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Air Conditioning Saifee Hospital & Research Centre

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S. V. Sandeep Nair, is an electrical and electronics engineer from Tamil Nadu University (1999) with more than 5 years experience in engineering projects and services. He is a member of ISHRAE Mumbai chapter.

Saifee Hospital is the newest addition to Mumbai's list of hospitals. Tell us about its size and any special building design features.

The community of Bohra Muslims is known for their philanthropy and social responsibilities. The new addition to Mumbai's prime hospitals, coming up in central Mumbai opposite Charni Road station of Western Railways suburban network, bears testimony to their social obligations. The Saifee Hospital which has been in existence for the last 55 years was ordered to be reconstructed by His Holiness Dr Syedna Mohammed Burhanuddin and the reconstruction work was started in 1999.

The hospital is planned to be a multispeciality hospital providing advanced medical and diagnostic facilities. The hospital will have 255 beds, 7 operating theatres, 37 ICU beds and a separate Sanatorium Block for convalescents.

The hospital building has 14 levels including 3 levels of basements designed by architects J P Parekh & Son. The building stands next to a busy thoroughfare and is adjacent to the suburban railway tracks through which a rake passes every 60 seconds during peak hours. The building has distinctive architectural features and is closely integrated with the neighbourhood heritage buildings.

The hospital is located on a very busy arterial road with lots of cars and buses throughout the day. Did this affect the building design and HVAC system design in any way?

Located on a busy road with hardly any large open spaces nearby, parking of vehicles was a problem the hospital had to face. This was solved by going for three levels of basement. Saifee Hospital is one of the first buildings in Mumbai where three levels of basements has been permitted by the Fire Authorities and the Municipal Corporation.

To improve life safety in the event of a fire, special smoke exhaust arrangements are made for the lower basements with smoke exhaust fans which provide 30 air changes an hour.

What was the scope of your assignment on this project?

Eskayem Consultants are providing engineering consultancy services covering all the electromechanical utilities such as HVAC, Electrical, Plumbing, Fire Safety and Fire Fighting Systems, Elevators, Steam Generation and Distribution, Hot Water systems, Building Management systems etc. In addition, Eskayem are also providing Consultancy

Services in specialized areas such as Food Service, Laundry, CSSD Systems, Medical Gases and Nurse Call System, Data and Voice systems, Hospital information & management systems, Bi-directional Audio and Video conferencing systems. Eskayem are also providing complete project management support for the electromechanical systems.

Tell us about the HVAC system you designed – its capacity, type of chillers, their power consumption, air and water circulation systems, temperature and humidity controls and the BMS.

Medical evidence has shown that proper airconditioning is necessary for maintaining a tenable hospital environment. The relatively high cost of airconditioning demands an appropriate design meeting international standards. The air-conditioning systems of the hospital are designed on the basis of the above concept. There are three 260 TR air-cooled screw chillers for the entire building except the seven operation theatres. Out of the three, one is standby. The systems have primary and secondary pumps. Primary pumps are of constant speed and secondary pumps are of variable speed. There are three 33 TR air-cooled scroll chillers serving seven operation theatres exclusively. Dedicated chillers are provided in consideration that no area of the hospital requires more careful control of temperature and humidity than does the surgical suite. The surgical staff can adjust the temperature inside the theatres over a range of 20 to 24°C and the relative humidity will be maintained at 50 - 60%. The entire air-conditioning system is controlled and monitored by an extensive Building Management System.

How many OTs does the hospital have? Are they all on the same floor? Is there a service floor above to house the air handling and air distribution systems?

There are in all seven operating theatres, all located on the eighth floor. All OTs have stainless steel ceiling and stainless steel cladding on the walls to maintain clean and self-cleaning surfaces. Two of the OTs' are with laminar flow air distribution while the remaining are with conventional turbulent distribution. All air handling equipment is located on the same floor owing to space restrictions.

What is the total air changes per hour and minimum outdoor air changes per hour in the OTs?

Air changes are largely for the control of airborne organisms by dilution. Way back in the 1970's 15 air changes of 100% outside air was the norm and mandate. (Srichitra Medical Centre, Trivandrum & Hinduja Hospital, Mumbai). In 1974, studies were made in

two running neurosurgical operating theaters at St Mary's Hospital, Rochester, MN under a research grant from U.S. Dept. of Health. The theatres had turbulent air distribution systems and established that the variable airborne particulates in the theatre were at least 30% more in the case of 15 100% outside air changes as compared to 25 recirculated changes with 30% being outside air. It was also seen that 25-30 air changes produced optimum results. **Figure 1** shows the trend lines. ASHRAE revised the guidelines thereafter to 5 outside air changes out of 25 total air changes. In an operating theatre, the greatest amount of contamination is generated by the operating team, as result of their activities during surgery. Broadly the contaminants and partial sizes are :

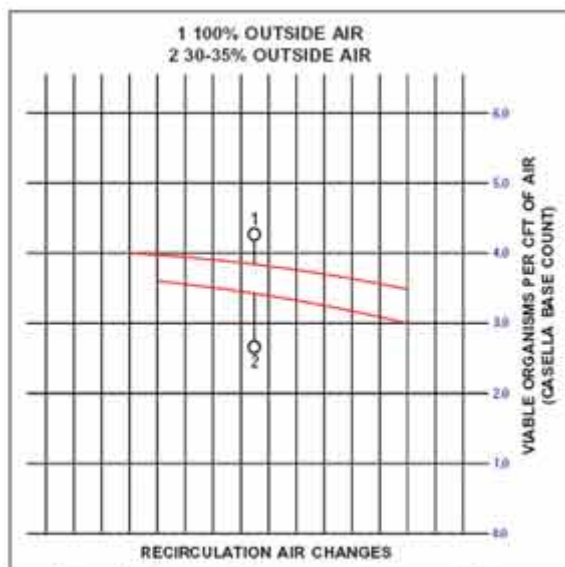


Figure 1 : Operating Room contamination trend lines.

Contaminants

- Skin Flora
- Staphylococcus Aurous
- Streptococcus
- Pseudomonas

Particle Distribution & size

- 33% more than 20 micron
- 50% more than 3-15 micron
- 17% 3 micron or less

Spread of contamination and its control and prevention of surgical wound infection is governed by several factors which are briefly narrated below :

Classes of microorganisms Protozoa, Fungi, Bacteria, Different

	viruses both Pathogenic and Non-pathogenic.														
Contamination	Presence of infection agents or pathogens on the surface of clothes, furniture, floor etc.														
Infection	Pathogens enter the human host, multiply and disease.														
Transmission Direct	Direct contact via sneezing, coughing, spitting, scratching.														
Indirect Vehicle borne	Soiled clothes, dressing, instruments, food, water, any biological or intermediate product.														
Vector borne	Agents like humans, insects, flies, vermin.														
Air borne	Dust particles, droplet nuclei.														
Control Measures (Patient Himself)	<table border="1"> <thead> <tr> <th></th> <th>Category</th> </tr> </thead> <tbody> <tr> <td>• Pre-op Antibiotics</td> <td>1</td> </tr> <tr> <td>• Hair removal and shaving</td> <td>2</td> </tr> <tr> <td>• Sterile drapery</td> <td>2</td> </tr> <tr> <td>• Preparation</td> <td>3</td> </tr> <tr> <td>• Bathing with antimicrobial soaps</td> <td>3</td> </tr> </tbody> </table>		Category	• Pre-op Antibiotics	1	• Hair removal and shaving	2	• Sterile drapery	2	• Preparation	3	• Bathing with antimicrobial soaps	3		
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	procedures	
	• Disinfection	2
Technics of Operation	• Minimum time of exposure in the OT	1
	• Minimum time of exposure in the OT	1
Monitoring & surveillance	• Record keeping of infections	2
	• Investigate infection growth	2
Cat 1 - Supported by clinical studies and considered effective by many expert reviewers		
Cat 2 Adequately studied but needs a logical theoretical rationale supporting probable effectiveness.		
Cat 3 - Proposed by some investigators but short of supporting data.		

Can these be reduced when the OT is unoccupied to save energy?

Thus since the number of air changes is one of the positive measures in controlling airborne contamination, one should ensure that the desired air changes do take place during and after an operating procedure. **Figure 2** shows a flow diagram where a supply fan and a return fan ensure positive displacement of air at the desired rate for outside and recirculated air, after the system flow balancing has been achieved. It is essential to sense the pressure drop across the filters and modulate the balancing damper in the supply air to compensate for the filter choke up. This is the only way that the desired air changes are maintained.

It is indeed possible to reduce the air changes when the OT is in unoccupied mode. Since an air-distribution system is non-linear in character, it becomes impractical to re-balance the system for lower air changes, risking a pressure imbalance and consequent distortion of the sterile conditions. Secondly, the savings are not worth the risks involved. A standard operating theatre is about 100-120 m³ in size and the total air circulation involved is 2500-3000 m³/h. Savings in energy per theatre will be in the region of 1.0 to 1.5 kW per hour with lower air change rate.

On the other hand we propose to switch off the refrigeration but maintain the air system intact. This maintains sterile conditions in the operating theatres and saves refrigeration energy, which will be about 6 to 7 kW per hour per theatre. Many hospitals

antibiotics. If airborne infection is a major cause of deep joint infections and if laminar clean airflow rooms will remove these contaminants, we should expect an abrupt defined reduction in infection rate when such rooms are used. This is not the case. In most of the studies, the improvement is slow and incremental. In reviewing recent references, it seems clear that standard measures, appropriate use of perioperative antibiotics and tight surgical team discipline should reduce clean wound infection rates to 1 to 1.5 percent. Laminar clean airflow cannot be expected to compensate for poor operating room practices¹.

"This article does not debate the need of 10 cfu in operating theatres, despite the fact that Norwegian research shows no significant correlation between systems for ultra clean air in operation theatres and reduction of postoperation infections².

We have two laminar airflow operating theatres and five conventional turbulent airflow units.

Today the generally accepted practice is to use Laminar Airflow Ultra Clean Systems (10 cfu) for organ transplant, joint replacement, bone marrow transplant and in areas of required immune deficiency. In all general purpose areas 2-bed filters with turbulent flow (100 cfu) are employed.

What is the design inside temperature in the OTs and is there independent control of temperature in each OT?

Inside room temperature is by and large, for comfort of the operating team. Comfort being a subjective matter, the design provides for a room temperature between 20 and 24°C, settable by the Surgeon.

Is the air movement relationship to adjacent areas monitored and controlled in any way?

ASHRAE guideline suggest "positive air pressure within the operating rooms relative to the pressure of any adjoining rooms by supplying 15% excess air". The pressure maintained by virtue of the excess air depends on the leakage paths in the room and door openings. The CORE (Committee on Operating Room Environment) of the American College of Surgeons suggests a pressure differential of 1.2 pascals. Since the major contamination in an operating theatre is caused by the operating team and the containment of contamination is through dilution and by establishing desired air changes, 15% excess air is a more appropriate measure to ensure limited positive pressure. Hence, sensing pressure differential between the OT and adjoining has little significance.

How is the Intensive Care area handled in terms of air distribution, fresh air quantity, air filtration and temperature control?

An Intensive Care unit or Critical Care unit is yet another nursing unit where the patient is not likely to be ambulatory and requires intense nursing care and constant monitoring. These units are fitted with monitors which constantly monitor various body parameters like ECG, Heart rate, Alarm limits & QRS flash. In so far as air-conditioning is concerned, the requirements are the same as in a normal nursing unit.

1. Variable room temperature
2. 2 outside air changes
3. 2 filter beds of 25% and 90% efficiency

In a normal nursing unit however, unitary equipment like a fan coil unit with 68% efficient filters can be used. Therefore, a central air handling unit with ceiling mounted Variable Air Volume units for each ICU are installed. Since two outside air changes are mandatory, the systems are designed to ensure two minimum air changes at all times. Each ICU has individual temperature control.

How many patient rooms are there and what type of air distribution and temperature control do they have? Please elaborate.

There are 128 patient rooms. Lately ASHRAE has permitted use of unitary equipment like fan coil units with a single filter bed of at least 68% efficiency. Each patient room has a special fan coil unit with individual room thermostat. Outside air is supplied at 100 m³/h for a room of above 50m³ to meet the guidelines.

Would you say the FA quantity, air filtration and air circulation in the above areas complies with the 2001 Edition for Guidelines for Design & Construction of Hospitals & Health Care Facilities published by the American Institute of Architects Academy of Architecture for Health and / or the latest ASHRAE Standards. I'm asking this because there are no pertinent standards for hospital design in India and it is better to go by some standards rather than no standards?

There are no valid Indian guidelines in the matter of air-conditioning of Hospitals and Clinics. So much so, there are many hospitals, small and big, where unitary equipment is used indiscriminately. The idea is to provide comfortable room temperature without any regard to control of airborne organisms and infection control. Filters used in all the commercial unitary equipment are just not fit for use in a hospital.

Under these circumstances, one has to be guided only by American Standards & Guidelines. India is speedily being integrated with American and other Western healthcare facilities and accreditation is not far off. For accreditation with any major American health facility, it is incumbent that the Indian entity is in line with the American Standards.

What is the material of construction of all ductwork?

All duct work is made of galvanized sheet steel which is tried and tested, except in the MRI where non-magnetic aluminum sheets are used. Any synthetic material is not only more expensive but brings in fire-related issues. However, we would have preferred better galvanizing say 370 mg/m² than 180 mg/m² easily and commercially available now.

Can you describe the chilled water distribution system and any special feature it has with the help of a sketch.

The chilled water system for the operating theatres is a simple constant flow primary only system with 3-way control valves at the terminal (AHU) end. The other system covering the rest of the hospital, is a constant flow primary + variable flow secondary system to avail the daily load variations. **Figures 3a & 3b** show the schematic chilled water system. Secondary flows are regulated through a return water temperature sensor limited by the minimum pressure at the farthest terminal.

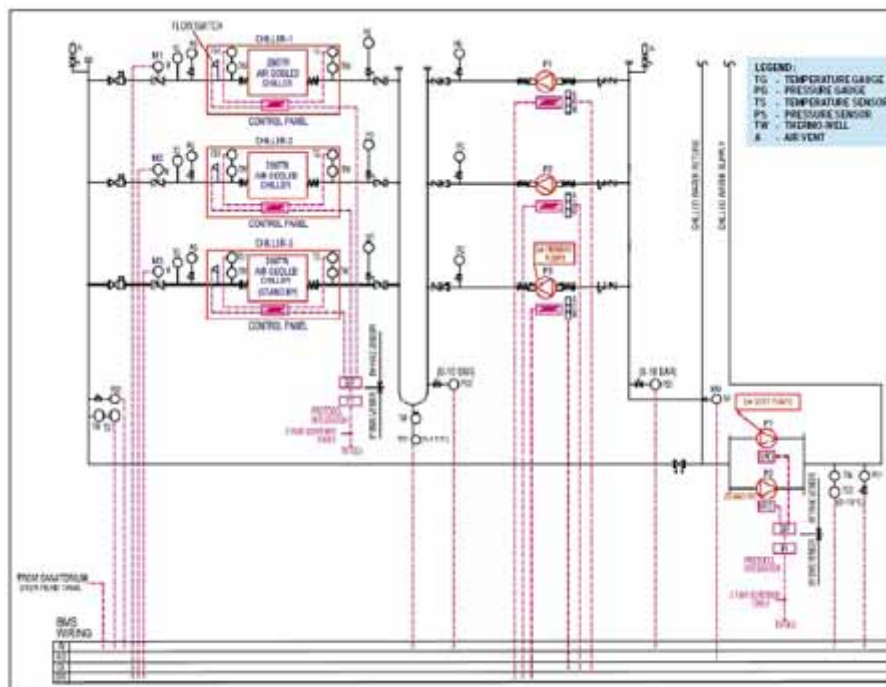


Figure 3a : Main chilled water flow diagram.

Is there a central ventilation system for the toilets and how may air changes does it provide?

There is no central ventilation system to cover all the toilets. Each toilet shaft has a centrifugal roof extractor. Exhaust systems are designed on the basis of 25 l/s per WC or

urinal according to ASHRAE 62 Standards.

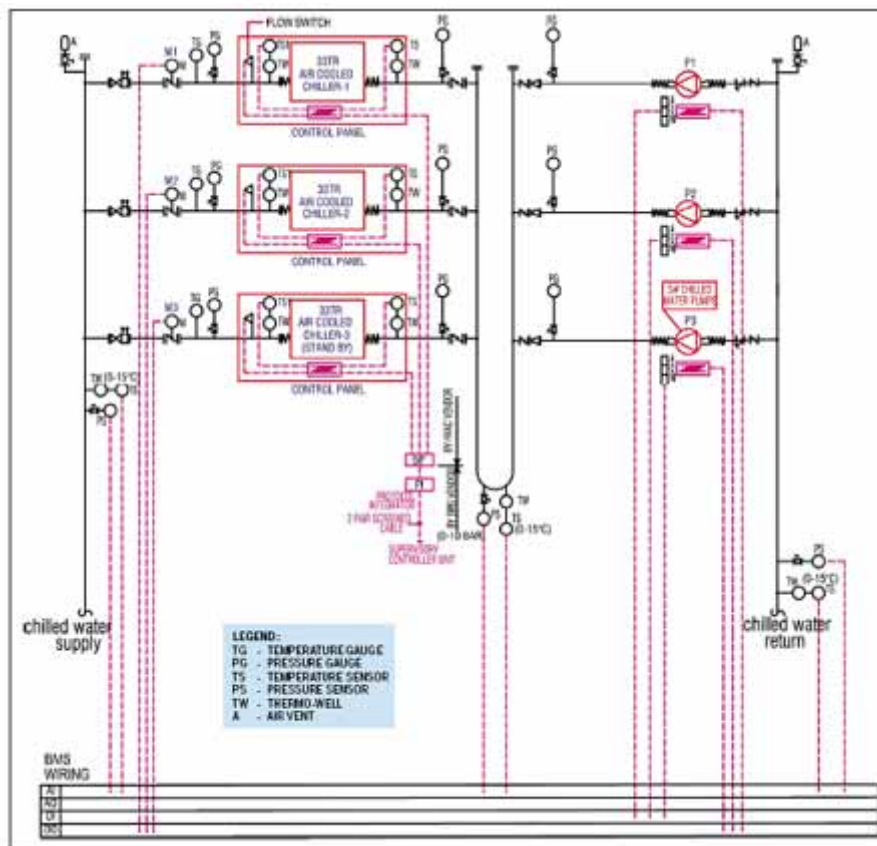


Figure 3b : OT chilled water flow diagram.

What other areas of the hospital are ventilated and with how many air changes?

All mechanical areas are ventilated on the basis of heat dissipation. The areas are Transformer & Switch rooms, Pump & Filtration rooms, Laundry and CSSD. We have not taken air changes as a design basis.

Please give some features of the Building Management System.

The Building Management System is meant to monitor and control the following building systems :

1. HVAC systems
2. Water Management Systems
3. Electrical Systems
4. D G Set
5. Ventilation and Exhaust Systems
6. Boiler Management Systems

A) HVAC Systems

1. Chilled water management system – 1. There are three 260 TR (2 working 1 standby) chillers provided for the entire building except the OTs. The system has primary and secondary pumps. Primary pumps are of constant speed and secondary pumps are of variable speed. Chillers and pumps shall be sequenced to ensure equal run hours in a week

Operation of primary circuit. BMS shall monitor the chilled water flow and switch on the pumps and chillers as required. If any of the primary pumps fails to start, the alarm shall be generated and standby pump shall be started. The BMS shall monitor the supply and return temperature of the chilled water. Chiller loading and unloading to be done by the respective control panels on the basis of constant leaving temperature of 8-9°C. The BMS shall integrate with chiller microprocessor panel and provide the data as defined in the monitor and control logic.

The BMS shall maintain secondary chilled water temperature by modulating the 2-way valve. Secondary flows are controlled by the VFD through a sensor in the return water but subject to maintaining minimum pressure at the farthest point. The BMS will interface with VFD and monitors the various parameters as defined in the monitor and control logic.

2. Chilled water management system – 2 (OTs). There are 3 nos. 33 TR chillers (2 working 1 standby) provided for the seven operation theatres in the hospital building. The system has three chilled water pumps out of which two are running and one is standby.

The BMS shall monitor the chilled water flow and switch on the pumps and chillers as required. If any of the pumps fails to start, alarm shall be generated and standby pump shall be started. The BMS shall monitor the supply and return temperature of the chilled water and while chiller loading and unloading is to be done by the respective control panel maintaining common leaving chilled water temperature of 5-6°C. The BMS shall integrate with chiller microprocessor panel and provide all the data as defined.

3. AHU Management System – OT Start & Stop. All AHUs shall be started and stopped from the control room through BMS. Once the start signal is activated BMS shall start the return air fan (RAF) 60 seconds after supply air fan starts in order to maintain positive pressure inside the OT. Once the stop signal has been activated BMS shall shut off the chilled water supply to the coil and stop supply air fan and return air fan after room temperature reaches 27°C in order to prevent condensation inside the OTs.

In the septic OT BMS shall start the supply air fan (SAF) 60 seconds after return air fan starts, in order to maintain negative pressure. When stopped, the same procedure as above follows:

Operation. Since the number of air changes in an OT is of prime importance, the BMS shall maintain constant air flow into the OT by modulating the supply air damper to compensate for the pressure drop in the filters. BMS shall maintain the temperature and humidity inside the OT through temperature and humidity sensors. Provision also exists for setting of room temperature and humidity by the operating surgeon. During fire condition BMS shall shut off the AHU if fire is inside the OT and BMS shall give a discrete signal to the OT staff if fire is in other areas.

4. AHU Management System – ICU Start & Stop. All the AHUs shall be started and stopped from the control room through BMS.

Operation. Return air temperature sensor shall regulate the fan speed through VFD, but shall maintain the static pressure of 200 Pa air pressure in the remotest point of the duct. Each IC Unit will have a VAV terminal with temperature control. The AHU cooling coil will run wild. During fire mode in the AHU floor, BMS shall shut off the AHU and close SAFD and RAFD.

5. AHU Management System – Other Areas

Starting & Stopping. All the AHUs shall be started and stopped from the control room through BMS

Operation. Return air temperature sensor shall regulate the two way control valve to maintain constant temperature inside the space. The differential pressure switch across the filter shall generate an alarm when the filter is clogged.

B) Water Management System

1. BMS shall monitor the water levels in Raw, Fire and Domestic water tanks.
2. BMS shall generate a signal on underground tank high and low level indication.
3. BMS shall maintain the pH value (6-8) of the treated water through pH value analyser. BMS shall operate the acid and alkali dosing pumps depending upon the pH value of the treated water.
4. BMS shall record the water consumption daily and shall integrate for the week and month.

Sump Pumps. The BMS shall monitor the high / low switches to start and stop the sump pumps. Each sump has been provided with 2 pumps, one working and one stand by. The BMS shall alternate the two pumps after every stop. If low level cut off is not reached

within 10 minutes of operation of first pump, stand by shall be started; if still the low level cut off is not achieved in 5 minutes, BMS shall set off an alarm.

C) Electrical Management System BMS shall monitor the power consumption of electrical panels defined below using digital energy meters:

1. Consumer HT panel - total energy - hourly, daily, monthly
2. Main MV panel - total energy - hourly, daily, monthly
3. AC and other feeders - total energy - hourly, daily, monthly
4. Monitoring of earth leakage current

D) DG Set

The BMS shall monitor power consumption from the DG through a digital energy meter. BMS shall also monitor the low level in the day tank where diesel is stored. In case of low level the alarm shall be reported to BMS room. BMS shall monitor start and stop of the DG Set.

E) Ventilation and Exhaust Systems

All ventilation and exhaust fans shall be started and stopped as per the schedule and shall be monitored for run and trip status. When the unit is turned on the same shall be indicated on the computer screen. BMS shall generate an alarm if the equipment trips. In case of fire, the fire alarm system shall activate through BMS to start all exhaust fans automatically for smoke evacuation.

F) Boiler Management System

1. BMS shall monitor the steam pressure level in:
 - a) Steam header
 - b) Laundry header
 - c) CSSD header
 - d) Calorifier inlet
2. BMS shall maintain the hot water output temperature at 55°C by modulating the steam control valves. Cold feed to the hot water / steam calorifier will be from the solar panels at the terrace where the water temperature is raised to 45°C.
3. BMS shall record the steam consumption daily and will integrate for the week and month.

References

1. *Laminar Airflow Systems : A 1991 update* – American College of Surgeons' Committee on Operating Room Environment.
2. *Health Estate Journal* May 2003.