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DESIGN AND DEVELOPMENT OF A MODEL REFRIGERATOR FOR ICE BLOCK PRODUCTION

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Abstract

The ambient temperature of tropical countries like Nigeria is as high as 40°C during the dry season. This ultimately gives rise to increase in demand for ice which is used to reduce the temperature of water, soft-drinks as well as other storage uses. This increase in demand for ice block makes this project a worthwhile venture. In order to achieve quick freezing, certain design considerations, such as the quantity of water to be frozen, the choice of cooling system and the methodology of attaining the desired result were discussed. The design methodology adopted in this project involves a study on the possibility of increasing the area of heat transfer and employing a refrigerating system to generate the effect that can result to the formation of ice block, using a rectangular chamber of external mild steel framework and internal aluminum material with assembled compressor and condenser units. The coefficient of performance(COP) of the Ice block refrigeration process is 2.26

Keywords: ***Coefficient of Performance, Compressor, Condenser,Rectangular Chamber , Heat Transfer.***

INTRODUCTION

The process of transforming water to ice by cooling below the freezing point of water 0°C is termed ice formation. Since ice formation is a cooling process, it could be said that ice formation is a heat transfer process that result to a phase change. For cooling to occur, the temperature gradient must be brought down by expediting the heat in the water and achieving a temperature in the range of -5 °C to -1 °C in a process called refrigeration (Gutkowski, 1996). -

For specific applications, efficiencies of both living and non-living beings depend to a great extent on the physical environment. The nature keeps conditions in the physical environment in the dynamic state ranging from one extreme to the other. Temperature, humidity, pressure and air motion are some of the important environment variables that at any location keep changing throughout the year. Adaptation to these many a times is unpredictable. A variation is not possible and thus working efficiently is not feasible either for the living beings or the non-living ones. Thus for any specific purpose, control of the environment is essential. Refrigeration is the subject which deals with the techniques to control the environmental temperature in an enclosure.

Refrigeration is the production of cold confinement relative to its surroundings. In this temperature of the space under consideration is maintained at a temperature lower than the surrounding atmosphere. To achieve this, the mechanical device extracts heat from the space that has to be maintained at a lower temperature and rejects it to the surrounding atmosphere that is at a relatively higher temperature. Since the volume of the space which has to be maintained at a lower temperature is always much lower than the environment, the space under consideration experiences relatively higher change in temperature than the environment where it is rejected. The precise meaning of the refrigeration is thus the following:

Refrigeration is a process of removal of heat from a space where it is unwanted and transferring the same to the surrounding environment. It is a well-known fact that the spoilage of food and many other items reduces at a lower temperature. At a lower temperature, molecular motion slows down and the growth of bacteria that causes food spoilage also retards. Thus to preserve many types of perishable food products for a longer duration, we use refrigerators in our homes, canteens, hotels, etc. The temperature of the food products has to be maintained at a level below that of surroundings (Meryman, 1966) Hence, we keep the food products in a refrigerator. The inside volume of the refrigerator where we store food products or any other items is much less than the volume of the room where the refrigerator is kept. The room in this case is the surrounding environment. Food products in the refrigerator initially were at a higher temperature than desired temperature, meaning that it had some unwanted heat. If its heat is removed, its temperature will decrease. The refrigerator removes unwanted heat from the food products and throws away that heat to the room the surrounding environment of the refrigerator. The amount of heat makes a big difference in temperature inside the refrigerator and almost little or no difference in the temperature of the room.

Temperature in the Refrigerated Space is lower than the room where Refrigerator is kept. Refrigerator throws away Heat from the Food Products to the Room. This means that heat has to be supplied or pumped inside the car and thus its temperature has to be increased. The machinery that performs this operation is known as heat pump. But in applications such as that of the comfortable driving in a car that depending upon the season requires temperature to be lower or higher than the surroundings, Heat has to be pumped to the car or rejected from the car. The machinery that performs this operation is known as heat pump.

ICE BLOCK PRODUCTION

Ice has been used for cooling for a very long time. It has a large cooling capacity for a given weight and involves little or no complication in the design and operation of the storage space. Ice, in addition to keeping a product cool, also keeps it moist and prevents the drying that may accompany other chilling methods. Ice melts at a fixed temperature, so there is some control over product temperature for most people the word refrigeration evokes the container used in chilling water. Estimates by the International Institute of Refrigeration suggest that on average more than 25% of the world food spoilage is due to poor and inadequate storage device (Bald, 1993), Food Freezing. The introduction of refrigeration and ice block making has provided greater accessibility to preservation in very remote areas due to the production of ice blocks stuffed in chilling boxes and transferred to many kilometers away in order to assist in food preservation and chilling of drinks/water in very hot environment

DEVELOPMENT TREND IN REFRIGERATION

In the past around 4000 years ago, people in India and Egypt were known to produce ice by keeping water in the porous pots outside the home during the night period. The evaporation of water in almost dry air and radioactive heat transfer between the water and the deep sky that is at a very low temperature (much below the freezing point of ice) caused the formation of ice even though the surrounding air was at a higher temperature than the freezing point of water (Muldrew, Dan McGann, 1997). There are a few accounts in China about the use of ice around 1000 BC for cooling the beverages. In 4th century A.D., East Indians were producing ice by dissolving salt in water. Because of the very small amount of production, the aforesaid methods were not feasible for commercial applications. Natural ice is limited to certain regions, therefore, the absence of good quality insulation systems in those days forced the man to develop methods to produce ice artificially. Out of many pioneers' work on refrigeration side, a few are presented here. In 1790 the first British Patent was obtained by Thomas Haris and John Long In 1834 Jacob Perkins developed a hand operated refrigeration system using ether as the working fluid.

Ether vapor was sucked by the hand operated compressor and then high temperature and pressure ether vapor was condensed in the water-cooled chamber that served as the condenser.

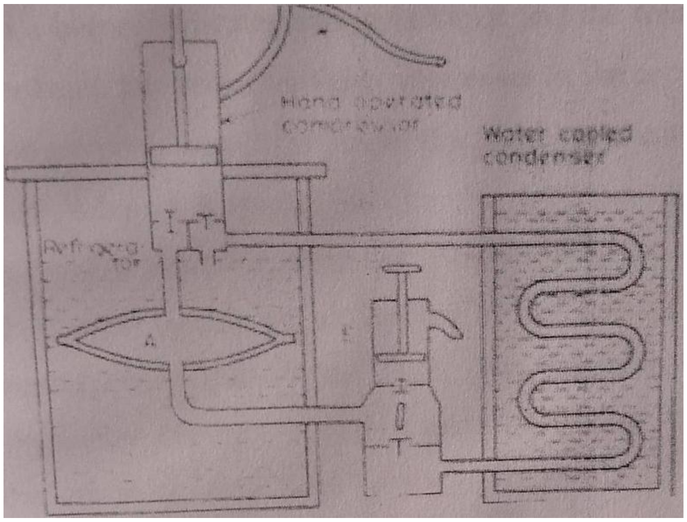
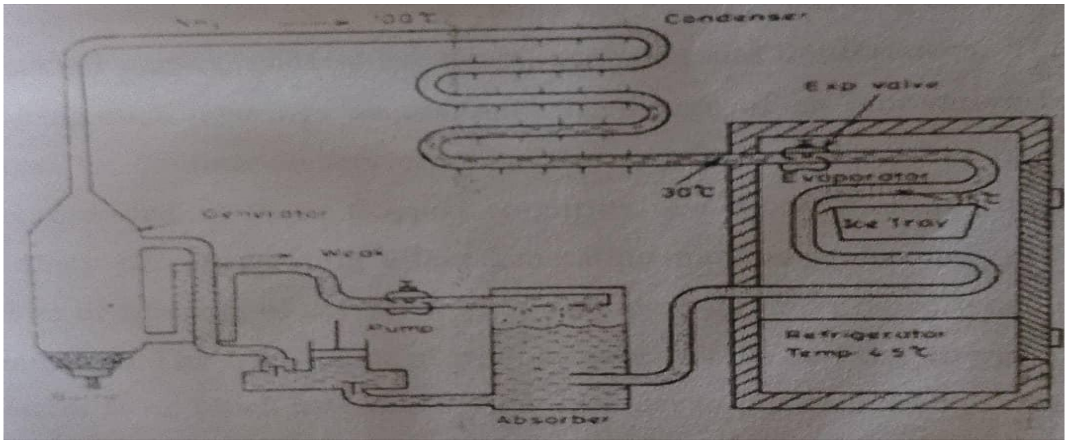


Figure 1.1: Schematic of the Hand-Operated Refrigeration Machine of Jacob Perkins

Liquid ether was finally throttled to the lower pressure, which was then evaporated in a chamber called evaporator. With the evaporation, temperature of the water surrounding the evaporator fell down and finally the ice was formed. In this system, ether was used again and again in the cyclic process with negligible wastage. The first American patent of a cold air machine to produce ice in order to cure people suffering from high fever was obtained by Dr. John Gorrie of Florida in 1851. In 1860, instead of air or ether, Dr. James Harrison of Australia used sulfuric ether. This was the world's first installation of refrigeration machine for brewery. In 1861, Dr. Alexander Kirk of England constructed a cold air machine similar to that of Dr. Gorrie. In his machine, air was compressed by a reciprocating compressor driven by a steam engine running on coal. In the 19th century, there was remarkable development of refrigeration systems to replace natural ice by artificial ice producing machines (Mohammed, Elaigu, Hassan, & Adeniyi, 2012). In the beginning of the 20th century, large sized refrigeration machines were developed. In 1904 in the New York Stock Exchange, about 450 ton cooling machine was installed. In Germany, people used air conditioning in theater. Around 1911 the compressors with speed between 100 to 300 rpm were developed. In 1915, the first two-stage modern compressor was developed. To meet the demand for ice during the civil war, Ferdinand Carre of the USA developed a vapor- absorption refrigeration system (Figure 1.6) using ammonia and water. Carre's system consisted of an evaporator, an absorber, a pump, a generator, a condenser and an expansion device. Theevaporated vapor is absorbed by the week ammonia-water mixture in the absorber yielding strong aqua ammonia. The pump delivers this strong solution into generator where heat transfer from a burner separates ammonia vapor and the weak ammonia returns to the absorber. On the other hand, the ammonia vapor condenses in the condenser before being throttled. The throttled liquid ammonia enters the evaporator resulting in completion of the cyclic process (Mohammed, Elaigu, Adeniyi, & Hassan 2012).

Vapor-Absorption Machine of Ferdinand Carre until about 1920s the development in refrigeration system was restricted to the refinement in the cold-air machines and vapor- compression systems. After 1920s, there has been extensive diversification in the growth of refrigeration systems leading to new developments such as vortex tube, thermoelectric, pulse- tube, steam-jet, centrifugal compression systems, etc. The most important development can be the invention of new refrigerants which were chlorofluoro hydrocarbons. This development occurred in 1930 in GE Corporation of USA at a time when Refrigeration industry had begun



The aim of this project is to Design and Develop a Model Refrigerator for Ice Block Production.

METHODOLOGY

This project presents the methodology of design, development and evaluation of ice-block making process using the principle of a vapor compression system, heat transfer processes and thermodynamic design approach to establish parameters including the coefficient of performance(COP), detailed fabrication procedure and cost analysis using the Bill of Engineering Measurement And Evaluation approach.

THEORETICAL COMPONENT DESIGN

Theoretical components include

i. VAPOUR COMPRESSION
ii. Evaporator Analysis
iii. Condenser Analysis
iv. Compressor Analysis
v. Accumulators
vi. Strainer Drier

EVAPORATO.1R DESIGN VALUES

PARAMETERS	DESIGN VALUES/UNIT
Freezing chambers height	h=0.45m
Freezing chambers width	W=0.3m
Thickness of sheet, t	t = 0.0015m
Mass flow, m	, m= 0.00194kg/s
Reynolds number, Re	, Re = 1042
Prandtl number, Pr	Pr = 4
Nusselt number, Nu	Nu=13.5
Overall heat transfer coefficient,	, U = 196.48 W m k
Leakage load, QL	QL = 86.15w
Usage load QU	QU123W
Supplementary load, QSP	QSP=18.5W
Coefficient of performance, cop	Cop=2.26

COMPRESSOR DESIGN VALUES

PARAMETERS	DESISN VALUES/UNIT
Power capacity, p	P = 67.9W
Theoretical volume, v	V = 1.49 x 10.4m3

MATERIAL SELECTION AND FABRICATION

Material Selection

The material selections are based on the material properties, availability, cost and ease of fabrication. The components to which material selection process are required include: the freezing chamber, the refrigeration system, the ice conveying mechanism, the stands and support frame. The materials selected for the freezing chamber is mild steel in the external and the installation of aluminum sheet in the interior. Aluminum has a great level of heat transfer across its walls, high thermal conductivity, low cost, ease of fabrication and availability when compared to other materials such as copper and stainless steel. In selecting the refrigeration system, the absorption and vapor compression systems were considered. The absorption cycle requires heat input from a gas burner and a liquid pump with an electrical power input to circulate the working fluid. Vapor compression cycle was chosen for the present study due to fewer components required and lower complexity. This is because the key components in the system serve as the driving force for the entire cycle. Though R-12 has an adverse effect on the depletion of ozone layers when compared toR134a, R-12 was selected due to low cost. The ice conveying mechanism, stands and support frames materials was constrained by weld ability, workability and strength. As a result mild steel was used due to its good weld ability and workability with its fair strength when compared to high carbon steels

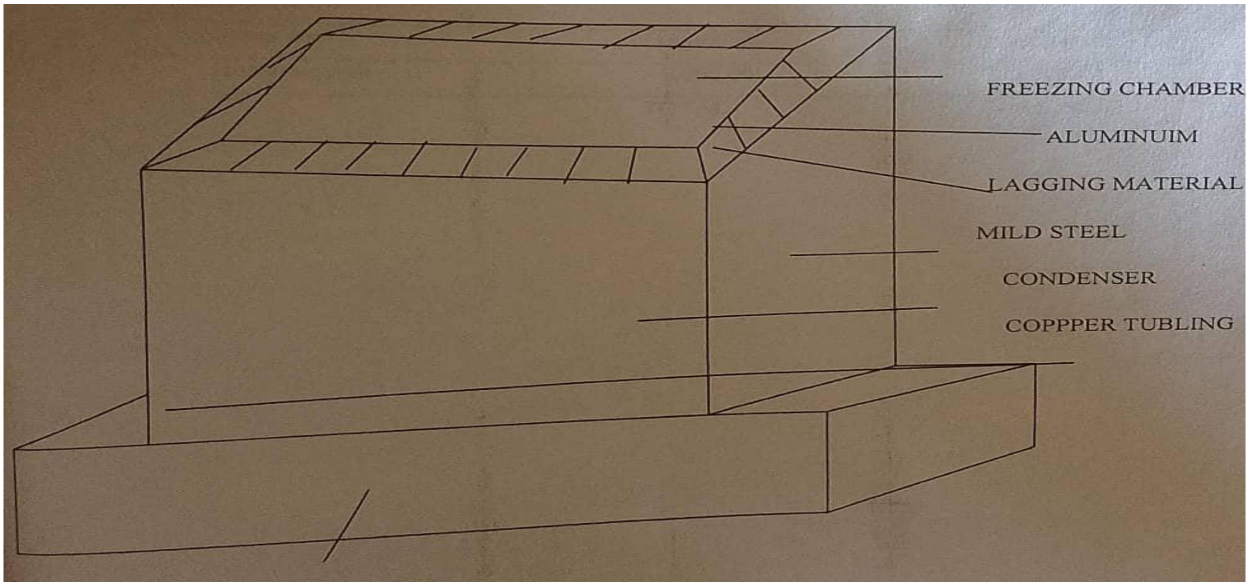
FABRICATION

The fabrication process is discussed in stages below,

Stage 1.

(1) Construction of the Refrigerator chamber,

The refrigerator chamber of rectangular cross-section has the external surface constructed from mild steel sheet of 0.45m height, 0.3mand thickness of 0.00015m and welded together with 12mm electrode. The interior is folded with aluminum sheet and in between is insulator material of synthetic foam to reduce heat transfer across the wall. The reduced conductive heat transfer is as a result of complete lagging technique applied. FIG 3.2 below depicts the construction of the refrigerator chamber.



COMPRESSOR AREA

Fig 2.2 **ICE BLOCK REFRIGERATOR CHAMBER**

Stage 2

The next stage is the installation of the compressor unit. The copper tubes, the condenser and throttling device. All these component parts were assembled together, and electrical connections completed

BILL OF ENGINEERING MEASUREMENT AND EVALUATION(BEME)

Component parts	Unit price/Quantity	Cost
Compressor	25,000.00/1	N25.000.00
Fabrication of framework	26,000.00/1	N26,000.00
Condenser	16,500.00/1	N16,500.00
Copper subbing coil	15,000.00/1	N15,000.00
Throttling valve	10,000,00/1	N10,000.00
Labor cost	18,000.00	N18,000.00
Transport cost	9,000.00	N9,000.00
	TOTAL	N106,500.00

TEST RESULTS AND DISCUSSION

PERFORMANCE TESTS

The performance test of the designed and developed refrigerator model for ice block making is investigated by adopting such tests as test for leakage and test for freezing chamber temperature.

Tests for Leaks

The system was tested for leaks using soapy water solution. The soapy water was applied at all brazed nodes and along the entire condenser line. Detergents have the desired properties of foaming with bubbles in the presence of leaking gas. From the test conducted, the system was confirmed free from leaks.

Test for Freezing Chamber Temperature

The test was conducted using a digital thermometer and stop watch. The temperature variation with time in the freezing chamber was studied by measuring the temperature of the walls of the freezing chamber at regular intervals of 10 minutes The time at which the freezing chamber will attain its stabilized temperature during operation and the minimum temperatures attained in the freezing chamber are noted and recorded. The experiment was repeated three times and in all cases the values were recorded. Figure 4.1 shows the plots of the average values of temperatures against time. The error represents the maximum and minimum values at each interval

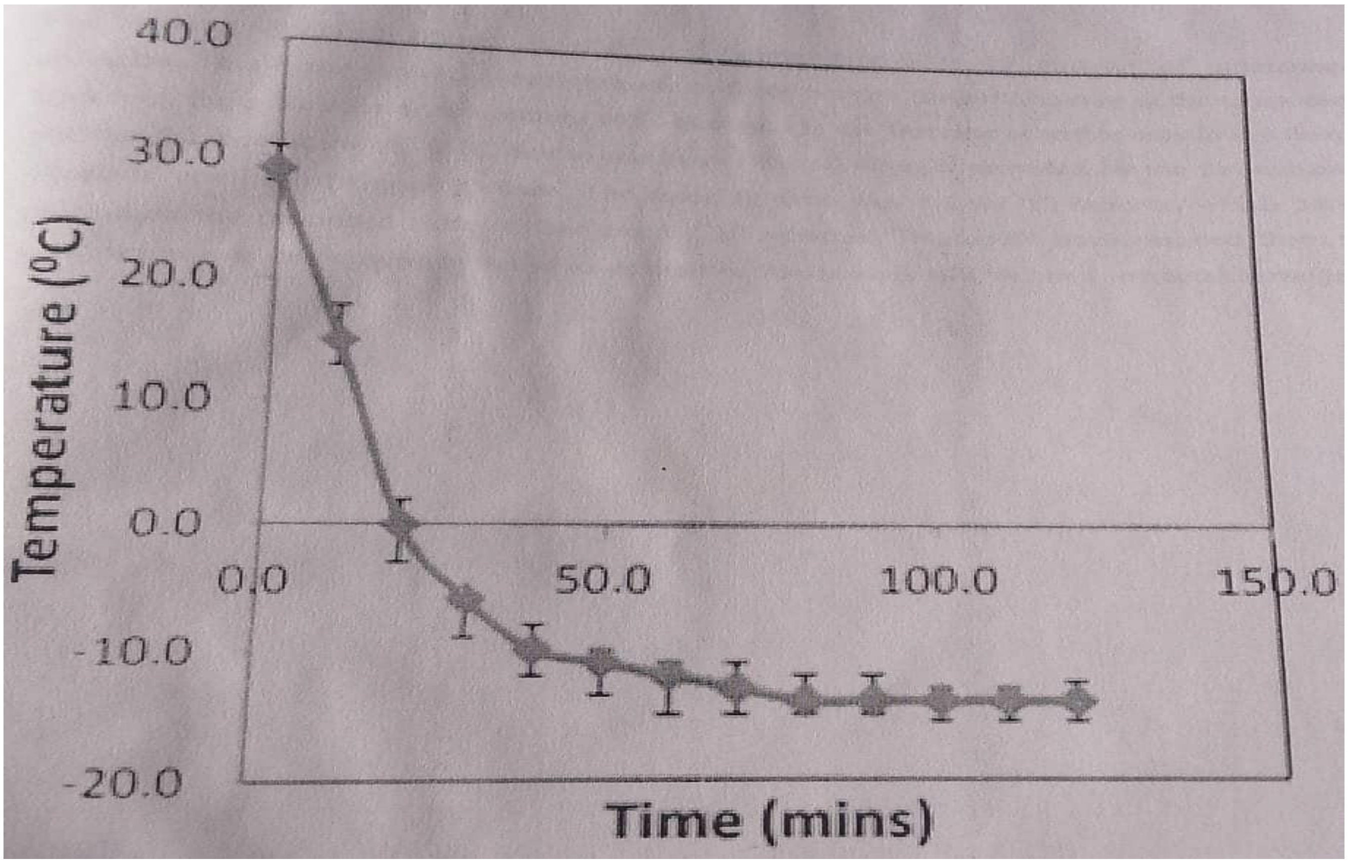


Fig 3.1 plot of Temp °C Versus Time(mins)

DISCUSSIONS

The sequence of variation of the temperatures in the freezing chamber with time was observed to exhibit an initial drastic fall from 29°C to 15°C due to the sudden cooling effect as a result of the vast temperature difference. However, as the cooling proceed further, it was noted that the temperature drop became reduced until a constant temperature was reached. Hence, no further reduction in temperature occurred. This indicates the trend towards the saturation temperature. The freezing chamber attains its stabilized temperature after 80 minutes of uninterrupted operation. This is the saturation temperature as there was no further decrease in the temperature. However, the saturation temperature, - 14 deg * C obtained in the freezing chamber was lower than the proposed temperature of - 8 deg * C due to the heavy forced draught provided by the fan enhancing adequate cooling of the condenser. The freezing time was 1 hour 10 minutes which extends more than the proposed time of freezing by 10 minutes. This could have resulted from non- compactness of the lagging material as desired but the error is still within a correctable range.

CONCLUSION AND RECOMMENDATION

CONCLUSION

An ice-block making production process is discussed and presented on the basis of the thermodynamics principle. This project was based on the principle of vapor compression, and the materials for the construction were selected based on the material properties, availability, cost and ease of operations. The findings from the project test run were a huge success. This shows that the ice block production is economically viable and increasing the surface area of heat transfer in a freezing compartment will reduce the freezing duration.

RECOMMENDATION

The following recommendations are necessary for improvement of this prototype.

(1) The framework could be replaced with stainless material to reduce the occurrence of rusting

(2)The cooling chamber could be increased in dimension to get more blocks of Ice and improve the coefficient of performance (COP)

(3)The coiling of copper tubing should be handled carefully as not to introduce leaks in the system

(4) That other materials can be used to achieve the same results should be looked into

(5)This prototype should be adopted by big industries such as Thermocool, Westpoint, LG and others for strictly ice block production to be used in household and event centers.

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