Revised Study Material

For GATE – PSU

Mechanical Engineering

Refrigeration and Air Conditioning

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REFRIGERATION
&
AIR CONDITIONING

CHAPTER 5 AIR-CONDITIONING

COOLING LOAD ESTIMATE

a. ROOM SENSIBLE HEAT (RSH)
   - I) Solar and transmission heat gain through walls, roofs etc.
   - II) Solar and transmission heat gain through glass.
   - III) Transmission gain through partition walls, ceiling etc.
   - IV) Infiltration
   - V) Internal heat gain from people, power, lights etc.
   - VI) Additional heat gain not accounted above.
   - VII) Supply duct heat gain, supply heat leakage loss and fan horsepower.
   - VIII) Bypassed outside air load.

Sum of all these give Effective Room Sensible Heat (ERSH)

b. ROOM LATENT HEAT (RLH)
   - I) Infiltration
   - II) Internal heat gain from people, steam etc.
   - III) Vapour transmission
   - IV) Additional heat gain not accounted above
   - V) Supply duct leakage loss
   - VI) Bypass outside air load

The sum of all these gives the Effective Room Latent Heat (ERLH)

GRAND TOTAL LOAD ON AIR-CONDITIONING SYSTEM

A. Sensible Heat
   - I) Effective room sensible heat
   - II) Sensible heat of the outside air that is not bypassed.
   - III) Return duct heat gain

Sum of all these gives the Total Sensible Heat (TSH)

B. Latent heat
   - I) Effective room latent heat
   - II) Latent heat of outside air which is not bypassed.
   - III) Return duct leakage gain

Sum of all these gives the Total Latent Heat (TLH)

Sum of A and B gives Grand Total Heat (GTH)

HEATING LOAD ESTIMATE

Heat load estimate is made on the basis of the maximum probable heat loss of the room or space to be heated

I) Transmission heat loss
Transmission heat loss through wall and roof etc. is calculated on the basis of just the design outside and inside air temperature difference.

$$Q = UA(t_i - t_o)$$

II) Solar radiation
There is no solar heat gain at the time of peak load which normally occurs in early hours of morning.

III) Internal heat gains
It is the heat gain from occupants, lights , motor and machinery etc. diminish the heat requirement.

Bypassed outside air loads on the room are:

$$SH = (OASH)(BPF)$$
$$LH = (OALH)(BPF)$$

Effective room sensible heat

$$ERSH = RSH + (OASH)(BPF)$$

Effective room latent heat

$$ERLH = RLH + (OALH)(BPF)$$

The effective sensible heat factor (ESHF) is the ratio of the effective room sensible heat to the effective room total heat.

$$ESHF = \frac{ERSH}{ERSH + ERLH} = \frac{ERSH}{ERTH}$$

INTERNAL HEAT GAINS

1. OCCUPANCY LOAD
   The occupants in a conditioned space give out heat at metabolic rate that more or less depends on their rate of working. The relative proportion of sensible and latent heats given out depends upon the ambient dry bulb temperature.
2. LIGHTING LOAD

Electric lights generate heat equal to the amount of electric power consumed. Most of the energy is liberated as heat and the rest is liberated as light which also becomes heat after multiple reflections.

3. APPLIANCES LOAD
Most appliances contribute both sensible and latent heats. The latent heat produced depends upon the function the appliances perform. Electric motors contribute sensible heat to the conditioned space.

SYSTEM HEAT GAINS

1. SUPPLY AIR DUCT HEAT GAIN AND LEAKAGE LOSS
Supply air has a temperature lower than the ambient temperature. If the duct passes through such a unconditioned space having ambient temperature, a significant heat gain will occur till the air reaches the conditioned space.
2. HEAT GAIN FROM AIR CONDITIONING FAN
The heat equivalent of an air-conditioning fan horsepower is added as the sensible heat to the system. If the fan motor is outside the air stream, the energy loss due to the inefficiency of the motor is not added to air.
3. RETURN AIR DUCT HEAT AND LEAKAGE GAIN
Heat gain for return duct is done in exactly the same way as for supply air ducts. But the leakage in this case is that of the hot and humid outside air into duct because of suction within the duct.
4. HEAT GAIN FROM DEHUMIDIFIER PUMP AND PIPING
The horsepower required to pump water through the dehumidifier adds heat to the system and is to be considered like that of other electric motor.
5. SAFETY FACTOR
Safety factor is strictly a factor of probable error in the estimation of load.

HEAT TRANSFER THROUGH WALLS AND ROOFS

Heat transfer through the walls and roofs of building structures is not steady and difficult to evaluate. This is due to variation of outside temperature and also in the variation of solar radiation intensity. The combined effectof these temperatures can be incorporated into a singleeffectivetemperature.

The governing equation will be unsteady state one dimensional heat transfer

$$\frac{\partial t}{\partial \tau} = \alpha \frac{\partial^2 t}{\partial x^2}$$

Where t = temperature at any section of the wall at a distance x from the surface at any time τ.

SOL-AIR TEMPERATURE

An expression for rate of heat transfer from the environment to the outside surface of the wall may be written as

$$q_0 = f_o(t_0 - t_{s0}) + aI$$

f_o = the outside film coefficient
t_{s0} = temperature of the outside surface
a = absorptivity of the surface
I = the total radiation intensity

Introducing an equivalent temperature,

$$q_0 = f_o(t_e - t_{s0})$$

From the two equations

$$t_e = t_0 + \frac{aI}{f_o}$$

Where t_e = sol-air temperature and can be considered as an equivalent outside air temperature such that the total heat transferred is same as due to the combined effect of the incident solar radiation and outside air and the wall temperature difference.

SUMMMER AIR CONDITIONING

In summer, outside air temperature and humidity are both high. The room gains heat as well as moisture. It is thus required to cool and dehumidify the recirculated room air in the air conditioning apparatus either by the use of a cooling coil or by using air washer in which chilled water is sprayed. The process follows the room sensible heat factor (RSHF).

$$RSHF = \frac{RSH}{RSH + RLH} = \frac{RSH}{RTH}$$

The temperature at which the RSHF line intersects the saturation curve is called room apparatus dew point (Room ADP).

WINTER AIR CONDITIONING

In winter, the building sensible heat losses are partially compensated by the solar heat gains and the internal heat gains. The latent heat loss due to low outside air humidity is more or less offset by the latent heat gain from occupancy. Hence heating load is likely to be less than the cooling load in summer. However, the actual situation both in summer and winter depends upon the swing of the outside temperature and humidity with respect to the inside conditions.

The process in the conditioning apparatus for winter air conditioning for comfort involve heating and humidifying.

Two of the typical process combinations are:

i. Preheating the air with steam or hoot water in a coil followed by adiabatic saturation and reheat.
ii. Heating and humidifying air in air washer with pumped recirculation and external heating of water followed by reheat.

YEAR –ROUND AIR-CONDITIONING SYSTEM

It should have equipment for both the summer and the winter air-conditioning. The outside air flows through the dampers and mixes up with the recirculated air. The mixed air passes through a filter to remove dirt, dust and other impurities. In summer cooling coil operates to cool the air to a desired value. The dehumidification is obtained by operating the cooling coil at a temperature lower than the dew point temperature. In winter, the cooling coil is made inoperative and the heating coil operates to heat the air. The spray type humidifier is also made use in the dry season to humidify the air.

CENTRAL AIR CONDITIONING

This is the most important type of air-conditioning system, which is adopted, when the cooling capacity required is 25 TR or more. The central air conditioning is adopted when the air flow is more than 300 m^3/min or different zones in a building to be air conditioning.

INDUSTRIAL AIR CONDITIONING

There are various categories of applications requiring varying load standards of inside design conditioning. One category comprises those where constancy of temperature is the prime consideration. Other category may be where the relative humidity is to be kept constant at high value. There is still another category of applications where strict control of both temperature and relative humidity are required.

COMFORT AIR CONDITIONING

There is a problem of measuring comfort in terms of a single parameter which would include all of the three parameters governing comfort i.e. air temperature, humidity and air velocity in addition to air purity. Often a single parameter called the effective temperature is used as an index of comfort.

Effective temperature ET is defined as that temperature of saturated air at which the subject would experience the same feeling of comfort as experienced in the actual unsaturated environment.

Another effective temperature may be defined as the temperature at 50% RH at which the subject would experience exactly same feeling of comfort as at ET at 100% RH.

At lower humidities, the DBT's of the air can be higher for the same ET and for the same feeling of comfort. Thus at a higher DBT, the body would lose more heat in form of latent heat. Sn increase in temperature can also be compensated by an increase in velocity.

Factors affecting the effective temperature:

1. Climatic and seasonal differences
2. Clothing
3. Age and sex
4. Duration of stay
5. Kind of activity
6. Density of occupants