DESIGN & DEVELOPMENT OF COMBINED UNIT FOR AN AIR–CONDITIONING & REFRIGERATION AND SIMULATION OF SYSTEM

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ABSTRACT

For many industrial and residential application, we require different temperature for different application, for example in office application one refrigeration system require at low temperature for chiiling product atmedium temperature, whereas one more system may require, which has somewhat higher temperatures compare to other for human comfort.To obtain such different temperature by normal single refrigeration system is very difficult, as temperature requirement is different for different application but basic operation of cycle is same so, to follow economy, low initial cost, and operating cost it is essential to run a single refrigeration system with multi evaporator.In current research multi-evaporator system, with two evaporators is developed. These two evaporators are designed for three different temperatures. These two evaporators may be used for different application one is for refrigerator & another is for air conditioner. The arrangement is made to vary the load on evaporator by using electrical heater. The prime objective is to check the performance of system with variation in the temperature and load on the evaporator and simulate the system with Cool Pack software.

Keywords: Multi Evaporator Combined Refrigerator & Air Conditioner, Cool Pack, Simulation.

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. And simulation is useful tool to obtain the results of system in different operating conditions.

II DESIGN OF SYSTEM

2.1 Deign of low temperature evaporator

1. It is recommended that the evaporator temperature should be kept 5°C below the temperature of the fluid to be cooled.

Here let us consider the temperature of the fluid to be cooled as -10°C i.e.263K.

The design temperature of the evaporator = (263– 5) = 258K

2. Let us select an appropriate refrigerant for the evaporator temperature to be obtained.

A little consideration shows that R 404a is a good choice because it is having a boiling point of about -47°C (226 K). This is a commonly used refrigerant used in low temperature refrigeration.

3. **a) Calculation of Refrigeration effect**

Let's consider the low temperature evaporator is used to store milk chocklet having specific heat of 0.20 Btu/lb°f.mass of milk chocklet to be stored= 1 kg.Specific heat of chocklet(C_p) = 0.20 Btu/lb°f. = 0.46488KJ/KgK

Let us consider an ambient temperature of 30°C (303 K)The milk chockletis supposed to store at temperature of -10°C (263 K)Hence temperature difference, ΔT = (303 – 263) K = 40 K.

We can calculate the Refrigeration effect as

$$Q_D = m.C_p.\Delta T$$

$$= 1 \times 0.46488 \times 40$$

$$= 18.59\text{kJ.}$$

From p-h chart of R 404a,

Enthalpy h_5 =360 kJ/Kg .Enthalpy h_4 = 260kJ/Kg.

b) Calculation of mass of the refrigerant flowing through the system (m)

$$m_1 = \frac{Q_D}{q_c}$$

$$m_1 = \frac{Q_D}{(h_5 - h_4)}$$

$$m_1 = \frac{18.59}{(360 - 260)}$$

$$m_1 = 0.1859 \ kg.$$

4. a) Evaporator tube selection- Copper tube is selected due to its good workability, high thermalconductivity, and corrosion resistance.

b) Selection of copper tube diameter is made 3/8" or 10 mm, as per manufacturer'ssuggestion.

c) Tube wall thickness is selected as 1 mm, as per manufacturer's suggestion.

5. Calculation of surface area of evaporator (A)- For this calculation we need the values of

ΔT_m= Log mean temperature difference (LMTD).And$U$ = overall heat transfer coefficient.

LMTD is given as

$$LMTD = \frac{[(T_1 - T_L) - (T_2 - T_L)]}{\ln\left[(T_1 - T_L) \big/ (T_2 - T_L)\right]}$$

where, T_L is the boiling temperature of the refrigerant and T_1, T_2 are temperatures of the milk chocklet before storage and final temperature of chock let respectively.

Here, T_L is boiling point of R 404a,(as we know that the refrigerant temperature should be 5°C less than that of the evaporator temperature i.e.263K) = 268 K.

For getting the values of T_1, T_2let us decide ΔT.

T_1 = 303 K and T_2 = 263 so that ΔT = 40 K.

Thus, we can calculate

$$LMTD = \frac{[(303 - 258) - (263 - 258)]}{\ln\left[(303 - 258) \big/ (263 - 258)\right]}$$

Thus, ΔT_m= 18.20 K

Thus, surface area of evaporator,

$$A = \frac{Q_D}{(\Delta T_m . U)}$$

$$A = \frac{18.59}{18.20 \text{ x } 5}$$

A = 0.2042 m^2

6. Calculation of length of Evaporator

$$L = \frac{A}{\pi d}$$

$$L = \frac{0.2042}{(3.142 \text{ x } 0.01)}$$

L = 6.49m = 21.29 ft, say 21 ft.

2.2 Deign of medium temperature evaporator

1. It is recommended that the evaporator temperature should be kept 5 K below the temperature of the fluid to be cooled.

Here the temperature of Evaporator to be maintained is 273K.

The design temperature of the evaporator = (273 – 5) K

= 258 K.

2. It is quite obvious that refrigerant selected while designing the low temperature evaporator i.e. R-404a will serve the purpose in medium temperature evaporator also

3. a) Calculation of Refrigeration effect

Let's consider the medium temperature evaporator is used to store vegetable let having specific heat of 0.29 Btu/lb^{o}f.Vegetable to be stored = 1 kg.

Specific heat of vegetable (C_p) = 0.29 Btu/lb^{o}f. =1.172 KJ/KgK

Let us consider an ambient temperature of 30^{o}C (303 K)

The vegetable is supposed to store at temperature of 0^{o}C (273 K)

Hence temperature difference, ΔT = (303 – 273) K = 30 K.

We can calculate the Refrigeration effect as

$$Q_D = m.C_p.\Delta T$$

$$= 3 \times 1.172 \times 30$$

= 105.48kJ

From p-h chart of R 404a ,

Enthalpy h_7 =362 kJ/Kg .Enthalpy h_6= 260kJ/Kg.

b)Calculation of mass of the refrigerant flowing through the system (m)-

$$m_2 = \frac{Q_D}{q_c}$$

$$m_2 = \frac{Q_D}{(h_7 - h_6)}$$

$$m_2 = \frac{105.48}{(362\text{-}260)}$$

= 1.034 kg.

4. a) Evaporator tube selection- Copper tube is selected due to its good workability, high thermal conductivity, and corrosion resistance.

b) Selection of copper tube diameter is made 3/8" or 10 mm, as per manufacturer's suggestion.

c) Tube wall thickness is selected as 1 mm, as per manufacturer's suggestion.

5. Calculation of surface area of evaporator (A)

For this calculation we need the values of

ΔT_m= Log mean temperature difference (LMTD).

and U = overall heat transfer coefficient.

LMTD is given as

$$LMTD = \frac{[(T_1 - T_L) - (T_2 - T_L)]}{\ln\left[(T_1 - T_L)/(T_2 - T_L)\right]}$$

where, T_L is the boiling temperature of the refrigerant and T_1, T_2 are temperatures of the vegetable before storage and final temperature respectively.

Here, T_L is boiling point of R 404a,(as we know that the refrigerant temperature should be 5^{o}C less than that of the evaporator temperature i.e.273K) = 258 K.

For getting the values of T_1,T_2let us decide ΔT.

T_1 = 303 K and T_2 = 263 so that ΔT = 40 K.

Thus, we can calculate

$$LMTD = \frac{[(303 - 268) -(273 - 268)]}{\ln[(303 - 268) / (273 - 268)]}$$

Thus, ΔT_m= 15.41 K

$$A = \frac{Q_D}{(\Delta T_m . U)}$$

Thus, surface area of evaporator,

$$A = \frac{105.48}{(15.41 \text{ x } 50)}$$

A = 0.1388 m^2

6. Calculation of length of Evaporator-

$$L = \frac{A}{\pi d}$$

$$L = \frac{0.1388}{(3.142 \text{ x } 0.01)}$$

L = 4.35m = 14.27ft, say 14 ft.

III SIMULATION BY USING COOL PACK

COP of machine can be found out by using cool pack software:

Cool pack Approach

In the software simulation, some of the readings that taken actually on the machine are required to check the results obtained from the actual machine are ok or not. The cool pack gives us the direct calculations of the actual COP of the machine for the given pressure and the temperature. So that we can check that machine is working well or not.

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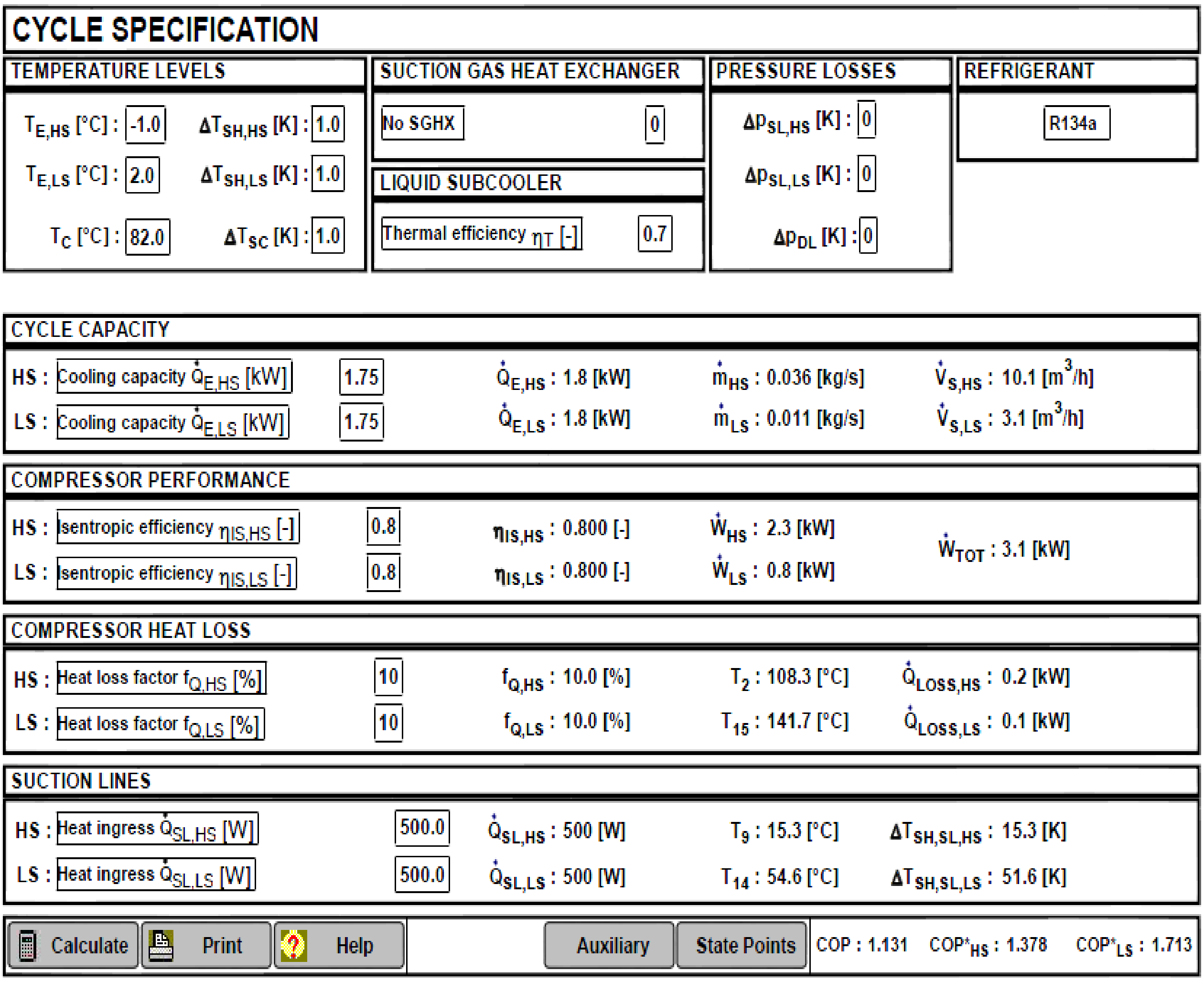


Figure 2: Cycle generated by cool pack software

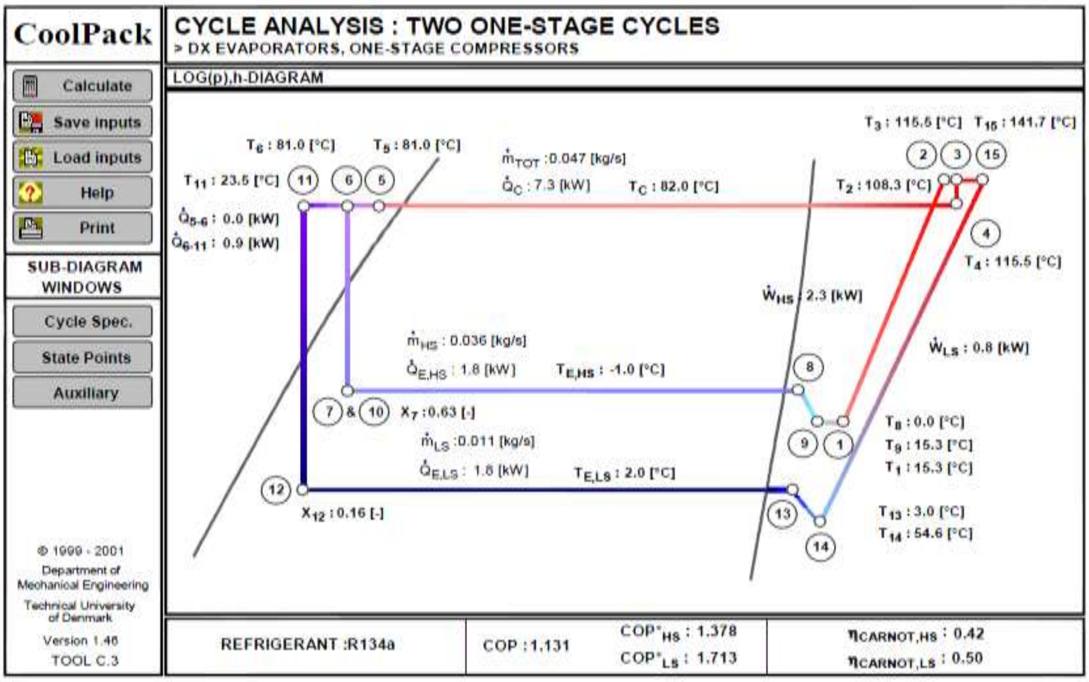
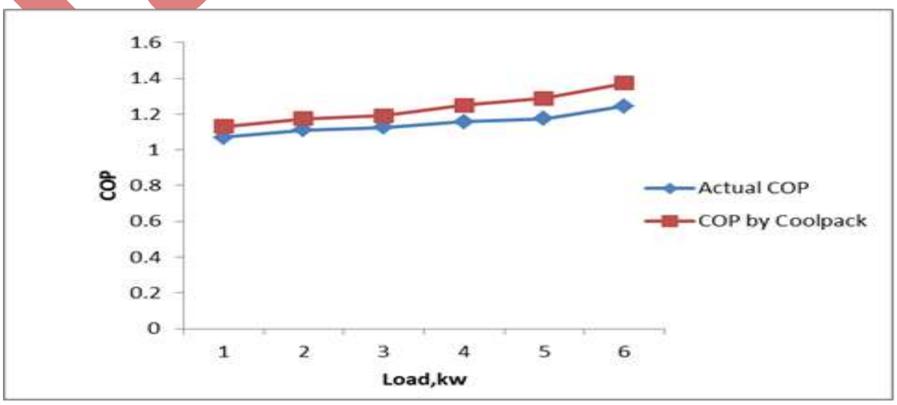


Figure 2: Cycle generated by cool pack software

IV RESULTS AND DISCUSSION

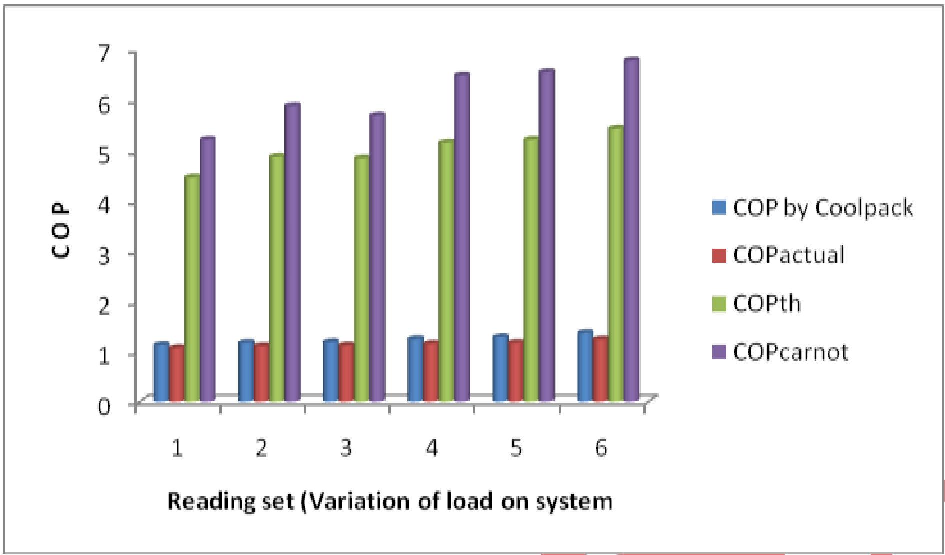
Load.kW	Actual COP			Theoretical COP	Carnot COP
	By calculations	By Cool Pack	% Change	By calculations	By calculations
0.9	1.070	1.131	6.1	4.47	5.22
1.0	1.112	1.175	6.5	4.88	5.89
1.1	1.125	1.19	6.5	4.85	5.70
1.7	1.157	1.25	9.3	5.16	6.48
1.9	1.175	1.287	11.2	5.22	6.55
2.4	1.243	1.373	13	5.44	6.78

Table No.1 Result for COP with variation of load on system



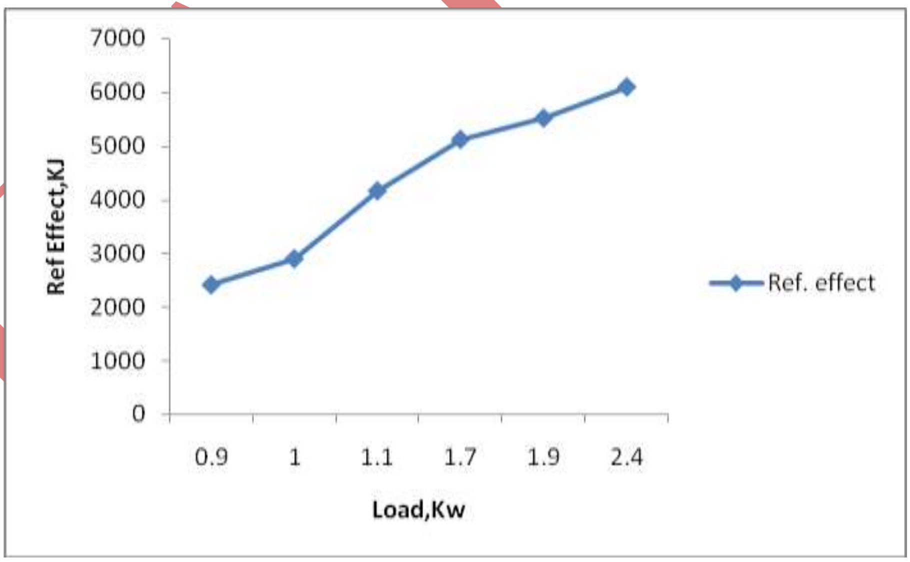
Graph No.1 Comparison of actual COP and COP by cool pack

Above graph no.1 shows that as the load on the evaporator increases the COP also increases. Rise in actual COP is observed from the load change from 0.9kW to 2.4kW.



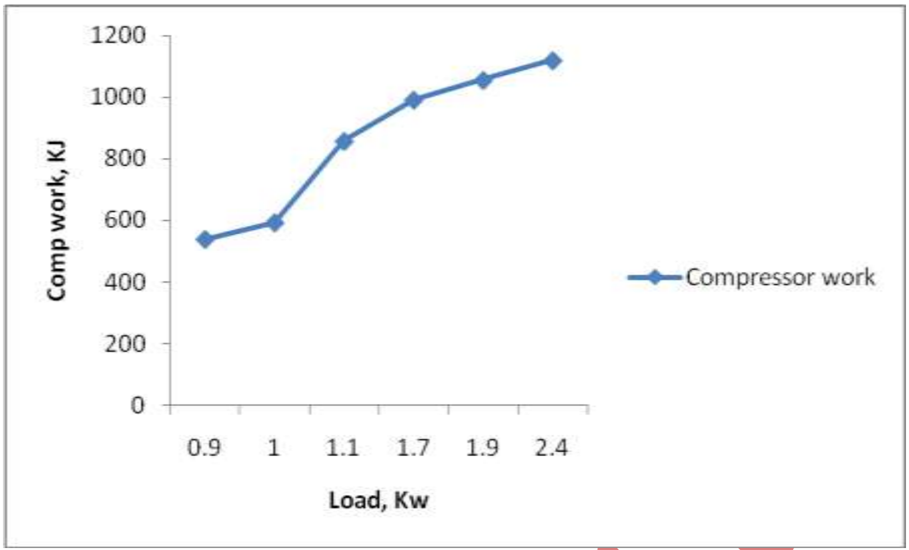
Graph No.2 Comparison of actual, theoretical and Carnot COP

Above graph no.4 shows the comparison of COP actual, COPth and COP Carnot. COP Carnot is greater than COP actual and COPth. COP actual varies from 1.07 to 2.43, COP theoretical varies from 4.47 to 5.44 and COP Carnot varies from 5.22 to 6.78.



Graph No .3 Refrigerating effect

Above graph no.6 shows the refrigerating effect. Refrigerating effect increases because of its heat transfer coefficient increases. At higher load refrigerating effect is about 16% more but as load decreases refrigerating effect decreases.



Graph No.4 Compressor work

Above graph no.6 shows compressor work. Compressor work is more it because of more pressure drop across evaporator so more compressor work required. At higher load up to 6.67% more work required.

V COMPARISON OF RESULTS

Following conclusion are made from the work carried out on effect of combined unit of VCR system.

- When system is operated at same loading conditions in individual mode and in combined mode, the actual COP increased about 1.27% to 7.28%, theoretical COP about 2.07% to 5.93% and Carnot COP 2.38% to 7.42%.
- At the same when system simulate with Cool pack software results obtained are close to the actual output given by the combined unit, the difference in the results of actual output and simulation varies from 6% to 13%.
- The main reason for the improved performance of this system in combined mode is due to reduction in compressor work and increase in refrigeration effect. Refrigerant effect also improved about 2% to 16%.
- As the system is simulated with Cool Pack software, so we can get many output by varying the different parameters which will gives us very close results as that of actual working machine or system.

VI CONCLUSIONS AND SCOPE FOR FUTURE WORK

Conclusions

The current project work can be continued and thus has a scope for further of work. For this purpose, the following points can be considered with the same set-up. They are as follows-

1. There is scope for analyzing the system performance by using different feasible refrigerants.
2. Performance evaluation of the system can be performed at different ambient temperatures. For this purpose, change in the temperature of local ambient air should be done by artificial means.

3. Simulation of the system can be done by using various software's like Matlabetc, and can be compared with experimental result.
4. Effect of heat transfer coefficient of refrigerant in evaporator can be studied.

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