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How Not to Design, Install & Maintain AC Systems for Operating Theatres

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On occasions we have been called upon to inspect exisitng air conditioning systems for operating theatres in hospitals, comment on their condition and suggest changes or improvements. Generally, this occurs when the hosptial management has received several complaints from the surgical team and at times from patients who have suffered from infection after the surgery has been satisfactorily performed. What we have seen in two such hospitals is described in this article for the benefit of readers, some of whom may be involved in designing AC systems for new hospital projects. For the sake of confidentiality, we have avoided mentioning names of such hospitals.

No area of the hospital requires more careful control of the temperature, relative humidity and the asceptic condition of the environment than does the surgical suite. The systems serving the operating theatres require careful design to reduce to a minimum the concentration of airborne organisms. Materials selection, maintenance access, filtration and humidity control are important design parameters that must receive careful consideration during planning, design and installation stages.

All the deficiencies we have noticed could have been avoided if an experienced engineer, knowledgeable about the hospital environment, could have been involved in the planning and design stages along with a concerned management and a cooperative, understanding architect.

Hospital XYZ

This was a 200 bed institution in a large city. There were three OTs on the second floor, two for cardiac cases and one for orthopaedic. The original air conditioning system installed in 1983, was designed for maintaining indoor design conditions of 24.5°C ±1017°C and RH not exceeding 60% and consisted of standard comfort packaged air conditoners. In 1993, due to an increase in internal heat loads and the need felt by the surgical team for a lower inside temperature of 20°C in the cardiac theatres, the old units consisting of 3 x 7½ ton were replaced by 3 x 10 ton packaged air conditioners. We were asked to study and comment on the entire AC system for all three OTs but the observations we give below refer mainly to the two cardiac theatres.

System Description

Three 10 ton water-cooled, standard comfort packaged air conditioners formed a common plant feeding the two cardiac theatres with one unit acting as a standby and two units in operation. The supply air connections from the three units were connected to a common duct made of galvanized steel sheet. A manual damper at the fan outlet was used to isolate the non-working unit. A booster fan helped to overcome the pressure drop across the medium efficiency Microvee filters and the HEPA filters installed in series inside metal plenums. The plant room was located on the floor above the OTs and the supply air duct came down through a floor slab cut-out, above the false ceiling of the two OTs to laminar flow plenums, one per OT.

Return air was picked up from a low level in each OT, connected to a common duct and led back to the plant room, which acted as a common return air plenum.

Our Observations

For the purpose of this article and for the benefit of the reader, we have combined our observations with what we learned a little later from the engineering department, who naturally, knew a lot more about the day to-day operating problems in the course of their interaction with members of the surgical team.

1. The surgeons were unhappy with the temperature being maintained in the OTs by the packaged ACs either due to inadequate capacity or inadequate performance.
2. There was frequent water leakage from the AC plant room to the OT corridor, a sterile area, through a floor slab opening used for bringing the supply air duct down from the plant room to the OTs.
3. The AC plant room was extremely crowded and cramped, leaving little or no space for maintenance and repairs of the air conditioners and cleaning or replacement of the air filters. To make matters worse, a plywood partition separated the AC plant room from the EDP room and the entrance to the AC plant room was through the EDP room resulting in direct mixing of the recirculated air from the EDP room with the OT air. The floor slab of the AC plant room was not waterproofed, and whenever the condensers in the packaged ACs were descaled, there was water all over the floor of the plant room which leaked through the slab to the false ceilings over the OTs. Drain lines from the packaged ACs did not have an adequate slope because of the low headroom and as a result, they often got choked causing more leakages of water through the floor slab to the OTs below.
4. There were black fungus stains on the walls and ceiling of the AC plant room which appeared damp. The duct insulation and the filters had similar stains. Some of the filters also had a green lint-like growth.
5. The walls, door and the floor of the OTs were also damp, possibly due to infiltration of humid outside air. The inspection was carried out in June, a monsoon month with high ambient relative humidity.
6. Inadequate sealing of walls and floors of the OTs would have made it impossible to maintain any semblance of a positive pressure inside the OTs, leading to contamination from areas outside the OTs.
7. At places the fibreglass duct insulation was loose, exposed fibreglass was visible and the fibres could easily mix with the air stream.
8. The return air grilles in the OTs were rusted and so also the duct hangers.

Obviously, our recommendation was to scrap the entire system and design and install a totally new system keeping in mind the energy aspects, since the system operates 24 hours a day, and also the ease of maintenance and expandibility.

When the original duct distribution system was dismantled, all the accumulated dust, dirt and the lint inside the ducts was collected and weighed 16 kgs. The lint was green in colour and obviously came from the green gowns worn by members of the surgical team in the OTs. This explains why the Microvee and HEPA filters would get choked every month or oftener, necessitating expensive replacement and frequent shutdowns of the OTs.

The fungus stains on the walls of the OTs, the AC plant room, the loose fibreglass insulation and the rust on the grilles and hangers, all of which were in the path of the return air most likely contributed to all the cases of post-operative infection suffered by patients, who were successfully treated by the surgeons in the first place. We read newspaper reports and heard from friends about several such cases of infection.

The ducting material used should have been stainless steel or aluminum, especially after the HEPA filters, but better throughout the system, because of the corrosive atmosphere where the hospital was located. The same reasoning should apply in the case of steel duct hangers and air outlets, all of which should have been of stainless steel or aluminum. Selecting the right materials is therefore very important.

We have reservations about the use of standard comfort packaged ACs with three row cooling coils in OT applications with 20 percent fresh air. During the monsoon months when outdoor air is close to 100% RH, the humidity inside the OTs must have been very high causing condensation on cooler surfaces such as water pipes or other cold surfaces. This in turn would result in increased microbial and fungal growth contamination on walls, ceilings and other damp surfaces.

The location, size and floor finish of an AHU room which is akin to the AC plant room of Hospital XYZ must be carefully worked out, in close association with the architect. If this room happens to be on an upper floor and a floor cutout is necessary, for passage of pipes or ducts, make sure that a curb is cast around the opening, at least 100 mm in height, to prevent water spillage on the floor from cascading down through the opening. A floor drain is essential in every AHU room.

Maintaining a positive pressure in the OTs and ensuring that air movement is from clean to less clean areas is essential. The fresh air supply must always exceed the exhaust air and careful air balancing of the AC system is important.

One more drawback of the system installed in Hospital XYZ was the absence of any monitoring system that would enable the maintenance staff to check important parameters such as the actual temperature and humidity being maintained in each OT, the pressure drop across the air filters, the pressure difference between OTs and the adjoining area. A mini BAS, 'must' for any installation, is as important as a hospital OT because without this, the maintenance staff will be totally at sea and ignorant about the system performance.

Hospital ABC

This was a new 50 bed community hospital in a small town with a large power plant, meant for employees of the plant and the local town residents. The hospital was under construction and the air conditioning systems for the OTs had been recently installed. The complaint we received from the hospital management was that there was no air being discharged from the units.

System Description

On inspection we found that there were three OTs, each one being connected to an indpendent 5 ton standard, comfort type, ducted split AC with the evaporator unit of the horizontal ceiling suspended type, mounted above the false ceiling in the corridor outside the OT. Two sets of air filters, a Microvee on the inlet and a HEPA in the discharge air ducting were installed at each evaporator unit. A typical air distribution system comprised four square ceiling diffusers uniformly spaced in the OT false ceiling. Return air from ceiling mounted grilles led the air back through a ceiling plenum to the evaporator unit.

Our Observations

There was no return air sheet metal ducting connecting the return grilles to the evaporator unit nor was there any plenum constructed above the false ceiling, that would isolate and connect the OT to its evaporator unit and thus the evaporator could draw air from anywhere above the false ceiling in the corridor.

The external static pressure of the evaporator blower was inadequate to overcome the pressure drop across the two sets of filters as well as the duct distributon system, thus starving the OT of supply air.Even if it had been adequate the evaporator would have had to handle 100 per cent air from the space above the corridor, which it was certainly not capable of performing with its three row cooling coil.

Clearly, this was a case of total misapplication and wrong design by a person not experienced enough to know the basics of duct design let alone what hospital OT environments require. The hospital manangement realized that they had been short-changed, the complete plant as installed was scrapped and a new system designed and installed. The only saving grace was that the problem had been noticed and rectified before the hospital started functioning.

Maintenance

Maintenance of hospital air conditioning systems is clearly outside the scope of the planning or design engineer. It has been our experience that while chief engineers and their assistants may be quite knowledgeable about operating and maintaining chillers, pumps, AHUs, FCUs and cooling towers, they require to be trained to understand the intricacies of air distribution and air movement in OTs, ICCUs and sterile areas; sources of air contamination, and guarding against the formation of mildew, fungus, molds and spores; when to change air filters by measuring pressure drops across them and how to take a proactive approach to avoiding infection problems before they arise.

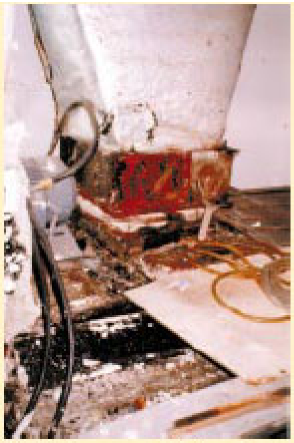
Editor's Note

At the same Hospital XYZ, on a typical floor for patient rooms, the lift lobby has highly polished granite on the wall and a shining floor, giving one the impression of an immaculately clean building. All the way along the wide corridor leading to the rooms, bright ceiling lights are reflected off the shining floor.

But, just off the lobby, behind closed doors, is a room housing the Treated Fresh Air AHU, shown in the photos alongside. Notice the rust on the fan outlet damper, the fungus on the flexible canvass connection, the shabby unfinished external insulation, with black bitumen on the AHU and the aluminum vapor seal over the duct insulation, falling apart. Closer examination revealed that the AHU was made of black mild steel sheet. It was obvious that it had never been painted or renovated since the original installation. Out of sight, out of mind !

The treated fresh air from the unit was fed into the corridor and all the patient rooms on the floor. Just imagine the conditon of the air passing across the rusty insides of the AHU, fungus laden canvass cloth and possibly a dirty cooling coil and drain pan.

Wrong material specifications, poor installation and bad maintenance combined with a management that was oblivious of the state of affairs behind the doors of the AHU room. This is a great pictorial example of "how not to design, install and maintain AC systems for health care facilities."



A view of the fan outlet damper, badly rusted and the flexible canvass connection with fungus growth.

An end view of the AHU with external insulation

Aluminum vapor barrier separated from the duct insulation, and falling apart