AI3001 REFRIGERATION AND COLD STORAGE

UNIT V

Sensible heat

Heat which a substance absorbs, and while its temperature goes up, the substance does not change state. Sensible heat gain is directly added to the conditioned space by conduction, convection, and/or radiation. Note that the sensible heat gain entering the conditioned space does not equal the sensible cooling load during the same time interval because of the stored heat in the building envelope. Only the convective heat becomes cooling load instantaneously. Sensible heat load is total of a. Heat transmitted thru floors, ceilings, walls b. Occupant's body heat c. Appliance & Light heat d. Solar Heat gain thru glass e. Infiltration of outside air f. Air introduced by Ventilation

Latent Heat Loads

Latent heat gain occurs when moisture is added to the space either from internal sources (e.g. vapor emitted by occupants and equipment) or from outdoor air as a result of infiltration or ventilation to maintain proper indoor air quality. Latent heat load is total of

a. Moisture-laden outside air form Infiltration & Ventilation

b. Occupant Respiration & Activities

c. Moisture from Equipment & Appliances

 To maintain a constant humidity ratio, water vapor must condense on cooling apparatus at a rate equal to its rate of addition into the space. This process is called dehumidification and is very energy intensive, for instance, removing 1 kg of humidity requires approximately 0.7 kWh of energy

Space Cooling V/s Cooling Load (Coil)

Space cooling is the rate at which heat must be removed from the spaces to maintain air temperature at a constant value. Cooling load, on the other hand, is the rate at which energy is removed at the cooling coil that serves one or more conditioned spaces in any central air conditioning system. It is equal to the instantaneous sum of the space cooling loads for all spaces served by the system plus any additional load imposed on the system external to the conditioned spaces items such as fan energy,

fan location, duct heat gain, duct leakage, heat extraction lighting systems and type of return air systems all affect component sizing.

COMPONENTS OF COOLING LOAD

The total building cooling load consists of heat transferred through the building envelope (walls, roof, floor, windows, doors etc.) and heat generated by occupants, equipment, and lights. The load due to heat transfer through the envelope is called as external load, while all other loads are called as internal loads. The percentage of external versus internal load varies with building type, site climate, and building design. The total cooling load on any building consists of both sensible as well as latent load components. The sensible load affects the dry bulb temperature, while the latent load affects the moisture content of the conditioned space.

Buildings may be classified as externally loaded and internally loaded. In externally loaded buildings the cooling load on the building is mainly due to heat transfer between the surroundings and the internal conditioned space. Since the surrounding conditions are highly variable in any given day, the cooling load of an externally loaded building varies widely. In internally loaded buildings the cooling load is mainly due to internal heat generating sources such as occupants, lights or appliances. In general the heat generation due to internal heat sources may remain fairly constant, and since the heat transfer from the variable surroundings is much less compared to the internal heat sources, the cooling load of an internally loaded building remains fairly constant. Obviously from energy efficiency and economics points of view, the system design strategy for an externally loaded building should be different from an internally loaded building. Hence, prior knowledge of whether the building is externally loaded or internally loaded is essential for effective system design.

Sources of Cooling Load
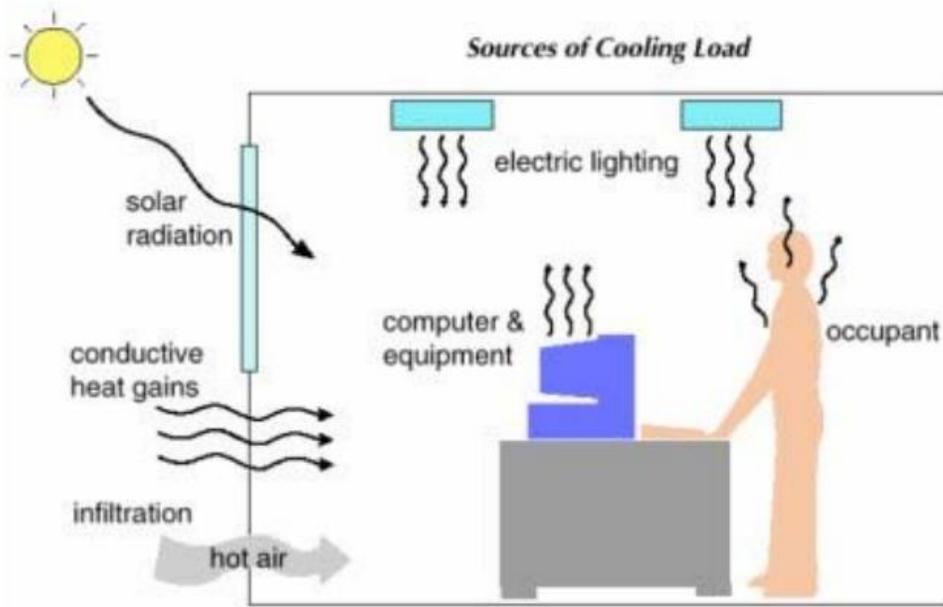
COOLING LOAD CALCULATION METHOD

For a thorough calculation of the zones and whole-building loads, one of the following three methods should be employed:

a. Transfer Function Method (TFM): This is the most complex of the methods proposed by ASHRAE and requires the use of a computer program or advanced spreadsheet.

b. Cooling Load Temperature Differential/Cooling Load Factors (CLTD/CLF): This method is derived from the TFM method and uses tabulated data to simplify the calculation process. The method can be fairly easily transferred into simple spreadsheet programs but has some limitations due to the use of tabulated data.

c. Total Equivalent Temperature Differential/Time-Averaging (TETD/TA): This was the preferred method for hand or simple spreadsheet calculation before the introduction of the CLTD/CLF method.

Building Characteristics

To calculate space heat gain, the following information on building envelope is required: a. Architectural plans, sections and elevations – for estimating building dimensions/area/volume b. Building orientation (N, S, E, W, NE, SE, SW, NW, etc), location etc c. External/Internal shading, ground reflectance etc. d. Materials of

construction for external walls, roofs, windows, doors, internal walls, partitions, ceiling, insulating materials and thick nesses, external wall and roof colors - select and/or compute U-values for walls, roof, windows, doors, partitions, etc. Check if the structure is insulated and/or exposed to high wind. e. Amount of glass, type and shading on windows

Operating Schedules

Obtain the schedule of occupants, lighting, equipment, appliances, and processes that contribute to the internal loads and determine whether air conditioning equipment will be operated continuously or intermittently (such as, shut down during off periods, night set-back, and weekend shutdown).

Gather the following information: • Lighting requirements, types of lighting fixtures • Appliances requirements such as computers, printers, fax machines, water coolers, refrigerators, microwave, miscellaneous electrical panels, cables etc • Heat released by the HVAC equipment. • Number of occupants, time of building occupancy and type of building occupancy

COOLING LOAD METHODOLOGY – CONSIDERATIONS & ASSUMPTIONS

Design cooling load takes into account all the loads experienced by a building under a specific set of assumed conditions. The assumptions behind design cooling load are as follows: a. Weather conditions are selected from a long-term statistical database. The conditions will not necessary represent any actual year, but are representative of the location of the building. ASHRAE has tabulated such data.

a. Weather conditions are selected from a long-term statistical database. The conditions will not necessary represent any actual year, but are representative of the location of the building. ASHRAE has tabulated such data.

b. The solar loads on the building are assumed to be those that would occur on a clear day in the month chosen for the calculations.

c. The building occupancy is assumed to be at full design capacity.

d. The ventilation rates are either assumed on air changes or based on maximum occupancy expected.

e. All building equipment and appliances are considered to be operating at a reasonably representative capacity.

f. Lights and appliances are assumed to be operating as expected for a typical day of design occupancy.

g. Latent as well as sensible loads are considered.

h. Heat flow is analyzed assuming dynamic conditions, which means that heat storage in building envelope and interior materials is considered.

i. The latent heat gain is assumed to become cooling load instantly, whereas the sensible heat gain is partially delayed depending on the characteristics of the conditioned space.

CLTD/SCL/CLF METHOD OF LOAD CALCULATION (ASHRAE FUNDAMENTALS 1997)

As mentioned before, the heat gain to the building is not converted to cooling load instantaneously. CLTD (cooling load temperature difference), SCL (solar cooling load factor), and CLF (cooling load factor): all include the effect of (1) time-lag in conductive heat gain through opaque exterior surfaces and (2) time delay by thermal storage in converting radiant heat gain to cooling load. This approach allows cooling load to be calculated manually by use of simple multiplication factors.

a. CLTD is a theoretical temperature difference that accounts for the combined effects of inside and outside air temp difference, daily temp range, solar radiation and heat storage in the construction assembly/building mass. It is affected by orientation, tilt, month, day, hour, latitude, etc. CLTD factors are used for adjustment to conductive heat gains from walls, roof, floor and glass.

b. CLF accounts for the fact that all the radiant energy that enters the conditioned space at a particular time does not become a part of the cooling load instantly. The CLF values for various surfaces have been calculated as functions of solar time and orientation and are available in the form of tables in ASHRAE Handbooks. CLF

factors are used for adjustment to heat gains from internal loads such as lights, occupancy, power appliances.

c. SCL factors are used for adjustment to transmission heat gains from glass.

External Cooling Load

As discussed before, the total cooling load on a building consists of external as well as internal loads. The external loads consist of heat transfer by conduction through the building walls, roof, floor, doors etc, heat transfer by radiation through fenestration such as windows and skylights. All these are sensible heat transfers.

ROOF

The basic conduction equation for heat gain is $q = U A \Delta T$

- q = Heat gain in Btu/hr

- U = Thermal Transmittance for roof in Btu/hr.ft².°F

- A = area of roof in ft^2

- ΔT = Temperature difference in °F

The heat gain is converted to cooling load using the room transfer functions (sol-air temperature) for the rooms with light, medium and heavy thermal characteristics. The equation is modified as

$Q = U * A * (CLTD)$ Where

- Q = cooling load, Btu/hr

- U = Coefficient of heat transfer roof or wall or glass, Btu/hr.ft².°F

- A = area of roof, ft^2

- CLTD = cooling load temperature difference °F. The values are determined from tables available in chapter 28 of AHSRAE fundamentals handbook.

Since the ASHRAE tables provide hourly CLTD values for one typical set of conditions i.e. outdoor maximum temperature of 95°F with mean temperature of 85°C and daily range of 21°F, the equation is further adjusted to apply correction factors for conditions other than the mentioned base case.

Thus, $Q \text{ Roof} = U * A * CLTD$

The typical steps to calculate the Roof load are as follows:

Step #1 Determine roof construction and overall heat transfer coefficient (U) (Chapter 28 ASHRAE 1997, Table A24-4, A29-5)

Step #2 Select roof no. from ASHRAE Table 31 or Text table 7-34 which is closest to matching actual roof construction.

Step #3 Select CLTD Roof for time of interest, typically on an hourly basis (Chapter 28 ASHRAE Table A28-32, A28-34). Step #4 Corrections: Values on tables are for

a. Four latitudes on July or August

b. Indoor temperature of 78°F c. Outdoor maximum temperature of 95°F with mean daily temperature of 85°F and daily range of 21°F

$$\text{CLTD}_{\text{ROOF Corrected}} = [\text{CLTD}_{\text{Roof}} + (78 - TR) + (TM - 85)]$$

Where

o (78 – TR) = indoor design temperature correction

o (TM – 85) = outdoor design temperature correction

o TR = Indoor room temperature

o Tm = Mean outdoor temperature

o Tmax = Maximum outdoor temperature

o Tm = Tmax – (Daily Range) / 2

Step # 5 Calculate roof area (A) from architectural plans

$$Q_{\text{Roof}} = U * A * \text{CLTD}_{\text{Roof Corrected}}$$

Step #6