International Journal of Research in Engineering, Science and Management
Volume-3, Issue-6, June-2020
www.ijresm.com | ISSN (Online): 2581-5792

Design of Air Conditioning System for an Operation Theatre in Hospital

B. Phanindra Kumar[1], G. Amith[2*], G. Shashikanth[3], D. Surya[4]
[1]*Assistant Professor, Department of Mechanical Engineering, Guru Nanak Institute of Technology, Ibrahimpatnam, India*
[2,3,4]*UG Scholar, Dept. of Mechanical Engineering, Guru Nanak Institute of Technology, Ibrahimpatnam, India*
*Corresponding author: gundelliamith00@gmail.com

***Abstract*: The economic problems multiplying due to the deterioration of environmental conditions and the exhaustion of fossil based energy sources in today's world brings into question endeavors towards designing environmentally compatible hospital buildings that causes less carbon emissions to the nature and that reduces the construction and management costs of the buildings and that considers energy efficiency for the hospital buildings as well covering different functions and requirements. However, in the operating room units where the hospital comfort requirements have been utilized to the utmost level, endeavours for providing green criteria and energy efficiency have remained limited. The objective of this study is to determine other studies to be undertaken in compliance with green building criteria in the operating room units having complicated design characteristics in relation to the other hospital units. The green design criteria for operating rooms in line with national and international studies were researched within the context of this study and the raise in efficiency was explained using examples.**

***Keywords*: Operating room units, Green design criteria.**

1. Introduction

In the present days, as the population increases the need for the comfort also increases. The human being needs more comfort because of inferior environment (like light, sound, machine which produce heat). Sound, heat and light affect human comfort a lot. They may adversely affect the human comfort positively or negatively. Researchers suggest that, human body is lower or higher than this temperature of 22'C to 25'C. When the temperature of room is lower or higher than this temperature, then the human body feels uncomfortable. This is because, the human body is structured in a way that, it should receive a certain amount of light, failure to which it can cause sunburns and other skin conditions. There are many types of air conditioning systems like window air conditioners, split air conditioners etc., but these AC systems are used in small room or office where cooling load required is low. When the cooling load required is very high like multiplex building, hospital etc., central AC systems are used. In central AC's system the cooled air is directly not distributed to rooms or spaces to be cooled in order to provide comfort condition. When the cooled air cannot be supplied directly from the air conditioning equipment to the spaces to be cooled, then the ducts are installed. The duct systems circulate the cold air from the air conditioning equipment to the proper air distribution point and also carry the return air from the room back to the air conditioning equipment for recirculation and reconditioning. As the duct system for the proper distribution of cold air, costs nearly 20% to 30% of the total cost of the equipment required. Thus, it is necessary to design the air duct system in such a way that the capital cost of the ducts and the cost of running the fans is lower.

A. HVAC (Heating, Ventilation and Air Conditioning)

Heating, Ventilation and air conditioning (HVAC) system is designed to achieve the environmental requirements of the comfort of occupants and a process. These HVAC systems are commonly used in different areas such as industrial, commercial, residential and institutional buildings. The main mission of HVAC system is to satisfy the thermal comfort of occupants by adjusting and changing the outdoor conditions, the outdoor air is to drawn into the buildings and heated or cooled before it is distributed into the occupied spaces, then it is exhausted to the ambient air or reused in the system. The selection of HVAC systems in a given building will depend on the climate, the age of the building, the individual preferences of the owner of the building and a designer of a project, the project budget, the architectural design of the buildings.

B. HVAC system and Equipment Design

There are a number of issues that must be resolved before the proper HVAC system can be designed, whether it is intended for the isolation rooms, surgical suite, the patient rooms, or the administration offices.

Initially, the proper ambient design conditions must be selected. Too often, only the peak cooling design conditions are considered for sizing the capacity requirements of the system. These ambient conditions are listed in the ASHRAE Handbook – Fundamentals as the dry-bulb temperatures with mean coincident wet-bulb temperatures, representing conditions on hot, mostly sunny days. These conditions are used in sizing cooling equipment such as chillers or package equipment for cooling control. In some climates, this might be satisfactory; however, in geographic areas known for higher humidity levels, considering only this cooling condition might not be sufficient. Extreme dew-point temperature conditions may occur on days with moderate dry-bulb temperatures, resulting in high relative humidity's and peak absolute moisture loads from the weather.

For the critical areas such as isolation rooms, intensive care units and operating rooms, critical diagnostic and examination rooms, consider only the centralized HVAC system encompassing "all air systems". All air systems can be classified as single-zone, multi-zone, dual-duct and reheat systems.

The amount of outdoor air and how it is supplied to the occupied spaces would depend upon the type of HVAC system used. When the fan coil units or radiant ceiling panels are used, a central ventilation unit supplies conditioned air to the spaces. With this arrangement, the source of outdoor air being external to the principle cooling and heating equipment, it is possible to ensure the predetermined amount of outdoor air distribution to all the spaces.

2. Literature Survey

S. M. Gheji et.al, in his paper entitled "Basic Classification of HVAC Systems for Selection Guide", concluded that air conditioning means providing out of air within the atmosphere to sustain the temperature, moisture, air excellence, air gesture and ventilation. Temperature is controlled either by cooling or heating the air. Moisture is controlled either by eliminating or addition of the moisture to air. Air eminence is preserved by purification which avoids admission of dust and particulate substance and provides clean air and ventilation is attained by supply of acceptable renewed outdoor air. Occasionally sound stages are too condensed by acoustic linings or sound attenuators [1].

G. R. K. D. Satya Prasad et. al, concluded from his paper entitled "HVAC system Performance and operational strategies in Green buildings" that in most of countries, buildings represent 30- 40 % primary energy use, including fuel input for production. Furthermore, today are almost exclusively dependent on energy supplied from outside, even though they have significant potential for self-support using renewable energy. Buildings have the physical probable to harness weak and occasionally unpredictable renewable energy. The building envelope and the ground create the basic resources for energy autonomous buildings. The significant objective of the project is to yield new, advanced and non-conventional scientific information in nonstop, hygienic and well- 19 organized energy technologies to give a healthier solution for rooftop PV supported buildings and reaching energy efficient buildings. The present-day work will be studied through recreation by using RETSCEEN software and equated with measured values and to decide on at certain general design rules for such systems [2].

Gonzalo Sánchez et. al (2019), Design parameters of HVAC installations in high-performance hospital operating theatres were evaluated according to UNE100713, ASHRAE Standard170, and pre-standard EN 16244-2. All of them establish a range of values for thermo hygrometric conditions. It was found that ASHRAE Standard was the most tolerant in values proposed for room over pressure. Pre-standard maintains the minimum value proposed by UNE standard but does not define a maximum, so in both, the value of this parameter is at designer criteria. ASHRAE Standard recommends a smaller number of filtering stages and less efficiency. The pre-standard adds an additional level of pre-filtering over UNE standard [3].

M. N. Rahman. Y et. al, (2018) The CFD simulation result for Minor Operation Theatre demonstrated differences in real measurement about 19% for air flow velocity and for the 0.04% temperature. The errors that occurred due to the uncontrolled mesh density and wall of minor operation theatre which hard to be quantified for CFD simulation, based on the observation, better location of AC unit must be proposed for better distribution of air flow in Minor Operation Theatre and it reveals that ANSYS Fluent can be utilized for air simulation in Minor Operation Theatre [4].

Essam E. Khalil et. al, (2017), The air is not just a medium but it can be regarded as a guard in the critical health applications. The proper direction of the airflow increases the possibilities of successful pollutant scavenging from healthcare applications. The numerical tool, used here, was found to be so effective to predict the airflow pattern in the healthcare facilities at reasonable costs and acceptable accuracy. Good architectural design allows the HVAC system designers to properly locate the supply outlets and extraction ports in the optimum locations [5].

Muhammad Idrus Alhamid et. al, (2014), The existing condition showed to have ACH value at 8 ACH. In order to comply with air discharge standard of 20 ACH, the fresh air discharge required by the operating room was 1,525ft^3/min (2,585m^3/h). The air flow in the operating room of the existing condition was not very good for sweeping the particles towards RAG because turbulence flow brought back the particles to the operating table. In the redesign condition, the airflow turbulence was minimized by lowering speed and increasing number of RAGs in the room [6].

Dng Lai Chet et. al, (2013), In order to ensure an OR is functioning well, four main design considerations, namely temperature, humidity, ACH and pressure have to be in accordance with available stipulated standards. Nowadays, LAF type of OR design is widely adopted. However, from the on-site survey in numbers of ORs located at Malaysia, most of the ORs designs are not fully comply with the recommended design criteria. Two common problems found are high RH in the OR as well as inappropriate architectural design. During the OR's design stage, the designer should evaluate different design schemes which the design of air inlet, air outlet, air flow rate and OR's layout may vary. After a long time in operation, the layout inside OR will change and hence the conformity on the performance of air distribution, checking of ACH and pressure differential as well as microbiology sampling should be carried out, to ensure the sustainability of OT [7].

Carla Balocco et. al, (2014), Numerical simulations of airflow, thermal fields and contaminant concentration distributions were carried out for a real OT under different ventilation schemes for supplying and recovering indoor air. Our investigation provides better understanding of which ventilation scheme can guarantee the best compromise between IAQ levels and comfort requirements under real use conditions of the OT (i.e. incorrect use, mainly due to the door being open during surgical operations). Results confirm the strong effects of a correct ventilation system design and location of the air supply diffusers on compliance of microclimatic conditions with the suggested standard limits, thermal comfort and IAQ levels guarantee and also on satisfactory contaminant removal results, with noticeable low contamination levels at the wound site [8].

Manish Shankar et. al, (2016), The design and development of air conditioning equipment needs data and results of the research on the thermal comfort and performance parameters of the system to be designed. These parameters are evaluated from the numerical and experimental studies. Thermal comfort and air distribution have close relation with each other. The literature shows that the air distribution is gaining importance in the development of better air conditioning effect and thermal comfort. Apart from the experimental methods, numerical methods are being used by the researchers for being the effective and low cost technology analysis and simulation. The role of air motion and temperature as the main parameters of the air conditioning needs to be optimized for the physical conditions of the conditioned space and the air distribution method [9].

Amer Abduladheem et. al, (2018), Ventilation in operating room needs to be favorable to occupants (patients and healthcare workers). The ventilation should also assist in preventing diseases and treating patients. In this article, a comprehensive review of previous efforts is presented for ventilation air distribution in hospital operating room through fluent. The effects of several Parameters in fluent, thermal boundary conditions, and types of ventilation were investigated. Previous studies have shown that the Ventilation and air conditioning are very important for health care facilities, machine shops, manufacturing and chemical processing facilities, and other commercial occupancies in order to thermal comfort as well as for the removal of contaminants and other pollutions, thus provides a healthy and comfortable environment for people such as patients, workers, and visitors [10].

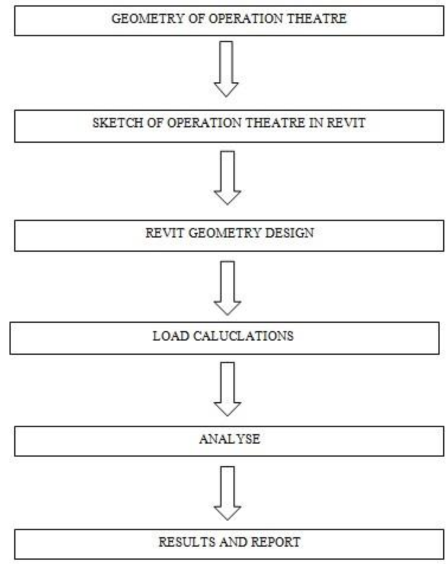

Fig. 1. Methodology

3. Design

Step 1: Geometry of operation theatre
Dimensions:

- Length: 7 m
- Width: 7m
- Height: 3.5m
- Door width: 1.2m

Step 2: Sketch of the operation theatre in Revit software

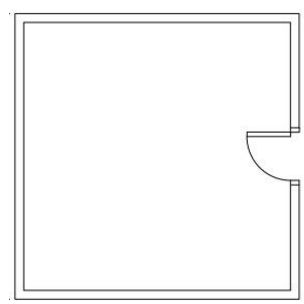

Fig. 2. Operation theatre room layout

Step 3: Design of the operation theatre in Revit software

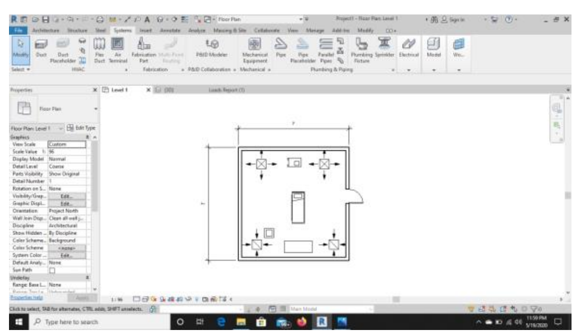

Fig. 3. Two dimensional view of operation theatre

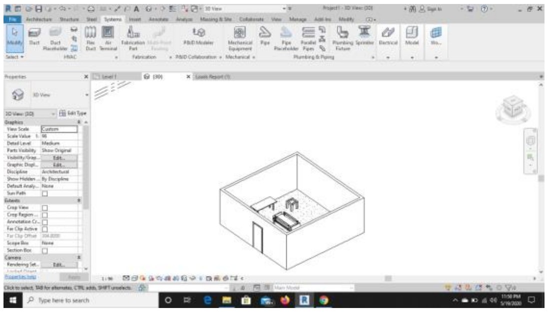

Fig. 4. Isometric view of operation theatre

4. Results and Discussion

Table 1
Project summary

Project Summary

Location and Weather	
Project	Project Name
Address	
Calculation Time	Tuesday, May 19, 2020 11:37 PM
Report Type	Standard
Latitude	42.36°
Longitude	-71.06°
Summer Dry Bulb	94 °F
Summer Wet Bulb	77 °F
Winter Dry Bulb	8 °F
Mean Daily Range	15 °F

Table 2
Building summary

Building Summary

Inputs	
Building Type	Office
Area (SF)	812
Volume (CF)	8,118.44
Calculated Results	
Peak Cooling Total Load (Btu/h)	**14,397.8**
Peak Cooling Month and Hour	July 4:00 PM
Peak Cooling Sensible Load (Btu/h)	11,897.2
Peak Cooling Latent Load (Btu/h)	2,500.6
Maximum Cooling Capacity (Btu/h)	14,397.8
Peak Cooling Airflow (CFM)	499
Peak Heating Load (Btu/h)	**15,638.4**
Peak Heating Airflow (CFM)	377
Checksums	
Cooling Load Density (Btu/(h·ft²))	17.73
Cooling Flow Density (CFM/SF)	0.61
Cooling Flow / Load (CFM/ton)	415.54
Cooling Area / Load (SF/ton)	676.64
Heating Load Density (Btu/(h·ft²))	19.26
Heating Flow Density (CFM/SF)	0.46

Table 3
Zone Summary

Zone Summary - Default

Inputs	
Area (SF)	812
Volume (CF)	8,118.44
Cooling Setpoint	74 °F
Heating Setpoint	70 °F
Supply Air Temperature	54 °F
Number of People	3
Infiltration (CFM)	0
Air Volume Calculation Type	VAV - Single Duct
Relative Humidity	46.00% (Calculated)
Psychrometrics	
Psychrometric Message	None
Cooling Coil Entering Dry-Bulb Temperature	76 °F
Cooling Coil Entering Wet-Bulb Temperature	63 °F
Cooling Coil Leaving Dry-Bulb Temperature	51 °F
Cooling Coil Leaving Wet-Bulb Temperature	51 °F
Mixed Air Dry-Bulb Temperature	76 °F
Calculated Results	
Peak Cooling Load (Btu/h)	**14,397.8**
Peak Cooling Month and Hour	July 4:00 PM
Peak Cooling Sensible Load (Btu/h)	11,897.2
Peak Cooling Latent Load (Btu/h)	2,500.6
Peak Cooling Airflow (CFM)	499
Peak Heating Load (Btu/h)	**15,638.4**
Peak Heating Airflow (CFM)	377
Peak Ventilation Airflow (CFM)	62
Checksums	
Cooling Load Density (Btu/(h·ft²))	17.73
Cooling Flow Density (CFM/SF)	0.61
Cooling Flow / Load (CFM/ton)	415.54
Cooling Area / Load (SF/ton)	676.64
Heating Load Density (Btu/(h·ft²))	19.26
Heating Flow Density (CFM/SF)	0.46
Ventilation Density (CFM/SF)	0.08
Ventilation / Person (CFM)	21

Table 4
Component

Components	Cooling		Heating	
	Loads (Btu/h)	Percentage of Total	Loads (Btu/h)	Percentage of Total
Wall	4,085.8	28.38%	10,495.2	67.11%
Window	0.0	0.00%	0.0	0.00%
Door	428.8	2.98%	853.0	5.45%
Roof	0.0	0.00%	0.0	0.00%
Skylight	0.0	0.00%	0.0	0.00%
Partition	0.0	0.00%	0.0	0.00%
Infiltration	0.0	0.00%	0.0	0.00%
Ventilation	3,255.9	22.61%	4,290.2	27.43%
Lighting	2,294.2	15.93%		
Power	2,982.5	20.72%		
People	1,038.2	7.21%		
Plenum	0.0	0.00%		
Fan Heat	312.4	2.17%		
Reheat	0.0	0.00%		
Total	**14,397.8**	**100%**	**15,638.4**	**100%**

Table 5
Space summary-1

Space Summary - 1 Space
Back to summary of spaces

Inputs	
Area (SF)	812
Volume (CF)	8,118.44
Wall Area (SF)	1,201
Roof Area (SF)	0
Door Area (SF)	21
Partition Area (SF)	0
Window Area (SF)	0
Skylight Area (SF)	0
Lighting Load (VA)	812
Power Load (VA)	1,055
Number of People	3
Sensible Heat Gain / Person (Btu/h)	250.0
Latent Heat Gain / Person (Btu/h)	200.0
Infiltration Airflow (CFM)	0
Space Type	Office (inherited from building type)
Calculated Results	
Peak Cooling Load (Btu/h)	**10,829.5**
Peak Cooling Month and Hour	July 4:00 PM
Peak Cooling Sensible Load (Btu/h)	10,328.0
Peak Cooling Latent Load (Btu/h)	501.6
Peak Cooling Airflow (CFM)	499
Peak Heating Load (Btu/h)	**11,348.2**
Peak Heating Airflow (CFM)	377

Table 6
Default spaces

Default Spaces

Space Name	Area (SF)	Volume (CF)	Peak Cooling Load (Btu/h)	Cooling Airflow (CFM)	Peak Heating Load (Btu/h)	Heating Airflow (CFM)
1 Space	812	8,118.44	10,829.5	499	11,348.2	377

Table 7
All Components

Components	Cooling		Heating	
	Loads (Btu/h)	Percentage of Total	Loads (Btu/h)	Percentage of Total
Wall	4,085.8	37.73%	10,495.2	92.48%
Window	0.0	0.00%	0.0	0.00%
Door	428.8	3.96%	853.0	7.52%
Roof	0.0	0.00%	0.0	0.00%
Skylight	0.0	0.00%	0.0	0.00%
Partition	0.0	0.00%	0.0	0.00%
Infiltration	0.0	0.00%	0.0	0.00%
Lighting	2,294.2	21.19%		
Power	2,982.5	27.54%		
People	1,038.2	9.59%		
Plenum	0.0	0.00%		
Total	**10,829.5**	**100%**	**11,348.2**	**100%**

5. Discussion

Load Calculations: Heat gain calculations are done in accordance with the procedure outlined in the latest ASHRAE Handbook of Fundamentals with a computer program (REVIT SOFTWARE).

The summary of the operating room area is of 812 Sq. ft & volume is of 8,118.44 Cb. ft.

Components considered inside the room are wall, window, door, roof, skylight, partition, infiltration, ventilation, lighting, power, people, plenum, fan heat, reheat.

The total peak cooling load (Btu/h)=10,829.5, peak heating load (Btu/h)=11,348.2, cooling airflow (CFM)=499, heating air flow (CFM)=377.

Inputs given is area (SF), volume (CF), cooling set point, heating set point, supply air temperature, number of people, infiltration (CFM), Air volume calculation type and relative humidity and psychrometrics.

Calculated results of Peak cooling total load (Btu/h), Peak cooling month and hour, peak cooling sensible load (Btu/h), peak cooling latent load (Btu/h), maximum cooling capacity (Btu/h), peak cooling air flow (CFM), Peak heating load (Btu/h), peak heating airflow(CFM) and Checksums of cooling load density (Btu/(h-ft^2)), cooling flow density (CFM/SF), Cooling flow /load (CFM/ton), cooling area/ load (SF/ton), heating load density (Btu/(h-ft^2)), heating flow density (CFM/SF), Ventilation density (CFM/SF), Ventilation/person (CFM) are obtained using revit load calculations analysis.

6. Conclusion

For a good air conditioning system of operating rooms the average relative humidity is 30-60% and the temperature of operating rooms is 18-24℃ as per the ASHRAE standards of HVAC and we have calculated 46% of humidity and mixed DBT of 24℃.

References

[1] S. M. Gheji, “Basic classification on HVAC systems for selection guide,” April 2016.
[2] G. R. K. D. Satya Prasad, “HVAC system performance and operational strategies in green building -A Simulation approach,” April 2016.
[3] Muhammad Idrus Alhamid, "Design and simulation of an air conditioning project in a hospital based on computational fluid dynamics", Archives of civil engineering, Volume 13, Issue 2, 2017.

[4] Dng, Lai Chet (2012) Case study of air distribution of the hospital operating room in Malaysia/Dng Lai Chet. Master's thesis, University of Malaya.

[5] Carla Balocco, "CFD analysis on thermal comfort and indoor air quality affected by partitions in air-conditioned building", Applied Mechanics and Materials, Vol. 836, pp. 121- 126, 2016.

[6] Manish Shankar, "Computational analysis of impact of the air conditioner location on temperature and velocity distribution in an office room," International Research Journal of Engineering and Technology (IRJET), Volume 3, Issue 9, Sept. 2016.

[7] Amer Abduladheem K. S. M. Sahari, H. Hasini, Wisam Ahmed, Raed Abed Mahdi, "Ventilation Air Distribution in Hospital Operating Room-Review," International Journal of Science and Research (IJSR), Volume 2 Issue 11, November 2013.