AL - MUSTAQBAL UNIVERSITY COLLEGE
Iraq – Babylon

Refrigeration and Air conditioning Engineering.
3rd year – refrigeration and Air conditioning Course

Lecture - 22 – COLD STORE LOAD part2

Msc. Zahraa AlKhafaji

$$C_u = 4.19 - 2.3x_s - 0.628x_s^3 = 4.19 - 2.3 \times 0.283 - 0.628 \times 0.283^3$$
$$= 3.524 \frac{kJ}{kg.K}$$
$$Q_1 = m.C_u.(T_1 - T_2) = 100 \times 3.524 \times (18 - 4) = 4935\ kJ$$

2. Heat removed to cool from the initial temperature to the freezing point of the product, in kJ:

$$Q_2 = m.C_u.\left(T_2 - T_f\right) \quad (7\text{-}5)$$

$$Q_2 = m.C_u.\left(T_2 - T_f\right) = 100 \times 3.524 \times (4 - (-1.7)) = 2009\ kJ$$

3. Heat removed to freeze the product in kJ

$$Q_3 = m.x_{wo}.h_{if} \quad (7\text{-}6)$$

$$Q_3 = 100 \times 0.717 \times 333.6 = 23919\ kJ$$

4. Heat removed to cool from the freezing point to the final temperature below the freezing point, in kJ.

$$Q_4 = m.C_a.\left(T_f - T_3\right) \quad (7\text{-}5)$$

$$c_a = 1.55 + 1.26x_s + \frac{(x_{wo} - x_b).L_o.t_f}{t^2} \quad (6\text{-}4)$$

$$x_b = 0.4.x_p \quad (6\text{-}5)$$

$$x_b = 0.4 \times 0.2124 = 0.085$$

$$c_a = 1.55 + 1.26x_s + \frac{(x_{wo} - x_b).L_o.t_f}{t^2}$$
$$= 1.55 + 1.26 \times 0.283 + \frac{(0.717 - 0.085) \times 333.6 \times -1.7}{(-18^2)}$$
$$= 1.9 \frac{kJ}{kg.K}$$

$$Q_4 = m.C_a.\left(T_f - T_3\right) = 100 \times 1.9 \times \left(-1.7 - (-18)\right) = 3018\ kJ$$

$$Q_t = Q_1 + Q_2 + Q_3 + Q_4 = 4935 + 2009 + 23919 + 3018 = 33881\ kJ$$

7.2 INTERNAL LOAD:

7.2.1 Electrical Equipment. All electrical energy dissipated in the refrigerated space (from lights, motors, heaters, and other equipment) must be included in the internal heat load. Heat equivalents of electric motors are listed in Table 27.

7.2.3 Fork Lifts. Fork lifts in some facilities can be a large and variable contributor to the load. While many fork lifts may be in a space at one time, they do not all operate at the same energy level. For example, the energy used by a fork lift while it is elevating or lowering forks is different than when it is moving.

7.2.3 Processing Equipment. Grinding, mixing, or even cooking equipment may be in the refrigerated areas of food processing plants. Other heat sources include equipment for packaging, glue melting, or shrink wrapping. Another possible load is the makeup air for equipment that exhausts air from a refrigerated space.

7.2.4 People. People add to the heat load, and this load varies depending on such factors as room temperature, type of work being done, type of clothing worn, and size of the person. Heat load from a person qp may be estimated as:

$$Q_p = 272 - 6.T \qquad (6\text{-}6)$$

Where:

T: Temperature of the refrigerated space in °C

7.3 Infiltration by Direct Flow Through Doorways:

A negative pressure created elsewhere in the building because of mechanical air exhaust without mechanical air replenishment is a common cause of heat gain from infiltration of warm air. In refrigerated spaces equipped with constantly or frequently open doorways or other through-the room passageways, this air flows directly through the doorway. The load imposed on the cold store can calculated from the following equation:

$$Q_{inf} = 1.2 \times \dot{V}[(T_o - T_{in}) + 2500 \times (g_o - g_i)] \qquad (6\text{-}7)$$

Where:

T_o: Outdoor temperature (^oC)
T_{in}: Cold store temperature (^oC)
g_o: Moisture content of outdoor air (kg_w/kg_a)
g_i: Moisture content of indoor air (kg_w/kg_a)
$\dot{V}$: Volume flow rate of air (lit/s)

$$\dot{V} = 3.8\sqrt{h}.\sqrt{\Delta T} \qquad (6\text{-}8)$$

h: Door height (m)
ΔT: Difference between outside and inside temperatures (^oC)
Example:

In cold store uses Expanded Polyisocyanurate for walls, ceilings and floors. Used to store a quantity of butter at-20 ℃, the butter is cooled butter firstly from initial temperature of 15^{o}C to initial freezing temperature, then freezes from initial freezing temperature to the final temperature of -20 ℃ . If the stored capacity 480 ton. 10 people working at the store 12 hours a day, the lighting in the store 20 W/m^2 operate continuously. Calculate the heat load to the cold store. If the outdoor conditions are dry bulb temperature equals of 40 ℃ and 50 RH. If the time required to cool and freezes the butter is 24 hr. calculate the cooling load of the cold store. Assume freezing point of butter is (- 5.6 ^{o}C). The dimensions of the cold store are 16 m Long, 10 m wide and 6 m height. Assume the maximum wall area facing north.

Solution:

From table (6-1) the properties of butter as follows:

Food Item	Moisture Content, % x_{wo}	Protein, % x_p	Fat, % x_f	Carbohydrate, % x_c	Fiber, % x_{fb}	Ash, % x_a	Initial Freezing Point, °C	Specific Heat Above Freezing, kJ/(kg·K)	Specific Heat Below Freezing kJ/(kg·K)
Butter	17.9	0.85	81.11	0.06	0.0	0.04	—	2.18	—

From table (7-1) the thermal conductivity of Expanded Polyisocyanurate is 0.027 W/m. K, while from table (7-2) the thickness of Expanded Polyisocyanurate is 100 mm.

The heat transfer coefficient of the wall is:

$$U = \frac{k}{x} = \frac{0.027}{0.1} = 0.27 \ W/m^2K$$

The addition on the temperature difference can be found from table (7-3) assuming dark color wall. The heat gain through store is as follows

	U	A	$\Delta T + correction\ (table - 3)$	Load
Qw/W =	0.27	10×6	× (40-(-20))+5	= 1053
Qw/N =	0.27	16×0	× (40-(-20))	= 1555
Qw/E =	0.27	10×6	× (40-(-20))+5	= 1053
Qw/S =	0.27	16×6	× (40-(-20))+3	= 1633
Qr =	0.27	10×16	× (40-(-20))+11	= 3068
Total				8362

Product load:
Load due to cooling butter from initial temperature to initial freezing point

5. Heat removed to cool from the initial temperature to initial freezing point.

$$Q_1 = m.C_u.(T_1 - T_2) \quad (7\text{-}4)$$

$$C_u = 4.19 - 2.3x_s - 0.628x_s^3 \quad (6\text{-}3)$$

$$x_s = 1 - x_{wo} = 1 - 0.179 = 0.821$$

$$C_u = 4.19 - 2.3x_s - 0.628x_s^3 = 4.19 - 2.3 \times 0.821 - 0.628 \times 0.821^3 = 1.951\,\frac{kJ}{kg.K}$$

6. Heat removed to freeze the product in kJ

$$Q_3 = m.x_{wo}.h_{if} \qquad (7\text{-}6)$$

7. Heat removed to cool from the freezing point to the final temperature below the freezing point, in kJ.

$$Q_4 = m.C_a.(T_f - T_3) \qquad (7\text{-}5)$$

$$c_a = 1.55 + 1.26x_s + \frac{(x_{wo} - x_b).L_o.t_f}{t^2} \qquad (6\text{-}4)$$

$$x_b = 0.4.x_p \qquad (6\text{-}5)$$

$x_b = 0.4 \times$ 034

$$c_a = 1.55 + 1.26x_s + \frac{(x_{wo} - x_b).L_o.t_f}{t^2}$$

$$= 1.55 + 1.26 \times 0.821 + \frac{(0.197 - 0.0034) \times 333.6 \times -5.6}{(-20)(-20)} = 1.68\,\frac{kJ}{kg.K}$$

$$Q_4 = m.C_a.(T_f - T_3) = 480000 \times 1.68 \times (-5.6 - (-20)) = 22464000\ kJ$$

$$Q_t = Q_1 + Q_3 + Q_4 = 19291488 + 31545216 + 22464000 = 73300704\ kJ$$

$$Q = \frac{Q_1 + Q_2 + Q_3 + Q_4}{3600.n} = \frac{19291488 + 31545216 + 22464000}{3600 \times 24} = \mathbf{848.4}\ kW$$

- Heat load from a person Qp

$$Q_p = 272 - 6.T = 10 \times (272 - 6 \times (-20)) \times \frac{12}{24} = 1960\ W$$ =1.96 kW

Lighting load

Q= 20*(16*10)= 3200 W=3.2 kW

- - Infiltration by Direct Flow Through Doorways

$$Q_{inf} = 1.2 \times \dot{V}[(T_o - T_{in}) + 2500 \times (g_o - g_i)]$$

$$\dot{V} = 3.8\sqrt{h}.\sqrt{\Delta T} = 3.8 \times \sqrt{3}.\sqrt{40 - (-20)} = 51\ lit/s$$

From pshychrometric chart

go=0.0229 kgw/kga,

gi=0.00055 kgw/kga

$Q_{inf} = 1.2 \times \dot{V}[(T_o - T_{in}) + 2500 \times (g_o - g_i)]$

$Q_{inf} = 1.2 \times 51 \times [(40 + 20) + 2500(0.0229 - 0.00055)]$

$Q_{inf} = 1.21 \times 51 \times (60 + 56) = 7100\, W$=7.1 kW

- Total load

$Q_t = 8.362 + 848.4 + 1.960 + 3.200 + 7.100 = 869\ \mathrm{k}W$