REFRIGERATION AND COLD STORAGE

UNIT III

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

ensible 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.

What is a Cooling Load?

The cooling load refers to the amount of heat energy that needs to be removed from a space to maintain a specified indoor temperature.

In simpler terms, it measures how hard an air conditioning system has to work to ensure a comfortable indoor environment.

What Impacts the Cooling Load?

Several factors can influence the cooling load:

External Factors: These include the surrounding temperature difference, solar gain (heat from the sun penetrating the building), and relative humidity.

Internal Factors: Inside the building, heat sources such as occupants, electronic devices, lighting, and machinery contribute.

Building's Construction: Materials used, insulation efficiency, type of windows, and building

Reduce the Cooling Load

Reducing the cooling load not only ensures energy efficiency, but also translates to cost savings.

Improve Insulation: Enhancing insulation reduces the heat transferred, thus decreasing the cooling load.

Use Energy-efficient Windows: Double-glazed or tinted windows can prevent excessive solar gain.

Strategic Landscaping: Planting trees or constructing shades to block direct sunlight can significantly reduce solar gain.

Limit Internal Heat Sources: Opt for energy-efficient appliances and lighting to reduce the internal heat generated.

Why is Calculating the Cooling Load Important?

Determining the cooling load is crucial for:

Energy Efficiency: An accurate cooling load calculation ensures the HVAC system operates with minimal energy wastage.

System Sizing: It prevents the installation of undersized (leading to an insufficient cooling process) or oversized (leading to cost inefficiencies) HVAC systems.

Occupant Comfort: Accurate calculations ensure that HVAC systems maintain a comfortable environment for occupants.

Cooling load estimation for crop storage systems is a critical process to determine the required capacity of the refrigeration equipment. The total cooling load is the sum of all heat gains that must be continuously removed from the cold room.

The total cooling load is typically broken down into several main components:

1. Transmission Load (Heat Leak)

This is the heat transferred through the insulated walls, ceiling, and floor from the warmer surroundings to the cold storage interior.

The calculation uses the formula:

Where:

•   Q is the heat load (kWh/day).

•   U is the overall heat transmission coefficient or U-value of the insulation (W/m2·K).

•   A is the surface area of the walls, roof, and floor (m2).

•   Tempout is the ambient external air or ground temperature (∘C).

•   Tempin is the desired air temperature inside the room (∘C).

•   The factor 24/1000 converts W·h to kWh/day.

2. Product Load

This includes two major sources of heat associated with the crops:

a. Product Pulldown Load (Field Heat Removal)

This is the heat that must be removed to cool the newly added produce from its initial temperature (field temperature) down to the storage temperature.

The calculation uses the formula:

$$Q_{pulldown} = m \times C_p \times (\text{Temp}_{\text{enter}} - \text{Temp}_{\text{store}}) \times \frac{1}{\text{Conversion Factor}}$$

Where:

- Q is the heat load (e.g., kWh/day or BTU/hr).

- m is the mass of new products loaded per day (kg).

- Cp is the specific heat capacity of the product (kJ/kg·°C).

- Tempenter is the entering temperature of the product (°C).

- Tempstore is the final storage temperature (°C).

- A conversion factor (e.g., 3600 for kJ to kWh conversion) is used depending on the units. The required cooling time is critical here to convert the total heat to be removed into a rate (load).

b. Respiration Load (Heat of Respiration)

Fresh fruits and vegetables are living organisms and generate heat as a natural by-product of their respiration process. This heat must be continuously removed.

The calculation uses the formula:

$$Q_{respiration} = m_{\text{total}} \times \text{Resp} \times \frac{1}{3600}$$

Where

- Q is the heat load (kWh/day).

- mtotal is the total mass of product in storage (kg).

- Resp is the respiration heat of the product at the storage temperature (kJ/kg·h). This value varies significantly by crop type and temperature.

- The factor 1/3600 converts kJ/h to kWh

3. Infiltration Load (Air Change Load)

This is the heat gain from warm, humid air entering the cold room, typically when doors are opened or through leaks (infiltration). This load depends on the volume of the cold store, the difference in enthalpy (heat content) between the inside and outside air, and the estimated number of air changes per day (ACH).

4. Internal Heat Loads (Service Loads)

These are heat gains generated inside the cold room from operational equipment and personnel:

- Lighting: Heat from lamps, calculated based on wattage and daily usage time.

- Personnel: Heat generated by people working inside, based on the number of workers, time spent, and heat output per person (which varies with temperature).

- Equipment: Heat from running motors for evaporator fans and other machinery like forklifts, or heat from electric defrost cycles.

Total Cooling Load and System Sizing

The Total Cooling Load is the sum of all calculated loads, often with a safety factor (typically 10-30%) added to account for unforeseen variations and errors

Finally, the required Refrigeration Capacity (kW or TR) is calculated by dividing the total daily heat load (kWh/day) by the anticipated run time of the refrigeration unit (e.g., 14 to 18 hours per day) to allow for defrosting and off-cycles.

$$\text{Total Cooling Load} = \left(\sum Q_{\text{all sources}} \right) \times \text{Safety Factor}$$

Heating Load V/s Cooling Load Calculations

As the name implies, heating load calculations are carried out to estimate the heat loss from the building in winter so as to arrive at required heating capacities. Normally during winter months the peak heating load occurs before sunrise and the outdoor conditions do not vary significantly throughout the winter season. In addition, internal heat sources such as occupants or appliances are beneficial as they compensate some of the heat losses. As a result, normally, the heat load calculations are carried out assuming steady state conditions (no solar radiation and steady outdoor conditions) and neglecting internal heat sources. This is a simple but conservative approach that leads to slight overestimation of the heating capacity.

For more accurate estimation of heating loads, one has to take into account the thermal capacity of the walls and internal heat sources, which makes the problem more complicated. For estimating cooling loads, one has to consider the unsteady state processes, as the peak cooling load occurs during the day time and the outside conditions also vary significantly throughout the day due to solar radiation. In addition, all internal sources add on to the cooling loads and neglecting them would lead to underestimation of the required cooling capacity and the possibility of not being able to maintain the required indoor conditions. Thus cooling load calculations are inherently more complicated. In determining the heating load, credit for solar heat gain or internal heat gains is usually NOT included and the thermal storage effects of building structure are generally ignored. Whereas in cooling load calculations, the thermal storage characteristics of the building play a vital role because the time at which the space may realize the heat gain as a cooling load will be considerably offset from the time the heat started to flow.