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Design and Development of HVAC Systems in Schools

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ABSTRACT

This study contributes to the understanding and process development for implementing solar assisted HVAC systems in buildings in school. The schools are unlike any other commercial property since they have special energy needs. High heat and electricity loads are the main key elements faced by design engineers.In the present scenario of India, we are facing the issues of pollution, temperature rise on a daily basis which are causing a lot of discomfort to the population and masses. Children nowadays are prone to the long term ill effects of these issues, and therefore it very crucial for us to take appropriate measures for improving the air quality and human comfort. Children spend most of their daily time in the schools, thereby making it essential for us to provide air conditioning to the schools.
Keywords: carbon dioxide, costs, health, performance, schools, ventilation

INTRODUCTION

Energy needs of a schools can not be compared with typical consumption of any other building (commercial or residential) because the energy needs is largely dependent on the specific event activity. Normally in schools the peak of required energy occurs after normal working hours or when offices are closed. Energy consumption usually depends on the time table of the center and event public attendance. Entertainment center air conditioning is one of the major consumers of electrical energy due to the high number of people attending a performance and the instruments used during the event.The energy consumed by school HVAC systems includes the energy consumption attributable to heating, cooling, and dehumidification of ventilation air and the energy consumption attributable to other processes, such as heat conduction through buildings envelopes. The portion of heating, ventilating, and air conditioning (HVAC) system energy use attributable to ventilation cannot normally be directly measured; thus, mathematical models of building energy performance have been employed to predict energy consumption and energy costs with and without ventilation or with different rates of ventilation.

In this project, we will design an air conditioning system for a school in Sangli, Maharashtra, India with a capacity of 500, which consists of 10 classrooms, 4 labs, 2 faculty rooms with attached toilet, 2 office rooms, 1 store room, 1 seminar hall for 300 people capacity, 1 mess with kitchen, 1 ladies' as well as 1 boys' room with attached toilet, washrooms, etc.

Associated with air conditioning's high use of energy is significant environmental pollution, in the form of greenhouse gas emissions with the resultant climate change impacting not only upon our environment, but also our health and productivity [1]. Of the many ways of individually addressing air conditioning's impact upon the grid and environment, solar air conditioning is one of the few solutions that provides cooling and addresses the demand of peak loading, and does so with reduced environmental impact. Solar air conditioning is a way to reduce the demand for electricity which means less demand for fuel and coal. In addition, many solar air conditioning systems are constructed in ways that eliminate the need for chloroflurocarbons CFC, Hydro chlorofluorocarbons HCFC or Chlorofluorocarbons HFC refrigerants. Alternatives to use solar energy is waste heat from different industrial processes such as refineries, garbage treatment facilities etc. [2]. Energy costs, for example, which typically represent up to 10 percent of a center's operating budget, can be reduced easily by 30% to 35% according to Fried Gil from sport facility management second edition [2-3]. Almost all schools treat energy costs as ongoing, uncontrollable costs extracted from core funding. By reducing energy costs, schools can keep more money for core funding and increase their discretionary spending [4]. This study presents why and how solar cooling technologies contribute to achieve energy and monetary savings and to reduce greenhouse gas emissions.

FUNDAMENTALS OF COOLING SYSTEM

Open Cycle Processes (Desiccant Solar Cooling)

Open cooling cycles produce directly conditioned air. Any type of thermally driven open cooling cycle is based on a combination of evaporative cooling with air dehumidification by a desiccant, i.e., a hygroscopic material. Again, either liquid or solid materials can be employed for this purpose. The standard cycle which is mostly applied today uses rotating desiccant wheels,equipped either with silica gel or lithium-chloride as sorption material (Fig. 2). All required components, such as desiccant wheels, heat recovery units, humidifiers, fans and water-air heat exchangers are standard components and have been used in air conditioning and air drying applications for buildings or factories since many years.Close cycle process

These are thermally driven chillers which provide chilled water, that is either used in air handling units to supply conditioned air (cooled, dehumidified) or that is decentralized room installations, e.g. fan coils. Close cycle consist of the following:

Absorption Chillers:

Absorption chillers offer an exciting alternative to conventional compression chillers, since their main energy input is heat instead of mechanical power. Fig. 3 shows the schematic of an absorption cycle. Absorption chillers come in a large variety of models and types, frequently requiring heat in the form of water vapour, or even direct fire. Applications with vapour frequently fit most waste heat rejection found in industrial processes such as combination heat and power. The COP is defined as in compression chillers but with the driving heat replacing the mechanical/electrical input. Traditionally absorption chillers are large machines with a large cooling capacity. Absorption chillers work much like conventional compression chillers, except that there is no mechanical compressor. Instead, the vaporised refrigerant leaves the evaporator to the absorber where it is diluted by a solution. The liquid solution is then pumped (pumps are more efficient than compressors), and then regenerated with heat (in the generator), so that the refrigerant is vaporised again, at a higher pressure and temperature. It then goes to the condenser to release the contained waste heat. Typically for chilled water temperatures less than 5°C, ammonia is used as the refrigerant and water as the absorber. For typical air-conditioning applications (chilled water above 5°C), the combination of water as refrigerant and lithium bromide (LiBr) as absorbent is more popular, while chillers using Ammonia as absorbent are more suited for industrial refrigeration, producing chilled water down to –10ºC [5]. The condenser's heat rejection is again critical to the COP of the chiller.

Figure2. Desiccant wheels

Adsorption chillers:

These chillers are similar to absorption chillers, since both are driven by heat. However, adsorption chillers can be driven by hot water at lower temperatures than absorption chillers, thus benefiting from a better efficiency on the solar collectors system because they are generating water at a lower temperature. The adsorption cycles is shown in Fig. 4. From a physical point of view, both technologies differ significantly since the sorbent used in adsorption is silica gel, a solid that cannot be compressed or pumped. Instead, each compartment containing the solid sorbent is alternately heated and cooled to adsorb and desorb the refrigerant in a periodic process. An adsorption chiller consists of two compartments on which the internal surfaces are covered with silica gel; a highly porous solid that captures water vapor (adsorbs the refrigerant). The same compartment is then heated (regenerated) with the driving hot water at temperatures ranging from 55°C to 95°C. The refrigerant at a higher temperature moves to the condenser where it is condensed, resulting waste heat that must be dissipated. A throttle valve drops the pressure of the condensed water to the level of the evaporator. At that low pressure, it receives enthalpy from the chilled water and evaporates, moving on to the other compartment, with the regenerated silica gel, thus completing the process. A cycle can take around seven minutes and it begins where the refrigerant goes to the evaporator, where it is evaporated with a strong vacuum, and produces chilled water. Then the refrigerant moves to one of the compartments filled with recently regenerated silica gel, where it is adsorbed. Then the cool/ hot water cycle inverts. Now heat is being supplied to the compartment, regenerating the silica gel. Back as in vapor form, the refrigerant is pressurized and goes to the condenser. And in the condenser, chiller condensates releasing waste heat (to be dissipated). The liquid refrigerant is then sprayed back to the evaporator completing the cycle [11- 13].

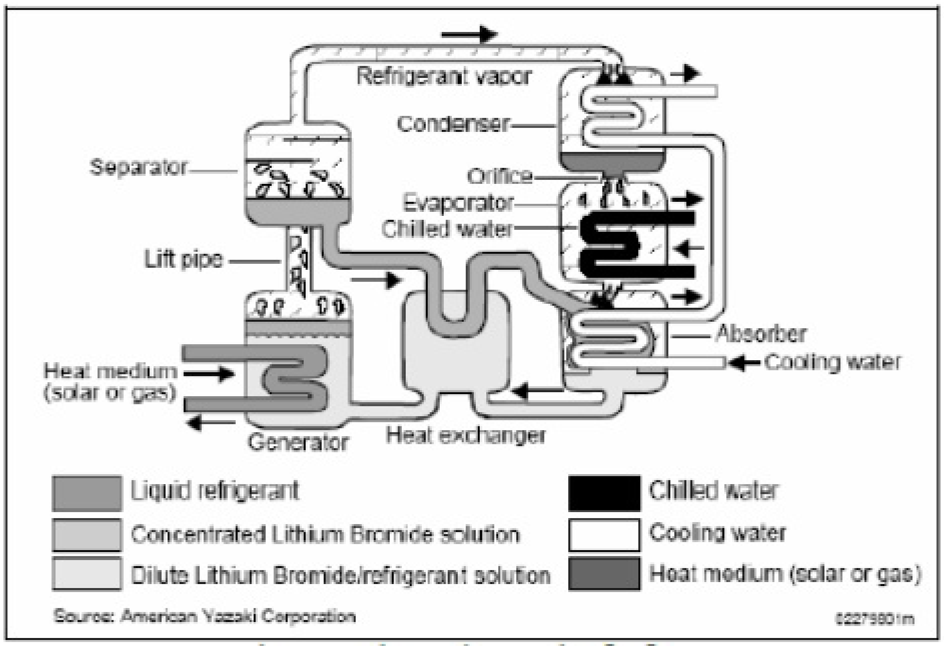

Figure3. Absorption cycles

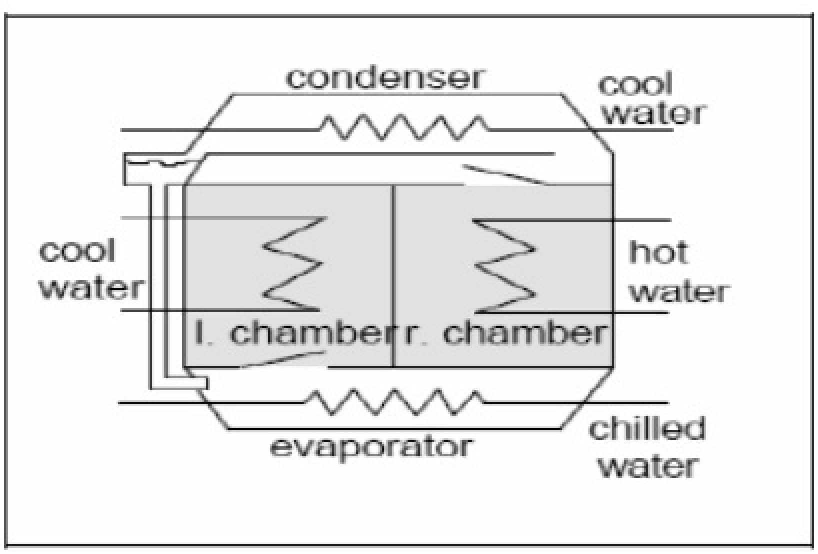

Figure4. Adsorption cycles

SUMMARY OF COMMERCIAL COOLING LOAD CALCULATION PROCEDURES :

The steps in determining commercial cooling loads can be summarized as follows.

• Select indoor and outdoor design conditions from Tables 2.1 and 2.2.

• Use architectural plans to measure dimensions of all surfaces through which there will be external heat gains, for each room.

• Calculate areas of all these surfaces.

• Select heat transfer coefficient V-values for each element from appropriate tables, or calculate from individual R-values.

• Determine time of day and month of peak load for each room by calculating external heat gains at times that they are expected to be a maximum.

• Calculate each room peak load, using the values for the external heat gains determined above and by calculating and adding the internal heat gains from people, lights, and equipment.

• The architect or building owner will furnish the data needed for the calculations. If there is infiltration, this must be added to the room load.

• Find the time of building peak load using a similar search process as in item 5 and the suggestions in Section 2.19.

• Calculate the building load at peak 'time, adding all external and internal gains and infiltration, if any. Add supply duct heat gain duct heat leakage, and draw-through supply fan heat gain, if significant.

• Find the cooling coil and refrigeration load by adding the ventilation load to the building heat gains; add blow-through fan, return air fan, and pump heat gains, if significant.

• Calculate required supply air conditions.

The outdoor temperature conditions for the location in consideration: Sangli, Maharashtra, India have been tabulated below:

Table2.1. Temperatures for Sangli, Maharashtra, India

City or Station Name	Longitude	Latitude	Elevation
Pune	16.8524° N,	74.5815° E	549
Daily Range DBT's			
Month	DB Deg F		
	Max	Min	Range
Jan	88.7	55.22	33.48
Feb	92.48	53.24	39.24
March	101.12	58.26	42.84
Apr	102.92	66.02	36.9
May	105.8	68.9	36.9
Jun	102.74	75.68	30.06
Jul	88.7	73.04	15.66
Aug	85.28	70.52	14.76
Sep	87.26	70.52	16.74
Oct	91.76	68	23.76
Nov	88.16	56.12	32.04
Dec	85.64	55.04	30.4

Table2.2. Indoor air quality and outdoor air requirements

Applications	Cfm/person
Offices, conference rooms, offices	20
Retail Stores	0.2 – 0.3 cfm/ft^2
Classrooms, theaters, auditoriums	15
Hospitals patient rooms	25

COOLING LOAD CALCULATIONS

The various conditions and data pertaining to the project has been mentioned in the start. The particular conditions of each room will be mentioned in the respective section.

3.1 Cooling Load Estimation for Classroom 1

Maximum Cooling Load

	Btu/Hr	Kw	TR
Q	9802.61	2.87	0.82

Details of cooling load

Table2.3. Cooling load calculations

Time of day	Roof	Walls(All sides)	Floor	Window		People		Light	Miscellaneous	Q		Qnet
				Conduction	Radiation	Sensible	Latent			Sensiblr	Latent	
8.00	130.54	1299.50	0.00	85.31	12.83	2250.51	3653.75	47.74	341.21	4167.64	3653.75	7821.39
9.00	130.54	1269.92	0.00	99.65	21.19	2632.68	3653.75	387.19	341.21	4882.38	3653.75	8536.13
10.00	130.54	1240.34	0.00	113.98	32.34	2929.91	3653.75	392.50	341.21	5180.83	3653.75	8834.58
11.00	130.54	1240.34	0.00	135.49	41.82	3142.23	3653.75	397.80	341.21	5429.43	3653.75	9083.18
12.00	130.54	1240.34	0.00	149.83	131.14	3269.61	3653.75	403.10	341.21	5665.78	3653.75	9319.53
13.00	130.54	1240.34	0.00	171.33	0.00	3397.00	3653.75	408.41	341.21	5688.84	3653.75	9342.59
14.00	130.54	1269.92	0.00	178.50	37.92	3524.39	3653.75	408.41	341.21	5890.89	3653.75	9544.64
15.00	130.54	1329.09	0.00	185.67	27.88	3609.31	3653.75	413.71	341.21	6037.42	3653.75	9691.17
16.00	130.54	1358.67	0.00	185.67	19.52	3694.24	3653.75	419.02	341.21	6148.86	3653.75	9802.61
17.00	130.54	1417.83	0.00	178.50	15.06	3779.16	3653.75	74.26	341.21	5936.56	3653.75	9590.31

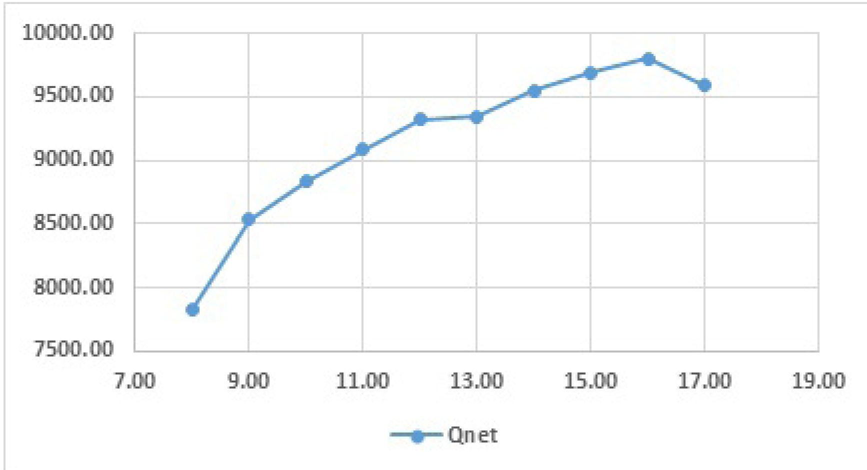

Figure5. Cooling load vs. time plot

DETERMINING THE SUPPLY AIR CONDITIONS FOR EACH ZONE AND THE APPARATUS DEW POINT

To determine the supply air conditions, the following procedure is followed:

• Point O corresponding to outside air conditions i.e. 31.4°C DBT and 60% RH is plotted on the psychrometric chart corresponding to normal temperatures and barometric pressure of 101,325 Pa.

• Point R corresponding to outside air conditions i.e. 25°C DBT and 50% RH is plotted on the psychrometric chart corresponding to normal temperatures and barometric pressure of 101,325 Pa.

• Point 3 corresponding to mixed air condition (75% recirculated air, 25% fresh air) is plotted on the psychrometric chart corresponding to normal temperatures and barometric pressure of 101,325 Pa.

• A line passing from point R and corresponding to the RSHF slope is drawn.

• The bypass factor is assumed to be 0.2 and the GSHF line is drawn to meet the RSHF line at point S which corresponds to the supply air condition. This line is further extended to meet the saturation line at Apparatus Dew Point (ADP) of the cooling coil.

For zone 1 and zone 2:

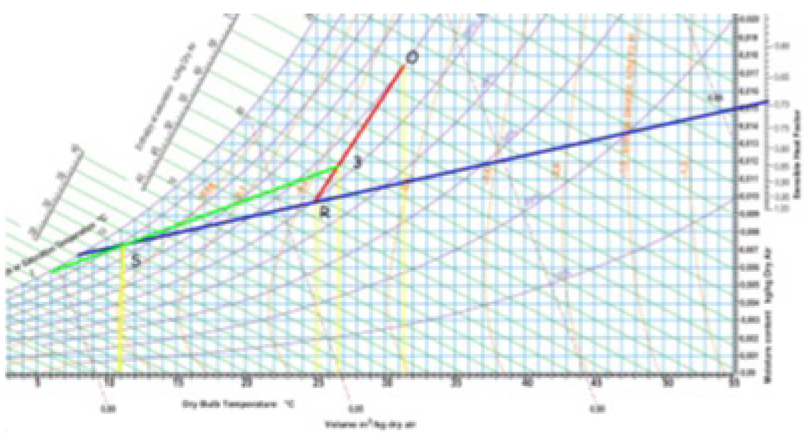

Figure6. Psychrometric process for zone 1 and 2

CONCLUSIONS

Ventilation rates in classrooms often fall far short of the minimum ventilation rates specified in standards. The evidence of an association of increased student performance with increased ventilation rates is compelling. There is evidence of associations of reduced respiratory health effects and reduced student absence with increased ventilation rates. Increasing ventilation rates in schools imposes energy costs and can increase HVAC system capital costs. The net annual costs, ranging from a few dollars to about ten dollars per person, are less than 0.1% typical public spending on elementary and secondary education in the US. Such costs seem like a small price to pay given the evidence of health and performance benefits.

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