OPEN ACCESS

International Journal Of Modern Engineering Research (IJMER)

Optimization of Skin Condenser Using Bundy Tube In Place Of Copper Tube

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ABSTRACT: *The condenser is an important device used in the high pressure side of a refrigeration system. Its function is to remove heat of the hot vapour refrigerant discharged from the compressor. The main objective of this work is to carryout experimental investigation on Bundy Condenser coil used in Skin Condenser for a Deep Freezer of 425 liters capacity; it is proposed to optimize the length of the condenser coil. R – 134A will be used as refrigerant for the proposed investigation.*

I. INTRODUCTION

CHEST-TYPE FEEZERS:

A chest freezer is nothing but a storage unit for frozen food such as meat, poultry, fish, prawns, some vegetables and some frits. The chest type freezer has certain advantages. Since cold air is heavier than warm air, the very cold air in a chest-type freezer does not spill out each time the lid is opened. This stops a considerable amount of moisture from entering the cabinet.

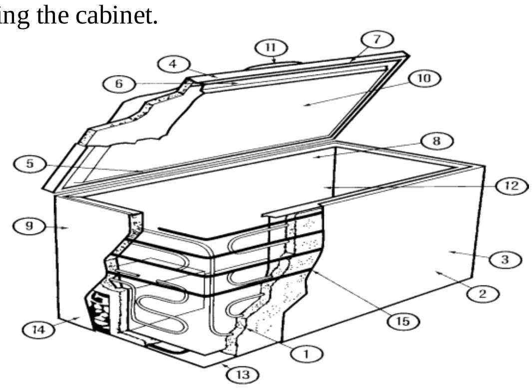


Fig 4.1 CHEST FREEZER 425L

Fig. 4.1 The parts of a chest-type freezer: 1—polyurethane foam insulation, 2—wrap-around steel cabinet, 3—baked-on enamel finish, 4— self-adjusting lid, 5—spring-loaded hinges, 6—vinyl lid gasket, 7—safety lock and self-ejecting key, 8—lift-out wire baskets, 9—temperature-control knob, 10—automatic interior light, 11—power-on light, 12—vertical cabinet divider, 13—defrost water drain, 13—sealed compressor, and 15—wrap-around condenser.

There is little air change when the cabinet opened. To make chest-type freezers more convenient to use, they are usually fitted with baskets that maybe lifted out to provide access to frozen food packages near the bottom. Also, the lids usually have a counterbalancing mechanism, which makes them easy to open. The chest-type freezer provides the most economical type of food freezing mechanism. Chest-type freezers require a manual defrost.

Defrosting may be accomplished best by unplugging the condensing unit. Then remove the stored food and place either an electric space heater or a pail or two of hot water in the cabinet. With the cabinet closed, the ice will soon drop water from the evaporator surface and will be easy to remove. These freezers have a drain, which makes removing the moisture from the cabinet quite easy. Remaining moisture must be wiped out of the cabinet. Cabinets are available in various capacities. Height and width are quite uniform. However, the length will vary with the capacity of the freezer k.

II. EXPERIMENTAL SETUP

In vapor compression refrigerating system basically there are two heat exchangers. One is to absorb the heat which is done by evaporator and another is to remove heat absorbed by refrigerant in the evaporator and the heat of compression added in the compressor and condenses it back to liquid which is done by condenser. This project focuses on heat rejection in the condenser this is only possible either by providing a fan. The rate of heat rejection in the condenser depends upon the length of Bundy copper coil attached to the condenser.

This project investigated the performance of condenser using Bundy Tube condenser in the present 425 L chest freezer.

III. BUNDY TUBE CONDENSER COIL

It is a type of double walled low – carbon steel tube manufactured by rolling a copper coated steel strip through 720 degrees resistance brazing. The performance of the condenser will also help to increase COP of the system as the sub cooling region.

Specifications of selected Domestic refrigerator
Refrigerant used: R-134a
Capacity of The Refrigerator: 425 liters
Compressor capacity: 933Btu/hr =273.435W

Bundy Tube Condenser Sizes
Length - 97.44 feet = 29.71 m
Diameter - 6.35*0.7mm

Evaporator
Length - 7.62 m
Diameter - 6.4 mm

Capillary
Length - 2.428 m
Diameter - 0.8 mm

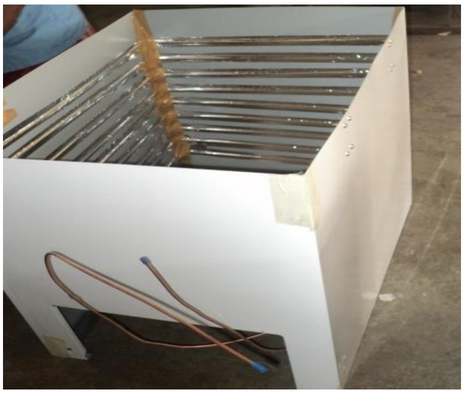


Fig. 2Bundy Coil Skin condenser arrangement

Fig.3 425 LITRES CAPACITY FREEZER OUTER

Fig.4 Freezer connected with Pressure gauges and Thermocouples

IV. CALCULATIONS

EXISTING SYSTEM

Compressor Suction Temperature, T_1 = 5°C
Compressor Discharge Temperature, T_2 = 82.2 °C
Condensing Temperature, T_3 = 42.8 °C
Evaporator Temperature, T_4 = -19 °C

Pressures

Suction Pressure, P_1 = 1.5 bar
Discharge Pressure, P_2 = 12.5 bar
Condenser pressure, P_3 = 12.2 bar
Evaporator pressure, P_4 = 1.65 bar

Enthalpies From P-H chart for R-134a, enthalpy values at state points1, 2, 3, and 4.

h_1 = 610 kJ/kg
h_2 = 660 kJ/kg
h_3 = 465 kJ/kg
h_4 = 465 kJ/kg

V. OPTIMUM DESIGN OF A CONDENSER COIL

The function of the condenser is to remove heat from the superheated high pressure refrigerant vapor and to condense the vapor into a sub cooled high pressure refrigerant. Since the condensing unit capacity depends on the capacity of the compressor, methods of designing condensing units are based on the saturated suction temperature and on the quantity and temperature of the condensing medium. Since the heat given up by the refrigerant vapor includes both the heat absorbed in the evaporator and the heat of compression, the heat load on the condenser always exceeds that on the evaporator an amount equal to refrigeration load.

Let U = overall heat transfer coefficient, W/ m^2 K
X_a = thickness of inner wall, $(0.7/3)x10^{-3}$ m
X_i = thickness of insulation, 0.04 m
K_c = thermal conductivity of copper, 386 W/m K
K_l = thermal conductivity of low carbon steel, 36.3 W/m K
K_i = thermal conductivity of insulation, 0.025 W/m K
h_o = outside heat transfer coefficient, 20 W/ m^2 K
h_i = inside heat transfer coefficient, 9 W/ m^2 K

Optimization of length of condenser coil

Q=U x A x LMTD
Let the diameter of coil=d=3/16"=0.00775 m
Properties of Bundy type material:
h_O =20 W/m²K
h_i =9 W/m²k
$x_1 = x_2 = x_3 = (0.7/3) \times 10^{-3}$ m
x_{insul} = 0.04 m

$k_1 = k_3 = 386$ W/m k
$k_2 = 36.3$ W/mk
$k_{insul} = 0.025$ W/mk

For air – cooled condensers, the quantity of air passing over the condenser is fixed by the fan selection, the only variable determining the capacity of the condensing unit, other than the suction temperature, is the ambient air temperature. The surface area and the value of U, and the capacity of condenser depend on the mean effective temperature difference between the air and the condensing refrigerant. The coils are made of double walled low carbon steel tube by rolling a copper coated steel strip.

Hence, the overall heat transfer coefficient of the Bundy Coil,

$$U = [1/(1/h_O)+(1/h_i)+(x_1/k_1)+(x_1/k_2)+(x_3/k_3)+(x_{insul}/k_{insul})]$$

$$U = [1/ (1/20) + (1/9) + (2.3\text{x}10^{-4}/386) + (2.3\text{x}10^{-4} / 36.3) + (2.3\text{x}10^{-4}/386) + (0.04/0.025)]$$

$U = 8.189$ W/m²k

From Table .1,

load (Q)=103 W

Condenser inlet Temperature = T_1=83ºC=356K
Condenser outlet Temperature = T_2=48.5ºC=321.5K
Condenser coil Temperature = T_C=43ºC=316K

$td_1 = T_1 - T_C = 40$K
$td_2 = T_2 - T_C = 5.5$K

$$LMTD = (td_1 - td_2) / \log (td_1/td_2) = 17.387 \text{ K}$$

we have,

Area (A) = Q / (U x LMTD) = (3.14 x d x L)
=0.72 m²

we know that $A = \pi dL \Rightarrow L = A/ \pi d$
= 0.72 / (3.14x0.00775) m
= 29.71m

Hence,

Optimized length of Evaporator coil= L=A / (3.14 x d)

L= 97.44 feet = 29.71 m

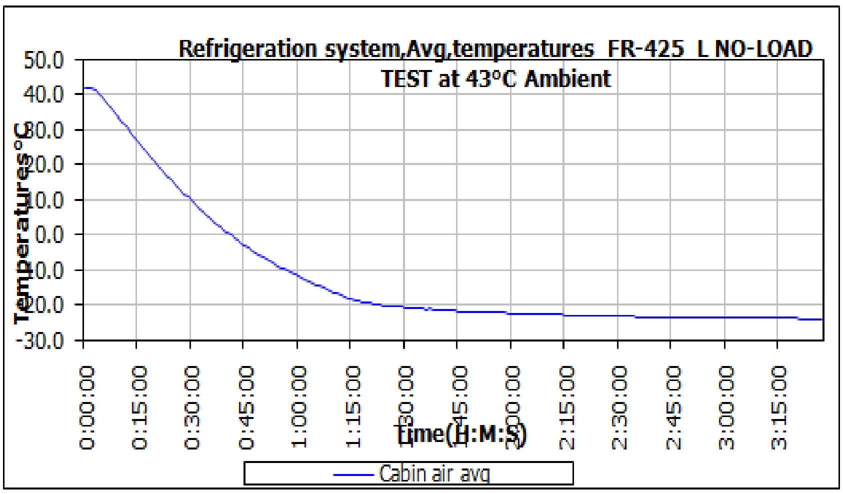
Calculation Performance Parameters

Net Refrigerating Effect (NRE) = $h_1 - h_4$
= 610-465 = 145 kJ /kg

Heat of Compression = $h_2 - h_1$
=660-610 = 50 kJ/kg

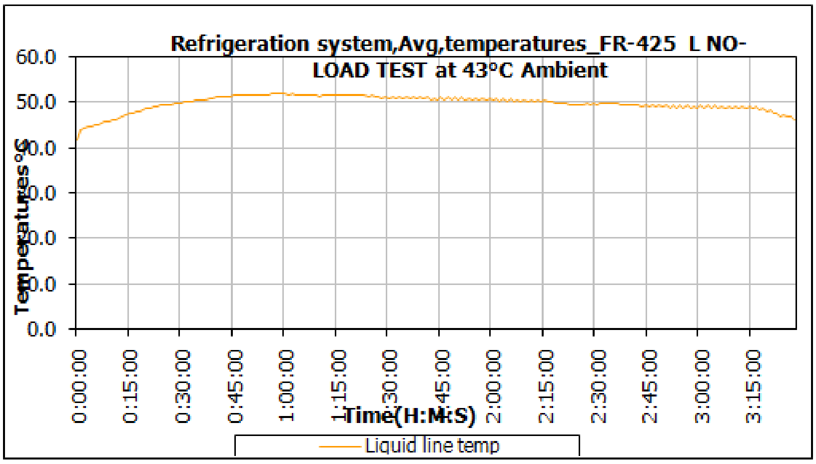
Coefficient of Performance (COP) = NRE/Heat of Compression
= 145/50 =2.9

VI. GRAPHS



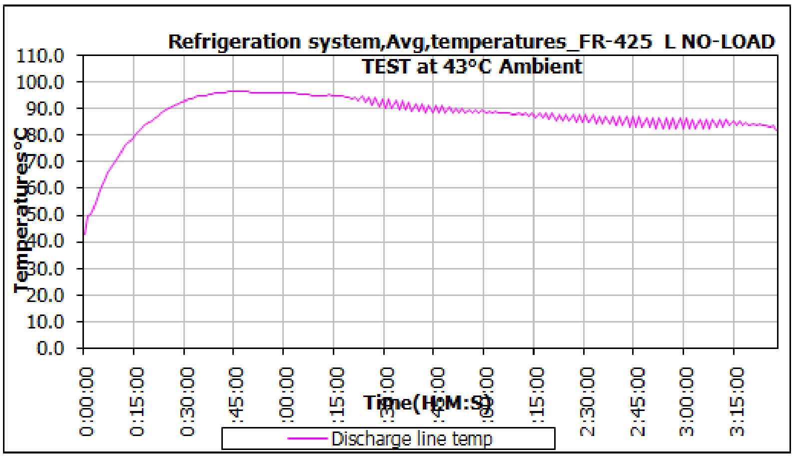
Graph.1. Temperature (Cabin air avg.) Vs Time

From the graph.1 it is observed that the cabin air average temperature decreased linearly with time in the first 1 hour, decreased till 1 hour 45 minutes and there after the variation is almost constant with time. The temperature at the end of the test is found to be -22.5^{0}C.



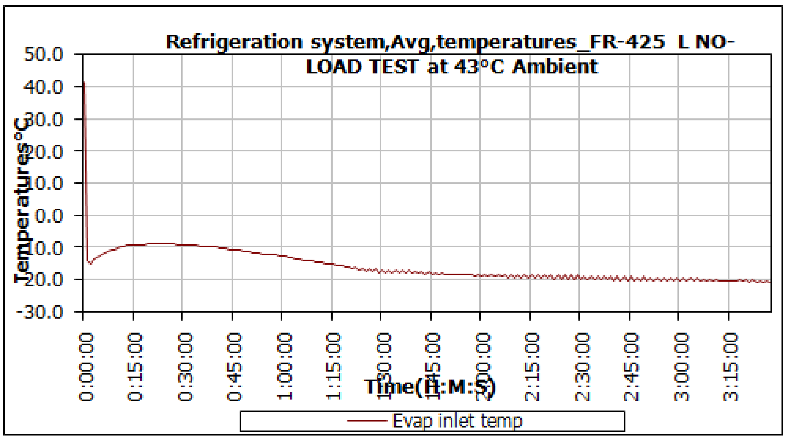
Graph.2. Temperature (Liquid line) Vs Time

From the graph.2 it is observed that the liquid line temperature increased initially in the first hour of operation there after the variation is almost constant till 3hours 15 minutes, and then sloped downwards at the end. The temperature at the end of the test is found to be 48.5^{0}C.



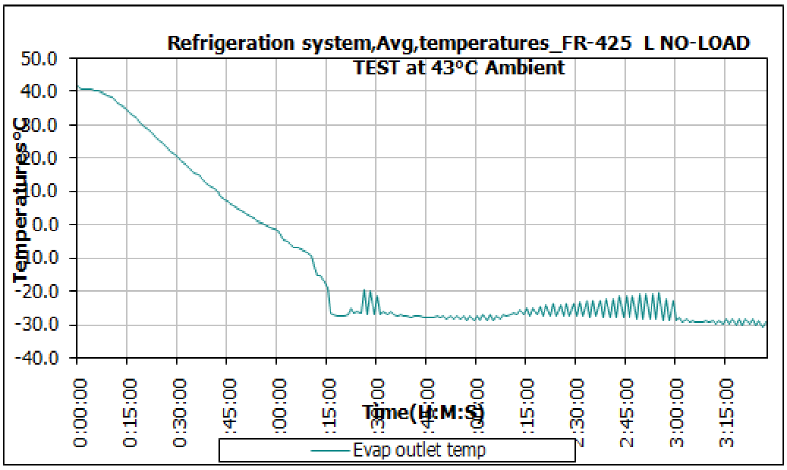
Graph.3. Temperature Vs Discharge line temperature

From the graph.3 it is observed that the discharge line temperature increased with time till 45 minutes decreased slightly and there after the variation is zigzag sloping slightly downwards. The temperature at the end of the test is found to be 82.2^{0}C.



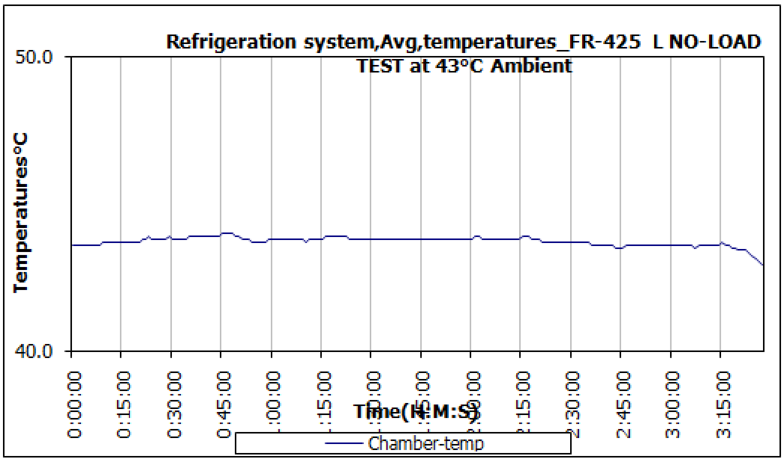
Graph.4. Temperature Vs Evaporator inlet temperature

From the graph.4 it is observed that the Evaporator inlet temperature decreased suddenly initially, then the variation is curvy till 1hour 30 minutes and there after the variation is zigzag. The temperature at the end of the test is found to be -19^{0}C.



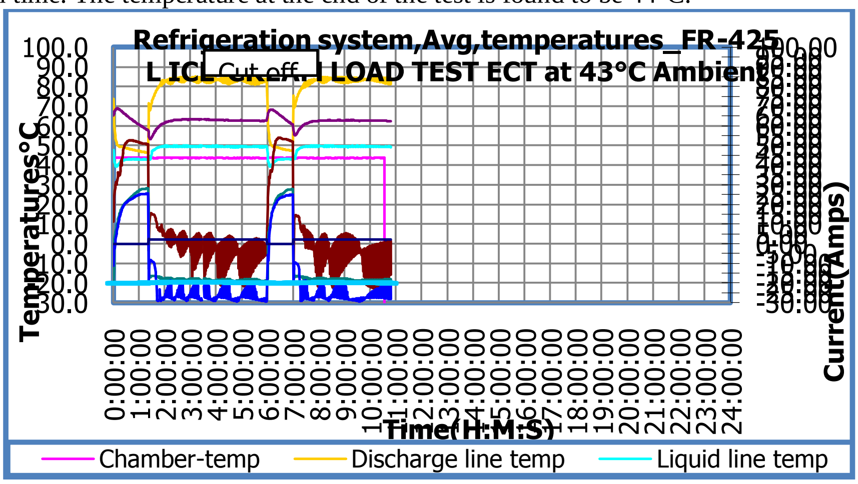
Graph.5. Temperature Vs Evaporator outlet temperature

From the graph.5 it is observed that the evaporator outlet temperature decreased initially till 1hour 15 minutes, and there after the variation is zigzag with slight change in temperature. The temperature at the end of the test is found to be 5^{0}C.



Graph.6. Temperature Vs Chamber Temperature

From the graph.6 it is observed that the variation of chamber temperature slightly deviated from the constant relationship with time. The temperature at the end of the test is found to be 44^{0}C.



Graph.7. for Load Test

VII. RESULTS AND DISCUSSIONS

- From the graph.7 the cut off thermostat position of 2.5, it is observed that compressor shell temperature decreased initially and there after remain constant with time, the variation is found to be repeatable. The cycle time is found to be 6 hours.
- From the graph.7 the cut off thermostat position of 2.5, it is observed that discharge line temperature decreased in the first hour of operation, increased till 2hours, and then remained constant with time till 6 hours. The variation is found to be repeatable. The temperature at the end of the cycle time is 83^0C.
- From the graph.7 the cut off thermostat position of 2.5, it is observed that evaporator outlet temperature increased initially till 1 hour, decreased up to 2 hours and there after the variation is wavy and the cycle is repeatable.
- From the graph.7 the cut off thermostat position of 2.5, it is observed that evaporator inlet temperature increased in first hour, decreased suddenly and then remained constant with time there after the variation is repeatable.

Table1. Results

Properties	R-134a
ODP	0
GWP	0.27
Outer cabinet	Cold rolled carbon steel(thkn=0.40mm)
Insulation	Polyol, isocyanate and cyclopentane
Condenser Fan	Plastic
Condenser coil	Bundy Tube
During power-off / Breakdown condition	8 hrs
Net refrigerating effect	145kJ/kg
Work done	50kJ/kg
COP	2.9

VIII. CONCLUSIONS

In the design of the refrigeration system for a freezer, rigid standards are maintained so as not to have any compromise with the quality and flexibility of the system. The system design is in such a way that it has optimum efficiency with moderate costs. Hence, efficient equipment design will result in conservation of energy, which reduces the running cost. Placement of the freezer also plays a major role in reducing the load on the system. The more it is exposed to the higher temperature the more will be the capacity requirement and power requirement.

On low temperature applications like Freezers, Skin type Condensers is often preferred. In this design the outer causing of the cabinet is equipped with a tube on the inside surface, so that the outer causing act as plate type heat transfer surface. Until now copper tube is used in Skin Condenser, copper has excellent heat transfer properties, but as the length increases the cost of the copper tube also increases. There by the vapor compression refrigeration system cost also increases.

The experimental investigation on Bundy Condenser Coil used in Skin Condenser for a Deep Freezer of 425 ltrs. capacity is done. Through the experiments, the length of the condenser coil is optimized. R–134A is used as refrigerant for the proposed investigation and the results are tabulated in table1. Experimental work is done using Bundy Tube for optimizing Skin Condenser.

The results infer that

1. COP of the proposed system decreased by 0.1(3.3%) compared to the existing system for optimized length.
2. Also cost of the Bundy Tube is less than the cost of copper coil.

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