International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 5 ǁ 2022 ǁ PP. 57-61

Design and Fabrication of Plate Ice Machine

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Abstract
Techniques of freezing vary for each application. Generally used R-12 refrigerant cannot be used for rapid cooling application. Later it is discovered that number of viable vegetative microorganisms in food are greatly reduced by quick freezing implementation. By the development of plate freezer this challenge has been met to enhance effective preservation. Plate type evaporators may be used in single or in banks. The plates may be manifold for parallel flow of refrigerant, or they can be connected in series. This project deals with the design and development of horizontal type plate freezer. In this Project, plate freezer consisting of two plates connected in parallel and having a cooling load is to be designed. Installing formed square tubing between two metal plates, which are brazed together at edges, forms the plate surface evaporator. The refrigerant used is NH3 which is now found out in market as a replacement of R-12.
Keywords: *Plate freezer, plate type evaporator, rapid cooling, perishable food preservation, COP, Diffuser, Divergence angle, Increasing efficiency*

Date of Submission: 18-04-2022 Date of acceptance: 03-05-2022

I. INTRODUCTION

Freezing and cooling is one of the most applicable preservation methods for food products there is. Frozen food has an image of preserving freshness, at least more than canned or dried food. Fish, especially fish caught from fishing vessels, may be frozen one, two or in some cases three times before it is consumed. The first time is on the fishing vessel while the capacity of the boat is being filled up. The frozen fish block is ideally held frozen until it reaches the slaughter facility, which might be in another country and must be transported in containers, boats, trains or trucks. The frozen fish is thawed, filleted, packaged, re-frozen and transported to a storage of the supermarket. Plate freezers are small and have relatively short freezing time due to direct contact between product and plates, in which refrigerant is evaporating. Fish is distributed in stations, formed by the evaporating plates. Multiple fish are packed in one station, forming frozen fish blocks with varying thickness, depending on plate freezer design. Fast freezing time, leading to increased capacity, is crucial to fishing vessels. Therefore, prediction of freezing time is an important parameter when designing new freezing systems or freezing facilities.

Conventional food preservation is done by keeping the food inside chambers having evaporator coils around it. This chamber is insulated from the surroundings by a casing. The vapour compression system is the most widely used system. The heat transfer takes place from the food to the freezer (chamber) surface through the air gap. As air is a bad conductor of heat, the freezing rate is low and time consuming. The freezing rate was increased by the development of the freezer. Only compactable foods can utilize this method. The Plate freezer under consideration is a multi-plate freezer. In the plate freezer there are two plates through which the refrigerant expands. The food is placed between the plates and are brought closer so that the food gets pressed to a pre-determined pressure. As the plates are in direct contact with the food, there is better heat transfer and hence the freezing rate is increased. The plate used is copper plate, which is having a high heat transfer coefficient. The two plates are brought closer manually.

Figure 1 Plate Freezer

II. Design Conditions – by the Manufacturer – INDO TEC Engineers.

1) Designed Ice Production: 20 Tons per day
2) Number of Plates: 10 Plates
3) Size of the Plate: 1.5-Meter-Wide X 1.0 Meter Height
4) Water temperature: 32°C
5) Ice Temperature: -6°C
6) Ice Thickness: 10 mm
7) Freezing time: 8 minutes
8) Harvest (Defrost) time: 2 minutes
9) Refrigerant used: Ammonia (NH 3)
10) Evaporation Temperature: -10°C (1.9 bar)
11) Condensing Temperature: +40°C (15.554)
12) Compressor used:
a. Make: Kirloskar Pneumtics
b. Model: KCX-3
c. Speed: 750 RPM
d. Motor: 75 HP
e. Refrigeration Capacity: 159.1 kW
f. Motor Power required: 47.97 BkW (Break kilo watt)

4.3 Design calculation
Capacity: 20 Tons
Freezing Cycle: 8 mins
Defrost Cycle: 2 mins
Freezing time in a day: 19.2 hours
Heat Load To Produce Ice:
Water inlet Temp. = 30°c
Freezing Temp. = 0°c
Ice Temp. = -2°c
Sp. Heat of water above freezing = 4.184 kJ/kgK
Sp. Heat of water below freezing = 2.092 kJ/kgK
Latent heat of freezing water = 334.72 kJ/kgK
Heat to be removed from 1kg of water @ 30°c to ice @ -2°c = 340.996 kJ/kgK
Heat to be removed from 20 tons = 6819920 kJ
Heat load per hour = 355204.1667 kJ/h

NH3required to produce ice @ -2°c from water @ 30°c
Evaporation temp. of NH3 = -10°c
Enthalpy of NH3 liquid @ -10°c = 372.376 kJ/kg
Enthalpy of NH3 vapour @ -10°c =1665.23 kJ/kg
Heat absorbed = 1292.854 kJ/kg
NH3 required to freeze 1 kg water

From 30°c to -2°c = 0.262902415kg
0.262902415kg of NH3 is required to freeze 1 kg water at 30°c to-2°c
Amount of NH3 required per hour (for refrigeration) =273.8566823 kg/h
NH3 circulated (using swept volume of compressor)

Swept volume of one cylinder @1000 RPM = 132.7 m3/h
Swept volume of one cylinder @750 RPM = 99.525 m3/h
Specific volume of NH3 vap. @-10°c = 0.418 m3/kg
Density of NH3 vap. @-10°c = 2.39234 kg/m3
Total swept volume (3Cylinders) @ 750 RPM = 298.575 m3/h
Total NH3 circulated in an hour @ 750 RPM = 714. 2929 kg/h
Total NH3 required to be circulated
Heat absorbed to convert +40°c liq. NH3 to -10°c liq. NH3 (1 kg) = (hf NH3 at +40°c – hf NH3 at -10°c) = 615.048 – 372.376= 242.672 kj
Heat absorbed to convert (1 kg) +40°c liquid NH3 to -10°c vapor NH3 = (hf NH3 at 40°c – hf NH3 at -10°c) =1050.182 kJ
Heat absorbed by evaporating 1kg -10°c vap NH3 = (hf NH3 at -10°c – hf NH3 at -10°c) =1292.854 kg
Weight of NH3 liquid required at -10°c = 273.8566823 kg/h
Refrigeration produced by NH3 in an hour = 273.8566823 × 1292.854 = 354056.7071 kg/h
Weight of +40°c NH3 liquid required to be evaporated to cool 273.8566823 kg of +40°c
NH3 to -10°c liquid (242.672 × 273.8566823) ÷1050.182 = 63.28174 kg/hr.
Total NH3 required to be circulated = 273.8566823 + 63.28174= 337.1384266 kg/h
Amount of NH3 evaporated to cool NH3 from +40°c liquid to -10°c liquid
When 714.2929kg/h is circulated= (63.28174÷3371384266) × 714.2929= 314.0745937 kg
Amount of NH3 evaporated in evaporator when 714.2929 kg is circulated= (273.8566823÷337.1384266) × 714.2929= 580.2182971 kg
Refrigeration produced by 580.2182971 kg of NH3 liquid at -10°c= 580.2182971 × 1297.044= 752568.611 kJ/h
COP (From calculation) = Refrigeration Effect ÷ Motor Power = 209.0468 kw ÷ 47.92kw = 4.3624
COP (From data by Kirloskar) = 159.1kw ÷47.92kw= 3.3201

4.4 Design Conditions – by the Manufacturer – INDO TEC Engineers.
Designed Ice Production
Calculation:
Factors used:
1) Specific Heat of Water Above Freezing: 4.184 kJ/ kgK
2) Freezing temperature of water: 0°C
3) Latent heat of water: 334.72 kJ/kgK
4) Specific Heat of Water Below Freezing: 2.092 kJ/ kgK

4.3.1 Calculation:
Heat load for Freezing:
a) Heat to be absorbed above freezing: =32°C × 4.184 =133.888 kJ/kgK
b) Latent heat to be absorbed: = 334.72 kJ/kg
c) Heat to be absorbed below freezing: =6 × 2.092 = 12.552 kJ/kgK
d) Total Heat to be removed to form 1 kg ice: = 481 kJ/kg
e) Total heat to be heat removed from 20000 Liters of Water= 20,000 X 481=
9623200kJ
Time available for freezing:
i) Freezing cycle per hour: 60 minutes ÷ 10 mins = 6 cycles
ii) Freezing time in 6 cycles: 6 X 8 mins = 48 mins
iii) Defrost time in 6 cycles: 6 X 2 mins = 12 mins
iv) Therefore, Total freezing time in 24 Hours: (48 mins X 24) ÷60 = 19.2 hours
Compressor capacity required for 20 tons' ice per24 hours:
9623200kJ ÷ 19.2 Hrs = 5012008.3333 kJ/h = 139.2245 kW
Adding 10% as factor of safety: = 139.2245 + 10% = 153.1469 kW

4.4 Observation
1) Saturated Suction Pressure-During freezing time: 1.9 bar (-10°C)
2) Condensing pressure During freezing time: 12.5 bar (+35°C)
3) Saturated Suction Pressure-During defrost time: 1.7 bar (-11 C)
4) Condensing pressure During defrost time: 9.5 bar (+27°C)
5) The recycle water temp: pre cooled to +1°C

4.5 Suggestion

Keep all the above designed factors but keep the ice temperature as -5°C as per the users -4°C ice temperature also OK for them.

Formula used: Freezing time of ICE in hours: (7 x A 2) ÷ (Ice temperature in °F – Refrigerant temperature in °F)

A = ice thickness in inches

Ice thickness: 10 mm = 0.3937 inches

Refrigerant Evap Temperature = -10°C = 14°F

Ice temperature: = -6°C = 21.2 °F

Freezing Time = (7 x A 2) ÷ (Ice. temp – Refrigerant Evap.temp) =

(a) As per original design: (7 x 0.3937 2) ÷ (21.2°F - 14°F) = 0.1506 hours = 9.09 minutes

(b) With -5°C (23°F) Ice temperature: (7 x 0.3937 2) ÷ (23°F - 14°F) = 0.1206 hours = 7.2 minutes

(c) Refrigerant temp (Evap Temp) Required:

With 9 minutes freezing time, -5 °C Ice temp, 10mm thick ice

= (Ice temp – (7 x A 2)) ÷ Freezing time)

= 23 °F - (7 x 0.3937 2) ÷ 0.15 hrs. = 15.76 °F = -9°C

(d) Compressor capacity at -9 deg C Evap. temp = 167. 73 kW

(e) Motor Power required: 48.78 Break kW

(f) Refrigeration Required: 133.888 kJ+ 334.72kJ +10.46kJ = 479.068 kJ/kg

(g) For 20 Tons in 19.2 Hours = (20,000 kg X 479.068) ÷ 19.2 hours = 499029.1667kJ/h = 138.6192kW

(h) With 10% safety = 152.481 kW

(i) Extra refrigeration available: Comp capacity – Refrigeration required = 167.73-152.418 = 15.312 kW

(j) Extra ice possible = (20 tons÷135.5kW) X 15.312 = 2.26 tons

III. CONCLUSION

The proposed system of plate freezer enhances the COP by 10% as compared to the normal conventional refrigerator. The system reduces the large mass flow rate requirement very efficiently because of parallel flow system through the evaporator section. The freezing rate is considerably reduced for the same volume as compared to the conventional refrigerator nearly by half of the time required. The evaporator heat load as a parameter shows an effect on the cycle performance, where the heat rejected from the condenser and COP increase with the increase of the evaporator load Compared to other conventional refrigerators our project is very compact and able to save energy and it is also cost effective. So, our project will play a major role in the field of engineering.

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