Design of an Air Conditioning System for a Laboratory- A Case Study

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Abstract

Comfort Air-conditioning is a process of controlling the air temperature, relative humidity, ventilation, air movement and air cleanliness of a given space in order to provide the occupants with a comfortable indoor temperature. Today air conditioning and refrigeration industry in India are able to meet the country’s entire requirements both for domestic and industrial applications. It has achieved the self-sufficiency in almost all the respects. The present task deals with the design an air conditioning unit for an engineering college laboratory. Also it deals with the selection of economical air conditioning system. The infiltration through doors and windows were reduced by providing proper insulations to all doors and windows. The cooling load was reduced by about 30% to 50% by sealing the control room and thereby reducing cost of plant. Ventilation was provided by adding 75% of re-circulated air from control room to 25% of fresh outside air. The entire conditioned air is delivered to control room through sheet metal ducts. Unitary type of system was preferred because it has the advantage of moderate initial cost.

Keywords: Air-conditioning, Infiltration, Ducts, Cooling load.

1. INTRODUCTION

Comfort Air-conditioning is a process of controlling the air temperature, relative humidity, ventilation, air movement and air cleanliness of a given space in order to provide the occupants with a comfortable indoor temperature whereas Air conditioning system consists of a group of components or equipment connected in series to control the environmental parameters [1]. Indian engineers had confidently tackled any complicated problem in the design of refrigeration and air-conditioning equipments used for different purposes. They have proved their competence by successfully designing complicated jobs like cooling system for dairy milk chilling units, railway air conditioning, quick freezing plants for fish and deep freezers for storage of fish, air conditioning and refrigeration system for ships and many other applications [6].

Today air conditioning and refrigeration industry in India are able to meet the country’s entire requirements both for domestic and industrial applications. It has achieved the self-sufficiency in almost all the respects. It has built on infrastructure that is envy of any other developing nation. However, the current paper deals with the design of an air conditioning unit for an engineering college laboratory.

2. METHODOLOGY (ACTUAL DESIGN CALCULATION):

The two kinds of heat plays important role in the design of air conditioning unit, those are sensible and latent heat. Let us discuss about them.

2.1 Sensible Heat (QS): Sensible heat is an expression of the degree of molecular excitation of a given mass. Such excitation can be caused by a variety of sources, such as exposure to radiation, friction between two objects, chemical reaction, or contact with a hotter object. When the temperature of a substance changes, it is the heat content of the object that is changing. Every material has a property called its specific heat, which identifies how much its temperature changes due to a given input of sensible heat. The three means of transferring sensible heat are radiation, convection, and conduction. Generally all bodies emit thermal radiation.

2.2 Latent Heat (LS): Heat that changes the state of matter from solid to liquid or liquid to gas is called latent heat. The latent heat of fusion is that which is needed to melt a solid object into a liquid. A property of the material, it is expressed per unit mass (per pound or per kilogram). The latent heat of vaporization is the heat required to change a liquid to a gas. When a gas liquefies (condenses) or when a liquid solidifies, it releases its latent heat.

2.3 Enthalpy: It is the sum of the sensible and latent heat of a substance. For example, the air in our ambient environment is actually a mixture of air and water vapor. If the total heat content or enthalpy of air is known, and the enthalpy of the desired comfort condition is also known, the difference between them is the enthalpy or heat that must be added (by heating and humidification) or removed (by cooling and dehumidification).

As the present task is to design an air conditioning unit for an engineering college laboratory. The following figure explains the same.
The details of laboratory (room) are as follows:
Outdoor design conditions: - 40°C Dry bulb temperature (DBT), 27°C Wet bulb temperature.
Inside design conditions: - 22°C Dry bulb temperature (DBT), 50% Relative humidity (R.H).
Apparatus dew point temperature of the coil (ADPT): - 10°C Dry bulb temperature (DBT).
By referring all above conditions, we need to determine the quantity of supplied air to the room, amount of reheat required, DBT and WBT of air entering apparatus and air leaving the apparatus.

2.4 Actual design calculation:-
- Sensible heat factor for the room (SHF) = QS / QS + LS = 25 / 25 + 20 = 0.55
- Properties at all the points:  
  - $h_a = 65$ kJ/kg, $h_b = 43$ kJ/kg, $h_d = 29.5$ kJ/kg,
  - $h_e = 39.5$ kJ/kg, $T_d = 110$ C, $T_e = 200$ C.
- Amount of reheat = $T_e - T_d = 90$ C.
- Amount of heat supplied in a heater = $m_a (h_e - h_d) = 128.6$ KW.
- Total heat carried from: $QS + LS = 45KW$.
- Heat carried = $m_a (h_b - h_e) = 12.86$ KW.
- The condition of air entering the cooling apparatus at point “a” where DBT & WBT is 40 & 27°C.
- The condition of air entering the cooling apparatus at point “d” $T_d = 110$ C, R.H =95%.
- The supply air condition to laboratory is represented at point “e”
  Therefore, $T_{de}= 200$ C, R.H =52%

2.5 Classification of air conditioning systems:
- An individual system uses a small, self-contained factory-assembled refrigeration system that uses a coil to cool air.
- A packaged system always has a refrigeration system that uses a DX-coil to cool air directly.
- A central system has a refrigeration system that uses chilled water as a cooling medium to cool air indirectly.
In addition, in order to designate an air conditioning system more clearly and correctly, the main characteristics of its air system may be added to the description of its basic category (that is, individual, packaged, or central). More clearly specified terminology for an air conditioning system with a designated air system and primary cooling and heating plant is a combination of items from two or three of the following columns:-

<table>
<thead>
<tr>
<th>Air system</th>
<th>Refrigeration</th>
<th>Air conditioning system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant volume</td>
<td>Centrifugal</td>
<td>Central system</td>
</tr>
<tr>
<td>Fan-coil</td>
<td>Reciprocating</td>
<td>Rooftop packaged system</td>
</tr>
<tr>
<td>Single-zone VAV</td>
<td>Screw</td>
<td>Indoor packaged system</td>
</tr>
<tr>
<td>Perimeter-heating VAV</td>
<td>Scroll</td>
<td>Split packaged system</td>
</tr>
<tr>
<td>VAV reheat</td>
<td>Absorption</td>
<td>Rooftop heat pump system</td>
</tr>
<tr>
<td>Dual-duct VAV</td>
<td>Gas cooling</td>
<td>Split heat pump system</td>
</tr>
<tr>
<td>Fan-powered VAV</td>
<td>Desiccant evaporative</td>
<td>Water-loop heat pump system</td>
</tr>
</tbody>
</table>

2.6 Air Conditioning System Selection:
When considering and selecting an air conditioning system, the designer must understand the building and the client’s requirements and try to study and evaluate the following factors:
- Building location, surrounding environment and external climate.
• Uses and functional requirements of the building.
• Client’s budget, investment policy and expected quality of service.
The designer should consider various system options and recommend one or several that will be likely to perform as desired. Some of the selection criteria include:
• Performance requirements– on comfort, noise, control options, flexibility and meeting requirements of local regulations/codes.
• Capacity requirements– range of capacity, multiple units, zoning, etc.
• Spatial requirement– plant room space, space for ducting and piping (vertical shafts), Space for terminal equipment.
• Costs– initial cost, operating cost and maintenance cost.
• Energy consumption – for both economic and environment reasons.
• System qualities– e.g. aesthetics, life, reliability and maintainability.
However for the present work unitary air conditioning system is selected.

3. CONCLUSIONS:
The load calculations and equipment selection calculations have been done keeping in view all the practical aspects of design. The infiltration through doors and windows were reduced by providing proper insulations to all doors and windows. The cooling load was reduced by about 30% to 50% by sealing the control room and thereby reducing cost of plant. Ventilation was provided by adding 75% of re-circulated air from control room to 25% of fresh outside air. The entire conditioned air is delivered to control room through sheet metal ducts. Unitary type of system was preferred because it has the advantage of moderate initial cost.

References

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