ME 329: THERMAL SYSTEMS DESIGN

INDUSTRIAL REFRIGERATION APLICATIONS

DESIGNING A COLD STORAGE

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LIST OF ABBREVIATIONS

CLTD – Cooling Load Temperature Difference

ASHRAE – American Society of Heating, Refrigerating and Air-conditioning Engineers

CHAPTER 01: THEORY AND RESULTS

1.1. Introduction

A refrigerated chamber, also known as a refrigerated room or a walk-in cooler, is a type of temperature-controlled storage unit used for preserving and storing perishable food items, medical supplies, and other items that require a specific temperature range for preservation. It is designed to maintain a low temperature range, which slows down the growth of bacteria, yeast, and other microorganisms that cause spoilage and degradation.

Refrigerated chambers come in a variety of sizes and styles, including floor-mounted units, reach-in units, and walk-in units, and can be custom-built to meet specific storage requirements. They can be used in a range of applications, including commercial kitchens, supermarkets, pharmaceutical companies, and more.

Figure 1. 1- Cold Room

Refrigerated chambers are typically powered by refrigeration units that use either a compressor-based refrigeration system or a thermoelectric refrigeration system. These systems regulate the temperature and maintain the desired conditions inside the chamber, ensuring that the stored items remain fresh and safe for consumption or use.

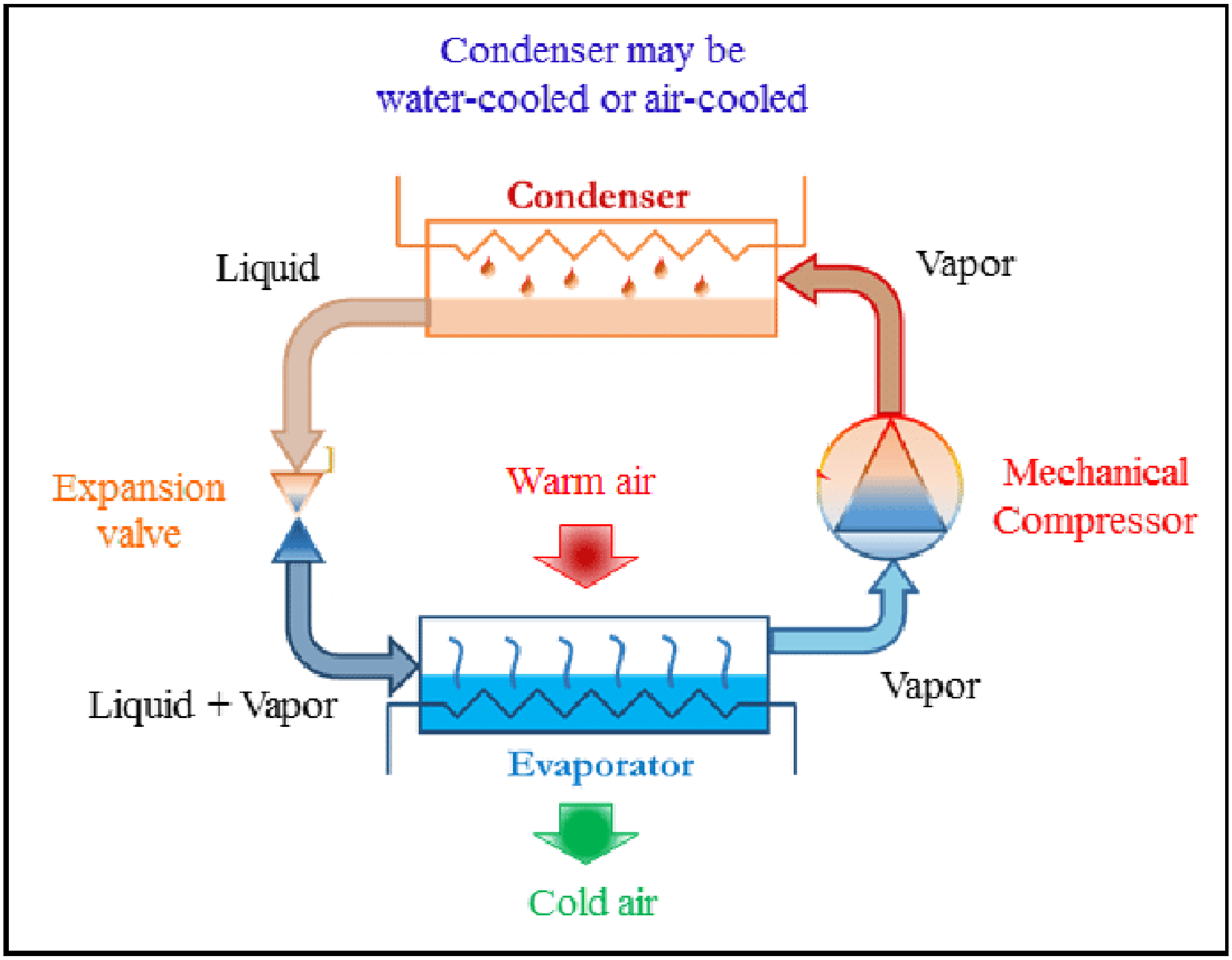


Figure 1. 2- The process

In a refrigerated chamber or cold room, the cooling load refers to the amount of heat that must be removed from the space in order to maintain the desired temperature. The cooling load depends on several factors, including the size of the space, the temperature difference between the room and the outside environment, the insulation properties of the walls, roof, and floor, the amount of heat generated by the stored items and equipment, and the air exchange rate (the rate at which air is exchanged between the room and the outside environment).

To determine the cooling load of a cold room, engineers use mathematical models and simulation tools that take into account the above-mentioned factors. The cooling load can then be used to select the appropriate refrigeration unit for the cold room, as well as to optimize the design of the room for energy efficiency.

It's important to note that the cooling load can change over time due to changes in the temperature of the stored items, the ambient temperature, and other factors. Therefore, it's recommended to regularly monitor the temperature inside the cold room and adjust the refrigeration unit as needed to ensure that the desired temperature is maintained.

1.2. The Design Problem

Table 1-1: The Design Parameters and Constraints for the Problem

Design Details	Values
Incoming temperature (C^0)	38
Incoming Rate (Pallet/hr.)	15
Final product temperature (C^0)	+4
Allowed Cooling Rate(C^0/hr.)	10
Basis Pallet Details (m^3, Product mass, kg)	1.2×1.2×1.5 450
Production Hours	0600-2200
Storage Duration (Days)	3

1.3. The Data for Calculations

The specific heat of the product	- 3.52 kJ/kg.K
The location for the cold room	- Nuwara Eliya
The average outdoor Temperature	- 29 C^0
The relative humidity	- 78%

1.4. The Assumptions Made

- The weight of the packing material of the youghurt is neglected.

CHAPTER 02: DESIGN CALCULATIONS

2.1 Design of the building

No of pallets in the store room

Calculating the total number of pallets.

$$\text{Total pallets} = \frac{\text{pallets}}{\text{hr}} \times \text{production hours} \times \text{storage duration}$$

$$= 15 \times 16 \times 3$$

$$= 720\, pallets$$

Considering safety precautions, the maximum height of the pallet rack was taken as 5.7 m. Therefore, the maximum height that the folk lift has to lift is in the safe region.

Pallet rack

The height of the pallet the product was given as 1.5 m

Number of pallets to be kept vertically = 4

The detailed cross section of the pallet rack is shown in figure 2.1

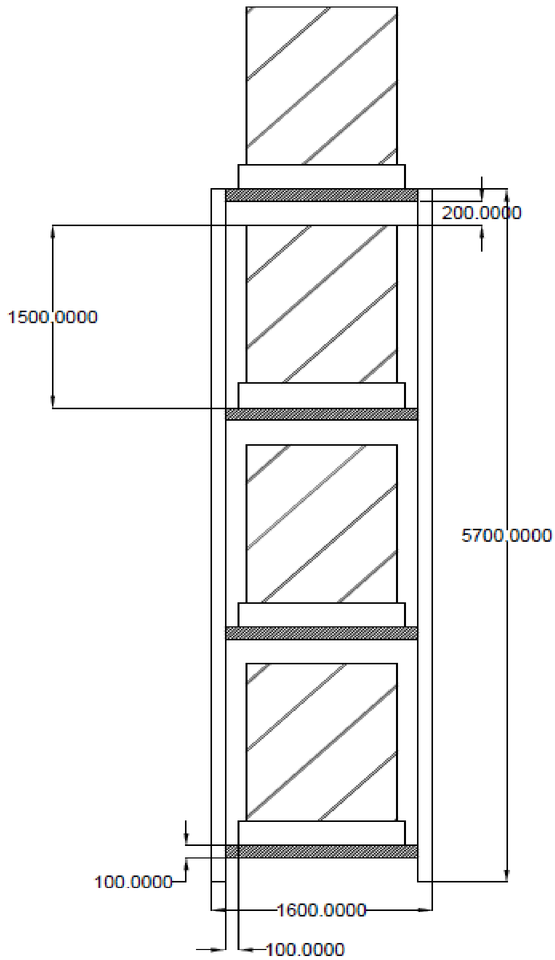


Figure 2. 1- Rack Design

Clearance between the product and the rack = 0.2 m

Thickness of the rack beam = 0.1 m

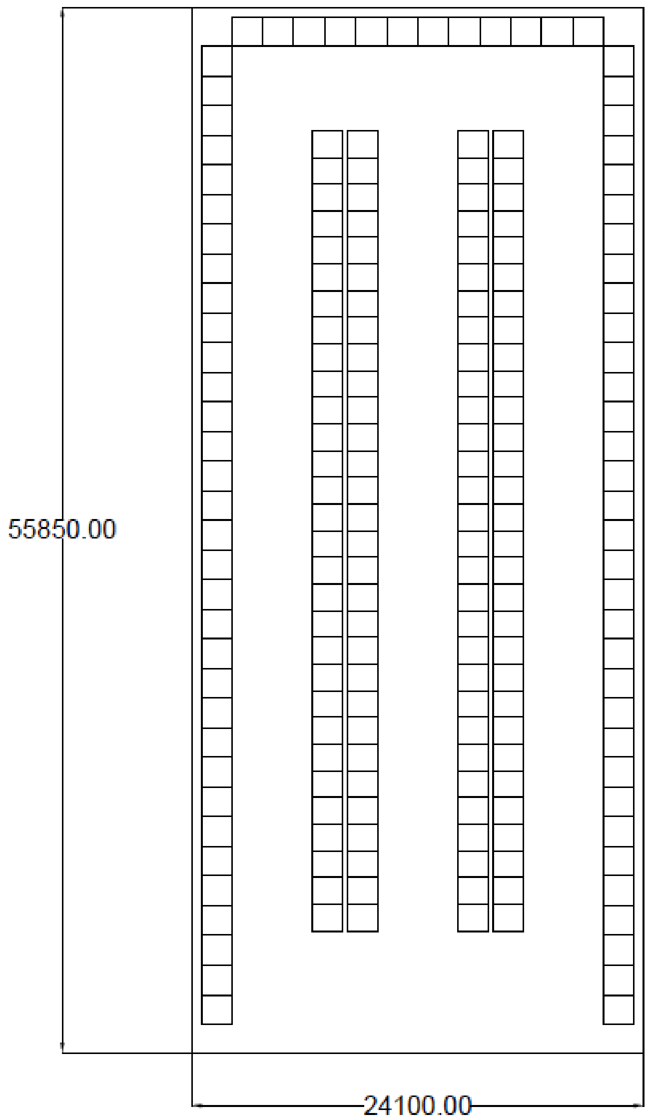
Total height with the product = 7.2 m

According to ASHREA standards the roof height should be at least 2 m from the top pallet. Therefore, the roof height was considered 2.8 m away from the top end of the product.

Roof height from the floor level = 7.2m + 2.8m

= 10 m

The rack arrangement in the store room is shown in figure 2.2



Floor length = 55.85 m

Floor width = 24.10 m

Area = 1345.985 m^2

Figure 2. 2- Floor Room Design

After adding 10% excess amount to 720 total pallets. The pallets are arranged such that 198 pallets can be stored in one layer. Hence, a total of 792 pallets can be stored in the cold room. Overall dimensions of the cold room are shown in the figure 2.2.

The clearance between the wall and the product and the clearance between two product lines are shown in figure 2.3. In addition, 4.3 m is kept to the forklift to reach anywhere.

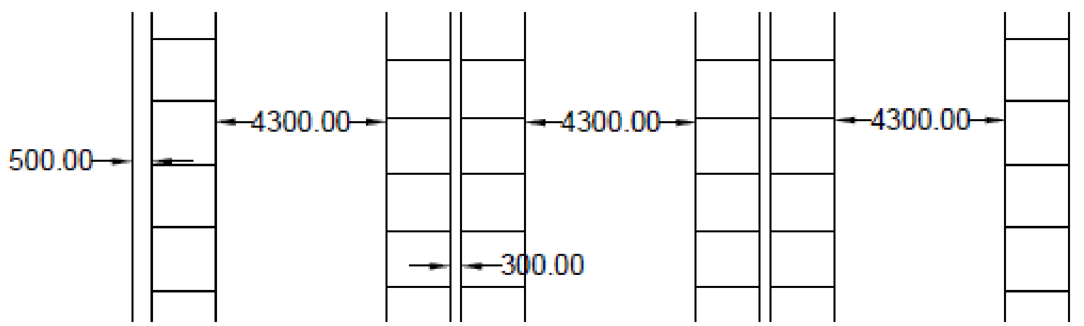


Figure 2. 3- Details 1

If the forklifts are driven through are large door (8 m door) continuously, a large amount of energy is being loosed. Therefore, an incoming and outgoing convey belts have been replaced to reduce the heat exchange. Then the product can be transferred in and out more efficiently.

The dock space is located in the front part of the building as shown in the figure 2.4.

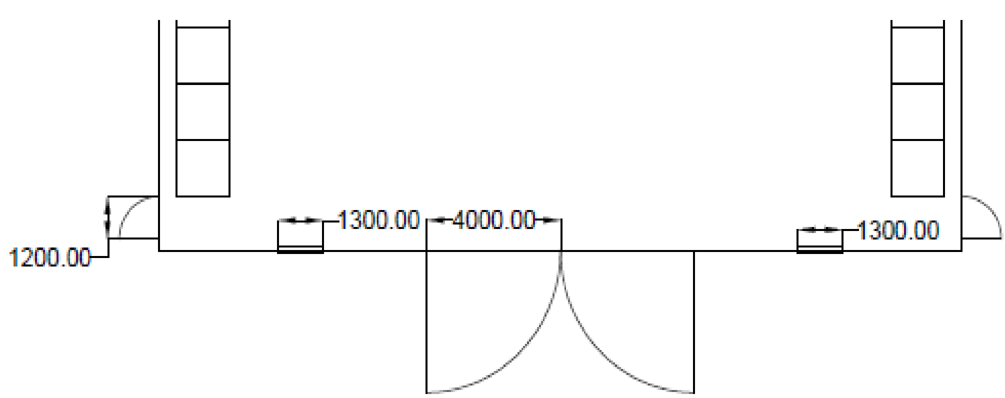


Figure 2. 4- The Door Space

There are two conveyor belt openings such that one is taking the product in and the other one is taking the product out.

Height of the belt opening	=	1.6 m
Width of the belt opening	=	1.3 m
Area of the opening	=	2.08 m^2

The larger door is design to move the forklift in and out. In addition to that, there are two small doors (1.2 m door) for people who work there to enter/exit.

Area of the doors,

Lager doors,

Height	=	4 m
Width	=	4 m
Area	=	16 m^2

Small doors,

Height	=	1.2 m
Width	=	2 m
Area	=	2.4 m^2

Insulation panels

Insulation panels are used to reduce the heat exchange through the walls and the roof. It would be a more efficient way to maintain the desired temperature inside the cold room. According to ASHREA standards, floor insulation is not necessary.

EIP CSP (emirates industrial panels) are used for the insulation. The following figure shows the insulation panel used in the room.

Figure 2. 5- Insulation Panel

Thermal performance is shown in table 2.1.

Table 2.2: Thermal performance of insulation panel

t: Core Thickness (mm)	55	80	100	120	140	150	170	200
Weight (kg/m²)[1]	10.40	11.40	12.20	13.00	13.80	14.20	15.00	16.20
U value - PIR (W/m²K)[2]	0.38	0.26	0.21	0.17	0.15	0.14	0.12	0.10
U value - PUR (W/m²K)[2]	0.41	0.28	0.23	0.19	0.16	0.15	0.13	0.11

Selection of Forklift

Considering the heat emission of the forklift, it was decided to use fully electric forklift. That will also reduce the CO_2 emission. In order to reduce the heat emission and increase the efficiency, the forklift is selected. The selected forklift was MR-14 manufactured by Yale shown in figure 2.5.

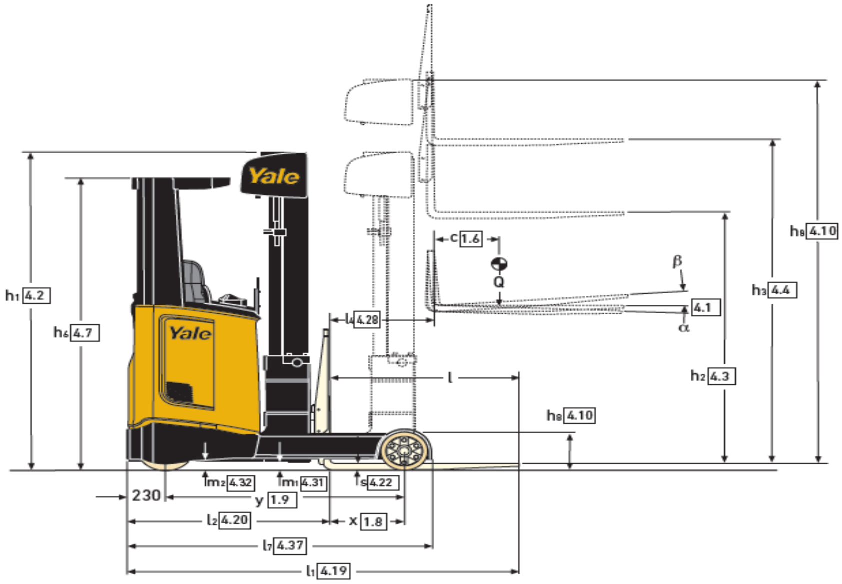


Figure 2. 6- The selected Forklift

Details of the forklift is shown in the following table 2.2.

Table 2.2: Details of forklift

Make	Yale
Model	MR-14
Max. Height	7 m
Width	1.265 m
Length	2.375 m

CHAPTER 03: HEAT LOAD CALCULATIONS

There are many heats loads that can affect for the refrigeration system.

1. Transmission heat load
2. Product Load
3. Internal Load
4. Infiltration Air Load
5. Equipment related Load

3.1 Transmission Heat Load

Corr. CLTD = CLTD + (25.5 - 4) + (20 – 8/2 - 29.4)

= CLTD + 1.1

= 8.1

3.1.1 The Transmission Heat Load from Roof,

Roof type - type 03

Area of the roof - 1321.9 m^2

Calculation Of Heat Loads at different clocks.

The Corrected CLTD values for Roof type 03

Table 3.1: CLTD values for roof type 03

Hour (00.00 to 24.00)	For Roof Type 3 (CLTD values)
1	15.1
2	12.1
3	11.1
4	9.1
5	8.1
6	7.1
7	8.1

8	11.1
9	15.1
10	21.1
11	27.1
12	34.1
13	40.1
14	45.1
15	48.1
16	49.1
17	49.1
18	45.1
19	41.1
20	35.1
21	29.1
22	25.1
23	21.1
24	17.1

U Factor - 0.6351

Calculating the Q value for Roof

Table 3.2: Q values for the roof

Hour (00.00 to 24.00)	For roof Type 03	Heat Load (W)
1	28.1	23494.6
2	25.1	20986.2
3	24.1	20150.1
4	22.1	18477.9
5	21.1	17641.8
6	20.1	16805.7
7	21.1	17641.8

8	24.1	20150.1
9	28.1	23494.6
10	34.1	28511.1
11	40.1	33527.8
12	47.1	39380.6
13	53.1	44397.3
14	58.1	48577.7
15	61.1	51086.0
16	62.1	51922.1
17	62.1	51922.1
18	58.1	48577.7
19	54.1	45233.3
20	48.1	40216.7
21	42.1	35200.0
22	38.1	31855.6
23	34.1	28511.2
24	30.1	25166.8

Then Maximum Heat loss through Roof = 51 922.1 W

= 51.92 kW

3.1.2 Heat Load from Walls

200 mm Concrete Low density Walls

20 mm plaster on both sides

R value - 1.699

U factor - 0.5886

Areas of the walls

East /West - 546.1

North - 241

South - 220.84

The Corrected CLTD values for Walls in different Directions

Table 3.3: CLTD values for walls

Time	N	S	E	W
1	19.1	10.21111	12.98889	18.98889
2	17.1	8.211111	10.98889	14.98889
3	16.1	7.211111	9.988889	12.98889
4	15.1	6.21111	8.988889	10.98889
5	14.1	5.21111	7.988889	8.988889
6	13.1	5.21111	7.988889	7.988889
7	13.1	4.21111	7.988889	7.988889
8	14.1	5.21111	9.988889	6.98889
9	15.1	4.21111	14.98889	7.988889
10	16.1	5.21111	21.98889	7.988889
11	17.1	7.211111	27.98889	9.988889
12	19.1	11.21111	31.98889	10.98889
13	20.1	15.21111	33.98889	12.98889
14	22.1	20.21111	32.98889	14.98889
15	24.1	23.21111	30.98889	18.98889
16	25.1	27.21111	28.98889	23.98889
17	26.1	28.21111	27.98889	28.98889
18	27.1	27.21111	25.98889	34.98889
19	28.1	26.21111	24.98889	9.988889
20	28.1	23.21111	22.98889	42.98889
21	27.1	21.21111	20.98889	39.98889
22	25.1	17.21111	18.98889	34.98889
23	24.1	15.21111	15.98889	28.98889
24	21.1	12.21111	14.98889	23.98889

The Heat load that affects in different Directions

Table 3.4: Heat load for walls

N (W)	S(W)	E(W)	W(W)	Total Heat
2709.385	1327.306	4175.077	6103.684	14315.45
2425.679	1067.333	3532.208	4817.945	11843.17
2283.827	937.3465	3210.773	4175.077	10607.02
2141.974	807.36	2889.339	3532.208	9370.881
2000.122	677.3736	2567.904	2889.339	8134.739
1858.269	677.3736	2567.904	2567.904	7671.451
1858.269	547.3871	2567.904	2567.904	7541.464

2000.122	677.3736	3210.773	2246.47	8134.739
2141.974	547.3871	4817.945	2567.904	10075.21
2283.827	677.3736	7067.987	2567.904	12597.09
2425.679	937.3465	8996.594	3210.773	15570.39
2709.385	1457.292	10282.33	3532.208	17981.22
2851.237	1977.238	10925.2	4175.077	19928.75
3134.942	2627.17	10603.77	4817.945	21183.83
3418.648	3017.129	9960.897	6103.684	22500.36
3560.5	3537.075	9318.028	7710.856	24126.46
3702.353	3667.061	8996.594	9318.028	25684.04
3844.205	3537.075	8353.725	11246.63	26981.64
3986.058	3407.088	8032.29	3210.773	18636.21
3986.058	3017.129	7389.421	13818.11	28210.72
3844.205	2757.156	6746.553	12853.81	26201.72
3560.5	2237.211	6103.684	11246.63	23148.03
3418.648	1977.238	5139.38	9318.028	19853.29
2993.09	1587.279	4817.945	7710.856	17109.17

Then,

The Maximum Heat Load is = 26 981.64 W

= 26.98 kW

3.1.3 The Heat Load From Floor

300 mm High Density Concrete with inside surface resistance

20 mm plaster of gypsum

Floor is polished concrete interior

R value - 0.354

U factor - 2.825

Area of the Floor - 1321.89 m^2

The heat load from floor, $= U \times A\ (20\text{-}4)$

$= 59749.20$ W

$= 59.75$ kW

The heat Load From Doors,

There are 3 doors for the cold room.

1. Main door, which use for entering forklifts and maintenance purposes The area of main door is $16m^2$
2. Small Door – To use to in and out of workers. area of the small door is $2.4\ m^2$
3. Emergency Door – To get out when there is an emergency. The area of the emergency Door is $2.4\ m^2$

Considering the R value,

For the Door material - 4.54545

Inside surface Resistance - 0.121

Outside surface resistance - 0.059

T_{total} - 4.72545

Then U factor will be,

$U = 1/ R_T$

$= 0.21162$

Then the heat loads are,

For main Door = 54.1747 W

For Small Door = 8.1262 W

For Emergency Door = 8.1262 W

Total Heat loss from Doors = 0.074 kW

The heat loss that can happen from belt system,

As we mentioned in chapter two the input and output of yogurt is supplying and removing using a two-belt drive system. Then the power loss happens from belt system is,

The cross-sectional area of the belt which suits for yogurt entering,

A = 1.3 × 1.6 m^2

Thickness = 100 mm

U Factor = 0.21162

Then the heat load is, = 7.04 W (0.007 kW)

Total transmission heat load = 51.92 + 26.98 + 59.75 + 0.07 + 0.074

= 138.794 kW

3.2 Product Heat Load

According to a journal article on the heat transfer and rheology of yoghurt, the specific heat capacity of yoghurt is as follows,

$$Specific\ heat\ capacity\ of\ yoghurt = 3.52\ kJ/(kg.K)$$

Calculating the weight of yoghurt entering the facility per day,

$$\begin{aligned} New\ pallets\ per\ day &= 15\ pallet/hr \times 16\ hours \\ &= 240\ pallets \end{aligned}$$

The heat from one pallet per hour = 450 × 3.52 × 10

= 15 840 kJ

The power for one pallet is = 15 840 / 3 600

= 4.4 kW

When one pellet enters the room the cooling rate required is 4.4 kW, Since the incoming rate of pellets is 15 per hour, we can assume a new pellet comes every 4 minutes. Then if the rate at 6.00 AM is 4.4 kW then the rate at 7.04 would be twice that value, which is 8.8 kW.

The time needed to cool down one pallet upto 4 ^{0}C,

= (38-4)/10

= 3 h and 24 min

It means, the cooling load will be increased until 3hours and 24 mins and then it comes to steady state. (After 52 pallets came)

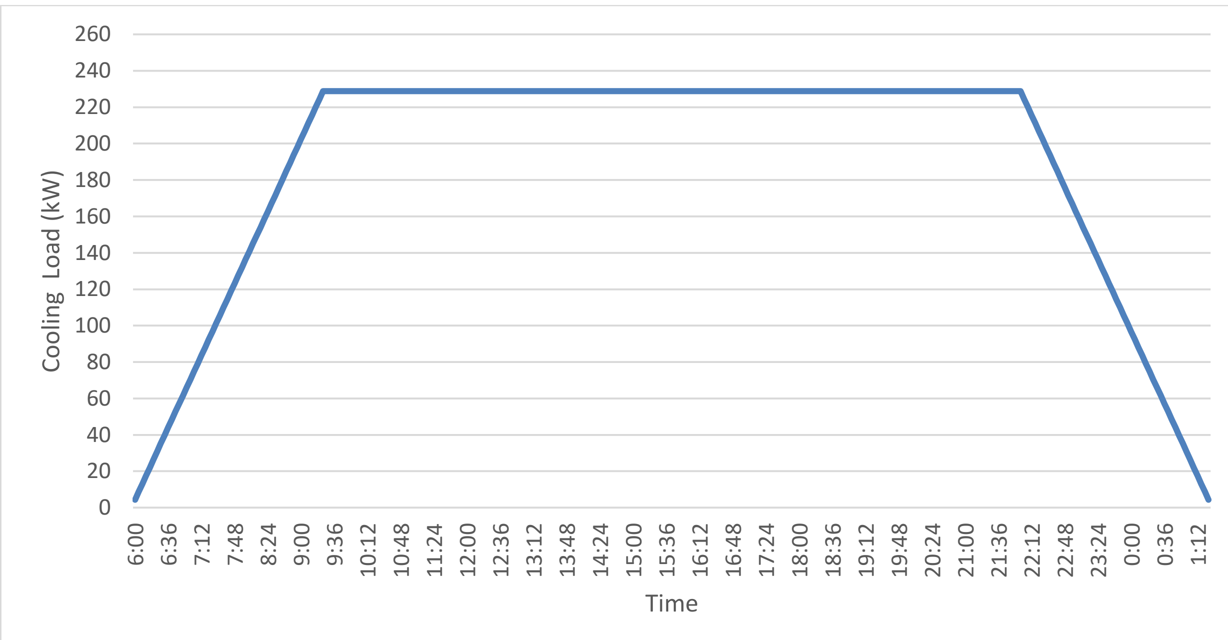


Figure3.1: Cooling load with time

The maximum cooling rate required is 9.24 am to 10.00 pm.

= 4.4 kW × 52 pallets

= 228.8 kW

3.3 Internal Loads

The internal heat load can be addition of lightning loads, Heat generated From Forklifts, and the heat generated from the workers.

The heat generated from lightning,

According to the plan there are 72 number of 25 W bulbs inside the coldroom,

Brightness of one bulb - 4000 lumens

Then the total heat load would be,

$$= 25\ W \times 72$$

$$= 1800\ W$$

Then the heat generated from forklifts,

As we all aware the diesel and other fuel used forklifts produce huge amount of heat due to engine working and other stuff. Hence its good to use fully electric forklifts to reduce the heat from the vehicles.

Assumption - The forklift takes 3 min for loading and unloading a pallet throughout the time. Then total forklift working time is,

$$= 15 \times 3\ min$$

$$= 45\ min\ per\ hour$$

Hence forklift works 12 hours for the total 16 working hours. There are two forklifts for loading and unloading. Then the total working time for two forklifts is 24 hours.

It's assumed the forklift total energy wastage is 10% from the overall power,

The total power power of the forklift

The lifting motor power = 9.9 kW

Drive motor power = 5.4 kW

The forklift total working time per 1 move is 3 minutes

Assumption – The total working time it's getting the 1 min time for driving and 2 min time for lifting.

Then The driving power for one pallet = 5.4 × 60

= 324 kJ

Then the lifting power for one pallet = 9.9 × 120

= 1188 kJ

Then the total power = 1188 + 324

= 1512 kJ

Then the power consumption for the forklift = 1512 / 180

= 8.4 kW

Then the energy wastage for the forklift is 10 % from the total power

= 0.84 kW

Then the heat loss from the two forklifts = 1.68 kW

Then the total energy loss as heat = 0.84 × 24 × 3600 ×2

= 145 152 kJ

According to ASHRAE refrigeration manual, Chapter 24 Page 4, the heat load from a person in a refrigerated space at 4 °C is 246 W. Assuming that two people are inside the refrigeration facility at one time, the two operators of the forklifts,

$$\begin{aligned} Heat\ load\ from\ people &= 246\ W \times 2 \\ &= 0.492\ kW \end{aligned}$$

Then the overall internal heat load = 0.492 + 1.68 + 1.8

= 3.972 kW

3.4 <u>Infiltration Load</u>

The whole belt system is working with belt system to input and the output the pallets.

Hence it is assumed the infiltration load of from the outside is near equal to zero. The reason is belt system is suddenly closing after pallet comes in.

3.5 <u>The equipment heat load</u>

This is the heat load that is added from the refrigeration equipment such as motors and defrosting equipment. The ASHRAE manual recommends an equipment heat gain of about 5% when the refrigerated space is above -1°C. However, it also recommends that a higher heat gain should be considered in high humid conditions due to the extra heat added during defrosting.

Hence, an equipment heat gain of 10% of the total load is considered.

$$
\begin{aligned}
Equipment\ heat\ load &= Total\ load \times 0.1 \\
&= (0.007 + 0.074 + 228.8 + 3.972) \times 0.1 \\
&= 23.29\ kW
\end{aligned}
$$

3.6 <u>Overall Heat Load</u>

The total of the loads, transmission, product load, infiltration and equipment heat load are,

$$
\begin{aligned}
Total\ Heat\ load &= 138.794 + 228.8 + 3.972 + 23.29 \\
&= 394.856\ kW
\end{aligned}
$$

A safety factor of 10% is added to allow for possible discrepancies between design criteria and actual operations. The overall heat load is as follows,

$$
\begin{aligned}
Overall\ Heat\ Load &= 394.856 \times 1.1 \\
&= 434.3416\ \mathrm{kW}
\end{aligned}
$$

CHAPTER 05 Refrigeration System Design

The refrigeration system is designed for a cooling capacity of 382 kW. An ammonia refrigeration system is selected for this refrigeration system.

5.1 Refrigerant

The refrigerant chosen for this application is Ammonia (R717).

It provides the following advantages:

- Low cost for the refrigerant charge.
- High latent capability offers higher operating efficiency.
- Narrow piping required gives lower initial cost.
- Environmentally friendly (does not deplete Ozone layer)

5.2 Compressor

A rotary screw compressor is selected considering the large cooling capacity required.

The Bitzer brand of compressors is chosen due to it being a German company with a solid reputation, producing refrigeration products for 86 years.

The following advantages are offered by a Bitzer ACP series compressor designed for operation with ammonia as a refrigerant:

- Variable Frequency Drive (VFD) to offer high part load efficiency.
- Motors used are IEC premium-efficiency motors with IP55 rating.
- Shutdown safety mechanisms including internal check valves to prevent rotors spinning backwards and oil solenoid/shut-off valve to ensure oil flow is stopped.
- Quality is ensured by a robust industrial-strength frame, coupling housing to ensure perfect motor-compressor shaft alignment, etc.

The compressor model will be selected based on:

$$Total\ cooling\ capacity\ required\ =\ 434.34\ kW$$

According to the above requirements, the following compressor model is selected

$$Compressor\ Brand\ =\ Bitzer$$

$$Series\ =\ ACP\ series$$

$$Model\ no\ =\ \mathrm{ACP8571K-2C}$$

5.3 Condenser

The condenser is used to cool the high temperature refrigerant which comes out of the compressor. The condenser is selected based on the heat rejection capacity.

A safety factor is used to account for the heat load added by the compressor motor and any additional heat gains in the system.

$$\begin{aligned}
Cooling\ Capacity\ of\ System\ &=\ 434.34\ kW\\
Safety\ Factor\ &=\ 12\%\\
Required\ Capacity\ of\ Condensor\ &=\ 434.34\ \times\ 1.12\\
&=\ 486.46\ kW
\end{aligned}$$

Accordingly, the selected condenser is as follows : (R134a Refrigerant)

$$\begin{aligned}
Condenser\ brand\ &=\ Bitzer\\
Model\ &=\ K3803T\\
Heat\ Rejection\ Capacity\ &=\ 511\ kW\\
Air\ Volume\ Flow\ &=\ 73.7\ m^3/hr\\
Tube\ Material\ &=\ Stainless\ steel\ 304\\
Fin\ Material\ &=\ Aluminium
\end{aligned}$$

5.4 Evaporator (Air Cooler)

The air cooler is selected based on the cooling capacity. Four air coolers are used at different locations of the cold room to ensure uniform cooling of the entire cold room.

$$\begin{aligned}
Total\ Cooling\ Capacity\ &=\ 434.34\ kW\\
Number\ of\ coolers\ &=\ 6\\
Cooling\ capacity\ per\ cooler\ &=\ \frac{434.34}{6}
\end{aligned}$$

$$= 72.39\ kW$$

Accordingly, the selected evaporator r is as follows

$$Evaporator\ brand = Bitzer$$
$$Model = DH - 164\ R454\ B$$

Table 5.1 Cooler specification

Cooling Capacity	76.7 kW
Air Outlet Temperature	(-4°C) - (-5°C)
Air Flow Volume	(-4°C) - (-5°C)
Fin Spacing	4 mm
Tube Material	*Stainless steel*
Fin Material	*Aluminium*
Number of Fans	2
Fan Diameter	1200 mm
Defrost Type	Electric

CHAPTER 06 Cost Estimation

Table 6.1: Bill of quantities

Item No	Item Name	Quantity	Estimated Unit Cost (Rs.)	Total Cost (Rs.)
1	Compressor; Bitzer ACP series ACP8571K-2C	1	4500000.00	4500000.00
2	Condenser; $Bitzer$ $K3803T$	1	9300000.00	9300000.00
3	Cooler; Bitzer $DH - 164\ R454\ B$	6	5700000.00	33300000.00
4	Forklift; Yale MR-14	2	6500000.00	13000000.00
5	Sliding door for forklift	1	769000.00	769000.00
6	Smaller insulated doors	2	96000.00	192000.00
7	Insulation panels		5000000.00	5000000.00
8	Racks		2000000.00	2000000.00
Total				68061000.00

REFERENCES

1. *Start a quote today* (no date) *Forklift Trucks and Materials Handling Equipment*. Available at: https://www.yale.com/en-sg/asia-pacific/contact/start-a-quote/

2. *ACP series* (no date) *BITZER // ACP.85 / ACP.95*. Available at: https://www.bitzer.de/gb/en/products/ammonia-compressor-packs/ammonia-compressor-packs/acp/acp.85-acp.95/

3. *2014 ASHRAE Handbook: Refrigeration* (2014). Atlanta, GA: ASHRAE.

4. *Compressor selection criteria* (no date). Available at: https://www.supercool.com.au/files/pdfs/unicla/CompressorSelectionCriteria.pdf

5. *Condensers information* (no date) *GlobalSpec*. Available at: https://www.globalspec.com/learnmore/building_construction/hvac/cooling/condensers

6. Gopalnarayanan, S. (1998) "Choosing the right refrigerant," *Mechanical Engineering*, 120(10), pp. 92–95. Available at: https://doi.org/10.1115/1.1998-oct-6.

7. *Insulation panel* (2023) *Cryo Systems Refrigeration*. Available at: https://www.cryocoldroom.com/?gclid=Cj0KCQiAo-yfBhD_ARIsANr56g4W2dstjdHDgqYhCLGhsoJfVJq2aPbpuDw8KH6KfJ9vEAQSJDIuRJUaApwUEALw_wcB