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Design and Development of Ice Plant Setup

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Abstract - The aim of the project is to design an experimental set up for a Refrigeration and Air conditioning laboratory. The ice plant test rig is used to find out the capacity of the ice plant, calculate coefficient of performance (COP), reduce the refrigeration time and plot the system performance on P-H chart. For the design purpose cooling load required to produce definite quantity of ice estimated using heat transfer relation is calculated by using vapor compression cycle. The model is examined for its cooling capacity assumed per unit mass flow rate of refrigerant. As per the study, physical and chemical properties of different refrigerants, we come to the final decision that R134a is the best suitable refrigerant for the proposed system. Brine is better suited as a secondary refrigerant for the requirements of the system due to its excellent properties over conventional secondary refrigerant. Capillary tubes or thermostatic expansion valves can be used as expansion devices, copper tubes will be used as the evaporator of shell and tube kind. A hermetically sealed compressor is used in the system.

***Key Words**:* Refrigeration, Refrigerant, Evaporation, Coefficient of performance, Compression, Brine

1. INTRODUCTION

A. Introduction to Ice-Plant

An experimental setup of an ice plant involves the design, construction, and testing of a closed-loop refrigeration system to produce ice. This setup typically includes several key components such as a compressor, condenser, evaporator, and expansion device, which work together to create a continuous cycle of refrigerant flow. The first step in setting up an experimental ice plant is to select the appropriate components for the system. These components may include off-the-shelf items or custom-designed parts, depending on the specific requirements of the experiment. The compressor, for example, must be selected based on its capacity and ability to compress the refrigerant to the required pressure levels. The condenser is designed to dissipate heat from the refrigerant to the surrounding air, while the evaporator is designed to absorb heat from the water source to create ice. Once the components are selected and assembled, the next step is to charge the system with refrigerant. The refrigerant is typically a fluid that undergoes a phase change from liquid to gas as it absorbs heat from the evaporator and then back to liquid as it releases heat to the condenser. The refrigerant is chosen based on its ability to efficiently absorb and release heat, as well as its environmental impact. Overall, an experimental setup of an ice plant is a complex and important tool for understanding the performance of refrigeration systems and developing more efficient and effective ice-making processes. By carefully controlling the experimental parameters and collecting data on system performance, engineers can gain valuable insights into the underlying physics of the system and identify opportunities for optimization.

B. Vapour Compression Refrigeration System

The Vapor Compression Refrigeration System (VCRS) is a common method used for refrigeration and air conditioning. It works by circulating a refrigerant through a closed loop system that includes a compressor, condenser, evaporator, and expansion valve. The process begins when the compressor pumps the refrigerant, which is in a low pressure gaseous state, and raises its pressure and temperature. The high-pressure gas is then passed to the condenser, where it is cooled and condensed into a high-pressure liquid. The high-pressure liquid then passes through the expansion valve, where its pressure is reduced, causing it to expand and vaporize as it enters the evaporator. As it vaporizes, the refrigerant absorbs heat from the surrounding environment, which cools the area being refrigerated. The low-pressure refrigerant gas returns to the compressor, where the cycle begins again in same manner. By continually circulating the refrigerant through the system, the VCRS can create and maintain a cooling effect in the evaporator.

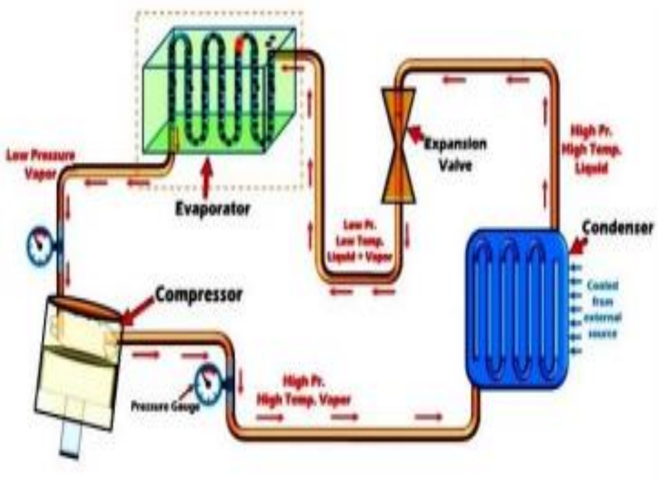

Fig -1: Vapour Compression Refrigeration System

Overall, the VCRS is a highly efficient and reliable method for providing refrigeration and air conditioning, and it is commonly used in a wide range of applications, from home and commercial cooling to industrial processes.

2. LITERATURE REVIEW

A. Design Optimization of Ice Plant Test [1]

Comprehending the operational process of ice plants and the selection of their components, various research papers were reviewed. The standard components used in an ice plant are the compressor, condenser, expansion valve, evaporator, chilling tank, refrigerant receiver, and measuring devices such as pressure gauge, voltmeter, and ammeter. These components are available in different specifications and types, and their working principles are also explained.

B. Methodology of Material Selection for Evaporator Coil in Air Conditioning System [2]

The selection of an evaporator coil was considered by looking at three main properties: thermal, mechanical, and corrosion. The thermodynamic efficiency of a refrigeration system depends mainly on its operating temperatures.

C. Refrigeration and Air conditioning [3]

The subsequent stage was to choose an appropriate compressor for the system. The selection of the compressor with the correct capacity was critical. Ultimately, a hermetically sealed compressor was chosen.

D. Selection of Condensers and Chillers Systems & Components (India) Pvt. Ltd., For Energy Efficient Refrigeration Systems. [4]

The paper helped in analyzing various types of condensers available in the market and selecting the best one for the project. After careful consideration, it was determined that an air-cooled condenser was the most suitable option for the project. An air-cooled condenser works by using ambient air to cool and condense the refrigerant. This type of condenser is particularly useful in areas where water is scarce or expensive, as it does not require a water source for cooling. Additionally, air-cooled condensers are more compact and easier to maintain than their water-cooled counterparts. Overall, the research paper provided valuable insights into the selection of condensers and chillers and helped in choosing the most appropriate air-cooled condenser for the project.

E. Improvement of Coefficient of Performance of Ice Plant [5]

The paper discusses the importance of COP and the factors that affect it, such as evaporator temperature, condenser temperature, and compressor efficiency. The authors then propose various methods to improve the COP, such as optimizing the refrigerant charge, improving the insulation of the evaporator and condenser, and using a variable-speed compressor. The research paper concludes that optimizing the refrigerant charge and using a variable-speed compressor are the most effective methods to improve the COP of an ice plant. The paper provides valuable insights for improving the energy efficiency and performance of ice plants, which can have significant economic and environmental benefits.

F. A study on analysis and fabrication of ice plant model [6]

The paper describes the development of a working model of an ice plant to understand its functioning. The paper explains the different components used in an ice plant, their roles in the ice-making process, and the factors that affect the plant's performance. The authors describe the fabrication and testing process of the ice plant model and conclude that the model simulated the operation of an actual ice plant and provided insights into its design and performance.

G. Ice Plant Test Rig. [7]

The research paper focuses on developing an experimental test setup for refrigeration purposes in college laboratories. The design of an ice plant test rig that can determine the ice plant's capacity, evaluate its coefficient of performance (COP), and reduce refrigeration time. Based on the research on different refrigerants' physical and chemical properties, we have determined that R134a is the best refrigerant for the proposed system.

3. METHODOLOGY

A. Process for creating a test rig for an ice plant

1) Design : The first step in the methodology of an ice factory is designing the facility. This involves determining the production capacity, ice storage capacity, and the type of ice to be produced. The design also includes the layout of the factory, the selection of equipment, and the design of the refrigeration system. The design process considers factors such as available space, accessibility, and ease of maintenance. The design may also include measures to ensure the environmental sustainability of the facility.

2) Procurement : Once the design is finalized, the necessary equipment and materials are procured. This includes ice-making machines, refrigeration equipment, storage tanks, water treatment systems, and other necessary components. The procurement process involves identifying and selecting vendors, negotiating contracts, and ensuring timely delivery of the equipment and materials.

3) Installation : The equipment is installed and commissioned, and the necessary piping and electrical connections are made. The refrigeration system is tested for leaks, and the ice-making machines are calibrated to produce ice of the desired size and quality. The installation process may take several weeks or months, depending on the size of the facility and the complexity of the equipment.

4) Operation : Once the installation is complete, the ice factory is ready for operation. The factory is operated according to a set of standard operating procedures (SOPs). These SOPs include guidelines for water treatment, ice production, ice storage, and quality control. The ice factory also employs trained personnel to operate and maintain the equipment. The factory may operate 24/7 to meet the demand for ice.

5) Quality control : The ice produced by the factory is subjected to regular quality control checks to ensure that it meets the required standards. These checks include microbial testing, chemical analysis, and physical testing. The factory may have a laboratory to perform these tests, or it may outsource them to a third-party laboratory. The results of the tests are used to adjust the production process and ensure that the ice produced is of high quality.

6) Maintenance : The equipment is maintained according to a regular maintenance schedule, which includes cleaning, lubrication, and replacement of worn parts. The refrigeration system is also maintained to ensure that it operates efficiently. The maintenance process may involve shutting down parts of the facility temporarily to perform repairs or maintenance tasks.

7) Environmental sustainability : The ice factory may adopt measures to reduce its environmental impact, such as recycling wastewater, using energy-efficient equipment, and reducing greenhouse gas emissions. These measures may be part of the design process or implemented later as part of the factory's sustainability goals. The factory may also comply with environmental regulations and obtain certifications to demonstrate its commitment to sustainability.

In summary, the methodology of an ice factory involves designing, procuring, installing, operating, maintaining, and ensuring the environmental sustainability of the facility. The process requires careful planning and execution to produce ice of high quality, operate the facility efficiently, and minimize the environmental impact.

B. Experimental Plan

Determine the performance of the ice plant test rig under certain operating conditions. Define the type of ice to be generated, the refrigeration capacity, and the operation circumstances. Ensure that all relevant equipment and materials are available. Install sensors and measurement tools to collect data on ice production rate, ice quality, refrigeration capacity, energy usage, and other important characteristics. Start the ice plant test rig and run it for a predetermined time period under experimental conditions. Analyse the acquired data to determine the performance of the ice plant test rig under experimental settings. Interpret the experimental results and develop judgements about the performance of the ice plant test rig.

Fig -2: Experimental plan

4. FABRICATION OF ICE PLANT

A. Selection of components

1) Compressor : Hermetic and semi-hermetic compressors are designed with an integrated motor that operates within the pressurized gas envelope of the refrigeration system. The motor is cooled by the gas or vapor being compressed, and both the motor and compressor are not separable in a hermetic compressor. On the other hand, a semi-hermetic compressor has a large cast metal shell with gasket covers that can be opened for maintenance purposes. These compressors are commonly used in ice-plant industries and the hermetically sealed reciprocating compressor is a popular type used in such industries. When selecting a compressor for an application, several factors such as evaporator operating conditions, refrigerant type, ambient conditions, required refrigeration capacity, compression ratio, and total required power input are taken into consideration. The main advantage of using a hermetic or semi-hermetic compressor is that it eliminates the possibility of gas leaks in the refrigeration system.

Selected Compressor: Hermetically Sealed Compressor

The hermetically sealed reciprocating compressor is a commonly used component in refrigeration and air conditioning applications, found in household refrigerators, deep freezers, window air conditioners, split air conditioners, and most packaged air conditioners. Compared to open-type compressors, the hermetically sealed compressor is easier to handle and maintain due to its compact, portable unit. In this type of compressor, the compressor and motor are enclosed in a welded steel casing and connected by a common shaft, while traditional open-type compressors have separate compressor and motor components connected by a coupling or belt.

2) Condenser & Fan : The condenser unit is a vital component of an HVAC system, as well as any refrigeration system. It works by taking in a refrigerant that is in a superheated state, then de-superheating and condensing it by releasing heat to an external medium. The refrigerant can exit the condenser as either a sub-cooled or saturated liquid, which depends on the condenser's design and the temperature of the external medium.

Selected Condenser: Air-Cooled Condenser

An air-cooled condenser is a heat exchanger used in HVAC and refrigeration systems that removes heat from the refrigerant by using ambient air as a cooling medium. This type of condenser is used when a water-cooled system is not practical or when water is scarce or expensive. The air-cooled condenser consists of a network of coils made of copper or aluminium, through which the hot refrigerant vapor flows. The coils are usually arranged in a serpentine shape, with fins or plates attached to the coils to increase their surface area and promote heat transfer. As the hot refrigerant vapor flows over the coils, it gives up its heat to the ambient air flowing over the fins. This causes the refrigerant vapor to cool down and condense into a liquid state, which can then flow to the evaporator to start the cooling process again. The air-cooled condenser requires a steady supply of ambient air to remove the heat from the refrigerant. This is usually achieved by installing a fan or blower that blows air over the condenser coils. The fan may be powered by electricity or may be driven by a belt connected to a motor. The efficiency of an air-cooled condenser is affected by several factors, including the ambient temperature and humidity, the speed and size of the fan, the surface area of the coils, and the refrigerant used in the system. The effectiveness of the heat transfer is directly related to the temperature difference between the refrigerant and the ambient air. The fan or fans are used to draw ambient air through the fins, which causes heat to transfer from the hot fluid to the fins and then to the air. The cooled fluid then condenses into a liquid state and is collected and circulated back to the system for reuse. The fan or fans are typically mounted on top of the condenser and are designed to provide the required airflow to maintain the desired temperature of the condenser. Overall, air-cooled condensers are a cost-effective and reliable option for HVAC and refrigeration systems in applications where water is scarce or expensive, or where water-cooled systems are not practical. However, they may require more maintenance than water-cooled systems due to the build-up of dust and debris on the condenser coils, which can decrease their efficiency over time.

3) Expansion device: Capillary tubes are commonly used as an expansion device in ice plants because they provide precise and reliable control over the refrigerant flow. An expansion device is used to regulate the flow of refrigerant between the high-pressure and low-pressure sides of a refrigeration system. This is necessary in order to maintain the proper pressure and temperature conditions needed for the refrigeration cycle to function effectively. Capillary tubes are ideal for use in ice plants because they are simple and inexpensive to manufacture, and they provide a very small orifice through which the refrigerant must flow. This small size allows for a precise control of the refrigerant flow rate, which is essential for ensuring that the evaporator temperature is maintained at the desired level. In addition, capillary tubes do not require any moving parts or external power sources, which makes them highly reliable and low-maintenance. They are also well-suited to handling the refrigerants commonly used in ice plants, such as ammonia or Freon. Overall, capillary tubes provide a reliable, cost-effective, and efficient way to regulate the flow of refrigerant in an ice plant, making them a popular choice for this application.

4) Evaporator : The evaporator coil in an ice plant is a heat exchanger that is responsible for absorbing heat from the water or solution that is being frozen, thereby causing the water to freeze and form ice. The evaporator coil is typically located inside a large insulated tank or vessel that contains the water or solution to be frozen. As the refrigerant flows through the evaporator coil, it evaporates and absorbs heat from the water or solution, causing the temperature of the water to drop below the freezing point. This process continues until the water is frozen solid and has formed a layer of ice on the surface of the coil. The design of the evaporator coil is critical to the efficiency and performance of the ice plant. The coil must be able to absorb heat from the water at a rate that is sufficient to freeze it within a reasonable amount of time. At the same time, the coil must be designed to prevent the formation of ice build-up, which can reduce the efficiency of the system. To achieve optimal performance, the evaporator coil in an ice plant should be designed with the appropriate surface area, refrigerant flow rate, and fin spacing to ensure
efficient heat transfer. Additionally, the coil should be constructed of materials that are resistant to corrosion and can withstand the low temperatures and pressures of the system Overall, the evaporator coil plays a critical role in the operation of an ice plant, as it is responsible for freezing the water or solution and producing the ice that is used for cooling and other applications.

5) Refrigerant : Selected Refrigerant: R134a - By considering these factors, R134a suits the criteria that will provide reliable and efficient operation while minimizing the environmental impact of the system. R134a is a hydrofluorocarbon (HFC) refrigerant that is widely used in refrigeration and air conditioning systems. It is a non-toxic, non-flammable, and non-ozone-depleting substance with a low global warming potential (GWP). R134a has good thermodynamic properties, including a boiling point of -26.3°C and a critical temperature of 101.1°C, which make it suitable for use in a wide range of applications, including automotive air conditioning, commercial refrigeration, and residential air conditioning.

6) Gauges: Two types of sensors are used in the circuit. K type and pt100. K-type sensors are commonly used for temperature indication in a wide range of applications. K-type sensors are thermocouples that generate a voltage proportional to the temperature difference between two junctions of dissimilar metals. The voltage is then measured and converted to a temperature reading.PT100 temperature indicating sensors are resistance temperature detectors (RTDs) that measure temperature by sensing the resistance of a metal, typically platinum, as it changes with temperature. PT100 sensors are known for their high accuracy, stability, and repeatability, and are commonly used in applications where precise temperature measurement is required. Sensors are connected to temperature indicators through a wired connection. The specific details of the connection will depend on the type of sensor and indicator being used. K-type thermocouples are typically connected to a temperature indicator through a pair of wires. One wire is connected to the positive (+) terminal of the indicator, while the other wire is connected to the negative (-) terminal. The voltage generated by the thermocouple is measured across these two wires and converted into a temperature reading. Similarly, PT100 sensors are typically connected to a temperature indicator through a pair of wires. One wire is connected to the positive (+) terminal of the indicator, while the other wire is connected to the negative (-) terminal. The resistance of the PT100 sensor is measured across these two wires and converted into a temperature reading. A pressure gauge is a device used to measure the pressure of a gas or liquid in a system. It typically consists of a round dial with a pointer, a Bourdon tube or diaphragm that is sensitive to changes in pressure, and a connection point for attaching the gauge to the system being measured. A compound gauge, also known as a vacuum/pressure gauge, is a type of pressure gauge that is capable of measuring both positive and negative pressure (vacuum). It typically has two scales, one for measuring positive pressure and another for measuring negative pressure. The positive pressure scale is typically labelled in pounds per square inch (psi), while the negative pressure scale is labelled in inches of mercury (inHg) or millimetres of mercury (mmHg).

7) Stirrer : The stirrer is an important component in an ice plant that is used to agitate the water in the ice-making process. The main purpose of the stirrer is to ensure that the water is cooled evenly and to prevent the formation of air pockets, which can reduce the quality and clarity of the ice. When water is frozen into ice, it forms a crystalline structure, and any impurities or air bubbles present in the water can become trapped within the ice. This can make the ice cloudy and less appealing to customers. The stirrer helps to prevent this by ensuring that the water is cooled evenly, and any air bubbles or impurities are dispersed throughout the water. The stirrer is typically a rotating shaft with paddles or blades attached to it. As the shaft rotates, the paddles stir the water, ensuring that it is cooled evenly and preventing any air pockets from forming. Some ice plants may also use a recirculating pump in conjunction with the stirrer to further improve the efficiency of the ice-making process.

Overall, the stirrer plays a critical role in the ice-making process, helping to ensure that the ice produced is of high quality and meets the standards expected by customers.

8) Insulation : Selected Insulation: PU foam - PU foam insulation, also known as polyurethane foam insulation, is a type of insulation material commonly used in ice plants to prevent heat gain and maintain the desired temperature within the refrigeration system. The insulation is made of a rigid foam material that is applied to the pipes, tanks, and other components of the refrigeration system to provide a layer of thermal protection. The main purpose of PU foam insulation in an ice plant is to minimize heat transfer between the environment and the refrigeration system. This helps to reduce energy consumption and increase the efficiency of the refrigeration system. The insulation also helps to prevent condensation and moisture build up, which can cause corrosion and other issues within the refrigeration system. PU foam insulation has several advantages over other types of insulation materials. It is lightweight and easy to install, making it ideal for use in tight spaces or hard-to-reach areas. It is also resistant to moisture, mold, and mildew, which can be a problem in the humid environments typically found in ice plants. In addition, PU foam insulation has a high insulation value, which means that it provides effective thermal protection with a relatively thin layer of material. Overall, PU foam insulation is an important component of an ice plant, helping to maintain the desired temperature within the refrigeration system and increase the efficiency of the plant. It is a cost-effective and practical solution that has proven to be reliable and effective in a wide range of applications.

B. Structure of Body

1) Body : The ice-plant is a rectangular body that is constructed from stainless steel sheet material, and it is divided into two separate chambers. The first chamber is designated for the refrigeration cycle, which includes various components such as the compressor, condenser, fan, capillary tube, and accumulator. The second chamber, on the other hand, houses the evaporator coil, secondary refrigerant, temperature sensors, and pump used for stirring.

2) Ice vessel : An ice container is a vessel or container that is specifically designed to store ice. It is typically made of plastic, metal, or other materials that can effectively insulate the ice to maintain its temperature and prevent it from melting quickly. Ice containers come in various sizes and shapes, ranging from small portable containers that can hold a few ice cubes, to large commercial containers that can store several hundred pounds of ice. Some ice containers may also have features such as lids, handles, and insulation to help keep the ice from melting too quickly.

3) Chilling tank : A chilling tank for brine in an ice plant is a container specifically designed to hold brine, a solution made of water and salt that is used as a refrigerant in ice plants. The chilling tank is typically made of a durable material such as stainless steel or plastic, and is capable of withstanding the low temperatures associated with the brine solution. In an ice plant, the chilling tank for brine is an essential component of the refrigeration. The brine solution is cooled to a low temperature and circulated through the evaporator coils, which in turn cool the water that is used to create ice. As the water freezes, the ice is formed and can be harvested from the ice plant. The chilling tank for brine plays a critical role in maintaining the proper functioning of the refrigeration cycle. It is responsible for holding the brine solution, which is used to absorb heat from the water and create ice. The bucket must be properly sized and insulated to prevent heat loss and ensure that the brine solution remains at the appropriate temperature. Chilling tanks for brine are typically available in a range of sizes, depending on the capacity of the ice plant and the amount of ice that needs to be produced.

4) Insulating Lid : Steel lids with rubber coatings are commonly used in various applications, such as food storage containers, water bottles, and beverage containers. The steel provides a durable and long-lasting base, while the rubber coating offers additional benefits such as protection against scratches, increased grip, and resistance to corrosion.

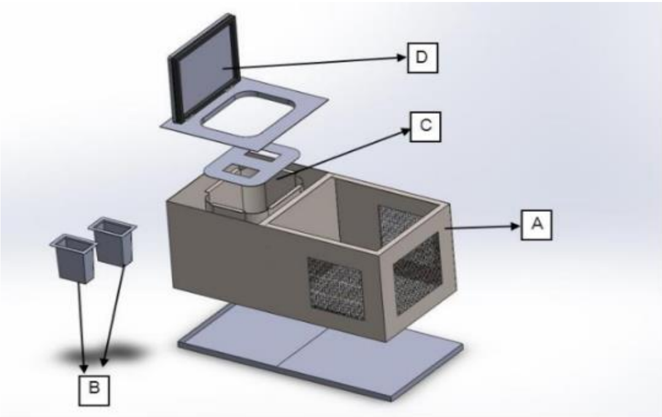

Fig -3: Structure of Body

5.EXPERIMENTAL PROCEDURE AND CALCULATION

A. Procedure

1) Preparation of unit for test: Empty before starting the refrigeration cycle and please check the following. The pressure gauges should indicate equal pressure, that Indicate HP and LP side are balanced. Proper earthing is provided to the unit. See that the motor shaft along with the fan is free in its bearing. This can be confirmed by rotating the shaft in its bearing. Put water in the brine tank approximately up to the mark. Add 100 kgs. Of common salt into the tank without splashing the water. Then stir this water by using the stirrer for some time. If the strength is proper then close the door of the tank. Also confirm that there is no leakage at the drain of the tank.

2) Test procedure: Now, the unit is ready for experiment. Start the condenser fan and after 2-3 minutes start the compressor. When the refrigeration circuit starts functioning, put the stirrer fan on. Note down the brine solution temperature at certain interval of time say ½ hour or so. The temperature of the brine drops slowly. The stirrer may be put off for some time. If necessary, now when the temperature of secondary refrigerant reaches 3° -4°. Stop the stirrer, open the door of the tank. Load the ice cans on the frame of the chilling tank. Close the door properly. Note down the exact time when the cans are loaded. Now let the refrigeration system run for some time. The dial thermometer temperature will rise. Then start the stirrer motor. The temperature of the dial thermometer will start dropping. The system runs continuously and the fan observations are entered into the table. Now at the end of the 24 hours period from the loading the cans stop the stirrer motor. Open the door and see the condition of water in the cans. The ice should have formed. Take out the cans properly. Keep the can one by one in the water tank so that the ice slab will come out. Weight of the slab and confirm that the weight of all slabs is 30 kg..

3) Observations: Temperature of water filled in cans at time of loading(Tw)= 26° C

Weight of empty can = 817 + 960
= 1777g

Starting time=
Refrigerant inlet temperature to evaporator (T1)= 0° C
= 273 K

Refrigerant outlet temperature from evaporator(T2) = 46° C
= 319 K

Refrigerant outlet temperature to condenser (T3) = 30° C
= 303 K

Refrigerant outlet temperature from condenser (T4) = - 4.7° C
= 268.3 K

Brine solution temperature = - 6 ° C

Weight of ice with can =
Weight of ice = 3 kg
Time required for 10 rev. Of energy meter = (Tc)

Energy meter constant =
HP = 7 bar
LP = 1.5 bar

4) Graph:

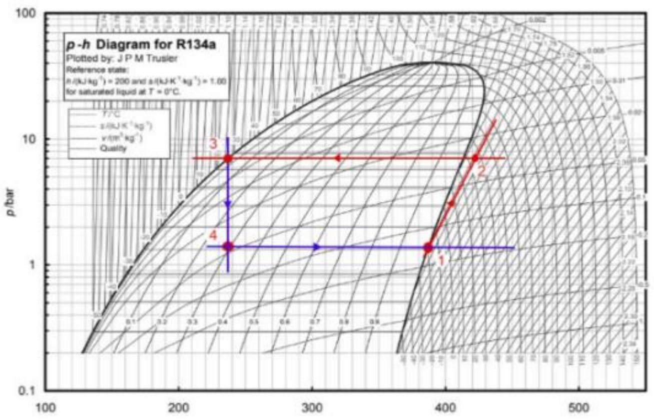

Fig -4: R134a P-H Chart

From the P-H Chart, the enthalpy of each point can be noted, i.e.
h1 = 395 kJ/kg
h2 = 426 kJ/kg
h3 = h4 = 268 kJ/kg

B. Calculations

1) Calculate the actual coefficient of performance (COP) -

$$\text{Actual COP} = \frac{h1 - h4}{h2 - h1} = \frac{395 - 268}{426 - 395}$$

Actual COP = 4.096

2) Calculate the ideal coefficient of performance (COP) -

$$\text{Ideal COP} = \frac{TL}{TH - TL} = \frac{268.3}{319 - (-268.3)}$$

Ideal COP = 5.29

3) Calculate the total heat removed (Q) –

Specific heat of ice = 2.09 kJ/kg K
Specific heat of water = 4.167 kJ/kg K
Latent heat of ice = 335 kJ/kg K
Mass (m) = 3 kg
Initial temperature = 26° C
Final temperature = 0° C

Now, to calculate the sensible heat required (Q1) to be taken out from water to convert it from 26° C to 0° C is
$Q1 = mw \cdot Cp_w \Delta \cdot t$
$= 3 \times 4.187 \times (26 - 0)$
Q1 = 326.58 kJ

Now, to calculate latent heat (Q2) from 0° C of water to convert it into 0° C of ice is –
Q2 = m . L
= 3 x 335
Q2 = 1005 kJ

Also, the heat required (Q3) to be removed from 0° C to - 6° C is -
$Q3 = mi \cdot Cpi \cdot \Delta t$
$= 3 \times 2.09 \times [0 - (-6)]$
Q3 = 37.62 kJ

The total heat removed (Q total) is calculated as –
Q total = Q1 + Q2 + Q3
= 326.58 + 1005 + 37.62
Q total = 1369.2 kJ

4) To calculate the Work done (W) by -

Work done = V. I
= 2.63 x 224
= 582.4 W or J/s

$$= \frac{582.4 \times 60 \times 60}{1000} \text{ kJ/hr}$$

Work done = 9706.66 kJ/hr

5) To calculate the refrigeration effect (RE)-

$$COP = \frac{RE}{W}$$

RE = 4.096 x 161.77
RE = 662 kJ/ hr

6) To Calculate the theoretical COP –

$$\text{theoretical COP} = \frac{Q}{W} = \frac{1369.2}{161.77 \times 2}$$

theoretical COP = 4.231

7) Efficiency of Ice-plant (ὴ) -

ὴ = Actual COP

Carnot COP

$$= \frac{4.096}{5.29}$$

ἠ = 0.774

ἠ = 77.4 %

6. RESULT AND CONCLUSION

A. Result

1) Actual COP = 4.096
2) Theoretical COP = 4.231
3) Refrigerant effect produced = 662 kJ/ hr
4) Efficiency = 77.4 %

B. Conclusion

1) It concludes that the theoretical COP of the test rig is greater than actual COP.
2) When the evaporator tank is perfectly insulated then the COP of the system increases.
3) Pressure drop in condenser and evaporator takes place.

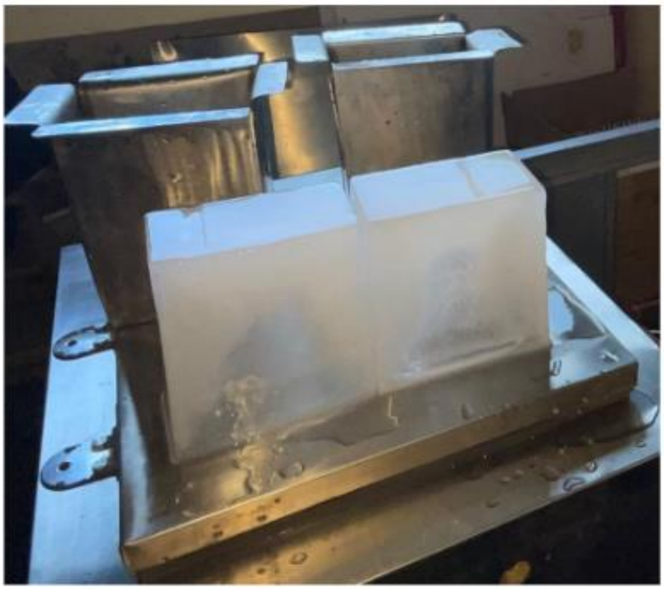

Fig -5: Ice produced in the ice plant setup

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