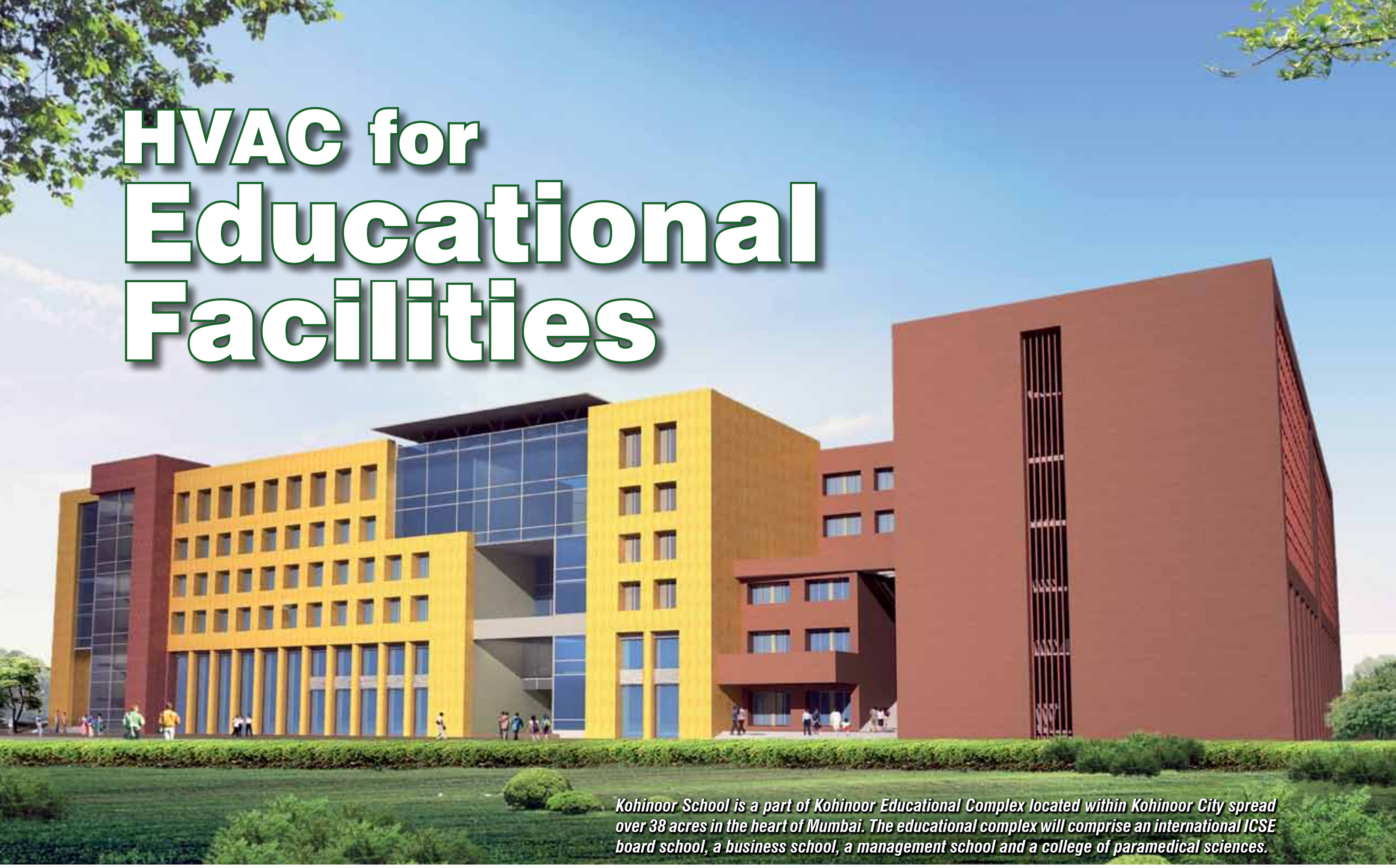
HVAC for Educational Facilities



Kohinoor School is a part of Kohinoor Educational Complex located within Kohinoor City spread over 38 acres in the heart of Mumbai. The educational complex will comprise an international ICSE board school, a business school, a management school and a college of paramedical sciences.

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Introductory Remarks by the Consulting Editor

Pick up any Indian newspaper or magazine and chances are you will come across stories of the changing aspirations of ordinary people all over the country, hoping and planning for a better life and how this is fueling the demand for better education and more educational facilities. From the farmers in Burhanpur, a village in Maharashtra pooling money to establish an engineering college of their own with preference for children of farmers to Oracle CEO, Larry Ellison, planning a JV for a chain of premium K12 schools in the country, and the likes of the Ambanis, the Birlas and the Oberois, who have already established premium schools in Mumbai, the private sector is grabbing the opportunities available in the business of education. Competition and the quest for excellence are driving many owners to plan for comfort cooling of such facilities.

Due to the lack of any uniform standards for such cooling and ventilation requirements for schools, there is a wide disparity between what consultants design based on foreign standards, or what the school owners think is adequate or what design-build contractors install based on the lowest price. Hence you have the IIMs, Ambanis, Oberois and Kohinoors, at one end of the spectrum, with the HVAC system design as described in this article, and at the other end are simple room ACs that can cool a classroom packed with students but with no provision for fresh air.

Educational Facilities

Educational facilities can be broadly classified into the following heads:

i. Pre-schools: From the infant age group (1-2 years) to toddlers and older toddlers (up to 4-5 years).
ii. Schools: Kindergarten, elementary, middle and high schools.
iii. Graduation schools and university campuses.
iv. Course programme schools, such as management schools, catering institutes, computer academies.

Many times, all or some of these are part of an integrated educational campus; however, standalone entities are not uncommon.

Design Conditions

Outdoor design conditions depend upon the city and latitude of the educational facility. ISHRAE provides

About the Author

Pradeep Nadkarny passed his B.E. in mechanical engineering from Maharaja Sayajirao University, Vadodara in 1970. He worked in a reputed HVAC firm till 1993 before joining Spectral. He has handled design of engineering services for large hotels, hospitals, IT offices, corporate offices, malls, residential and Green Building projects.

tabulation of outdoor design conditions for various cities for 0.4%, 1% and 2% cumulative frequency of occurrence. Unlike hospitals and data centres where weather data corresponding to 0.4% is used, educational facilities can be sized based on 1% cumulative frequency of occurrence.

Indoor conditions are selected for occupant comfort. As occupants in schools are generally seated with low metabolic rates, relatively higher indoor temperatures are required for thermal comfort. *ASHRAE Applications* recommends the range of indoor design conditions in various zones in an educational complex (see *Table 1*).

Table 1: Recommended design mean values for different areas

Area	Dry bulb temp (°F)	Relative humidity (%)
Class rooms	75	60
Administrative offices	74	60
Cafeteria/ dining rooms	78	-
Kitchen	86	-
Filtration level of minimum MERV-8 shall be provided		

Fresh air rates should be selected from maximum of ASHRAE 62.1 and *ASHRAE Applications – Educational Facilities*. For example, fresh air rates for class rooms should be:

Max [(17cfm/person) : (10cfm/person+0.12 cfm/ft^2)]

Noise levels within class rooms need to be within acceptable limits as higher levels interfere with the concentration ability of students. Recommended sound levels are between 25-30 RC (N).

Typical Facilities

Newer educational complexes offer multiple educational facilities ranging from toddler preschool to post graduation. All facilities are part of a bigger complex, providing a complete range of comprehensive education and training. A few critical zones in an educational complex are:

Class rooms

Class rooms are important constituents of the educational process. Heat load in class rooms is predominantly a function of ambient conditions, because class rooms typically have exterior exposures and ventilation load requirement is higher. Both these factors contribute to higher latent load. Load due to lighting is generally minimal during daytime working of the school.

Computer rooms

These rooms need not face exterior exposure and are characterised by higher sensible load factors due to the computer equipment.

Laboratories

A school can house many laboratories like chemistry, physics and biology. The physics laboratory generally does not require any exhaust, while chemistry and biology laboratories often require exhaust. For secondary schools, exhaust hoods also may be necessary. In such cases, dedicated exhaust system is planned and make-up air is provided for. Exhaust from chemistry and biology laboratories can contain traces of H_2SO_4, HCL, and formic acid. Hence regular GI ducting is not recommended. FRP ducting should be used so that the effect of these chemicals on the interior of air distribution system can be avoided. In case an elaborate hood system is not feasible, chemistry and biology laboratories should at least be provided with an exhaust fan with a switch in the room so that air can be exhausted whenever required.

Auditoriums

Auditoriums require large latent loads to be removed due to occupancy and ventilation air requirements. Quietness in operation is also very critical. Auditorium air handling systems often need to have deeper rows of coil, re-heating arrangement and low velocity ducting and air outlets. Smoke evacuation system should be installed as per recommendations of National Building Code of India (NBC).

Locker rooms

These areas are used for keeping the belongings of students and the faculty. Locker rooms need not be air conditioned; however, they need to be provided with an exhaust system in order to avoid stale air and smell accumulation.

Load Characteristics

The load profile in educational facilities is different in many ways from other applications like offices and hotels. Specific timings of operation make the load profile non-typical.

Schools often operate in two shifts. The first shift starts at 7.00 AM and goes upto 11:30-12 noon. The second shift starts at 12 noon and goes up to 5.00-6.00 PM. A third shifts for non-curriculum courses is also not uncommon, which may go up to 7.00-8.00 PM. Yearly operating schedule is also a critical consideration, as operating loads are minimum in the months of April-May due to summer vacations. (This is true during Christmas holidays in colder climates). Facilities like the gymnasium and the cafeteria impose loads when the main educational facility demand is non-peak. In addition, facilities may be closed on Saturdays and Sundays.

Hence, it is very important to define operating schedules for various facilities while carrying out heat load estimation. Load estimation on HAP software is recommended as it can predict nearly accurate loads profiles – which in turn help to size plant equipment in an optimum way.

Cooling Systems

A majority of schools in India are not air conditioned. Large numbers of non-air conditioned schools can be found in rural areas. These are naturally ventilated by operable windows and sometimes ceiling fans.

For naturally ventilated schools, it is advisable to have cross ventilation so that air movement across the class room creates thermal comfort. Building orientation should be in line with prevalent wind direction, and at least 10% of the external wall area should be provided with operable windows. Many older schools have solid thick walls with large storage effect that cuts down instantaneous heat gains during peak hours.

Some of these schools are mechanically ventilated. Air is supplied from one side through side grilles, and exhausted from the opposite end to maintain cross flow. Supply air ducting generally runs through the corridor. Exhaust air can be centrally ducted, or exhausted through each class room using low noise inline fans. Supply fans should have minimum filtration of 90% down to 10 microns (MERV-8), and should be sized for a minimum of 5 air changes per hour (NBC-2005).

For non-air conditioned buildings, it is also recommended to provide underdeck/over deck insulation for the top most floor, so that roof heat gain is minimised.

Newer high end schools in cities like Mumbai and Chennai are centrally air conditioned. Depending upon their size, various air conditioning systems are employed.

Standalone facilities (like a preschool), are generally provided with direct expansion type unitary systems. Depending upon the size and requirement of the facility, system selection can range from standard split units, rooftop packaged units or variable refrigerant flow (VRF) systems. VRF systems provide operational benefits as they can adapt to variable load pattern better than split systems. In a VRF system, outdoor unit configuration should be done after careful analysis. The configuration can be common outdoor unit(s) for complete facility, or dedicated outdoors floor-wise, or operating time-wise. In any case, this distribution should be discussed with the customer so that it is in line with his operational needs.

In larger educational complexes, it is common to use a chilled water plant for air conditioning. Such a complex will often have a central utility building housing chillers, emergency power generation sets, transformers, hot water generators, etc. Services are piped to each building and department through trenches, or are buried.

The following considerations should be kept in mind while designing the system and selecting the equipment:

Refrigeration system

As explained above, the load pattern in an educational facility is quite different from an office or IT building. Hence, while arriving at the maximum demand load, all diversities like operational schedule, holidays coinciding with peak summer temperature etc. should be considered. While chillers will have to be selected to cater to peak demand load, the minimum system load is also required to be considered. Chiller configuration (capacity and size) should be decided based on the minimum anticipated load. Ideally, chiller selection should be such that during minimum load conditions, no working chiller is unloaded below 60-65%. However, chiller configuration also has commercial and space requirement aspects, which many times do not result in optimum configuration. In such cases, chillers with variable frequency drives can provide excellent part load performance. Hot gas bypass is another option. However, while exercising this option, limits of hot gas bypass capacity should be observed as per ASHRAE 90.1. *Table 2* gives these guidelines.

Table 2: Guidelines for bypass capacity

Rated capacity	Maximum hot gas bypass capacity (% of total capacity)
< 240,000 Btu/hr	50%
>240,000 Btu/hr	25%

Evaporative cooling

In drier climates, evaporative cooling (see *Figure 1*) can be used for areas like kitchen, cafeteria and work areas. Systems with adiabatic saturation efficiency of 90-95% are available nowadays. The lower the wet bulb temperature, better is the system performance. These systems reduce power requirement as no compressors are required for cooling.

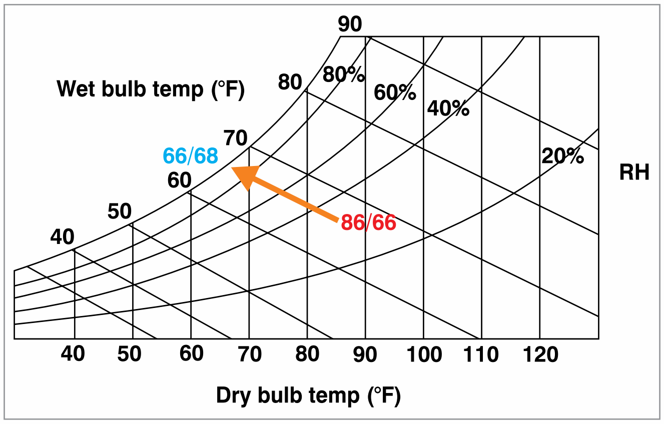

Figure 1: Adiabatic cooling

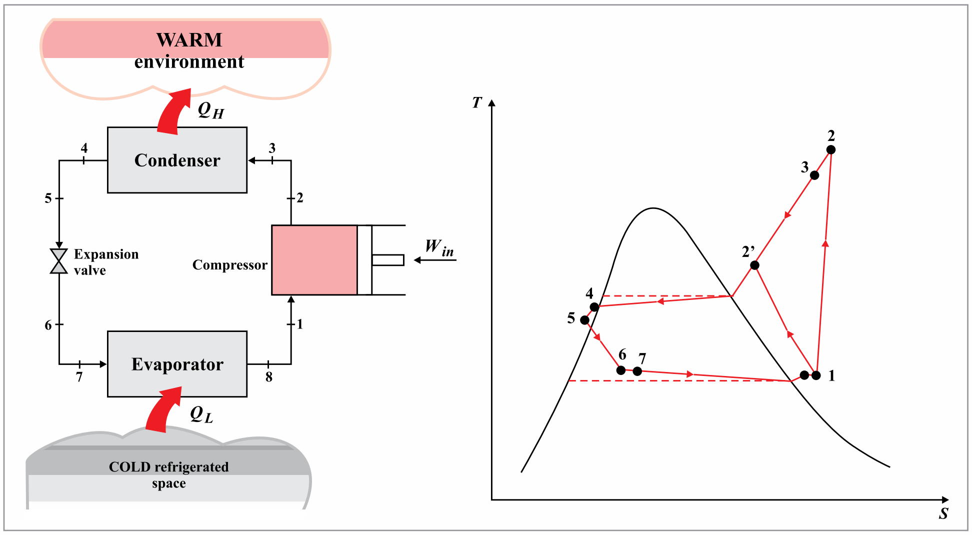

Figure 2: Heat pump cycle schematic and on a TS diagram

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Such systems are effective in climates where the air washer achieves supply temperature up to 27-28°C. Higher supply temperatures do not address thermal comfort requirements adequately and need very high supply air quantities.

Hot Water System

In a large educational complex, hot water requirement can exist for kitchen, laboratories etc. Hot water can be produced through gas or diesel fired hot water generators. However, this requires expensive fuel and contributes to environmental pollution. Alternatively, solar hot water system is a clean source of hot water.

Vapour compression heat pumps (total heat recovery chillers) can be used to produce hot water. Heat pumps can produce hot water upto 50-55°C by elevating saturated condensing pressure-temperature (see *Figure 2*). However, careful analysis of the load profile is mandatory before finalising heat pump configuration, as refrigeration capacity drops down by 50-65% during heat pump mode. Profile curves of hot water requirement and air conditioning load should be examined so that the reduced refrigerant capacity during heating mode does not go below the required cooling capacity.

Dedicated Outdoor Air System (DOAS)

Fresh air is a very critical component for IAQ. Especially in an educational complex, where students and the faculty spend much of their time indoors, good IAQ is of paramount importance for productivity and health. In humid climates like Mumbai and Chennai, this fresh air brings in moisture and raises electrical consumption. DOAS is an excellent tool to maintain humidity within acceptable limits while keeping energy efficiency in mind.

An appropriate definition of DOAS is:

DOAS is a decoupled load system in which the primary air (primary air does not necessarily mean fresh air) *unit takes care of - (i) fresh air sensible load (ii) fresh air latent load and (iii) room latent load.* Room sensible load is taken care of by a recirculation unit, which can be VAV, AHU, FCU or chilled beams.

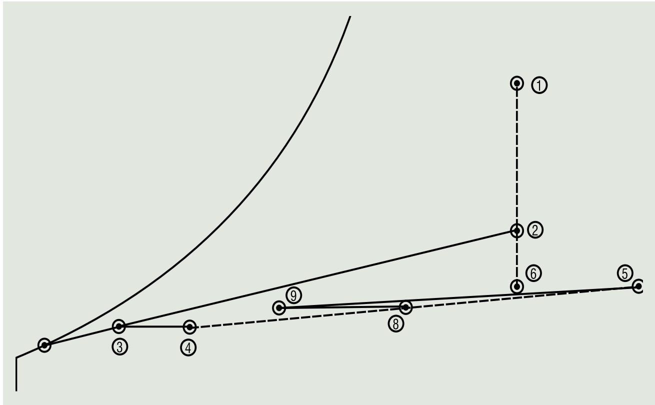

Figure 4: Psychrometric process of DOAS (please refer Figure 3 for key to numbers)

See *Figure 3* for DOAS system architecture. DOAS is the primary air unit, which houses a pre-heater (used only in areas where the temperature can drop sub zero), enthalpy wheel, cooling coil, sensible wheel, and supply and exhaust fans along with motors.

DOAS supplies cooled and dehumidified air to the recirculation unit, which circulates total air to the room. Air is exhausted from the room (equal to fresh air – leakage required to maintain minimum positive pressure) and is passed through DOAS. Energy exchanges in DOAS are explained on the psychrometric chart in *Figure 4*.

Internal components of DOAS can change as per design indoor and ambient conditions, and can include additional attachments like desiccant wheels, regeneration coil, regeneration exhaust heat recovery coil etc.

Some Projects Designed by the Author

Kohinoor Educational Complex, Mumbai

Kohinoor educational complex is situated in the central suburb of Kurla in Mumbai, and provides educational facilities to residents of Kohinoor City and adjoining areas. The built up area is approximately 3,50,000 ft², of which 1,75,000 ft² is air conditioned, having a demand load of 700 TR. The school is

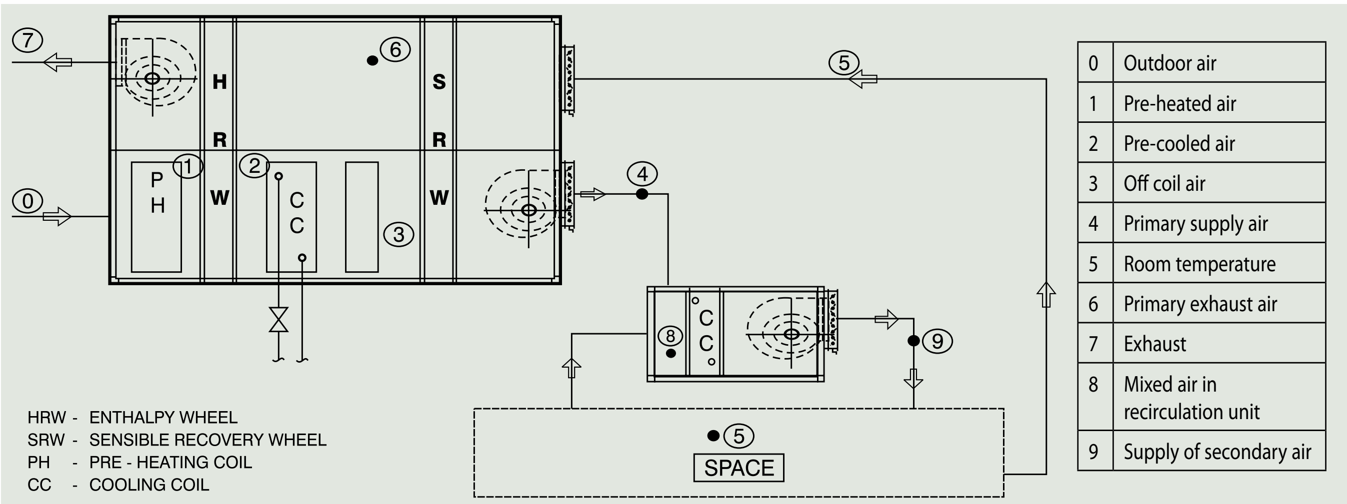

Figure 3: Schematic components of DOAS, with key to numbers

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Another facility in the Kohinoor Educational Complex, Mumbai

Entrance to the Lotus Valley School, Noida

North South University, Dhaka, Bangladesh

centrally air conditioned with four (3+1 standby) water cooled screw chillers of 200 TR each.

Lotus Valley School, Noida

The Lotus Valley School in Noida is spread over 2,37,000 ft^2 and is air conditioned and ventilated. The air conditioning load is 900 TR. Water cooled package units of various capacities (6.5TR, 8.3TR, 11TR etc.) are installed for the project. These package units have energy efficient scroll compressors. Low noise-low water loss cooling towers have been installed.

North South University, Dhaka, Bangladesh

North South University is spread over 4 acres, with a total built up area of 7,00,000 ft^2. The campus houses facilities like class rooms, lecture halls, laboratory spaces, auditorium and canteen, and is provided with a central chilled water plant to cater to the air conditioning load.

Conclusion

Educational complexes are increasingly becoming commercial in nature. Hence, occupant comfort is an important parameter. HVAC system for an educational facility must be designed to address all comfort related issues like temperature, humidity, noise levels and air quality. At the same time, energy efficiency has to be kept in mind so that the system can be operated economically. ❖