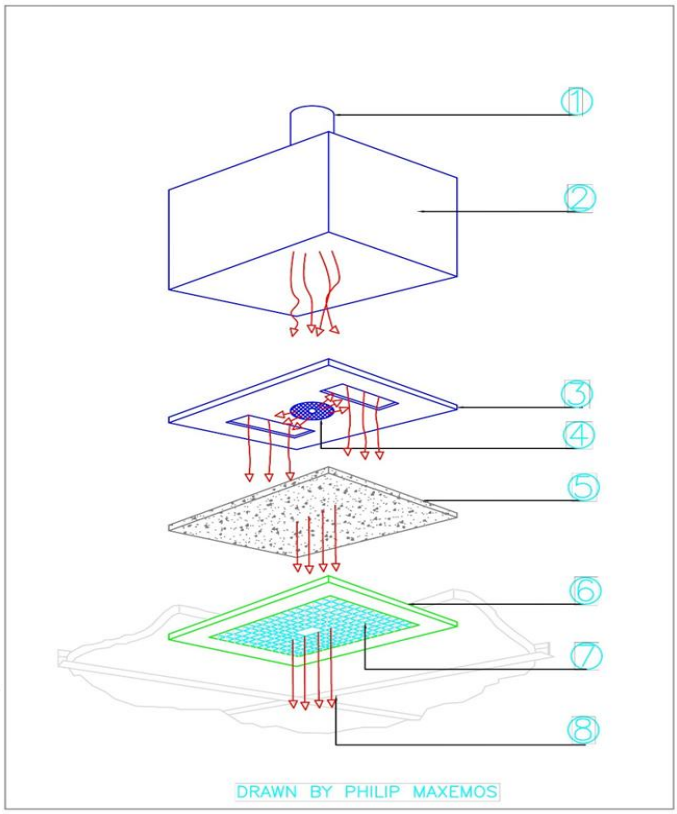
CONG WANG, 2019, [4] has appeared that the conventional mixing ventilation is not able to reliably create an ultra-clean environment. The using of air flow mixing ventilation in infection-prone surgery must be limited, particularly where a large surgical staff is involved. Laminar flow (LAF) ventilation demands a suitable flow rate to achieve coveted performance.

M. A. Rinjesh et al. 2020 [5] they used CFD to study and resolve the pattern of airflow distribution motion. The influence of shape of room on mixing of airflow within the surgical operating room, and the effect of location supply speed on airflow distribution motion pattern are analyzed. It is described that, laminar flow (LAF) distribution system is the good options in pollutions rejections as well as the power consumption scenario. LAF system minimize the power consumption and noise limit in the surgical room and ensures rejection of the pollutions from the critical area of a surgical room. Surgical air pollutions could be maximizer affected by air inlet speed as BehrangSajadi et al. 2011 [6] showed that in their research. The airflow is responsible for safe the wound from infectious airborne particles and would be readily disturbed where air inlet speed goes over 0.1 m/s.

Sanjeev Thool and ShobhaLata Sinha, 2019, [7] They reached to systems that supply with laminar airflow regimes represent the good choice for a surgical room in terms of contamination control, as their results in the smallest percentage of airborne particles impacting the surgical operating site. However, care require to be taken in the sizing of the laminar airflow array. A face speed of around 0.13: 0.18 m/s is acceptable from the airflow laminar diffuser array.

III. THE WORKING PRINCIPLE OF LAMINAR AIRFLOW DIFFUSER

The air supply from duct with turbulent and thigh velocity when enter to modular then there is plenum separator plate that can separate the flow through two patterns to able to reduce the high velocity to low velocity. Subsequently the airflow forced straightforward to baffle panel channels (diffusion basket with perforation pattern) with which make airflow laminar stream vertically over the site area as shown in Fig. 3.



1	Duct connection	2	Modular frame	3	Planum separator plate
4	Volume control	5	Diffusion basket	6	Framed face plate
7	Perforation pattern	8	False ceiling		

Fig. 3 shows the stage of airflow inside the laminar airflow diffuser and its components.

IV. INSTALLATIONS OF LAMINAR AIRFLOW DIFFUSER WITH EXHAUST AIR GRILLES

For the most efficacious laminar airflow diffuser shall be installed in the ceiling of the room covering the most critical surgical site above patient and for air exhaust grilles shall be installed in low level from finish floor as shown in Fig. 4.

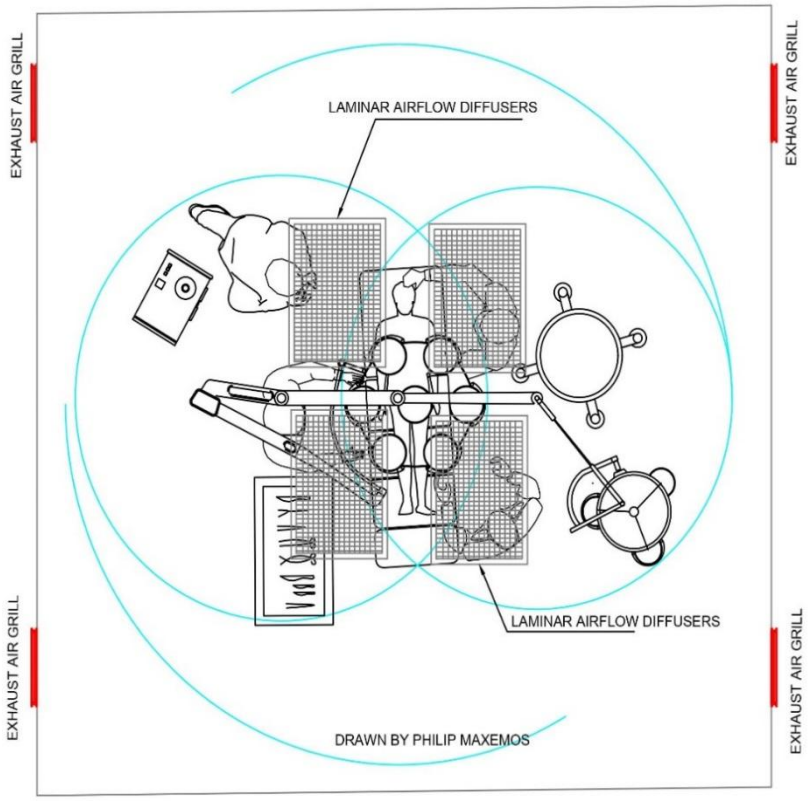


Fig. 4 Shows the locations for laminar airflow diffuser in the false ceiling with exhaust air grilles at sidewalls.

The coverage area supply laminar airflow diffusers shall be at least over the operating table on every side of 12 in. (305 mm). And shall be installed with minimum two low level exhaust grilles and it is consulting on install at opposite corners, with level of grilles 8 in. (203 mm) from finish floor. As recommend by ANSI/ASHRAE/ASHE Standard 170 [8]

V. STANDERS AND CODES

In order to the difference between the standards makes it difficult to choose a requirement that recommend in any surgical operating room, comparison between the minimum and maximum temperature, relative humidity, face supply air velocity, air change rate and differential pressure that recommend by standards is summarized in Table 1.

Table 1: Comparison between most importing different standers around the world.

Code or Stander	Face Velocity of supply air	Temperature	Humidity	Air change rate	minimum pressure differential
1	——	18-28	30-60%	——	——
2	——	——	——	>15 ACH	+ Positive
3	25 to 35 cfm/ft2	20–24ºC	20–60%	20 ACH	+ Positive
4	25 to 35 cfm/ft2	20–24ºC	20–60%	20 ACH	+2.5 Pa
5	——	18–23ºC	40–60%	——	+ 7.5 Pa
6	——	——	——	20 ACH	+ Positive
7	——	20–23ºC	30-60%	15 ACH	+ Positive

1. Operating Room Ventilation Systems Best Practices Guide for Energy Efficiency, Health and Safety. [9]
2. 2.Infection-Control and Ventilation Requirements for Operating Rooms HVAC Design for Healthcare Facilities, [10]

3. ANSI/ASHRAE/ASHE Standard 170-2017, ANSI/ASHRAE/ASHE Standard 170-2017. [8]
4. ANSI/ASHRAE/ASHE Standard 170-2013, [11]
5. Canadian Standards Association (CSA) Z 317.2 2010 Present, [12]
6. FGI (Guideline for Design and Construction of health Care Facilities) 2018, [13]
7. AIA (The American Institute of Architects) [14]

As summarized in Table 1. The minimum and maximum temperature, relative humidity, air change rate, minimum pressure differential recommend for the Standards are different.
For temperature minimum is 18ºC and the maximum is 28ºC.
For relative humidity minimum is 20% and the maximum is 60%.
For the air change rate minimum is 15ACH and the maximum is 25ACH.
For the differential pressure (between indoor and corridor) minimum is +2.5 pa and the maximum is +7.5 pa.
For the face velocity of supply air minimum is 20 fpm and the maximum is 35fpm.

VI. CONCLUSION

using laminar airflow system, is the best way to lead the distributions of ventilation for best performance, which the ability of the laminar airflow can reduce and sweep the contaminants especially vertical laminar air flow. For the most efficacious laminar airflow diffuser shall be installed in the ceiling of the room covering the most critical surgical site above patient and for air exhaust grilles shall be installed in low level from finish floor.

After that comparison in table 1, we will able to make out line difficulty of the ideal limit's requirements in standers as the temperature between 18ºC 28ºC,the relative humidity between 20% to 60%, the air change rate between 15ACH to 25ACH, the face velocity25fpm to 35 fpm and the differential pressure (between indoor and corridor) between +2.5 pa to +7.5 pa. but due to their different values. These standards and the future researches should be taken into consideration different kind of surgeries, because some surgeries demand a specific care requirement.

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