DESIGN AND FABRICATION OF SIMULTANEOUS HEATING AND COOLING IN VCR SYSTEM USING R134A REFRIGERENT

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Abstract – *This research paper present vapour compression refrigeration system for simultaneous heating and cooling. In normal refrigeration system the heat rejected in condenser is get wasted, in this paper we have utilized heat rejected in condenser. This rejected heat used for home purpose, like heating water, bathing, washing clothes and pots. The main advantage of simultaneous heating and cooling it carried out from one VCR system. It does not required separate equipment, It save the cost. For research purpose water cooled condenser water cooled evaporator is used. Refrigerant is the substance that transfer heat in refrigeration system that absorb heat in evaporator and rejected heat in condenser. In this system R134a refrigerant is used. ODP and GWP is low for R134a refrigerant .COP has to be calculated for selected good refrigerant. Refrigerant should have low boiling temperature, high critical temperature and higher liquid thermal conductivity which makes these properties as a good refrigerant. In this paper R134a environment-friendly refrigerant that have zero ODP and low GWP is used. We can use the hot water for cleaning textile, process heating industry, food industry also in milk industry.*

Key Words: VCRS, Heating, Cooling, ODP, GWP, Condenser.

1. INTRODUCTION

Refrigeration is a process of providing and maintaining temperature below the atmosphere. The medium used for refrigeration process is called as refrigerant. The basic element of refrigeration system are compressor, condenser, capillary tube, and evaporator. The ozone depletion potential and global warming potential have become the most important criteria for selecting any refrigerant, still lot of research is ongoing to decide the environmentally friendly refrigerants.[1]

Refrigerant is the fluid used for heat transfer from the region of low temperature and pressure and reject the heat in condenser at a region of high temperature and pressure. The environment-friendly halocarbon refrigerant that have zero ODP, non-flammable, non-toxic and low GWP is selected in vapour compression refrigeration system. The R134a has all this properties, so in VCR system R134a mostly used. Before selecting any refrigerant the following properties are requires, critical temperature of the refrigerant should be as high, The specific heat of the liquid should be as small as possible, The density of the refrigerant should be as large, ODP of refrigerants should be zero, Refrigerants should have as low a GWP[2]

The main aim of this research paper is to utilize the waste heat rejected in condenser, for this the water cooled condenser is used. The household refrigerator mostly used restaurant and in kitchens for the storage of fruits and vegetable but due to simultaneous heating and cooling This rejected heat used for home purpose, like heating water, bathing, washing clothes and pots. The term "refrigeration" in a broad sense is used for the process of removing heat from a substance. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. It transfer the heat from condenser to evaporator. In other words, the refrigeration means a continued extraction of heat from a body, whose temperature is already below the temperature of its surroundings.

The testing consists of a hermetic compressor, water cooled condenser, a capillary tube and a water cooled evaporator. In addition to these the other component are temperature sensor, pressure gauge, ammeter, and voltmeter. Pressure gauges are installed to measure the condenser and evaporator pressures. The household refrigerator works on vapour compression refrigeration cycle. In compressor the pressure and temperature of refrigerant is increase, this high pressure and high temperature refrigerant enter in condenser where the heat rejection takes place. The heat rejection in condenser takes place at constant pressure. In capillary tube the pressure is get reduce at constant enthalpy, and in evaporator the heat is get absorbed at constant pressure, finally from the outlet of evaporator we will get low pressure, low temperature vapour refrigerant. Copper tube is mostly used for supply refrigerant. In evaporator the liquid + vapour refrigerant absorb latent heat of vaporization from the medium which is to be cooled, the cycle get repeated. The miniature circuit breaker used to protect from over current. MCB can be easily reset [3]

Nomenclature

COP coefficient of performance
Cp specific heat at constant pressure (kJ/kg K)
h enthalpy (kJ/kg)
$\dot{m}$ mass flow rate (kg/s)

$\dot{W}$ compressor electrical power consumption (kW)
P pressure (bar)
Q_{cool} heat absorbed in evaporator (kW)
Q_{hot} heat rejected condenser (kW)
s entropy (kJ/kg K)
T Temperature (˚C HCFCs hydro chlorofluorocarbon

HCs hydrocarbons

CFCs chlorofluorocarbons

HFCs Hydro fluorocarbons

VCR Vapour Compression Refrigeration

1.1 Theoretical analysis

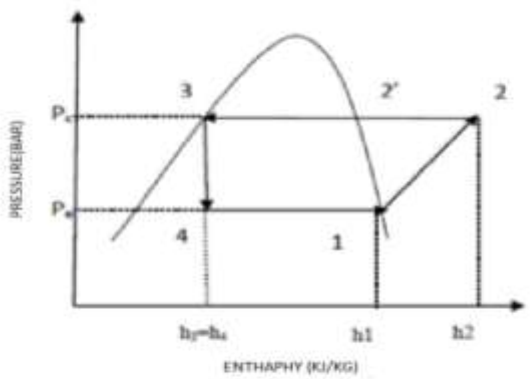

Fig-1: p-h chart

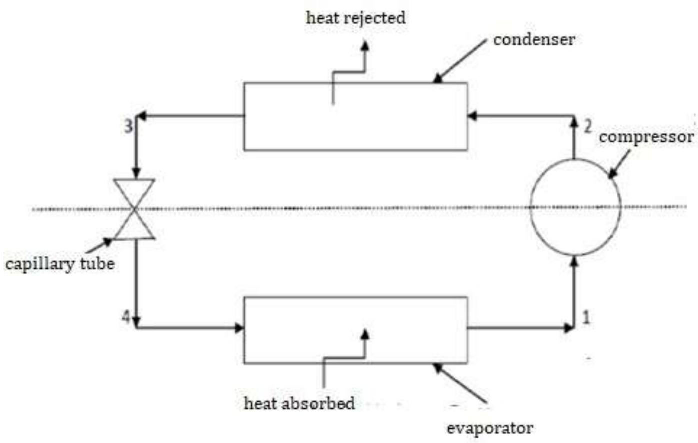

Fig-2: basic VCR system

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Process involved in VCR cycle:

1-2 isentropic compression

2-3 isobaric process heat rejected at constant pressure

3-4 Expansion process

4-1 isobaric process heat absorbed at constant pressure

The rate of heat absorbed by evaporator is given by
$Q_{cool} = \dot{m}\ (h1 - h4)$

The rate of heat rejected by condenser is given by
$Q_{hot} = \dot{m}\ (h2 - h3)$

Compressor power consumption is given by

$\dot{W} = \dot{m}\ (h2 - h1)$

Coefficient of performance for cooling
$COP_{cooling} = (h1-h4)/\ (h2-h1)$
Coefficient of performance for heating
$COP_{heating} = (h2-h3)/\ (h2-h1)$

1.2 Actual analysis

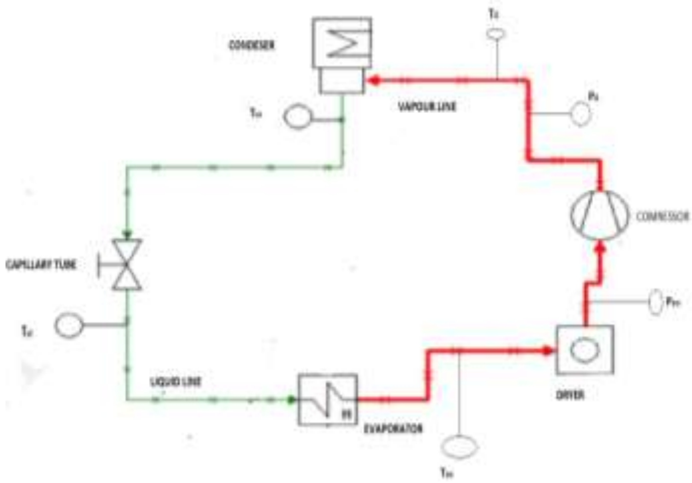


Fig-3 : actual VCR system

The rate of heat absorbed by evaporator is given by
$Q_{cool} = m\ c_p\ \Delta T$

The rate of heat rejected by condenser is given by
$Q_{hot} = m\ c_p\ \Delta T$

Compressor power consumption is given by

$W_c = V * I$

Mass flow rate of a refrigerant is given by

$\dot{m} = \Delta p * \rho$

Average heat of system is given by

$Q_{verage} = (Q_{hot} + Q_{cool})\ /2$

$COP_{cooling} = Q_{coll} / (Q_{hot} - Q_{cool})$

$COP = Q_{hot} / (Q_{hot} - Q_{cool})$

Methodology

The methodology of the system design is evaluated by following procedure.

- Selection of refrigerant.
- Selecting parameter like capacity, temperature ranges, compressor specification.
- Selection of capillary from three different diameter.
- Design of condenser.
- Design of evaporator.
- Selection of other components like temperature sensor, pressure gauge, voltmeter, ammeter, dryer.
- Modelling of system using CATIAv5 software.
- Manufacturing the actual system.
- Checking system parameter and actual systems review.

Objective

The main objective of this paper is in normal refrigeration system the heat rejected in condenser is get wasted, in this paper we have utilized heat rejected in condenser. Capillary used in normal refrigeration system did not have specific diameter in earlier days. Nowadays due to increase in pollution there are restrictions on the use of refrigerants. In such conditions it is very important to use having maximum COP. Also the cost of refrigerants are high therefore it has become priority to use the given refrigerants efficiently. To increase overall efficiency of refrigeration system

2.0 EXPERIMENTAL SETUP

2.1 Condenser

In condenser the heat is rejected and change of refrigerant phase takes place. Condenser is an important component of any refrigeration system. In a typical refrigerant condenser, the refrigerant enters the condenser in a superheated state. It is first de-superheated and then condensed by rejecting heat to an external medium. The refrigerant may leave the condenser as a saturated or a sub-cooled liquid, depending upon the temperature of the external medium and design of the condenser

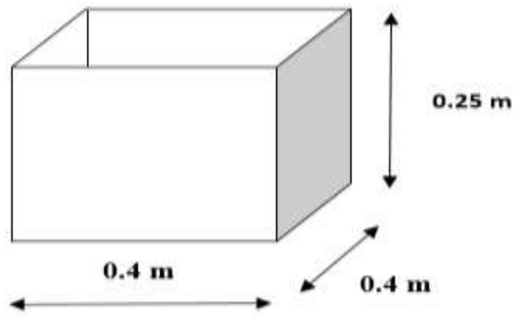


Fig-4 : condenser tank

Calculation of condenser :
Type- Water Cooled

Area (A) = 0.4 x 0.4 = 0.16 m^2

Diameter (d) = 6 mm

Area = πdl , $0.16 = \pi \times 6 \times 10^{-3} \times l$

Length of coil (l) = 8.48 m

Now, length of coil in one turn = $2 \pi r$

D=360 mm

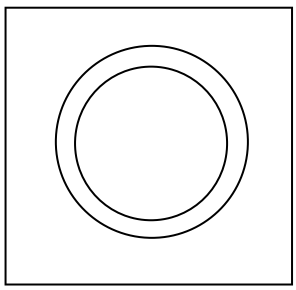
R = 180 mm = 0.18 m

Therefore, $l = 2\pi \times 0.18$

= 1.13 m = length of coil in one turn

Therefore, Number of turns = 8.48/1.13

= 7.49 ≈ 7 turns



Specification

- Water Cooled
- Copper tube
- Thickness-0.8mm
- Length-8.48 m

2.2 compressor

Compressor is a device which is used for converting low pressure low temperature refrigerant to high pressure high temperature refrigerant. In VCR system hermetically sealed compressor mostly used.

Fig-5 : compressor

Table- 1 : compressor selection chart

Application	Capa	Compressor
Water Cooler	20 LPH	MA53HAEF
Bottle Cooler	100-120 Ltrs	MA53HAEF
	150-200 Ltrs	MA62HAEG
	220-250 Ltrs	MA72HAEP / MA88HAEP
Visi Cooler	110 Ltrs (2 Case)	MA53HAEF
	150 Ltrs (4 Case)	MA62HAEG
	250 Ltrs (7 Case)	MA72HAEP / MA88HAEP

Table-2 : selection of copper tube chart

Pipe	OD (mm)	ID (mm)	T(mm)	Material	Remarks
Suction (A)	7.94	6.54	0.7	copper	Suction Pipe bend as per the customer requirement
		6.10	0.9	copper	
Discharge (B)	6.7	5.00	0.85	copper	
Process (C)	7.94	6.54	0.7	copper	
		6.10	0.9	copper	
Oil Cooling (D)	6.35	4.95	0.7	copper	

2.3 Capillary Tube

Capillary tube is device which reduce the pressure from condenser pressure to evaporator pressure

- Material Used- Copper
- Operation Used for Joining- Brazzing
- Diameters (mm)- 0.36

Fig- 6: capillary tube

2.4 EVAPORATOR

The evaporator is main component of a refrigeration system in which heat is removed from air, water or any other body required to be cooled by the evaporating refrigerant. The refrigerant boils or evaporates in this component and absorbs heat from the substance being cooled which is the main purpose of a refrigeration system. The name evaporator refers to the evaporation process occurring in the heat. Evaporator is device which absorb the heat and convert the liquid phase of refrigerant into vapour.

2.5 Copper Tube

Properties of Copper

Copper possesses the highest rating for both electrical and thermal conductivity.
2. Copper is a relatively soft and malleable metal with excellent formability.
3. Copper and its alloys are widely used in many environments and applications because of their excellent corrosion resistance.
4. Copper is ductile metal.
5. Copper is non-magnetic and non-sparking.
6. Copper can be recycled without any loss of quality

Copper tube size:
Outer diameter of copper tube = 6 mm
inner diameter of copper tube = 5 mm
Thickness of copper tube = 1 mm

2.6 TEMPERATURE SENSOR

Temperature indicator is a device which used for indicating the temperature in vapour compression refrigeration system. The PT100 type temperature indicator is used in this system.

Fig- 7: Temperature sensor

2.7 REFRIGERANT SELECTION

Refrigeration is defined as the process of achieving and maintaining a temperature below of the surroundings.

Desirable properties of refrigerants

1) Thermodynamic Properties

a) Critical Temperature should be above the condensing temperature

b) The boiling temperature should be low

c) Freezing temperature should be lower than evaporative temperature

d) High latent heat of vaporization at the evaporator temperature

2) Chemical properties

a) Refrigerant should not be inflammable

b) The refrigerant should not be toxic

c) It should be chemically stable for the operating ranges of temperature

3) Physical properties

a) The refrigerant in liquid and vapour state should have low viscosity

b) The refrigerant must have high thermal conductivity

c) If there is leakage, it should be easily detectable

d) The refrigerant should have low cost

Table-3: properties of different refrigerant

	Normal Boiling Point (°C)	Critical Temperature (°C)	ODP	GWP (per 100 Year)
R134a (HFC)	-26.07	101.06	0	1300
R22	-40.75	96.2	0.055	1700
R12	-29.8	111.9	1	8100
R290 (HC)	-42.1	96.8	0	20
R143a	-0.56	153	0	3800
R404a	-26.07	101.06	0	3260

3.0 Actual Experimental Set-up for VCR System

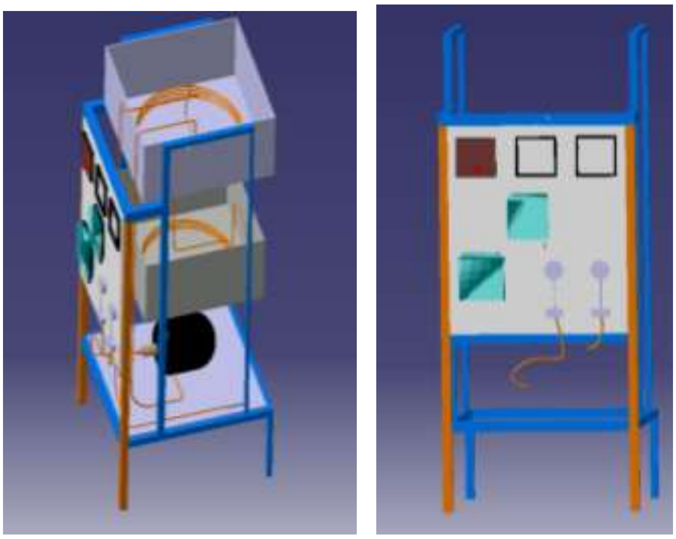


Fig-8 : cad model of system

Fig- 9 : actual model of system

4) ADVANTAGE

i) The heating and cooling is carried out in dual mode so there is minimizing the energy.
ii) There is no need of extra equipment for heating , due to that it save the cost of equipment
iii) Relatively inexpensive

5) APPLICATION

i) heating water
ii) hot water for bathing, washing clothes and pots
iii) Can be used as heater
iv) Food processing industry
v) Milk dairy
vi) cleaning

6) OBSERVATION TABLE

Table -4: Study of performance of R134a

Time	T_1	T_2	T_3	T_4
Start	30.9	31.1	31.1	31.2
5	29.2	34.2	32.1	30.1
10	27.9	35.4	33.4	29.5
15	23.1	36.9	33.7	27.1
20	18.3	37.7	34.5	24.5
25	16.4	38.1	34.6	22.1
30	14.2	39.8	34.9	20.8
35	12.3	40.4	35.1	17.1
40	11.6	41.7	35.3	15.5
45	10.1	42.9	35.9	14.7
50	9.5	44.1	36.5	12.3
55	8.4	45.3	36.9	10.1
60	7.3	46.2	37.2	10.8

Where

T_1 =Outlet temperature of evaporator
T_2 = Inlet temperature of condenser
T_3 =Outlet temperature of condenser
T_4 = Inlet temperature of evaporator

Table-5: pressure table

	P_1 (psi)	P_2 (psi)
Initial	75	90
final	10	160

P_1 = Inlet pressure of compressor
P_2 = Outlet pressure of compressor

7) CALCULATION

The rate of heat absorbed by evaporator is given by

$Q_{cool} = \dot{m}\ c_{p\ \Delta T}$
$= \dot{m} * 1.34 *(10.8-7.3)$
$= \dot{m} * 4.69$

The rate of heat rejected by condenser is given by

$Q_{hot} = \dot{m}\ \ c_p\ \ \Delta T$
$= \dot{m}\ \ * 1.34 * (46.2-37.2)$
$= \dot{m} * 12.194$

Compressor power consumption is given by

$W_c = V * I$

$=230 * 0.45$

$= 103.5$

Coefficient of performance of cooling

$COP_{cooling} = Q_{cool} / (Q_{hot} - Q_{cool})$

$= 4.69 / (12.194-4.69)$

$=0.625$

Coefficient of performance of heating

$COP_{heating} = Q_{hot} / (Q_{hot} - Q_{cool})$

$= 12.194 / (12.194-4.69)$

$=1.625$

$EER_{cool} = COP_{cooling} * 3.5$

$= 0.625 * 3.5$

$= 2.1875$

$EER_{hot} = COP_{heating} * 3.5$

$= 1.625 * 3.5$

$= 5.6875$

Average heat of system is given by

$Q_{verage}= (Q_{hot}+Q_{cool}) /2$

$Q_{Average} = (12.194 + 4.69) / 2$

$= 8.442$

Coefficient of performance

$COP = Q_{verage} / W_c$

$= 8.442 / 103.5 = 0.08156$

8) RESULT

1. $COP_{cooling} = 0.625$
2. $COP_{heating} = 1.625$
3. $COP_{system} = 0.08156$

3. CONCLUSIONS

Performance evaluation of simultaneous heating and cooling in vapor compression refrigeration system using R134a was studied. By using simultaneous heating and cooling, we save the Hugh amount of electricity and save the initial cost of extra equipment. We achieve hot water in low cost and in less time. R134a is eco-friendly refrigerant, it has zero ODP and low GWP. We can use this system in food process industry, and hot water for bathing, washing cloth and pot performance of R134a is good, but for further improvement the. Different refrigerant can be studied. In future, we will use R600a, R290 and R152 for research to achieve high coefficient of performance.

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BIOGRAPHIES

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