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Design and Analysis of Central Air Conditioning System

Ragul Subramanian¹, R.Reejan¹, J. Pravin¹, S. Aakash Kumar¹, K.Robinson²

U.G. Students, Department of Mechanical Engineering, Francis Xavier Engineering College, Vanarpettai, Tirunelveli,
Tamil Nadu, India¹

Associate Professor, Department of Mechanical Engineering, Francis Xavier Engineering College, Vanarpettai,
Tirunelveli, Tamil Nadu, India²

ABSTRACT: The present building of college auditorium posed the problem of ill-ventilated atmosphere and suffocation in most of its part during the programs. Major part of the building exposed to the sun the roof being heated throughout the day. The object of air cooling is to establish a stable thermal environment which satisfies the majority of occupants with respect to comfort under all the climatic conditions to which the building is subjected. Hence it was decided to provide the false ceiling and design air cooling system for college Auditorium for better comforts to the occupants during longer program. For the cooling system of auditorium requires two coolers with water requirement is estimated as 8 lit/sec and power requirement is 120 Watts.

KEYWORDS: Air cooling system, Cooling load estimation, Agricultural, Climatic conditions, Atmosphere.

I. INTRODUCTION

Electricity is used for many parts of a buildings operation the largest uses are lighting and air conditioning. Building energy can be saved and pollution decreased while utility expenditures are minimized if energy conservation measures are incorporated into the design, maintenance and operation of a facility¹. Evaporative cooling is one of the oldest forms of cooling known and has been used by man since 2500 B.C.². Air cooling Provision in building is undergoing a period of rapid expansion. Building cooling load components are; direct solar radiation, transmission load, ventilation/infiltration load and internal load. Calculating all these loads individually and adding them up gives the estimate of total cooling load. The load, thus calculated, constitutes total sensible load.

Normal practice is that depending on the building type certain percent of it is added to take care of latent load. Applying the laws of heat transfer and solar radiation makes load estimations. Step by step calculation procedure has been adequately reported in the literature³. Principles of solar energy calculation are applied to determine the direct and indirect solar heating component of the building. The requisite data of building material, climate conditions and ventilation standard are also established and reported⁴. New types of offices hall planning and making air cooling are an essential element in the total environment design. The object of air cooling is to establish a stable thermal environment which satisfies the majority of occupants with respect to comfort under all the climatic conditions to which the building is subjected.

The building of college auditorium posed the problem of ill-ventilated atmosphere and suffocation in most of its part during the programs. Major part of the building exposed to sun the roof being heated throughout the day. Hence it was decided to provide the false ceiling and design air cooling system for college Auditorium for better comforts to the occupants during longer program.

The one dimensional heat conduction equation in rectangular, spherical and cylindrical coordinates is solved using finite difference technique. The variation of product temperature with time is obtained in dimensionless forms in terms

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of biot number, wet bulb temperature of cooling air and initial product temperature⁵. Factors directly affecting thermal comfort of the human are air temperature, moisture content of the air, radiant exchange and air movement. It is the air cooling engineer's job to decide on the values of these factors, and design a system to maintain them within practical and economical limits. When the outside environment for most of the time (and in some cases continuously) will be hostile to this endeavour.

A wooden duct 8.5m in length and 0.7 m² in constant cross sectional area was characteristics by evaluating its friction coefficient and by measuring its full fan speed air displacement as a function of pressure differential across its upstream and downstream faces. The duct was then tested for air flow distribution for aperture ratios (total outlet area of duct cross sectional area) of 0.5, 1.0, 1.5, and 2.0 at full fan speed and at various fan speeds for a constant outlet area of 0.17m²

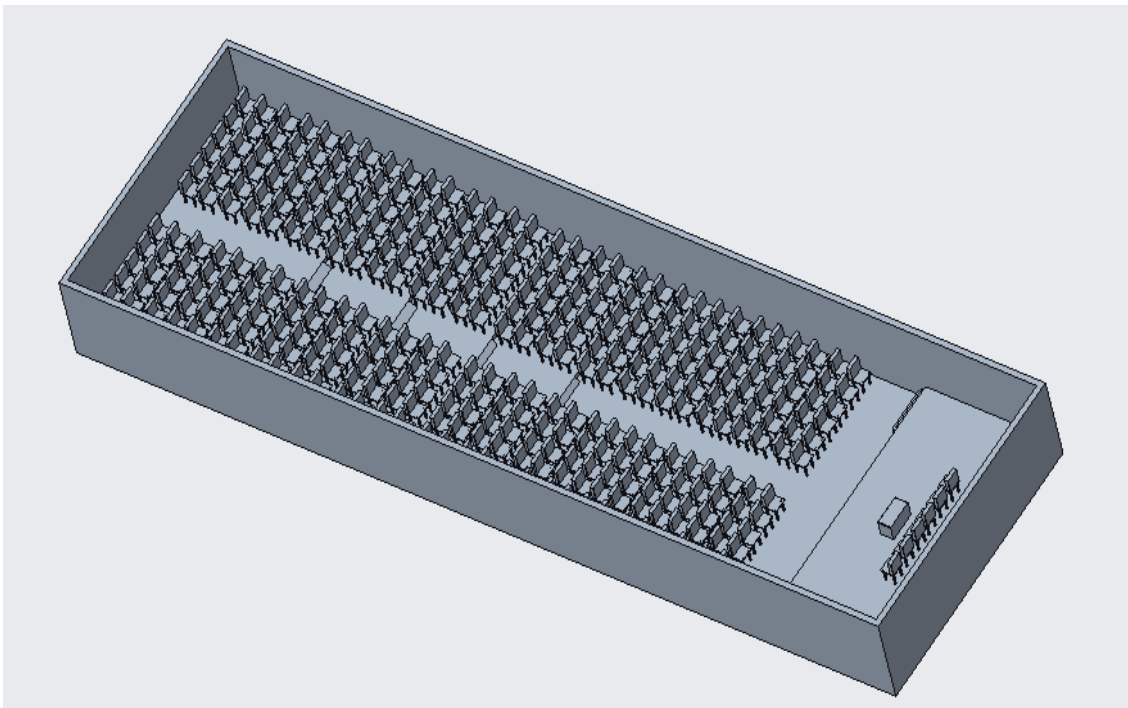


Fig. 1 : Isometric view of Auditorium

II. MATERIALS AND METHODS.

Five factors to be considered in selection and design of evaporative cooling system

Air supply and exhaust

The air should be picked up at lowest possible DBT and WBT so as to get maximum benefit from the evaporative cooling system. Point of exhaust from the room should be at roof level to pick up hot air and eject it outside, up and away from the cooler intake to permit maximum efficiency from the unit. Evaporative cooling provides cool, fresh, filtered air to work space. The design air change rate necessary to cool the plant depends on heat generated and work activity level.

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Air motion

It is necessary to provide adequate means for moving air out of the conditioned space when designing an evaporative air cooling system. Air must move through and out of building as quickly as possible. An evaporative cooling system proves unsatisfactory when it is found inability to move air out as rapidly as the cooler brings air in. Cooler capacity and installation Excess cooler capacity is not a matter of concern because an evaporative cooler cannot cool below WBT. Cooler installation planning starts with the consideration of the structural strength of the mounting pad. Another basic importance is the need for access for regular service as periodical cleaning of cooler pads and spray heads is essential. Coolers should be located where it can draw an uncontaminated free air from outdoor.

Duct work

Duct work should be kept short; there is little need for reduction of duct area as branches take off. An arbitrary rule is to limit duct length 15m as a practical measure for simplicity. In large spaces where longer air to separate zones that can be served with short duct runs.

Cleaning of the system

The maintenance procedure used in evaporative cooling system is simple, wood excelsior pads must be replaced after every year as they deteriorate. Water spray heads should be cleaned and checked once or twice in the course of a cooling season. The growth of the algae in evaporative cooler rapidly plugs the holes of nozzles and also creates sources of undesirable odour and possibly corrosion. The outside summer condition for Tirunelveli are DBT are 46 °C and 18% relative humidity its conditions shall be considered in the design of an evaporative cooling system for the auditorium

Air distribution system

The supply air must be delivered at the proper combination of temperature, humidity and air motion in proper place and proper amount with most comfort to the human or occupants. In this system that deliver conditioned supply air to the spaces through the flow channels called duct. In addition to control in temperature and humidity air must be filtered to remove dust, pollutants, and other objectionable particles and odour. Removal is a problem in some installations.

The following three points are preferred in air distribution system

1. Flow direction of air toward the face of the people is preferred instead of back or side.
2. Downward flow is preferable over upward flow.
3. The temperature of conditioned air may be above or below of the air in the occupied zone.

The main components of air distribution system are:

1. The fan, also called as air handling unit
2. Duct work
3. Terminal distribution equipment, diffuser, grilles registers etc.
4. Accessories such as dampers, turning vanes, equalizing, grilles, canvas of flexible connections.

III. RESULT

Load Estimation

Following are the factors which add to the room environment in the form of sensible heat.

1. Solar and transmission heat gain through walls and roofs etc.
2. Solar and transmission heat gain through doors, windows or wall glasses.
3. Transmission gain through partition wall ceiling floor etc.

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4. Infiltration of direct air from some inlets like doors or windows.
5. Internal heat gain from occupants, light appliances etc.
6. Additional heat gain not accounted above, safety factors etc.
7. Return duct heat gains, supply duct leakage, heat gain from door, fan and pump.

Solar heat load from walls and roof

For summer conditions the design recommendations for assembly place are 23°C dry bulb temperature 60% relative humidity (Arora and Donkundwar, 1994) Condition in summer for air cooling design in Akola which includes outdoor Dry Bulb Temperature (DBT), Wet Bulb Temperature (WBT) and Relative Humidity (RH) are 46 °C, 23.2 °C and 18% respectively. Indoor DBT, WBT and RH are 34 °C, 23.2 °C and 60% respectively. Outdoor minimum temperature is assumed as 32 °C. Daily temperature range, $td=T_0(\max)T_i(\min)$ calculated value is 14 °C (46-32) and room temperature difference is 12 °C (46-34). Dimensions of walls of auditorium was measured and area was calculated east (61.94 m²), west (64.87 m²), north (56.96 m²), south (64.87 m²).

Overall heat transfer coefficient (U)

Thickness of Brick wall (L_b):450 mm, Slab wall (L_c):120 mm, Floor concrete (L_f):200 mm, Plaster (L_p):25 mm. Thermal conductivity of Brick (K_b):1.32 W/mK, Concrete (K_c):1.73W/mK, Plaster (K_p):8.65 W/mK. Surface heat transfer coefficient of Brick wall outside (h_{wo}):2.3 W/m²K, Brick wall inside (h_{wi}):3.5 W/m²K, floor outside (h_{fo}):1.5 W/m²K and floor inside(h_{fi}):4.4 W/m²K. Overall heat transfer coefficient can be computed by using following formula: where U is the overall heat transfer coefficient,

$$\frac{1}{U} = \frac{1}{h_o} + \frac{L_1}{K_1} + \frac{L_2}{K_2} + \dots + \frac{1}{h_1}$$

L1, L2 etc, are thickness of respective thermal conductivities, h_o is outside surface heat transfer coefficient, h_1 is Inside surface heat transfer coefficient .

Table. 1 shows that the calculated overall heat transfer coefficients for different building component in W/m²K are outside of wall (1.47), inside of wall (1.08), floor (0.99) and roof (1.12) using wall thickness and surface heat transfer coefficient. This table also shows the solar heat gain in watts by the walls and roof of the auditorium it is estimated as 5519.6 watts which used to calculate total heat lost by the auditorium. Occupancy load and lighting heat In addition to the solar heat load, the heat is added by the occupants and equipments in the hall. Occupants liberate heat 77 W and 113 W when seating at rest and dancing on the stage respectively at 23.2 °C DBT. Fluorescent light add heat load 1.25 times their wattage3.

Table 1 : Computation of solar gain through different walls of auditorium

Hall	Wall location	Area m ²	Equivalent temperature difference, °C	Factor 'U' W/m ² K	Heat gain (Q), watt
Auditorium	East	61.94	12.25	1.08819.5	
	West	64.87	5.34	1.47	509.2
	North	56.96	2.25	1.08	138.4
	South	64.87	2.25	1.08	157.6
	Roof	169	18.81	1.12	3560.3
	Floor	169	2	0.99	334.6
	Total				

when seating at rest and dancing on the stage respectively at 23.2 °C dbt. fluorescent light add heat load 1.25 times their wattage3.

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Appliances load

The appliances like electric fans heaters, refrigerators, mixers, gas ovens are the main heat generators, the ratio of actual wattage to the installed wattage is known as use factor. therefore, $q = kw * \text{use factor}$. the values of use factor for residential, commercial stores and shops are usually taken as one.

Safety factor

It is strictly a factor of probable error in the estimation of the load. for this purpose additional 10% heat should be added to the room sensible heat.

Table. 2 shows that the total heat liberated by the solar heat gain, occupancy load and equipment load 21828 watts. table also shows the total load in tonnage including 10% factor of safety is estimated as 7.06.

Table 2 : Total heat loss of auditorium

S/N	Item	Quantity/Number	Heat liberated, W Per unit	Total
1	Auditorium	-	-	5520
	Solar Gain			

Calculation for Duct Design

Supply Air Temperature :

$$\begin{aligned}
 t_s &= DBT_{out} - n_H(DBT_{out} - WBT) \\
 &= 46 - 0.875 \times (46 - 23.2) \\
 &= 26.05 \text{ } ^\circ\text{C}
 \end{aligned}$$

Where,

n_H have taken average of adiabatic efficiency (100, 95, 90, 85, 80 and 75)

Volumetric flow rate of air (m³/min) :

$$\begin{aligned}
 V_a &= Q / [0.0204(t_1 - t_2)] \\
 &= 24.611 / [0.0204 \times (34 - 26.05)] \\
 &= 150.42 \text{ m}^3/\text{min} \\
 &= 2.50 \text{ m}^3/\text{sec}
 \end{aligned}$$

Two coolers will provide for auditorium with 1.25m³/s air flow rate each. Considering the volume flow rate and velocity of air friction losses in the duct and duct size was worked out from the friction chart. Air velocities were considered 5m/s in main duct and 4 m/s in branch duct. After adding the frictional losses from different ducts attached to a single cooler. The power requirement for each cooler was found to be 1 hp considering the total air flow rate (Table 3).

Table 3 : Specification of distribution duct in auditorium

S/N	Component and Location	V _a , m ³ /s	v, m/s	F, mm/m	L, m	F _{total} mm	Req. D,mm
	North-West Side						
1	Main duct from cooler to wall	1.25	5.0	0.50	2.0	1.00	550
2	Duct from wall to false ceiling	0.75	5.0	0.65	2.0	1.30	440
3	Duct from false ceiling	0.75	5.0	0.65	9.0	5.40	440

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	to stage						
4	Down take near stage	0.50	4.0	0.44	2.0	0.33	400
5	Down take near entrance door.	0.50	4.0	0.44	2.0	0.88	400
6	Down take on stage	0.25	4.0	0.70	3.0	2.10	280
	South-East Side						
1	Main duct from cooler to false ceiling	1.25	5.0	0.50	3.0	1.50	550
2	Duct from false ceiling to the junction	1.25	5.0	0.50	3.6	1.80	550
3	Duct on false ceiling from junction to stage	0.75	5.0	0.65	9.8	5.88	440
4	Down take near stage	0.50	4.0	0.44	2.0	0.88	400
5	Duct from junction to entrance door and down take	0.50	4.0	0.44	4.8	2.19	400
6	Down take on stage	0.25	4.0	0.70	3.0	2.10	280

Where,

- V_a - Volumetric flow rate, m³/s,
- V - Velocity of Air, m/s,
- F - Friction loss, mm/m,
- L - Duct length, m ,
- F_{total} - Total friction loss, mm,
- Req. D_l - Required duct diameter, mm

Pump design

Moisture content from the psychrometric chart are indicated as :

W₁ = 10.7g/kg at 46 DBT and 18% RH, W₂ = 17.0 g/kg at 34 DBT and 50% RH. Assuming total water head = 1.0 m, Overall efficiency of pump $\eta = 75\%$ Specific Weight of water = 1000 kg/m³, For auditorium Water requirement Q_w is given by

$$\begin{aligned}
 Q_w &= \eta(W_2 - W_1)/1000 \\
 &= 75 (17.0 - 10.7)/1000 \\
 &= 0.47 \text{ m}^3/\text{min}
 \end{aligned}$$

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= 7.87 lit/sec Say 8 lit/sec.

$$\begin{aligned}\text{Power requirement} &= Q_w \times H / (75 \times \eta) \\ &= 7.8/7 \times 1.0 / (75 \times 0.75) \\ &= 0.14 \text{ hp} = 120 \text{ W}.\end{aligned}$$

So for the cooling system of auditorium requires two coolers with water requirement as 8 lit/sec and power requirement is 120 Watts.

IV. CONCLUSION

Climate change and energy waste e increasing the entropy of the system e are among the largest problems facing the world today [1,2]. This HVAC system is considered to be one of the most promising energy saving systems with a low life cycle cost. This paper provides an essential framework of designing the load calculation to the component sizing. For comfort conditioning, the reduction in trunk method for the duct sizing gives most appropriate flow rates for the conditioned air giving proper cooling in the summer. Most importantly, the best HVAC systems cannot be designed according to the design of a building, but the building has to be designed with respect to the HVAC systems.

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