Design of Health Care Facility for Tropical Climate

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Abstract

Health Care's HVAC system is rather complicated than other type of buildings because it needs to control temperature and humidity not just for thermal comfort but also for the outcome of patient treatment, preventing germ growth, control air quality and circulation in the building. Design must be appropriate and meet standard requirement. HVAC of modern Health Care Facility approach has been significantly changed from past decade. Modern Health Care Facility is not only a place for sick patient but a place for health development and a social place. Therefore, it is important that both passive and active design has to be perfectly integrated.

Conceptual design must be planned to achieve 3 main goals, **Area Isolation** for contamination control, **Operation** to achieve excellent patient treatment and **Maintenance** as green and clean facility. Equipment room should be easily accessible for maintenance and clean, ready to provide 24 hours service for patient.

Keywords: Design approach for modern Health Care Facility for tropical climate

1. Introduction

Modern Health Care Facility has been aimed at providing excellent patient treatment services as well as preventive program and other services such as alternative medical treatment, nutrition medicine, etc. New Facility is also providing recreation services such as spa, restaurants, retails, etc. so that the heath care facility is not meant only for sick people but also as a social place. The varieties add more complexity to HVAC system in controlling air quality to meet standard requirement.

In order to meet Health Care standard requirements, the design of modern Health Care Facility has to include aspect of global warming and climate change as well. Therefore, this article will address the design on how to design modern Health Care Facility, comprising both passive and active design.

In tropical climate, where ambient temperature and humidity are prolonged most of the time, humidity control technology is crucial.

2. Area Isolation for contamination control

In fact, a hospital is not a social place. It is not a hotel, recreation place, conference, meeting, dining, etc. However, modern Health Care Facility has extended a normal hospital services to include health development program and quality of life for patient and visitors. Control of contamination in public is of concern. Health Care Facility has increased density with variety of services. Without proper area isolation, infection control could be jeopardized. While, isolation by building separation is not possible, area compartment is the solution for area isolation (Building Technology-Chapter 3.5) [1]. The area compartment is also normally integrated with fire and security compartment (For example: as shown on Figure1).

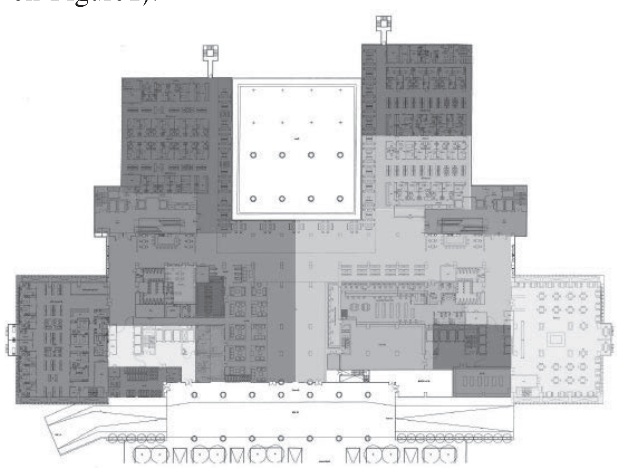


Figure1. Example of Area isolation by compartmented at new Siriraj Medical Center of Excellence, Bangkok. Each color is a compartment.

Services such as preventive program, traditional medicine, nutrition medicine, etc. which are services for healthy patients should be separated. If possible, these services should be in separated building to isolate healthy people from sick people. But if it is located in the same building, it should be compartmented and separated the air handling system. Entrance, exit, horizontal and vertical circulation route shall be separated to avoid the chances of infection. Services should be designed to be completed in the area. Nevertheless, restaurants, food center or retails, etc should be in separated building to avoid smell, kitchen exhaust, rats, insects, etc.

3. Operation to achieve excellent patient treatment

3.1 Indoor Air Quality Control

HVAC system is the key for indoor air quality control, including temperature and humidity control in hospital. These conditions are not only significant in term of thermal comfort but are vital for patient therapy, including bacterial, virus and mold growth prevention. Temperature and humidity condition in hospital should be in accordance with AIA Guidelines for Design and Construction of Health Care [2] as shown in Figure2.

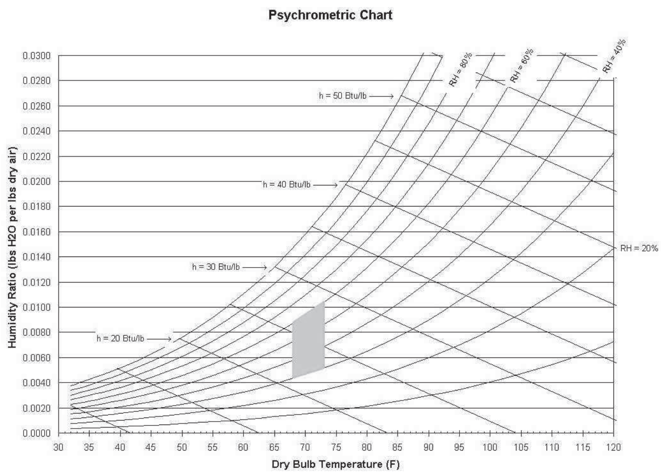


Figure2. Temperature and humidity condition n the hospital

In tropical climate where temperature and humidity climate are prolonged, conventional re-circulated air handling unit with mixing outdoor air in return air box as shown in Figure2 could hardly maintain humidity level. Re-circulated air handling unit has normally been designed to cover peak load. When operate at partial load, cooling coil dew point temperature is raised to maintain room temperature. With high cooling coil apparatus dew point, condensation capability is reduced. The outcome is high humidity with slime in drain pan as shown on Figure4, mold in supply air duct as shown on Figure5, mold on air diffuser, ceiling as shown on Figure6, and damp on interior surface.

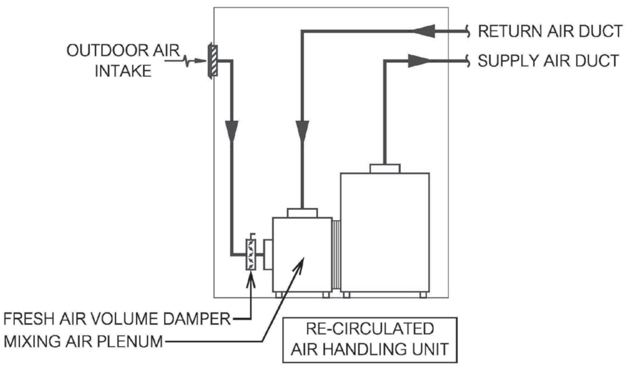


Figure3. The conventional re-circulated air handling unit with mixing outdoor air in return air box

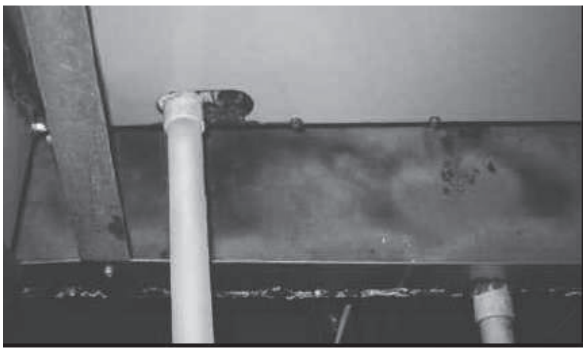


Figure4 "Slime in Drain Pan"

Figure5 "Mold in the Air Plenum"

Figure6 "Mold on air diffuser and ceiling"

To solve this problem, dedicated outdoor air handling unit (OAU) should be added to the air-conditioning system as shown in Figure7. OAU is designed to react with varied ambient conditions and controlling leaving air temperature and humidity as well as filtering outdoor air before supplying into air-conditioned space. Meanwhile, re-circulated air handling unit (AHU) acts as terminal unit and reacts with indoor condition.

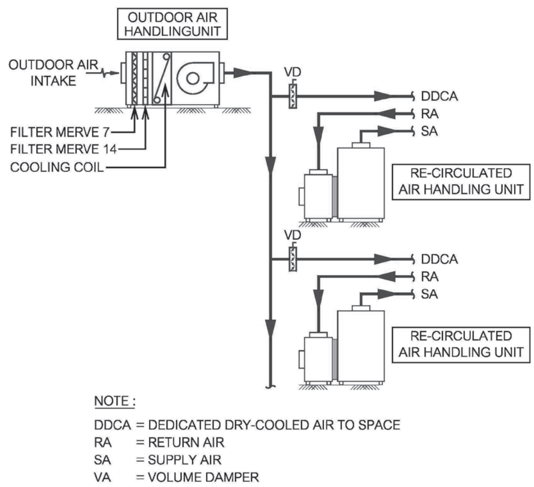


Figure7 the design of dedicated outdoor air handling unit (OAU) in an air-conditioning system

Outdoor air infiltration is significant factor of maintaining indoor air quality from varied ambient conditions including pollutants and dust. HVAC designer should advise architect and interior designer to provide passive building protection system. Building envelope should be air-tight. Entrances should be designed to control air infiltration by using double door or low leak door system. The finishing surface in hospital shall be easily clean, smooth and not harbor contaminants.

3.2 Air borne Contamination Control

Airborne contamination control is prime important in Health Care Facility design. To prevent and minimizing risk of airborne contamination, minimum requirement of outdoor air supply air change rate, re-circulating air change rate, selection of high efficiency air filter, controlling of room air pressure relationships between adjacent areas, air flow movement direction from clean area to less clean area are best practices of controlling airborne contamination.

In hospital, both OAU and AHU must have high efficiency air filter that suit function of each area. AHU air filter is actively clean room air by filtering both germs and particulates that come from patients and indoor sources. Criteria for choosing appropriate air filter for each area is based on 2011 ASHRAE Hand book - HVAC System [3] as shown on Table 1.

Table 1 Filter Efficiencies for Central Ventilation and Air-Conditioning Systems in General Hospitals[c]

Minimum Number of Filter Beds	Area Designation	Filter Efficiencies, MERV[a] Filter Bed No. 1	No. 2
2	Orthopedic operating room Bone marrow transplant operating room Organ transplant operating room	7	HEPA[b]
2	General procedure operating rooms Delivery rooms Nurseries Intensive care units Patient care rooms Treatment rooms Diagnostic and related areas	7	14
1	Laboratories Sterile storage	13	
1	Food preparation areas Laundries Administrative areas Bulk storage Soiled holding areas	7	

[a]MERV = minimum efficiency reporting value based on ASHRAE *Standard* 52.2-2007.
[b]HEPA filters at air outlets.
[c]For guidance on selection and placement of filters, see ASHRAE *Standard* 170.

Table1. Air filter efficiencies for Central Ventilation and Air Conditioning Systems in General Hospitals

Minimum outdoor air supply air change rate is required to dilute viral and bacterial contamination in Heath Care Facility and to maintain positive pressure, promoting air flow movement from the clean area to less clean area as well as maintaining differential room air pressure between adjacent areas.

The minimum requirement of outdoor air supply air change rate and re-circulating air change rate shall follow 2011 ASHRAE Handbook – HVAC Applications (Health Care Facilities) [4]

Air flow movement direction control is vital for Heath Care Facility., minimizing risk of air borne contamination between areas. For example, air flow direction for exam room should be from doctor work station (which is declared as clean area) to exam bed (which is declared as less clean area) as shown on Figure8. Air should be return via return air duct only to AHU (Ceiling return air is not allowed). Air flow direction for patient waiting area should be from nurse station (which is declared as clean area) to the end of patient's waiting seats row (which is declared as less clean area) as shown on Figure9.

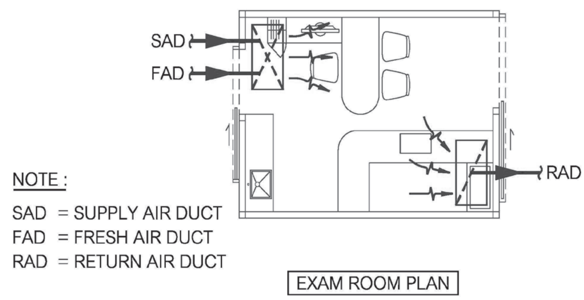


Figure8. Air flow movement direction in Exam Room

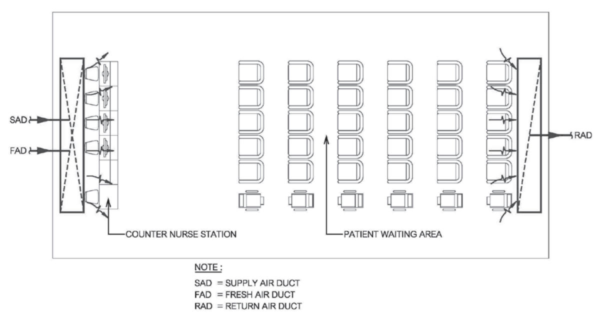


Figure9. Air flow movement direction in Patient waiting Area

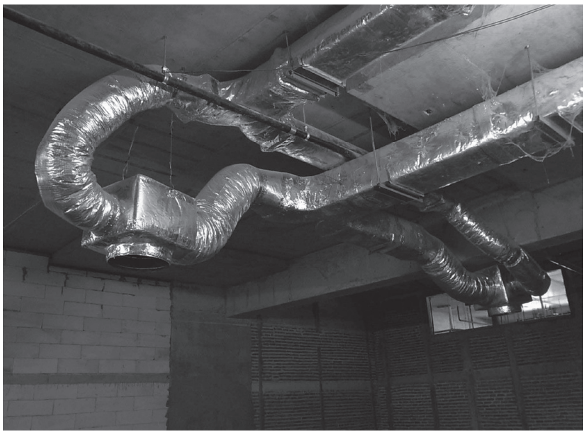


Figure10. Air diffuser with both re-circulated air and treated outdoor air supply

It is recommended that outdoor air supply should be dry and cool (for example: at 10 degree C dew point) and directly supply into the space in order to support air flow movement direction (Except OR, where outdoor air is supplied through OR AHU). In exam room, the dry and cool outdoor air supply should supply at doctor work station. In waiting area the dry and cool outdoor air supply should supply at nurse station. This is the method of assuring positive differential room air pressure that supports air flow movement direction.

Dew point of 10 degree C is normally designed for outdoor air supply condition. It has 7.6 g/kg dry air moisture content which is lower than average room moisture content of 10 g/kg dry air. Since AHU is not reliable for moisture removal as already mentioned, dry outdoor supply air is beneficial for reducing humidity, especially in tropical climate.

There are several methods of drying and cooling of outdoor air. At dew point of 10 degree C, leaving air could be too cool and could jeopardize room temperature control. Pre-cool and reheat system as shown on Figure11 is a proven solution. Pre-cooling coil enhance cooling coil for moisture removal, while reheat coil raise outdoor air supply temperature (for example: to 18 degree C). Outdoor air supply temperature at 18 degree C will maintain relative humidity level in outdoor air supply duct within 60% RH, which is a safe zone to avoid mold growth in air duct.

All return air system in the Heath Care Facility shall be via return air duct system. Air shall return directly from each area back to AHU in order to minimizing risk of airborne contamination between areas.

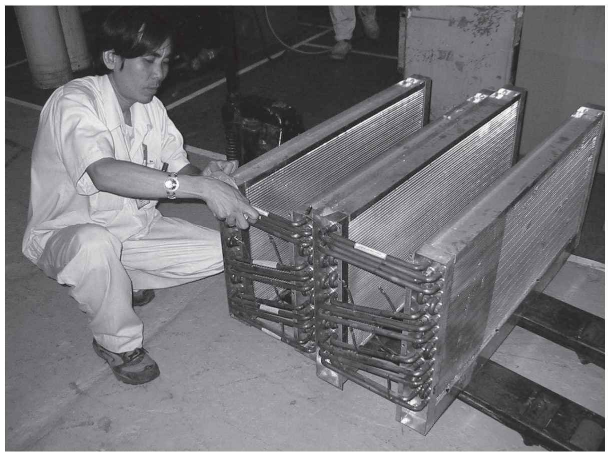


Figure11. Pre-cool and reheat system

As mentioned, dedicated AHU for each department or clinic is essential for the control of airborne contamination between areas. In case of airborne disease emergency, health care facility manager could shut down any infected department if necessary for sterilization and to prevent spread of airborne disease.

In order to maintain air change rate, the OAU and the AHU should be equipped with variable speed drive (VSD) motor to compensate for increasing air filter pressure drop during operation as shown on Figure12. The amount air change rate should be recorded, monitored by health care facility manager.

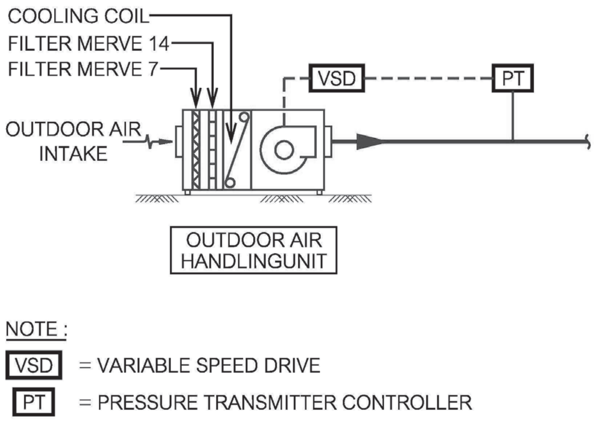


Figure12. OAU and AHU with variable speed drive (VSD) motor

4. Maintenance as green and clean facility

4.1 Mechanical Floor

Most of Health Care Facility includes out-patient department (OPD) in podium level and in-patient department (IPD) on the tower above OPD as shown on Figure13. Operating room department (OR) is normally located on the highest floor of OPD for convenient transfer of patient from OR to recovery room/ ICU or patient ward.

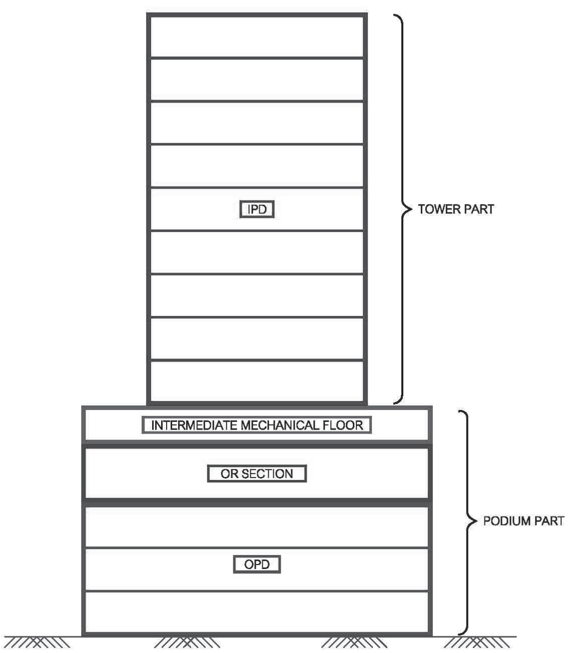


Figure13. Typical high rise hospital layout

It is recommended that mechanical floor should be provided above OR area, providing easily access for maintenance, convenient for facility management, efficient control and operation. Furthermore, duct floor should be provided under patient ward tower for all pipes collections and transfer of pipes from tower to podium. It should be noted that pipes, especially waste pipes are prohibited in OR ceiling (Figure14).

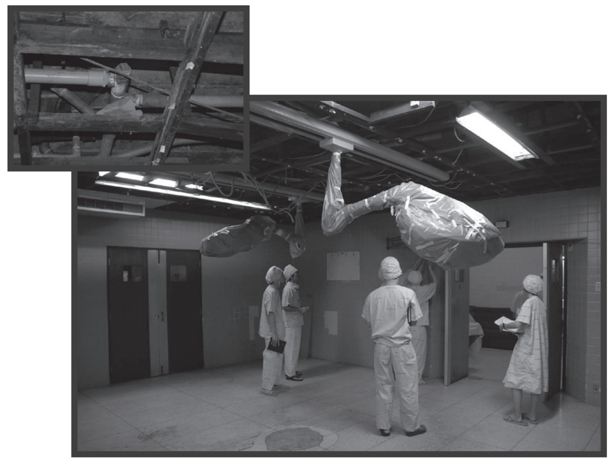
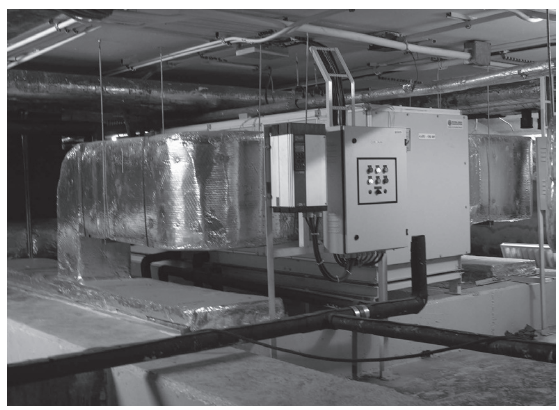


Figure14. Problem of many sanitary pipes above OR in an old hospital



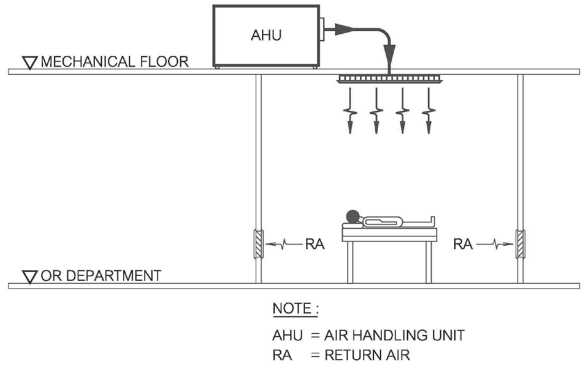


Figure15. Mechanical Floor above OR and OR AHU

The mechanical floor above OR as shown on Figure15 is essential for individual AHU for each OR that should be installed right above the OR with shortest possible air duct to prevent contamination in air duct system. The mechanical floor is also providing space for OAU and ventilation fans. When appropriate, the mechanical floor could be combined with duct floor. However, AHU for OR should have separated compartment from waste drain pipes, since pipes leak could contaminate the area. Though typical AHU for OR is low leak double skin AHU, but air leak through the unit is still possible. Therefore, AHU area for OR should be maintained as clean area.

Outdoor air intake location shall be located away from any stack exhaust outlet, ventilation exhaust outlet, cooling tower or any polluted source.

4.2 Energy saving and reliability

With many specific requirements, large amount of out door air intake, high air change rate, high efficiencies filter, etc. and non stop operation, HVAC system for Health Care Facility uses more energy than other buildings. It is important that utility systems in Health Care Facility should be designed to minimize energy consummation as well as carbon emission.

Both passive and active design should be considered. On passive design, HVAC designer should work closely with architect from building orientation to building insulation in order to minimize heat load. Building skin shall be air tight with controlled entrances to protect building from infiltration load.

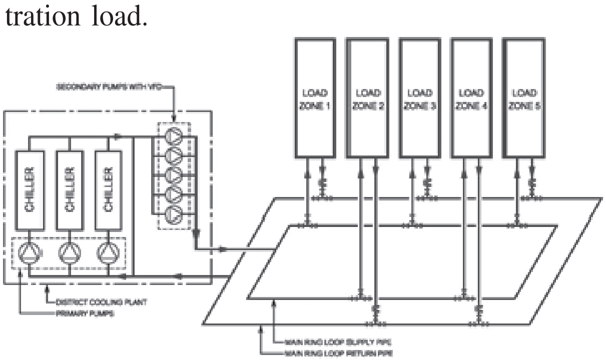


Figure16. Example of District cooling (DC) system

On HVAC design, efficient load sharing system such as "district cooling (DC) system" as shown on Figure16 should be considered. Health Care Facility as large complex has high potential for DC system since there are varieties of functions at different peak load duration. Bangkok Hospital has been successfully renovated in 2011, turning into DC system with 70 MB investment and 4 years payback period. Rama Hospital is on going for DC system.

Main utility distribution shall be designed as ring loop to protect system from single-point of failure. M&E utility core should be designed as multi core system spreading through out overall plan and comply with zone fire compartment for convenient operation and maintenance.

5. Conclusion

A successful design of modern Health Care Facility should achieve 3 main goals, Area Isolation for contamination control, Operation to achieve excellent patient treatment and Maintenance as green and clean facility. Equipment room should be easily accessible for maintenance and clean, ready to provide 24 hours service for patient. Modern Health Care Facility trend is aiming for "Green and Clean".

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