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DESIGN AND FABRICATION OF A SOLAR DEEP FREEZER

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ABSTRACT
This project work is all about a deep freezer which is constructed and designed using locally available materials. The purpose of this project is to aid in providing the basic understanding of the fundamentals, construction designs and principles of refrigeration (deep freezer) has thus, become more important with the growing numbers of applications of its uses both in domestics and commercial area. However, this refrigeration consist of five main parts via; the cabinet, compressor, condenser, evaporator and the capillary tubes. The cabinet was prepared with galvanized metal sheet that has been cut to the required sizes and shapes. The compressor, the condenser and the evaporator coil were installed at various positions in the cabinet as predetermined during its construction. More so, the condenser was connected to the discharge pipe of the compressor by means of copper pipe in a similar manner. The condenser was then connected to the evaporator via a filter drier and a capillary tube. Then the deep freezer was tested and it was found to function satisfactorily.

Keywords: *refrigeration, compressor, rate of heat flow, capillary tubes, ambient temperature*

INTRODUCTION
Experiments and research has shown that engineering has a vast field of study entails the science by which the properties of matter and the source of power in nature are made useful to man in structures, machines and products. But to embrace modern civilization, the understanding of the scientific principle as

well as their applications, is very important to man. Thus, as related to the world of engineering, the world design could be basically be defined as an act of making decorative patterns to suit the designed purpose through drawing, sketching, outlining as well as selecting prototypical options.

In a nutshell engineering design entails the recognition of a problem, the conception of ideas (brain storing) and utilization of the available materials by transforming the idea into functional device, which can then solve the problem.

Living in the tropics, makes it absolutely necessary for us to study and carry out research on refrigeration and air conditioning owing to our harsh weather conditions which is especially during the dry seasons. Refrigeration can basically be defined as the systematic cooling of a space or bodies or fluid or any substance to a temperature lower than those in surrounding at a given time, while an air conditioning is known as climate control. It is the transfer of heat from chamber which is at a temperature lower than that of its surroundings.

In refrigeration, the principle of thermodynamic plays important role in the design and construction of a deep freezer. The deep freezer is an assemblage of components designed specifically to maintain the temperature of a confirmed space, or fluid below that of the surroundings.

The heat transfer during cooling flow as a result of temperature gradient which has been assisted by insulating the chamber from the surroundings by the use of suitable insulating materials, but practical requirements and conditions make it necessary a continuous means of transfer of heat from the chamber.

In refrigeration, the thermodynamic principles summarize the process where a refrigerant is taken through a cycle so that heat can be transferred from a lower temperature to sink by expanding mechanical work. This refrigerant is the working fluid of the refrigerating system and the fluid is always in a continuous circulation.

This refrigerant releases energy as mentioned earlier in the cold chamber at a temperature below that of the surroundings, and the energy must be rejected before the refrigerant can return to the cold chamber in its initial state. It is a normal phenomenon to transfer energy from low temperature to a higher one. But in this case of refrigeration, energy is transferred against the natural temperature gradient from low higher temperature. The quantity of energy removed from the cold chamber is called refrigerating effect.

The refrigerating plant chosen depends on the particular purpose since each application have to meet specific requirement a number of substance are utilize as refrigerant and most methods use the refrigerant in the liquid vapor state. The application of deep freezer as refrigeration system can be broadly classified into four areas, these include,

FOOD PRODUCTION AND STORAGE

Freezing is one of the oldest and most widely used methods of food preservation, which allows preservation of taste, texture, and nutritional value in foods better than any other method. The freezing process is a combination of the beneficial effects of low temperatures at which microorganisms cannot grow, chemical reactions are reduced, and cellular metabolic reactions are delayed (Delgado and Sun, 2000). Freezing preservation retains the quality of agricultural products over long storage periods. As a method of long-term preservation for fruits and vegetables, freezing is generally regarded as superior to canning and dehydration, with respect to retention in sensory attributes and nutritive properties (Fennema, 1977). The safety and, nutrition quality of frozen products are emphasized when high quality raw materials are used, good manufacturing practices are employed in the preservation process, and the products are kept in accordance with specified temperatures.

Freezing has been successfully employed for the long-term preservation of many foods, providing a significantly extended shelf life. The process involves lowering the product temperature generally to -18 °C or below (Fennema *et al.*, 1973). The physical state of food material is changed when energy is removed by cooling below freezing temperature.

The extreme cold simply retards the growth of microorganisms and slows down the chemical changes that affect quality or cause food to spoil (George, 1993). Competing with new technologies of minimal processing of foods, industrial freezing is the most satisfactory method for preserving quality during long storage periods (Arthey, 1993). When compared in terms of energy use, cost, and product quality, freezing requires the shortest processing time. Any other conventional method of preservation focused on fruits and vegetables, including dehydration and canning, requires less energy when compared with energy consumption in the freezing process and storage. However, when overall cost is estimated, freezing costs can be kept as low (or lower) as any other method of food preservation (Harris and Kramer, 1975).

DOMESTIC USES

i. For producing ice-block.
ii. For producing cold water and chilling drinks.
iii. For food storage

INDUSTRIAL APPLICATION

The deep freezer refrigerator system has many industrial applications, which include:

Medical application; such as mortuary cooling and storage of hospital appliances. Industrial application; these include cold treatment of metals to attain the desire qualities.

Fermentation control: such as the control of alcohol production.

THERMODYNAMICS ANALYSIS OF THE DESIGN

The thermodynamic cycle will be based on the performance characteristics of the major components to provide the desired refrigeration effect.

THE COMPRESSOR

The performance characteristics of a refrigerating cycle are guided by the compressor. Therefore the compressor performance is guided by three factors these are:

The refrigerating capacity

The power requirement

Condenser length

These two factors are controlled by the discharge pressure and the suction pressure of the compressor.

Refrigerating Capacity Q

$QC = m(h_2-h_1)$ (1)

Where

M = mass flow rate of the refrigerant

(h_2-h_1)= difference in enthalpy (2)

THE POWER REQUIRE P IS GIVEN BY

P = ∫ Q= m (h2-hl)

Ti = Temperature of cold refrigerant

T3 = Wet bulb temperature of air

Pc = cooling effectiveness ∫ =Efficiency of the compressor

CONDENSER LENGTH

The length of the condenser can be determined by using the empirical method that is based on the number of passes of the copper tubes and the length of each pass. It can be expressed mathematically as follows.

LC = Np x Lp

Where

Lc = condenser length

Np = number of pass

Lp = length of passes

EVAPORATION

Similarly, the magnitude of the evaporator depends largely on the amount of the heat to be transferred either by absorption or evaporator.

The evaporator capacity Q_1 is given by Qc = m (h_1 - h_4). (4)

Heat to be absorbed by the refrigerant at the evaporator Q_1 is given by the mathematical expression. Qc = m (h_1 - h_4) (5)

Given the cooling load or heat which must be removed to the reduce the temperature of an item in freezer from the initial temperature at the item t_1 to the final temperature of the Item t_2 is given by:

Q=mCdt 6)

Where;

Q = heat removed expressed in kj/hr

M - mass of the item

C = specific heat capacity express in kj/kg/k

T_1 = initial temperature of the item in ^{0}C

T_2 = the finial temperature of the item in ^{0}C if the mean specific heat between t_2 and t_2 is known.

Q = mc mean ($t_1 – t_2$)

EVAPORATION LENGTH

The length of the evaporator also be determined on empirical method which entails the number of ceil round the length and width of the component. The length of the evaporator is given by,

Length of evaporator = 2(length) x number of coils (7)

INSULATION

Insulator is a material that prevents heat loss in either direction. It helps to keep the temperature or the compartment to a fairly constant value even when not in operation.

The area of the plan = 2(depth x width) (8)

Since there is no design that is perfect there are certain amount of heat that could filtrate into the compartment. This amount of heat is therefore given as

$$Q = NADT \quad (9)$$

Where $DT = T_0 - T_1$ (10)

Q = amount of heat transfer

N = Overall heat transfer coefficient

A = Area of the insulator

T = final temperature of the condemned compartment but heat per unit is expressed in Kj/hr. it is worthy to note that the insulator is embedded between the aluminum sheets for the design.

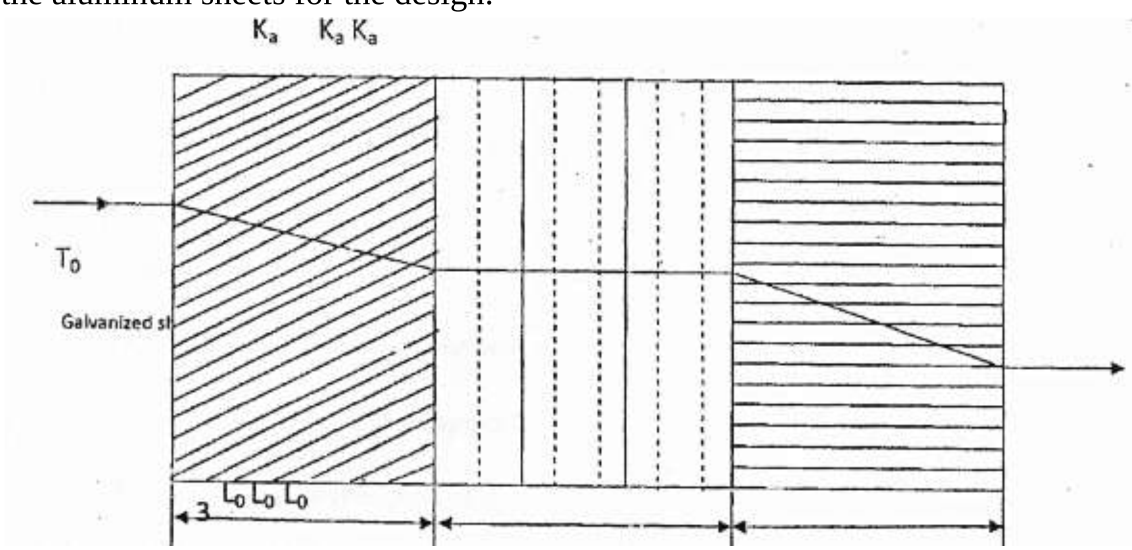

Figure 1: Heat conduction via composite wall

DESIGN CALCULATION

For proper design consideration therefore become foaming to certain degree of exactness for the desisted result.

DESIGN SPECIFICATION

Length L = 0.60m
Width W = 0.40m
Depth D = 0.50m
Plan = L x W = 0.60 x 0.40
Front = L x W = 0.6 x 0.5
Compressor space = (L x W x D) = (0.6 x 0.4 x 0.5)

Volume of freezer = Total volume - Compressor volume = (0.6x0.4 x0.5) - (0.4 x
0.25x0.20)
= (0.12 - 0.02) m2 = 0.10m^2
The cycle type is the vapor compression
Operating temperature of the evaporator = -25
Working temperature of the condenser35°C
Working pressure of it evaporator is represented as (ccl_2f_2)
The rated efficiency of the compressor is 35% Evaporator
Enthalpy h_1 = 155.48Kj/Kg
Condenser enthalpy h_2=?
From $S_{g1} = S_{g2} + CPLn\ (T_2 - T_1)$ (11)
Where $T_?$ = 313352K (calculate from eqn 11)
$H = h + cp\ (T_2 – T_1)$

H = 201.45 + 0.85 (313.52 - 303)
H = 201.45 + 8.416 = 209.866
But, $h_3 = h_4 – h_1$ = 69.55Kj/Kg at 35°C
From the steady flow energy equation
$H + C_1/2+Q = H2 + C_2/2$ (12)
Where; $C_1/2$ = kinetic energy at inlet
$C_2/2$ = kinetic energy at outlet

Other parameter is with their usual notation since the change in kinetic energy are neglected in most thermodynamics problems equation become

$H_1 + Q = h_2 + W$ (13)

Representing the above information on the P – H diagram and the vapor cycle.

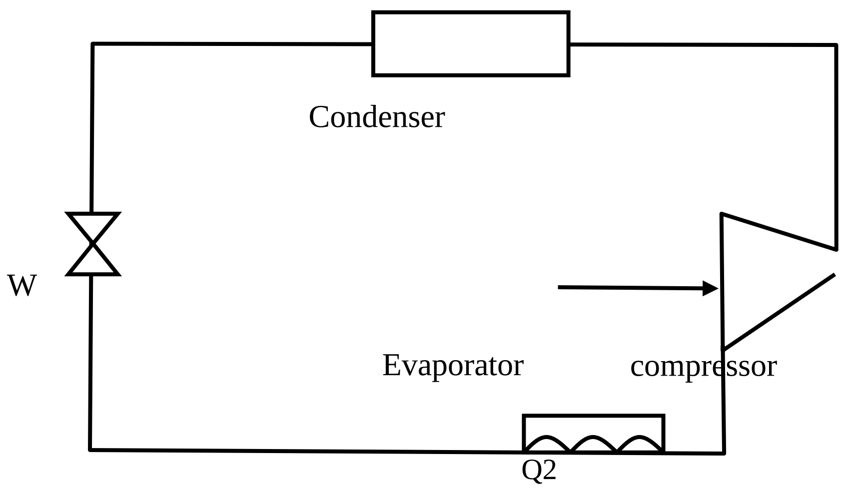

Fig.2; vapor compressor

The corresponding pressure enthalpy diagram is given below

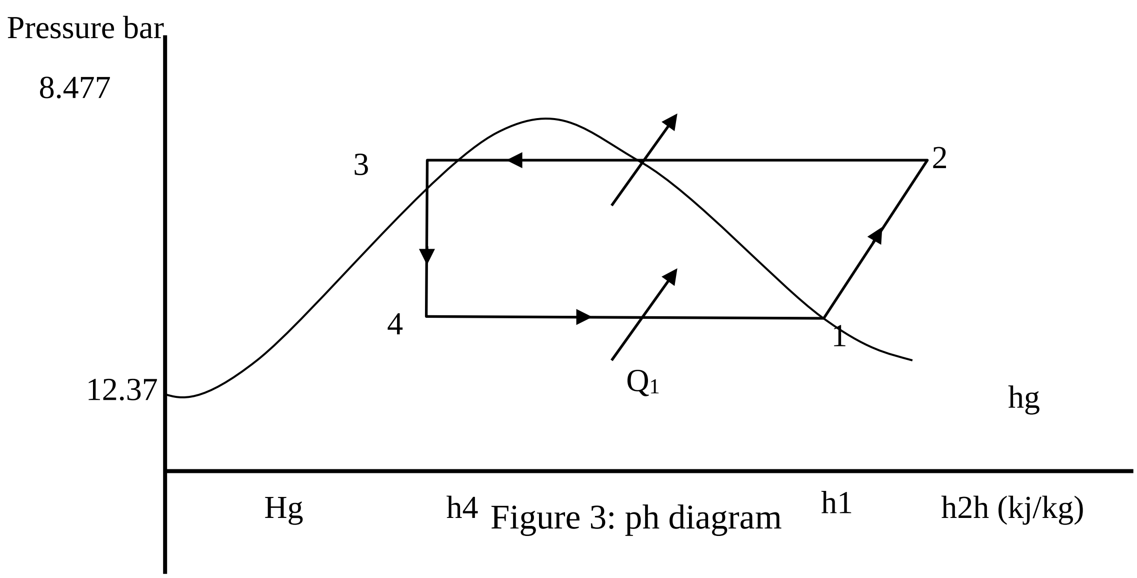

Figure 3: ph diagram

From the Ph diagram it was seen that $h_2 = h_4$ and from equation 13

$W = 0$

Hence

$Q = h_2 - h_1$ (14)

But the refrigeration capacity $Qc = m (h_2 - h_1)$
$Qc = m (209.866 - 155.48)$ (15)
Relating that,
$P_1V_1 = mRT_1$
Where R = 287 constant
$T_1 = 35 + 273.15 = 308.15K$
$P_1 = 123 \times 10^5$
$V_1 = 0.1M^3$
$M = 1.237 \times 10^5 \times 0.1$

$$M = \frac{P_1V_1}{RT} = \frac{1.237 \times 105 \times 0.1}{287 \times 308.15} = 0.1399\text{kg/hr}$$

Recall that
Qc = 0.1399kg/hr = 0.0023316 x 54.4 = 0.1268kg/kg
But power = Qc = 0.1268
But 1hp ------- 764w
Then, xhp --------------- 0.1501 (0.1501 x 1000)
Thus, xhp --------------- 0.1501kw (0.1501 x 1000) w x 1hp = 0.2hp = 1/5hp
Power = 1/5hp
Hence for design purposes a compressor with a power rating of 0.2kw is chosen from process 1 – 2 (during compression) there is no heat transfer. i.e.
Q = 0.
Hence $W = (h_4 - h_1) = Q (h_2 - h_1)$
Similarly,
Process 2-3 (during condensation) during this process, there is no work done i.e.
W = 0 hence equation 13 becomes
$Q_2 = h_2 - h4$
209.866-69.55 = 140.316kg/kg
From process 3-4 (during throttling) there is neither heat transfer nor work done i.e.
Q = 0 and W = 0
Hence,
$H_3 = 0, h_4 = 0$
$H_3 = H_4 = 69.55$kg/kg

The coefficient of performance (C.O.P) is given by

Refrigeration effect work done = $\frac{H_1-h_4}{H_2-h_1}$

$$C.O.P. = \frac{H_1 - h_4}{H_2 - h_1} = \frac{155.48 - 69.55}{209.9 - 15548} = \frac{85.93}{54.42}$$

C.O.P = 1.58

Effectiveness of the condenser is obtained using

$$P = \frac{T_2 + T_1}{T_2 + T_3} \times 100$$

$$= \frac{35 + 25}{35 + 47} \times 100 = \frac{60}{62} \times 100$$

= 0.9677 x 100

= 96.8%

Length of condenser 1

L = number of tube passes x length of each pass 8 x 0.4 = 3.2m

Relating that θ = mCDT (16)

Where; m = 1kg

DT = (35 + 25) = 60^0C

C = 0.13 from standard tables

C = specific heat capacity expressed in kj/kg

Q = 1 x 0.13 x 60 = 7.8kg

Length of the evaporator can be obtained using equation

Le = (2(width) + 2(length)) x number of coils = 60

Spaced equally at a distance of 8.33mm apart

Le = 2(0.4) x 6

= 12m long

Area to be insulated

Plan (lxw) 0.6 x 0.4 = 0.24m^2

Front (lxd) 0.6 x 0.5 = 0.3m^2

Side (wxd) 0.4 x 0.5 = 0.2m^2

Total area = (0.24 + 0.3 + 0.2) x 2

= 0.74 x 21.48m^2

Heat leakage in the system is given by

$$Q = WADT = \frac{T_2 - T_1}{R} \quad (17)$$

Q=R

Relating that to

$$R = \frac{L+R}{(18)} = \frac{1}{AK}$$

The thickness of galvanized sheet Lg = 0.00C5m

Thermal conductivity of galvanized sheet kg 50m^{0}c

Thickness of aluminum La = 0.0004m

Thermal conductivity of aluminum ka = 203w/m^{0}c

Condenser temperature to =35^{0}c

Inside temperature (evaporation) = 25^{0}c

For the plan p

$$\text{R} = \frac{0.005\ \times 2}{0.24 \times 50} + \frac{0.03 \times 2}{0.24 \times 0.043} + \frac{0.0004 \times 2}{0.24 \times 20}$$

$$\text{R} = \frac{0.001}{12} + \frac{0.06}{0.01032} + \frac{0.00008}{48.96}$$

R = 0.000083333 + 5.814 + 0.000016 = 5.814099

Q = leakage through plan = $\frac{35+25}{\text{R}}$

$$Q = \frac{35+25}{5.814099} = \frac{60}{5.814099}$$

Q = 103197kj/kg

From the front

$$R = \frac{0.0005 \times 2}{0.30 \times 50} + \frac{0.3 \times 2}{0.30 \times 0.043} + \frac{0.004 \times 2}{0.30 \times 204}$$

$$R = \frac{0.001}{15} + \frac{0.06}{0.0126} + \frac{0.0008}{61.2}$$

R = 0.0006 + 4.76 + 0.000013

R = 4.760801.

$$Q = \frac{60}{4.760801}$$

Q=12.5995kj/kg

For side

$$R = \frac{0.0005 \times 2}{0.30 \times 50} + \frac{0.03 \times 2}{0.2 \times 0.048} + \frac{0.0004 \times 2}{0.20 \times 204}$$

$$R = \frac{0.001}{10} + \frac{0.06}{0.0086} + \frac{0.0008}{40.8}$$

= 0.001 + 6.992 + 0.00000196

= 6.977120

$$Q = \frac{60}{6.9777120} = 8.5995kj/kg$$

Hence QT = Qp + Qf +Qs

Q = 10.3197 + 12.5995 + 8.5995 = 31.5187

QT = 31.5187kj/kg

Calculating for leakage per unit area

Q = 31.52kj/kg

A = $15m^2$

$$Q = \frac{31.52}{A} = \frac{2.1010kj/kgm^2}{15}$$

Hence, the leakage per unit area is calculated to be $2.10kj/kgm^2$

MATERIALS SELECTION

The choice of material selection for this project is based on; Cost and availability of local materials used. Physical, mechanical and chemical properties of materials used.

It is important to note that the selection of local material account for about 55% of the production cost for the finished product. When a material satisfies all design requirements but not readily available it should be chosen for the design. A physical, chemical and mechanical property plays a prominent role in the selection of material for project.

However some of the properties irrelevant to the design requirement all neglected. The material and component selected which include.

GALVANIZED SHEET

As a result of its high corrosion resistance, availability at relatively low cost, galvanized sheet is chosen for the body work of this design. The hardness of galvanized sheet is about 40H, its tensile strength is about $liOmm^2$. Its melting and boiling point are 419°C and 907^cC respectively.

CONDENSER AND EVAPORATOR TUBES

In this project work, the use of copper tubes for both evaporator and the condenser is as a result of its properties ranging from its ability to conduct heat quickly, its melting ability, ductility, resistance to corrosion and can be welded, soldered and brace easily, it is readily available in several forms The properties of copper are suitable for refrigerating purpose. The diameter of copper Is 1.4 (4.4 -10°m)

REFRIGERANT USED

The refrigerant selected for this project work is Freon -12 (cf_2cl2). A refrigerant absorb heat by evaporating at low temperature and pressure and rejects heat by condensing at high temperature and pressure. It is this medium for heat transfer. However, it is worthy of note to point out that this refrigerant has a negative effect to the ozone layer hence scientific researcher is on to investigate a better and non toxic refrigerant that will replace Freon -12 in the nearest future.

CONSTRUCTION

The body of the deep freezer is made of galvanized sheet. The sheet was formed into the required shape and item welded. After welding to the desired dimensions, the structure was test for leakage and it was found to be leak proof. However the thickness of the galvanized sheet is 0.0005m.

The compartment was insulated using the selected cork of 0.03m (3.0cm). The cork was equally used for the floor and not at the deep freezer.

The evaporator (which is the copper tubes) was coiled to the desired number of size (6) on the insulation which acts as a support and at the same time and insulator to the evaporator.

The aluminum plate was then listened, with the aid of an industrial adhesive (Gum).

During construction a space was designed for the compressor and its accessories so that the selected compressor will be installed in the space provided. The installation was made possible with the aid of bolt and damping rubber to avoid excessive vibration of the compressor in the space.

The aluminum sheet serve dual purpose in the compartments first it serves to protect the copper tubes form external hazards and equally serve as a transfer medium to conduct the coldness form the evaporator to the compartment where products one being cooled and kept under control.

The cover of the deep freezer was attached to the main body by hinge and to cover properly insulated and lagged externally to avoid leakages.

A thermostat is incur-operated to control the operation of the deep freezer, it is set as a regulator to the system.

A locomotive firm which helps lower the operating temperature of the compressor was equally sited in the compressor cavity.

CHARGING OF THE COMPRESSOR

The compressor was flushed and pressure tested charging simple means the introduction of the desired refrigerant (Freon -12) into the compressor under pressure. The oil help in lubricating the crank case while the compressor help in circulating the refrigerant to the evaporator and back to the compressor through the capillary tube. Charging is done through the connection provided in the compressor form the low -pressure side (i.e. suction line) from the lower and through higher temperature.

The operating temperature corresponds to the condenser and the evaporator temperature respectively.

TESTING

It was observed that minimum temperature attainable is 20°C, with the aid of thermometer. A little of water at room temperature was placed in the deep freezer of an operating temperature of 15°C. It was discovered that the water got frozen after about 6 (six) hours.

When the same experiment was carried out with an existing deep freezer at the same capacity, it was discovered that it got frozen after 5 (five) hours. Since the deep freezer was designed to attain a minimum temperature of about 20°C but it was observed that the minimum temperature attainable is 20°C. Its efficiency then becomes -20/-25 x 100% = 80%

Hence the efficiency of the system is 80%

CONCLUSION

From personal observation and experience carried out it has been shown or obvious that the existing freezer takes an hour and some minutes to perform better than our designed freezer.

The designed deep freezer can be used to preserve hospital equipment, dairy milk products, ice cream and other agricultural products; since the temperature can be varied using the thermostat setting calibrated different temperature ranges.

RECOMMENDATION

The performance of the deep freezer depends highly on the evaporator and the compressor; this does not mean that the condenser is not important.

Therefore a perfect curve that will uniform cooling is essential for the proper and effective cooling. The lagging materials should be such that is water light so that the condenser will not be observed in the insulator.

The evaporator cooling should be done in such a way that it will be uniformly spaced either in C. Curve or 90^0C curve so that the space will be uniformly. The compressor should be manufactured locally to increase the technology advancement.

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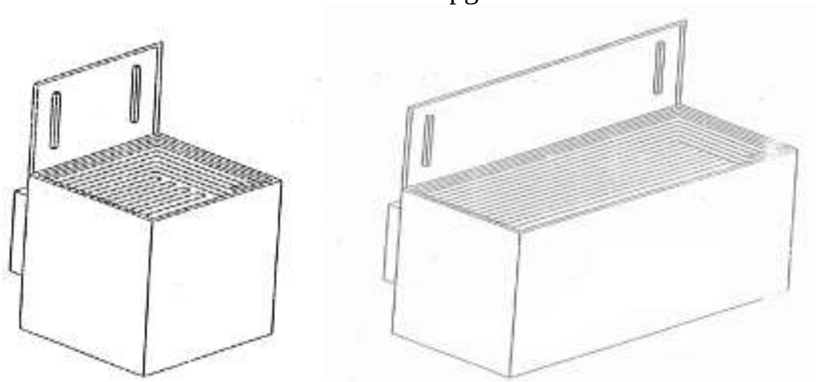

Isometric Drawing of the constructed deep freezer