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Design & Development of Multi-Evaporative Refrigeration System

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Abstract:- In many places, we require to maintain two different temperatures. Consider example of food market where 22^{0}C temperature is required for human comfort and 5^{0}C is required for food preservation. So to maintain two different temperatures we need to prefer multi-evaporator refrigeration system. As it very difficult to achieve different temperatures by normal refrigeration system. Also if we have to vary temperature we can vary it by adjustment of back pressure valve. Thus in this paper we added both theoretical calculation and software simulation by using COOLPACK software.

***Keywords**:- Multi Evaporator, Combined Refrigerator, Simulation, Cool Pack.*

I. INTRODUCTION

General refrigeration system is single evaporator system at one temperature. But many refrigeration installation, different temperature are required to be maintained at various points in the plant such as in hotels, large restaurants, institutions, industrial plants and food markets where the food products are received in large quantities and stored at different temperature. For example, the fresh fruit, fresh vegetables, cut meats, frozen products, dairy products, bottled goods, have all different conditions of temperatures and humidity for storage. In such cases each location is cooled by own evaporator in order to obtain more satisfactory control of the condition. For many industrial application, we require different temperature for different application, for example if we are using the refrigerator and air conditioner in the commercial space then we can get the cooling effect for storing the water bottles as well as the cooling effect for the human comfort. To obtain such different temperature by normal single refrigeration system is very difficult, as temperature requirement is different for different application, to follow economy, low initial cost and operating cost it is essential to run a single refrigeration system with multi evaporator.

In many refrigeration or air conditioning installations, different temperatures are required at various points in the plant. This occurs in the case of air conditioning of big residential complexes. Depending on the system requirements, various arrangements of vapour compression systems can be made that can serve that particular purpose with respect to environmental and energy conservation. A basic vapour compression system can thus be used as a building block to develop complex air conditioning and refrigeration units.

$$\gamma = \frac{\text{mass exiting vapor branch}}{\text{total mass flow entering separator}} = \frac{\dot{m}_v}{\dot{m}_T}$$

II. PROPOSED WORK

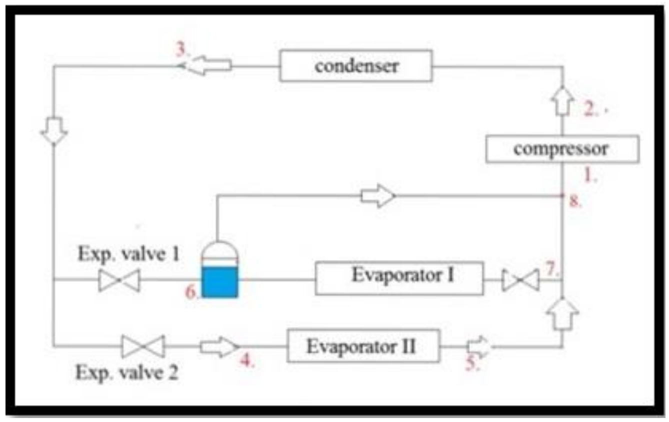

Fig. 1:- Proposed Work

The experimental setup is comprised of components typically sized for home appliance refrigerators. The schematic of the test facility in which the two separators to be tested is shown in Fig. In this experimental system the purpose of Condenser 1 was to maintain the working fluid in the sub cooled state. This permits a direct measurement of the pressure and temperature before the refrigerant enters the downstream heated coil section. With the known inlet enthalpy, the refrigerant quality leaving the heated coil section can be accurately calculated after measuring the heater input wattage and refrigerant mass flow. The fan on Condenser 1 is utilized to increase the heat transfer from the refrigerant to the ambient and to maintain pressure on the high side in steady state. The two-phase mixture enters the separator from the inlet top branch (state point 1); when the phases are segregated completely, ideally, 100% of the vapor will exit through the outlet top branch (state point 2) and 100% of the liquid exits through the bottom branch (state point 3). This can only occur if the top branch flow ratio (defined by Eq. [1]) is held equal to the inlet vapor quality, x1, for an adiabatic separator. The mass that exits the top branch (state point 2) should be comprised of vapor which will then proceed to be condensed into liquid in Condenser 2. The fluid once fully condensed continues through the variable expansion device, which consists of a needle valve upstream of a capillary tube. Similarly, the mass that exits through the bottom branch (state point 3) undergoes expansion through a second needle valve and capillary tube. The needle valve is used to adjust the restriction of the liquid branch.

Through the use of both needle valves, the top branch flow ratio (TBFR) was controlled. It is defined as:

Finally, the fluid at state point 4a and 5a is at a low temperature and pressure, and gains heat from the ambient, fully evaporating any remaining liquid. At point 4 and 5 the fluid exits the evaporator as either saturated or superheated vapor, and can be measured by Flow Meters 2 and 3, which are used to determine the overall mass flow in the system. The flow from 4 and 5 will combine (state point 6) and enter the suction side of the compressor to undergo the cycle again.

III. COMPONENTS INCLUDED

A. Hermetically Sealed Compressor

Fig. 2:- Hermetically Sealed Compressors

Product Details	Specification
Brand name	Emerson
Displacement	7.2 cc
Cooling Capacity	180 kcal/h
Frequency	50 Hz
Refrigerant	R134a
Voltage	220 V

Table 1

B. Condenser

Fig. 3:- Finned condenser

Product Details	Specification
Brand	Faridabad Coil Industries
Tube Thickness	1 mm
Tube Inner Diameter	10 mm
Tube length	9 m
Tube Material	Copper
Type	Fin and Tube
Cost	1400/-

Table 2

C. Evaporator

Fig. 4:- Finned Evaporator

Product Details	Specification
Tube length	16 m & 9 m
Tube material	Copper
Type	1st Plate Type Evaporator 2nd Fin and Tube type Evaporator
Cost	3500/-

Table 3

D. Evaporator

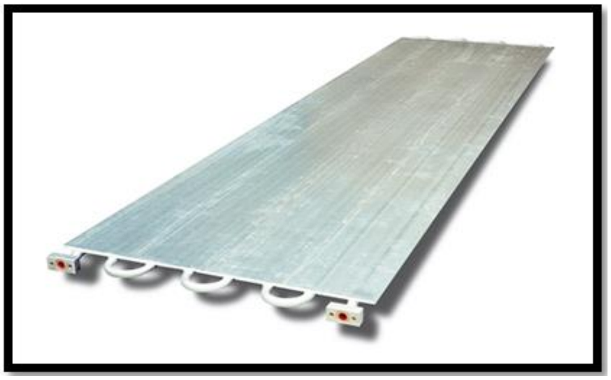

Fig. 5:- Plate type evaporator

In the plate type of evaporators the coil usually made up of copper or aluminum is embedded in the plate so as so to form a flat looking surface. Externally the plate type of evaporator looks like a single plate, but inside it there are several turns of the metal tubing through which the refrigerant flows. The advantage of the plate type of evaporators is that they are more rigid as the external plate provides lots of safety. The external plate also helps increasing the heat transfer from the metal tubing to the substance to be chilled. Further, the plate type of evaporators are easy to clean and can be manufactured cheaply.

IV. THEROTICAL CALCULATION (BASED ON IDEAL CYCLE)

Required readings of evaporator:
Temperature of high temperature evaporator : 22^0C
Temperature of low temperature evaporator : 5^0C

<u>Conditions at state 1:</u>
Temperature (T1) = 5^0C
Pressure (P1) = 350 KPa
Enthalpy (h) = 253.35KJ/Kg
Entropy (S) = 0 .9288KJ/KgK
Dryness fraction (X) =1

<u>Conditions at state 2 :</u>
Temperature (T2) = 57.23^0C
Pressure (P2) = 1400 KPa
Enthalpy (h) = 282.11KJ/Kg
Entropy (S) = 0.9288KJ/KgK

<u>Conditions at state 3:</u>
Temperature (T3) = 52.4^0C
Pressure (P3) = 1400 KPa
Enthalpy (h) =127.3KJ/Kg
Entropy (S) = 0 .4533KJ/KgK

<u>Conditions at state 4:</u>
Temperature (T4) = 5^0C
Pressure (P4) = 350 KPa
Enthalpy (h) =127.3KJ/Kg
Entropy (S) = 0.4756KJ/Kgk

<u>Dryness fraction at point 4</u>
$X_4 = 0.3225$
S4=Sf+x4(Sg-Sf)
= 0 .2288+.3525(.9288-.2288)
= 0.4756KJ/Kg

Compressor Capacity
1TR=3.5KW

Condenser calculations
Diameter : 10mm
Thickness : 1mm
Tube length : 9 m.

Expansion Device Calculations :
Inner diameter = 0.05”
Length = 9 ft.

Calculations for low temp. Evaporator :
Fruits are to be stored at temp. 5° c (278K) Ambient temp.=30°c (303K)
Mass of fruit = 1Kg
T=303-278 = 25K
Specific heat of fruit =0.87btu/lb°F
= 2.0222KJ/KgK

Refrigeration effect :
Qd= m.Cp.dT
=1*2.022*25
=50.55KJ

For mass flow rate:
$$M_1 = \frac{Qd}{h5-h4}$$
$$= \frac{50.55}{262.611-127.3} = 0.3735 \text{ kg/s}$$

Evaporative tube selection :
Copper tube is selected due to good workability high thermal conductivity & corrosion resistance.

Copper tube dimension is 10mm as per manufacturer’s suggestions

Calculation for area of evaporator (A):
$$\text{LMTD} = \frac{[(T1-TL)-(T2-TL)]}{\ln[\frac{T1-TL}{T2-TL}]}$$
$$= \frac{(303-247)-(278-247)}{\ln[\frac{303-247}{278-247}]}$$
= 50.45K

Surface area of evaporator:
$$A = \frac{Qd}{dT.m.U}$$
$$= \frac{50.55}{23.14*6} = 0.364\text{m}^2$$
$$L = \frac{A}{\pi.d} = \frac{0.364}{\pi*0.01} = 11\text{m}$$

Calculations for high temp.Evaporator :
Medicines to be maintained at temperature 22^0C (295k)
Ambient temperature 27^0C
Mass of medicine = 1 kg.
Specific heat of medicine = 3.02KJ/Kgk

dT = 8k

Refrigeration effect

Qd= m.Cp.dT

= 2*3.022*8

= 48.32KJ

For mas flow rate

$M_2 = \frac{Qd}{h7-h6}$

$= \frac{48.32}{262.611-127.3} = 0.357$ kg/s

Evaporator tube selection

$LMTD = \frac{[(T1-TL)-(T2-TL)]}{\ln[\frac{T1-TL}{T2-TL}]}$

$= \frac{(303-247)-(295-247)}{\ln[\frac{303-247}{303-247}]} = 50.45K$

Surface area of evaporator

$A = \frac{Qd}{dT.m.U} = \frac{48.32}{50.45*30} = 0.5082\ m^2$

$L = \frac{A}{\pi * d} = \frac{0.5082}{\pi * 0.01} = 16m.$

- Workdonebycompressor

$Q_C = (h_2 - h_1)*M$

$= 284.039 * 0.75$

$= 213.02$ kw

- Heat rejected by condenser

$Qr = (h_2 - h_3)* M$

$= (282.11-127.3)*0.75$

$= 116.107$ kw

- Heat absorbed by evaporator

$Qa = (h_1 - h_4)*M$

$= (253.35 - 127.3)*0.75$

$= 94.53$ kw

- Coefficient of performance

$COP = \frac{h1-h4}{h2-h1} = \frac{253.35-127.3}{282.11-253.35} = 4.38$

V. COOLPACK SOFTWARE ANALYSIS

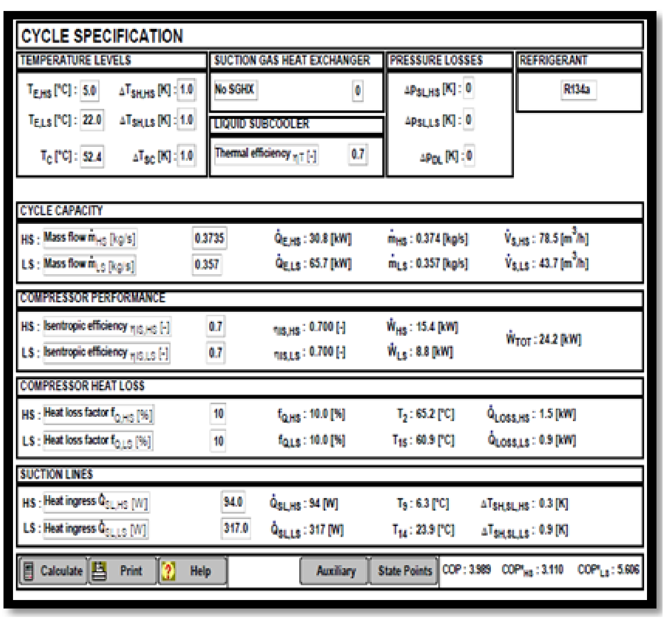

Fig. 6:- Software Calculations

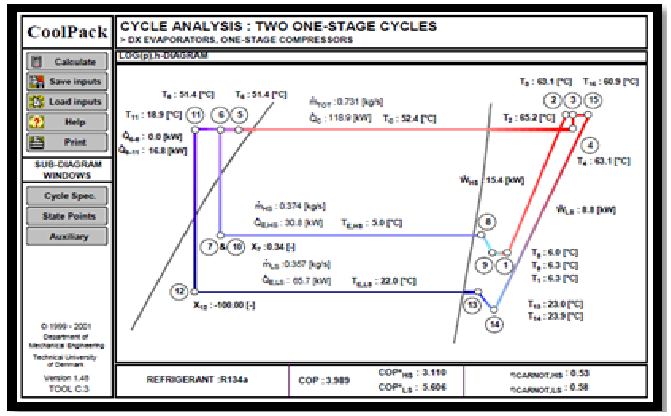

Fig. 7:- Ideal diagram as per software analysis

VI. CONCLUSION

Thus by using multi-evaporator system, We can achieve more COP than single evaporator system. According to above calculation;

COP achieved by theoretical calculation

$COP_{th} = 4.38$

COP achieved by COOLPACK software

$COP_{th} = 3.98$

REFERENCES

[1]. R. Shah,A.G.Alleyne, C. W. Bullard, B. P. Rasmussen, and P. S. Hrnjak, "Dynamic Modeling And Control of Single and Multi-Evaporator Subcritical Vapor Compression Systems" McGraw-Hill Book Company, August 2003.

[2]. Bhaskar Dixit C. S., "Design, fabrication and performance evaluation of a single compressor multi evaporator system for high temperature applications", M. E. Dissertation, WCE, Sangli1991.

[3]. Arora C. P., "Refrigeration and Air conditioning", Tata McGraw Hill Private Limited, 3rd Edition, 2008.

[4]. Amod A. Koyadwar, Prof. S.R.Karale, "A review on dual purpose automotive air-conditioning system",GH Raisoni College of Engineering, Nagpur, (India),February 2015.

[5]. Arif O. Hannure, "Application of Multi Evaporator RefrigerationSystem and Simulation",Assitant Professor, NKOCET Solapur, May 2017.

[6]. Mr.JeevanWankhade, Ms. MadhuriTayde, Prof. ShyleshaChannapattana, "Multi Evaporator System with Single Compressor and Individual Expansion Valve", Dr.D.Y.P.S.O.E. Ambi, Pune, 2014.

[7]. Mr.ThomasGillet, Mr.Gérard Olivier, "Modeling Of An Automotive Multi-EvaporatorAir-Conditioning System", Purdue University, July 2016.

[8]. Sanghachabukswar, "Analysis of Multi-Evaporative Refrigeration system", February 2015.