

Enhancement of Refrigeration Effect By using Additives for Making Instant Ice: A Review

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Abstract- Refrigeration is the process of maintaining a temperature of a system lower than the temperature of surrounding by continuous removal of heat. Refrigeration is the method used to cool the space around us to a particular temperature and to freeze water into ice. Based on the application we can use refrigeration to create large amount of ice with minimum consumption of energy. Ice plant is based on the simple refrigeration system which uses vapour compression refrigeration cycle and by using this we are analysing and fabricating the ice plant. The conventional ice plant uses the R-22 refrigerant which is ozone depleting refrigerant it is harmful to our environment and finally leads to degradation of our ozone layer. The environmental impacts like global warming and ozone depletion has become a challenge to the refrigeration industry. Chloro Fluoro Carbons (CFCs) and Hydro Fluoro Carbons (HCFCs) are referred to as an Ozone Depleting Substances (ODS) because once these gases are released into the environment and reach the stratosphere, depletes the ozone layer. Again the basic VCRS refrigeration cycle with its component having compressor $\frac{1}{2}$ Hp is used to obtain the instant ice required for the operation of the project.

Index Terms- Tetrafluoroethane (R-134a), Ethylene glycol (R22R36), Instant ice, VCR.

1. INTRODUCTION

Refrigeration and cooling is important in our day today life situation. It also as various industrial application too. Refrigeration is used in manufacturing of ice, domestic and commercial refrigerator, large scale ware house for storage and preservation of foods beverages and medicines. Ice manufacture is used for producing refrigeration effect to freeze potable water in can. Refrigeration is the

process of maintaining a temperature of a system lower than the temperature of surrounding by continuous removal of heat. It work on the vapour compression refrigeration cycle. The main component of the system are compressor, condenser, evaporator, expansion valve, receiver. Due to the phase out of CFC which was responsible for major ozone depletion and global warming are now being replaced by substitutes which are friendly to the environment. R134a is Zeotropic refrigerant which can be a suitable alternate for R404a, R410a and CFC R502 Zeotropic refrigerants therefore do not boil at constant temperatures unlike azeotropic refrigerants. Any substitute should generally possess some ideal properties like non flammability, non toxic, friendly to the natural environment, stable at all operating conditions and have similar characteristics of the refrigerant for which Hydro Fluoro Carbons (HFC's) and its blends of refrigerants such as zeotropes are finding its applications in most of the commercial refrigeration sector as alternate substitutes and are cost effective. In conventional refrigeration system CFCs and HFC refrigerant such as R-22 was widely used . The HFCs are accepted because they contain basically zero ozone depletion potential (ODP). They also have an assigned global warming potential (GWP) factor which is drastically lower than that of HCFCs. CFCs refrigerant should be replaced due to main reason 1) Due to harmful effect on ozone layer 2) Need of improvement in efficiency of system to conserves resources. Thus the requirement for environmentally friendly, working refrigerants necessitated the invention of refrigerant R-404A. Refrigerant R-404A was developed to replace CFC R-502 and HCFC R-22. Refrigerant R-404A is already known as a suitable replacement for R-22 in

low temperature applications. Refrigerant R-404a is blended product of 44% R125+ 52% R143A+4%R134A.

The Design Project Objectives and Requirements

Design Objectives

The major design objective was to produce a single serving of ice in as close to one minute as possible. The notion of a single minute comes from the potential commercial description of such a product. (e.g., “The one minute ice maker.”) The Ice Maker design was further constrained to be approximately the size of a microwave oven but with no energy consumption constraints for the initial prototype.

Design Requirements

The design requirements stipulate that the device may not exceed the size or weight of a microwave oven in order to classify the device in the countertop appliance category. The ice produced must be fit for human consumption, so no chemical additives or toxic materials may be used in any part of the device. The final device must meet FDA requirements for safe operation and health requirements so that units may be sold to the public. This device will require a similar amount of power and cost less than a high end microwave oven.

To Five initial refrigeration methods were researched and considered. These methods ranged from conventional to highly experimental, and included: magnetic, cryogenic, non-cyclic, cyclic and thermoelectric refrigeration.

Magnetic Refrigeration

Magnetic refrigeration, though potentially promising, was eliminated from consideration due to two major challenges. First, the material needed to make the device work, gadolinium costs upwards of \$450 per 100g. This cost is prohibitive for a capstone prototype, let alone for a consumer device. In addition, a large power supply is needed in order to achieve the 1.5-2 Tesla magnetic field required for the cooling effect.

Cryogenic

Cryogenic refrigeration is categorized as the use of liquids below negative 150oC as a refrigerant. The most commonly used is liquid nitrogen. Cryogenics

were considered due to their extremely low temperatures, however this method was eliminated due to cost (\$500 for a one-liter dewar), supply (cryogen must be procured and stored), and safety considerations. 3.

Non-Cyclic Refrigeration

Non-cyclic refrigeration is the action of using materials with a temperature significantly lower than ice, to freeze water. In essence, this is a less aggressive method similar to cryogenics. The method was eliminated due to the concern of storage.

Cyclic Refrigeration

Cyclic refrigeration is a system that includes a refrigerant chemical, a compressor and an expansion valve which allows a contained gas to expand rapidly, resulting in a temperature drop. Cyclic refrigeration was considered a viable option and is already used in several ice maker products that produce ice in the 7-10 minute range. After extensive research, it was decided to move away from cyclic refrigeration due to the fact that a custom shaped system would be needed and the refrigeration cycle took too long to cool down.

Thermoelectric Refrigeration

Thermoelectric refrigeration involves the use of an electric current in order to produce a direct temperature gradient. This method was selected as the primary refrigeration method due to the fact that subzero (oC) temperatures can be achieved rapidly, and simply maintained as long as the released heat is properly dissipated. In addition, no refrigerant material (as in #4) or moving parts would be required.

Design Description

The design can be broken down into two major parts; the ice production tower and the water cooling system. The ice production tower consists of an ice cube cavity bordered by three thermoelectric coolers: two on the sides and one on the bottom. The ice is manually ejected via a lever which lowers the ice, removing it from the chamber. The water cooling system is comprised of a reservoir, a pump, tubing and the heat sinks attached to the back of each thermoelectric cooler. Water is pumped through the system to remove the heat from the hot side of the

thermoelectric coolers, allowing appropriate heat extraction from the cold side to facilitate freezing.

2. BASIC THEORY AND PRINCIPLE

2.1 Vapour Compression Refrigeration Systems

As mentioned, vapour compression refrigeration systems are the most commonly used among all refrigeration systems. As the name implies, these systems belong to the general class of vapour cycles, wherein the working fluid (refrigerant) undergoes phase change at least during one process. In a vapour compression refrigeration system, refrigeration is obtained as the refrigerant evaporates at low temperatures. The input to the system is in the form of mechanical energy required to run the compressor. Hence these systems are also called as mechanical refrigeration systems. Vapour compression refrigeration systems are available to suit almost all applications with the refrigeration capacities ranging from few Watts to few megawatts. A wide variety of refrigerants can be used in these systems to suit different applications, capacities etc. The actual vapour compression cycle is based on Evans-Perkins cycle, which is also called as reverse Rankine cycle. Before the actual cycle is discussed and analysed, it is essential to find the upper limit of performance of vapour compression cycles. This limit is set by a completely reversible cycle.

The Carnot refrigeration cycle

Carnot refrigeration cycle is a completely reversible cycle, hence is used as a model of perfection for a refrigeration cycle operating between a constant temperature heat source and sink. It is used as reference against which the real cycles are compared. Figures 10.1 (a) and (b) show the schematic of a Carnot vapour compression refrigeration system and the operating cycle on T-s diagram.

As shown in Fig.1, the basic Carnot refrigeration system for pure vapour consists of four components: compressor, condenser, turbine and evaporator. Refrigeration effect ($q_{41} = q_e$) is obtained at the evaporator as the refrigerant undergoes the process of vaporization (process 4-1) and extracts the latent heat from the low temperature heat source. The low temperature, low pressure vapour is then compressed isentropically in the compressor to the heat sink temperature T_c . The refrigerant pressure increases

from P_e to P_c during the compression process (process 1-2) and the exit vapour is saturated. Next the high pressure, high temperature saturated refrigerant undergoes the process of condensation in the condenser (process 2-3) as it rejects the heat of condensation ($q_{2-3} = q_c$) to an external heat sink at T_c . The high pressure saturated liquid then flows through the turbine and undergoes isentropic expansion (process 3-4). During this process, the pressure and temperature fall from P_c, T_c to P_e, T_e . Since a saturated liquid is expanded in the turbine, some amount of liquid flashes into vapour and the exit condition lies in the two-phase region. This low temperature and low pressure liquid-vapour mixture then enters the evaporator completing the cycle. Thus as shown in Fig.2, the cycle involves two isothermal heat transfer processes (processes 4-1 and 2-3) and two isentropic work transfer processes (processes 1-2 and 3-4). Heat is extracted isothermally at evaporator temperature T_e during process 4-1, heat is rejected isothermally at condenser temperature T_c during process 2-3. Work is supplied to the compressor during the isentropic compression (1-2) of refrigerant vapour from evaporator pressure P_e to condenser pressure P_c , and work is produced by the system as refrigerant liquid expands isentropically in the turbine from condenser pressure P_c to evaporator pressure P_e . All the processes are both internally as well as externally reversible, i.e., net entropy generation for the system and environment is zero.

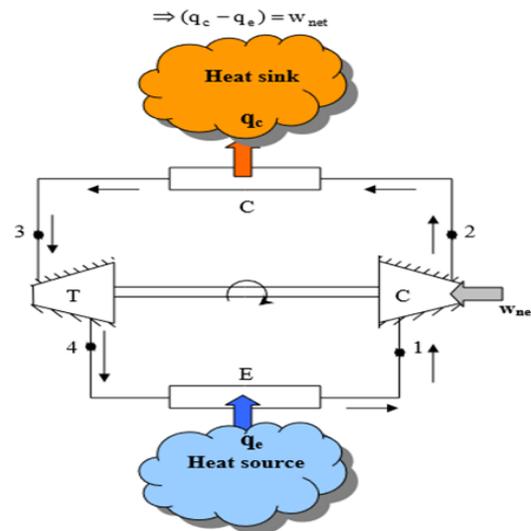


Fig.1: Schematic of a Carnot refrigeration system Applying first and second laws of thermodynamics to the Carnot refrigeration cycle,

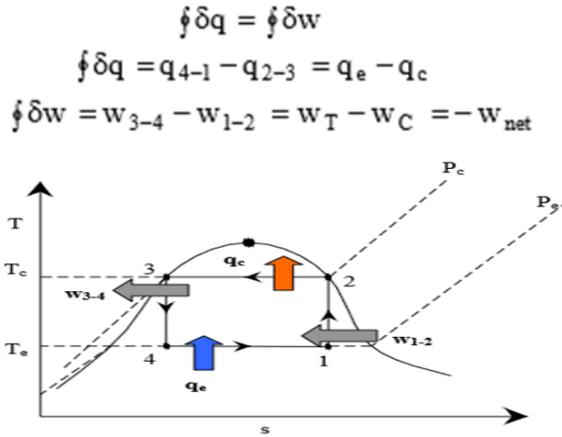


Fig.2: Carnot refrigeration cycle on T-s diagram
 Now for the reversible, isothermal heat transfer processes 2-3 and 4-1, we can write:

$$q_c = -q_{2-3} = -\int_2^3 T \cdot ds = T_c (s_2 - s_3)$$

$$q_e = q_{4-1} = \int_4^1 T \cdot ds = T_e (s_1 - s_4)$$

Where T_e and T_c are the evaporator and condenser temperatures, respectively, and, $S_1=S_2$ and $S_3=S_4$

The Coefficient of Performance (COP) is given by:

$$COP_{Carnot} = \frac{\text{refrigeration effect}}{\text{net work input}} = \frac{q_e}{w_{net}} = \frac{T_e(s_1 - s_4)}{T_c(s_2 - s_3) - T_e(s_1 - s_4)} = \left(\frac{T_e}{T_c - T_e} \right)$$

Thus the COP of Carnot refrigeration cycle is a function of evaporator and condenser temperatures only and is independent of the nature of the working substance. This is the reason why exactly the same expression was obtained for air cycle refrigeration systems operating on Carnot cycle (Lesson 9). The Carnot COP sets an upper limit for refrigeration systems operating between two constant temperature thermal reservoirs (heat source and sink). From Carnot's theorems, for the same heat source and sink temperatures, no irreversible cycle can have COP higher than that of Carnot COP.

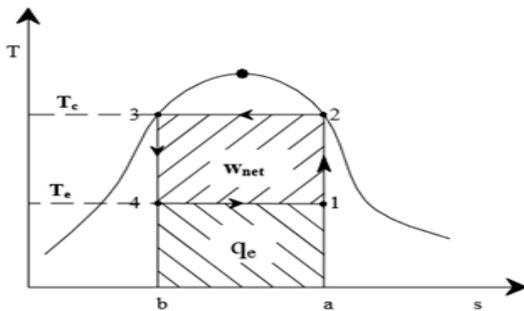


Fig.3. Carnot refrigeration cycle represented in T-s plan

It can be seen from the above expression that the COP of a Carnot refrigeration system increases as the evaporator temperature increases and condenser temperature decreases. This can be explained very easily with the help of the T-s diagram (Fig.3). As shown in the figure, COP is the ratio of area a-1-4-b to the area 1-2-3-4. For a fixed condenser temperature T_c , as the evaporator temperature T_e increases, area a-1-4-b (q_e) increases and area 1-2-3-4 (w_{net}) decreases as a result, COP increases rapidly. Similarly for a fixed evaporator temperature T_e , as the condensing temperature T_c increases, the net work input (area 1-2-3-4) increases, even though cooling output remains constant, as a result the COP falls. Figure 4 shows the variation of Carnot COP with evaporator temperature for different condenser temperatures.

It can be seen that the COP increases sharply with evaporator temperatures, particularly at high condensing temperatures. COP reduces as the condenser temperature increases, but the effect becomes marginal at low evaporator temperatures. It will be shown later that actual vapour compression refrigeration systems also behave in a manner similar to that of Carnot refrigeration systems as far as the performance trends are concerned.

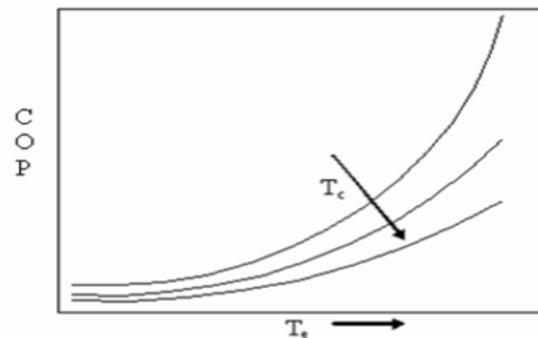


Fig.4. Effects of evaporator and condenser temperatures on Carnot COP

Practical difficulties with Carnot refrigeration system:

It is difficult to build and operate a Carnot refrigeration system due to the following practical difficulties:

- i. During process 1-2, a mixture consisting of liquid and vapour have to be compressed isentropically in the compressor. Such a compression is known as wet compression due to the presence of liquid. In practice, wet compression is very difficult especially

with reciprocating compressors. This problem is particularly severe in case of high speed reciprocating compressors, which get damaged due to the presence of liquid droplets in the vapour. Even though some types of compressors can tolerate the presence of liquid in vapour, since reciprocating compressors are most widely used in refrigeration, traditionally dry compression (compression of vapour only) is preferred to wet compression.

ii. The second practical difficulty with Carnot cycle is that using a turbine and extracting work from the system during the isentropic expansion of liquid refrigerant is not economically feasible, particularly in case of small capacity systems. This is due to the fact that the specific work output (per kilogram of refrigerant) from the turbine is given by

$$w_{3-4} = \int_{P_e}^{P_c} v \cdot dP$$

Since the specific volume of liquid is much smaller compared to the specific volume of a vapour/gas, the work output from the turbine in case of the liquid will be small. In addition, if one considers the inefficiencies of the turbine, then the net output will be further reduced. As a result using a turbine for extracting the work from the high pressure liquid is not economically justified in most of the cases.

One way of achieving dry compression in Carnot refrigeration cycle is to have two compressors – one isentropic and one isothermal as shown in Fig.5.

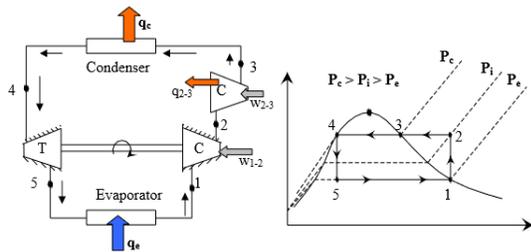


Fig.5. Carnot refrigeration system with dry compression

As shown in Fig.5, the Carnot refrigeration system with dry compression consists of one isentropic compression process (1-2) from evaporator pressure P_e to an intermediate pressure P_i and temperature T_c , followed by an isothermal compression process (2-3) from the intermediate pressure P_i to the condenser pressure P_c . Though with this modification the problem of wet compression can be avoided, still this modified system is not practical due to the difficulty

in achieving true isothermal compression using high-speed compressors. In addition, use of two compressors in place of one is not economically justified. From the above discussion, it is clear that from practical considerations, the Carnot refrigeration system need to be modified. Dry compression with a single compressor is possible if the isothermal heat rejection process is replaced by isobaric heat rejection process. Similarly, the isentropic expansion process can be replaced by an isenthalpic throttling process. A refrigeration system, which incorporates these two changes is known as Evans-Perkins or reverse Rankine cycle. This is the theoretical cycle on which the actual vapour compression refrigeration systems are based.

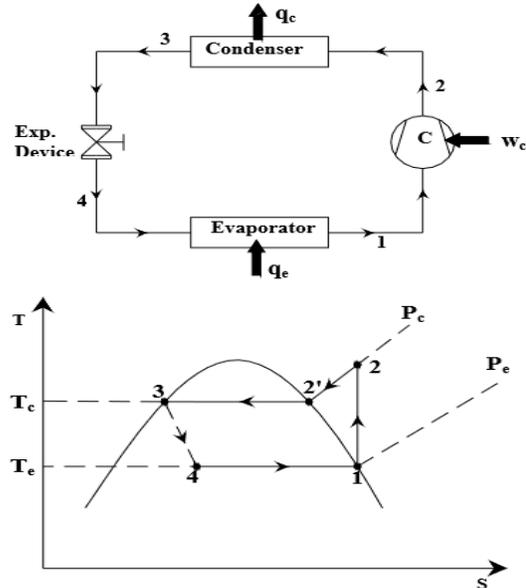


Fig.6. Standard Vapour compression refrigeration system

Psychrometric process:

Cooling and dehumidification (Process O-C):

When moist air is cooled below its dew-point by bringing it in contact with a cold surface as shown in Fig.7, some of the water vapor in the air condenses and leaves the air stream as liquid, as a result both the temperature and humidity ratio of air decreases as shown. This is the process air undergoes in a typical air conditioning system. Although the actual process path will vary depending upon the type of cold surface, the surface temperature, and flow conditions, for simplicity the process line is assumed to be a straight line. The heat and mass transfer rates can be expressed in terms of the initial and final conditions

by applying the conservation of mass and conservation of energy equations as given below:

By applying mass balance for the water
 $m_a \times w_0 = m_a \times w_c + m_w$

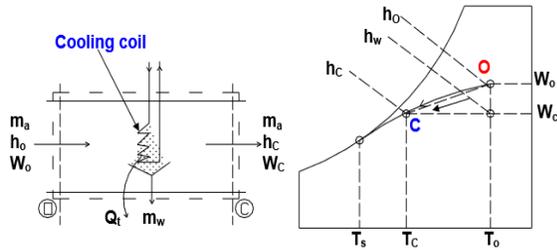


Fig.7: Cooling and dehumidification process (O-C)
 By applying energy balance

$$m_a \cdot h_o = Q_t + m_w \cdot h_w + m_a \cdot h_c$$

From the above two equations, the load on the cooling coil, Q_t is given by:

$$Q_t = m_a(h_o - h_c) - m_a(w_o - w_c)h_w$$

The 2 term on the RHS of the above equation is normally small compared to the other terms, so it can be neglected. Hence,

$$Q_t = m_a(h_o - h_c)$$

It can be observed that the cooling and dehumidification process involves both latent and sensible heat transfer processes, hence, the total, latent and sensible heat transfer rates (Q , Q_t l and Q_s) can be written as:

$$Q_t = Q_l + Q_s$$

$$Q_l = m_a(h_o - h_w) = m_a \cdot h_{fg}(w_o - w_c)$$

$$Q_s = m_a(h_w - h_c) = m_a \cdot c_{pm}(T_o - T_c)$$

By separating the total heat transfer rate from the cooling coil into sensible and latent heat transfer rates, a useful parameter called Sensible Heat Factor (SHF) is defined. SHF is defined as the ratio of sensible to total heat transfer rate, i.e.

$$SHF = Q_s / Q_t = Q_s / (Q_s + Q_l)$$

From the above equation, one can deduce that a SHF of 1.0 corresponds to no latent heat transfer and a SHF of 0 corresponds to no sensible heat transfer. A SHF of 0.75 to 0.80 is quite common in air conditioning systems in a normal dry-climate. A lower value of SHF, say 0.6, implies a high latent heat load such as that occurs in a humid climate.

From Fig.7, it can be seen that the slope of the process line O-C is given by:

$$\tan c = \frac{\Delta w}{\Delta T}$$

From the definition of SHF,

$$\frac{1 - SHF}{SHF} = \frac{Q_l}{Q_s} = \frac{m_a h_{fg} \Delta w}{m_a c_{pm} \Delta T} = \frac{2501 \Delta w}{1.0216 \Delta T} = 2451 \frac{\Delta w}{\Delta T}$$

From the above equations, we can write the slope as:

$$\tan c = \frac{1}{2451} \left(\frac{1 - SHF}{SHF} \right)$$

Thus we can see that the slope of the cooling and dehumidification line is purely a function of the sensible heat factor, SHF. Hence, we can draw the cooling and dehumidification line on psychrometric chart if the initial state and the SHF are known. In some standard psychrometric charts, a protractor with different values of SHF is provided. The process line is drawn through the initial state point and in parallel to the given SHF line from the protractor as shown in Fig.8.

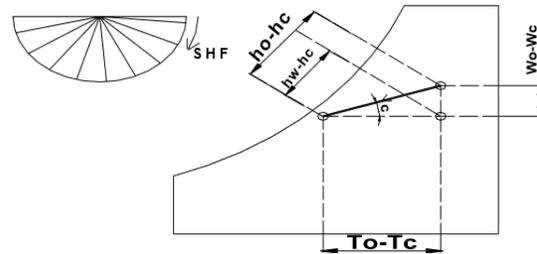


Fig.8: A psychrometric chart with protractor for SHF lines

In Fig.7, the temperature T_s is the effective surface temperature of the cooling coil, and is known as apparatus dew-point (ADP) temperature. In an ideal situation, when all the air comes in perfect contact with the cooling coil surface, then the exit temperature of air will be same as ADP of the coil. However, in actual case the exit temperature of air will always be greater than the apparatus dew-point temperature due to boundary layer development as air flows over the cooling coil surface and also due to temperature variation along the fins etc. Hence, we can define a by-pass factor (BPF) as:

$$BPF = \frac{T_c - T_s}{T_o - T_s}$$

2.2 Working of a Refrigeration System

A vapor compression cycle that is used in most household refrigerators, freezers and cold storages. In this cycle a circulating refrigerant enters a compressor as low pressure vapor at or slightly above the temperature of the refrigerator interior. The vapor is compressed and exits the compressor as high-pressure superheated vapor.

The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water. The condenser cools the refrigerant vapor, which then liquefies. This liquid refrigerant is forced through a metering or throttling device, also known as an expansion valve (essentially a pin-hole sized constriction in the tubing) to an area of much lower pressure. The sudden decrease in pressure results in explosive-like flash evaporation of a portion (typically about half) of the liquid. During evaporation, the liquid vapor refrigerant absorbs its latent heat of vaporization from the product which is to be cooled. This phenomenon known as “auto-refrigeration”. The typical lay out of the Vapour compression system in shown in Fig. 2.2a. Refrigerant leaves the evaporator, now fully vaporized and slightly heated and returns to the compressor inlet to continue the cycle (Tiwari and Gupta, 2011). The above Fig. 2.2b represents the pressure-enthalpy (p-h) diagram of a theoretical vapor compression refrigeration cycle. In this cycle, the refrigerant enters the compressor at state 1 at low pressure, low temperature and is compressed isentropically to dry saturated vapor state. The compressed dry saturated refrigerant is discharged at state 2 as a high pressure, high temperature and super heated vapor. The superheated vapor enters the condenser where it gives out the latent heat to the surrounding condensing medium. The refrigerant enters the expansion devise where it experiences a sudden drop in the pressure and superheated vapor refrigerant is converted into partial wet vapor. The liquid vapor mixture of the refrigerant enters the evaporator at state 4 where it absorbs latent heat of vaporization from the medium which is to be cooled. The heat that is absorbed by the refrigerant at this stage is called the refrigeration effect. The refrigerant leaves the evaporator at low pressure, low temperature and saturated vapor at point 1 and the cycle is completed (Arora and Kaushik, 2008; Boloji, 2011). The various zero ozone depleting refrigerants

used as substitutes in the refrigeration systems are listed in Table 2.2

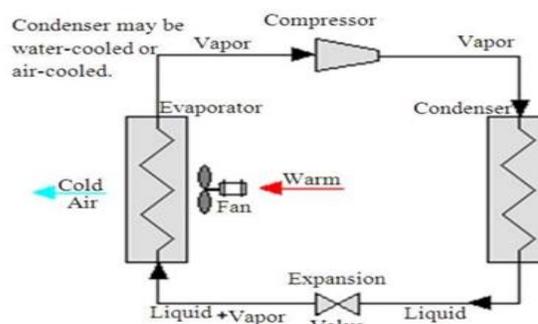


Fig.2.2a. Schematic diagram of a typical VCRs system

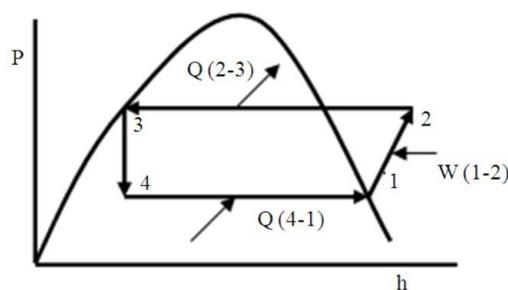


Fig. 2.2b Pressure enthalpy diagram of VCRs system.

Table 2.2 Properties of zero ODP refrigerants

Refrigerants	NBP(°C)	Tc(°C)	ODP	Safety group
R-134a	-26	101	1300	A1
R-413a	-35	101	1900	A1/A2
R-404a	-47	73	3800	A1/A1
R-507A	-47	71	3900	A1
R-407C	-44	87	1700	A1/A1
R-417A	-43	90	2200	A1/A1
R-401A	-31	78	1100	A1
R-410A	-51	72	2000	A1/A1
R-508	-86	13	1200	A1
R-717	-33	133	0	B1

3. LITERATURE REVIEW

Egolf et al. (2005) The energy savings obtained in the secondary refrigerant distribution system. An accurate assessment of these savings requires the knowledge of ice slurry thermal and rheological performances. Some of the most important works developed to predict heat transfer in ice slurry flow have been summarized.

Doetsch et al. (2005), Kitanovski et al. (2005) They have summarized ice slurry rheology and ice slurry pressure drop.

Kozawa et al. (2005) According to author two types of ice slurry thermal storage are distinguished: heterogeneous and homogeneous.

Lee et al., 2006; Niezgodna-Zelasko, 2006; Ionescu et al., 2007; The influence of mass flow rate, ice concentration, wall temperature or the distance from the heat exchanger inlet have been recently analyzed. Rivet, (2007); The energy efficiency of an ice slurry plant is Greater than that of a plant using a single phase secondary refrigerant.

Illán and Viedma, 2009a, 2009b; Experimentally developed a thermal and rheological model for the ice slurry produced using 9% wt sodium chloride brine as base solution.

Mr. S.I. Kolhe¹, Mr. V.B. Ekhande², Mr. T.P. Kale³, Mr. N.D. Jadhav⁴, Miss D.G. Waghulade (2013); The aim of this paper is to get a best performance by an ice cube making machine of refrigeration with suitable time. In present day hotels, resort and bar require more ice in very less time. So, to solve this problem and control the required time to ice formation, we construct an ice cube making machine. In present days, in market this machine is available with very high cost. So we try to make it at optimum price.

4. PROBLEM STATEMENT

There are many requirements in food industries to make instant ice to reduce long ice forming time in objective to increase production time of industry. In local economy it is very useful for ice candy for the production of *kulfi* which has good Indian market for this many problems it becomes essential to come up with a solution for instant ice making.

5. HYPOTHESIS

Everyone knows that water freezes at 0 °C - or does it? When water freezes, it needs a nucleus in order for the solid crystals to form and become ice. Water is typically full of particles and impurities which have no problem kicking off the crystallization process. However, purified water by definition doesn't have those impurities. With nothing for the water molecules to latch onto, purified water can be supercooled as far as -40°C.

For the purposes of your at-home experiment, the water doesn't need to be cooled that far. In just under 3 hours, the bottles of water have been chilled to -24 °C (-11 °F). Of course, individual settings on freezers will likely alter the time and temperature it will take to supercool the water.

The energy generated from firm hit on the side of the bottle forces the supercooled water molecules to form a crystal in a process called nucleation. That nucleus ice crystal is all that's needed to start a chain reaction of crystallization throughout the entire bottle. Shaking or jostling the bottle has the same effect, so be very careful and have a steady hand when removing the water from your freezer.

The other reactions in the work for the same reason. Pouring the water onto a bowl of ice cubes forms a slushy ice. As the supercooled water hits the ice cube nuclei in the bowl, the crystallization spreads up the stream of the water as it gets poured onto the pile. The latent heat that is released during the freezing process stops it from freezing solid. Dropping an ice cube directly down into a glass or just touching an ice cube to the surface of the water provides the nucleus needed for the supercooled water to freeze completely.

6. OBJECTIVE

The purpose of this VCRS Design Project was to design and build an 'instant' ice maker. The product is a local cube requirement for example in making instant ice candy require in food section. The instant ice maker is designed for people who do not typically plan ice-making, do not require a large or consistent quantity of it, and do not have the means to store it. Product design included with basic VCRS cycle using refrigerant as the transfer medium also having a digital thermometer to check the temperature dynamically with simple expansion valve, condensing is done by using air cooling with the help of axial flow fan.

7. CONCLUSION

The Ice making machine produce a specified quantity of ice cube by dispensing water into ice cube cavities in the evaporator which is coupled with cooling coils that are in turn coupled with a refrigeration system. Evaporator contains ice cube tray which has number of indentations on its surface where water flowing over the surface can collect. Typically the

indentations are die formed recesses within a metal plate having high thermal conductivity. As water flows over the indentations or cavities, it freezes into ice after completion of refrigeration cycle. The system Design of Ice Making Machine concludes that to making 2 ice cubes for each cycle using vapor compression cycle and water dispensing system with six nozzles; system takes 5 to 6 minutes to complete each cycle. The evaporator is heated by hot vapor flowing through the evaporator coils. To achieve this result a special additive is used known ethylene glycol which has is properties to hold deep cool temperature without changing its form.

REFERENCES

- [1] ETSU Good Practice Guides, Energy Efficiency Best Practice Programme, U.K.
- [2] Saving Electricity in Utility Systems of Industrial Plants, Devki Energy Consultancy Pvt. Ltd., Baroda, 1996.
- [3] Efficient Use & Management of Electricity, Devki Energy Consultancy Pvt. Ltd., Baroda, 2004.
- [4] Industrial Refrigeration Handbook, Wilber F. Stoeker, McGraw Hill (1995).
- [5] Refrigeration and Air conditioning, Manohar Prasad, New Age International (P) Ltd., 1996.
- [6] ASHRAE Handbooks, ASHRAE, Atlanta, Georgia, USA.
- [7] Cooling Tower Technology – Maintenance, Upgrading and Rebuilding, Robert Burger, The Fairmont Press Inc., Georgia, USA.
- [8] Low-E Glazing Design Guide, Timothy E. Johnson, Butterworth Architecture.
- [9] ISHRAE Journals (1998-2004), Indian Society for Heating, Refrigeration and Air Conditioning Engineers, Mumbai.
- [10] Catalogues of Manufacturers.
- [11] W. M. Conlon, C. N. Chang and D. M. Hendricks. Purified Water Dispensers for Refrigerators, 40th International Appliance Technical Conference. (May 1989).
- [12] S.Taylor. IceWater partition coefficients for RDX and TNT. USA Cold Regions Research and Engineering Laboratory, CRREL Report 89-8. ADA 209 248. (1989).
- [13] G.F.N. Cox and W.F. Weeks. Brine drainage and initial salt entrapment in sodium chloride ice. USA Cold Regions Research and Engineering Laboratory, Research Report 345. ADA 021 765. (1975).
- [14] C. J. Martel. Development and design of sludge freezing beds. USA Cold Regions Research and Engineering Laboratory, CRREL Report 88-20. ADA 205 955. (1988).
- [15] W.T. Sedgwick. Principles of Sanitary Science and the Public Health. New York: MacMillan, p. 251-262. (1903). 6. A. E. Corte. (1962) Vertical migration of particles in front of a moving freezing plane. Journal of Geophysical Research, 67(3): 1085-1090. (1962).
- [16] D.R. Uhlmann, B. Chalmers and K.A. Jackson. Interaction between particles and a solid/liquid interface. Journal of Applied Physics, 35(10):2986-2992. (1964).
- [17] V.H.S. Kuo and W. R. Wilcox. Removal of particles by solidification. Industrial and Engineering Chemistry Process Design and Development. 12(3): 376-379. (1973).
- [18] J.A. Heist. Freeze Crystallization, Chemical Engineering, May 7, 1979: 348 - 358. (1979).
- [19] K. S. Speigler, Saline Water Conversion Research in Israel, Advances in Chemistry Series 38; (American Chemical Society, Washington, D. C. 1963).
- [20] C. G. Moyers, and R. W. Rousseau. Crystallization Operations. Handbook of Separation Process Technology, R. W. Rousseau, ed. Wiley-Interscience. 578-643. (1987).
- [21] The C batch freeze crystallization process is known commercially as the Crystallix process, a trademark of Polar Spring Corporation.
- [22] C. N. Chang, Dual Freezing Chamber System and Method for Water Purification. U. S. Patent Number 4,799,945, (1989).
- [23] C. N. Chang, W. M. Conlon and D. M. Hendricks, Method and Means for Optimizing Batch Crystallization for Purifying Water. U.S. Patent Number 4,954,151, (1990).