Lesson 28: Cooling Load Calculation

Introduction:

To simplify the cooling load calculations, the total cooling load is divided into a number of individual loads i.e. according to the sources of heat supplying the load.

The total cooling load is divided into four separate loads;

1. The wall gain load
2. The air change load,
3. The product load,
4. The miscellaneous or supplementary load.

28.1 WALL GAIN LOAD

The quantity of heat transmitted through the walls, ceiling & floor of a refrigerated space per unit time is calculated as follows;

Wall gain load,

Where, U= Overall heat transfer co-efficient, W/m K

A= Area of the wall, m^2

= Temperature difference across the wall, K

The value of U depends on the materials used in construction and insulation used in the construction of wall as well as on the thickness of these materials. If either U or are different for different walls, then it is necessary to calculate Q_w of each wall/ceiling/floor separately taking corresponding values of U and .

The overall heat transfer co-efficient is given by

Where, h_o = Convection heat transfer Co-efficient on the outer surface

h_i = Convection heat transfer Co-efficient on the inner surface

x_1, x_2…..= thickness of different layers of wall including insulation

k_1,k_2,….= conductivities of different layers of wall including insulation

28.2 AIR CHANGE LOAD

This is the quantity of outside air entering a space through door openings in a 24hrs periods depends on the number, size & location of the door openings and the densities of the outside and inside air. The measurement of amount of air changed due to door opening is difficult and hence air change factor is used to estimate the amount of air changed.

Air change load, $Q_a = m (h_o - h_i)$

Where, m= mass of air entering, kg /h

h_o = Enthalpy of outside air, kJ/kg dry air

h_i = Enthalpy of inside air, kJ/kg dry air

Mass of air can be estimated by multiplying inside volume of space with air change factor. The volume of the air is converted into amount of dry air in the volume taking specific volume of the outside air.

28.3 PRODUCT LOAD

It is necessary to cool the product from initial temperature to the storage temperature. The amount of heat given off by the product in cooling to the space temperature depends upon temperature of the space and upon the mass, specific heat, and entering temperature of the product. It is also necessary to estimate the heat load for cooling of the packaging material along with the product as specific heat of product and material is different.

Product load, $Q_p = m_p \times C_1 \times (t_1 - t_2)$

Where m_p = Mass of the product, kg/h

C_1 = Specific heat of the product kJ/kg K

t_1 = Initial temperature of the product

t_2 = Final storage temperature of the product.

Similarly, heat load of packaging materials transferred in the cold store along with the product is estimated as above taking the mass of packaging material, its specific heat and temperature difference. This load is added in the actual product load.

For product freezing and storage: When a product is to be frozen and stored at some temperature below its freezing temperature, the product load is calculated in three parts; heat given off by the product(entering temperature to its freezing temperature), heat given off by the product in solidifying or freezing(heat removal to freeze the product) & heat given off by the product in cooling from its freezing temperature to the final storage temperature. This is calculated as below;

$Q_p = m_p \text{ x } C_1 (t_1 + t_f) + m_p h_{fg} + m_p \text{ x } C_2 (t_f - t_2)$

Where t_f = Freezing temperature, ^oC

h_{fg} = Latent heat of freezing, J/kg

Heat produced due to respiration of the fruits and vegetables are required to be considered for such types of cold storages.

$Q_r = m_p$ (kg/h) x Respirate rate (kJ/kg)

28.4 MISCELLANEOUS LOAD

The miscellaneous load consists of primarily of heat given off by light and electric motors present in the cold storage.

Cooling load for electric appliances in terms of kJ is given by

$Q_c = kW \times 3600$ kJ/h

Heat Load from occupants is calculated based on the data available for heat loss from human body. It is necessary to refer standard data if heat loss from human body under different temperature conditions. For example, a person at rest at 20 ^oC, total heat loss from the body is about 400 kJ/h (Q_l= 160 kJ/h and Qs = 240 kJ/h)

TOTAL HEAT LOAD

The total cooling load is the summation of individual loads

Total load, $Q_t = Q_w + Qa + Q_p + Q_m$

It is common practice to add 10-15% of total load as safety factor. After adding safety factor, the cooling load is multiplied by 24 hours and divided by the desired operating time in hours to find capacity of the plant required for the cold storage.