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DESIGN AND ANALYSIS OF ALTERNATIVE AZEOTROPE REFRIGERANT

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Abstract –*This work explores a theoretical investigation of an alternative eco-friendly refrigerant for R600a with a better Coefficient of Performance (COP), reduced Global Warming Potential (GWP). This study has been carried out using various refrigerant like R134a, R290, R1234yf, R170, R600a which were grouped together for deriving various refrigerant mixture pair with different mass proportion in REFPROP software. In this work liquid phase temperature (NBP) at 1 bar pressure has been considered for various pairs out of which the pair with lowest liquid phase temperature has been taken into consideration for p-h diagram from which COP has been calculated. GWP of the same pair has been calculated by their mass proportion and individual GWP. After calculation refrigerant mixture composing of R290/R170/R600a in the ratio of 16/60/24 by mass fraction which gives better performance than R600a.*

Key Words: Refrigerants, R290, R600a, R170, Coefficient of Performance, Global Warming Potential,

1. INTRODUCTION

Refrigeration is an important aspect used for both domestic and commercial food management. The first modern fridge was created in the late 1800's for food preservation and food service world. Later, this has further been advanced by new technology which has seen a current production of more than 1 billion refrigerators around the world. Most of the refrigerants used today are highly polluting and ozone depleting in nature. Hence for that there is a need to replace ozone depleting chemicals with environment friendly substances like Hydro Fluro Olefins (HFOs) and other such refrigerants.

1.1 Objective

- To find a new azeotrope refrigerant.
- To find azeotrope blend which will be more efficient and has a good performance than any of the refrigerants used in the present study. i.e., R290, R600a, R170.
- To find the azeotrope blend which will be having low GWP value than any of the refrigerants used in the present study.

2. METHODOLOGY

2.1Selecting refrigerant for mixture:

We have randomly selected refrigerants these refrigerants R290, R600a, R1234yf, R134a and R170.And classified them into different groups for making mixture.

2.2 Classifying refrigerants into different groups:

Group 1 (R290/R600a)
Group 2 (R290/R170/R600a)
Group 3 (R600a/R1234yf)
Group 4 (R290/R134a)
Group 5 (R290/R600a/R134a)

2.3 Finding liquid phase temperature:

After the classification of the reference into different groups we have calculated liquid phase temperature at 1 bar for each of the pair mentioned above with the help of refprop software. Now the pair giving the lowest liquid fast temperature is considered for further calculation and evaluation. following are the results that are drawn from performing above steps.

Group 1 (R290/R600a):

Group	Proportion	Liquid Phase Temperature
R290/R600a	50:50	-33.11
R290/R600a	40:60	-30.366
R290/R600a	30:70	-27. 141
R290/R600a	20:80	-23.258
R290/R600a	10:90	-18.417
R290/R600a	00:100	-12.085

Group 2 (R290/R170/R600a):

Group	Proportion	Liquid Phase Temperature
R290/R170/R600a	22:23:55	-66.852
R290/R170/R600a	28:30:42	-71.562
R290/R170/R600a	31:29:40	-70.946
R290/R170/R600a	36:36:28	-74.454
R290/R170/R600a	20:60:20	-82.417
R290/R170/R600a	16:60:24	-82.547

Group 3 (R600a/R1234yf):

Group	Proportion	Liquid Phase Temperature
R600a/R1234yf	50:50	-18.99
R600a/R1234yf	70:30	-15.856
R600a/R1234yf	90:10	-13.235
R600a/R1234yf	40:60	-20.785
R600a/R1234yf	20:80	-24.905
R600a/R1234yf	00:100	-29.785

Group 4 (R290/R134a):

Group	Proportion	Liquid Phase Temperature
R290/R134a	100:00	-42.412
R290/R134a	80:20	-45.21
R290/R134a	60:40	-46.321
R290/R134a	40:60	-46.417
R290/R134a	20:80	-46.52
R290/R134a	00:100	-26.361

Group 5 (R290/R600a/R134a):

Group	Proportion	Liquid Phase Temperature
R290/R600a/R134a	50:48:02	-33.266
R290/R600a/R134a	50:30:20	-41.641
R290/R600a/R134a	50:00:50	-46.394
R290/R600a/R134a	25:25:50	-40.102
R290/R600a/R134a	30:32:38	-39.897
R290/R600a/R134a	36:36:28	-39.953

2.2 Calculations of COP:

The calculation of COP was carried out by plotting the pH graph with the help of refprop software. The plot was then printed on paper. After printing off this plot on the paper the lines h1-h2, h2-h3, h3-h4 were drawn and by applying the following formula the COP was calculated. The line h2-h3 was drawn parallel to temperature line with temperature approximately equal to 37°C. h3-h4 is vertical straight line as h3 = h4.

COP= Q_L / W_{net}= $h_1 - h_4$ / $h_2 - h_1$
where,
Q_L = heat absorbed by the evaporator in refrigerant.
W_{net} = work input to the compressor.
h_1 = the refrigerant specific enthalpy at the outlet of the evaporator.
h_2 = refrigerant specific enthalpy at the outlet of the compressor.
h_3 = refrigerant specific enthalpy at the outlet of the condenser.
h_4= the refrigerant specific enthalpy at the inlet of the evaporator.

2.2.1 Theoretical calculation of COP R290:

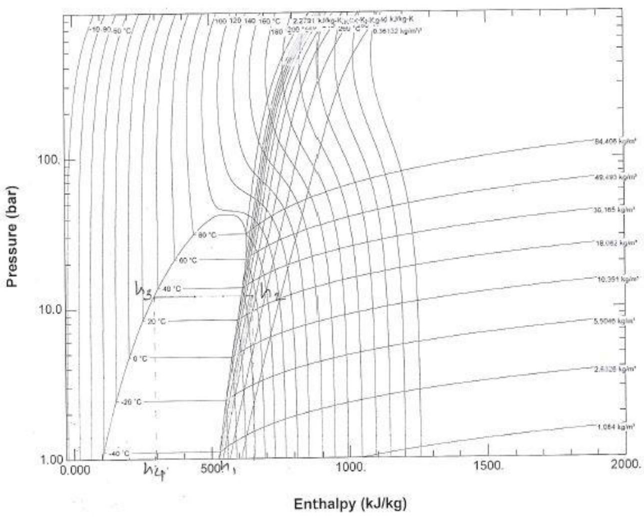

Figure 1. Pressure vs. enthalpy plot: propane

From the above graph we got the values of enthalpies as follows:

h_1 = 525 kJ/kg
h_2 = 650 kJ/kg
h_3 = h_4 = 305 kJ/kg
$\mathbf{(COP)_{th}}$ = $(h_1 - h_4)/ (h_2 - h_1)$
= (525 – 305)/ (650 – 525)
= 220/125
$(COP)_{th}$ = 1.76

2.2.2 Theoretical calculation of COP R600a:

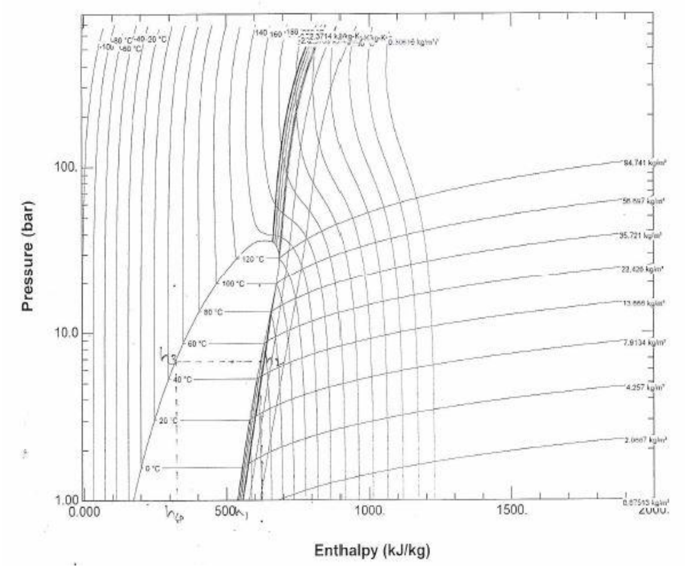

Figure 2 Pressure vs. enthalpy plot: isobutane

From the above graph we got the values of enthalpies as follows:

h_1 = 537.5 kJ/kg
h_2 = 625 kJ/kg
$h_3 = h_4$ = 325 kJ/kg
$(COP)_{th}$ = $(h_1 - h_4)/(h_2 - h_1)$
= (537.5 – 325)/ (625 – 537.5)
= 212.5/87.5
$(COP)_{th}$ = 2.43

2.2.3 Theoretical calculation of COP & GWP of R290/R600a/R170:

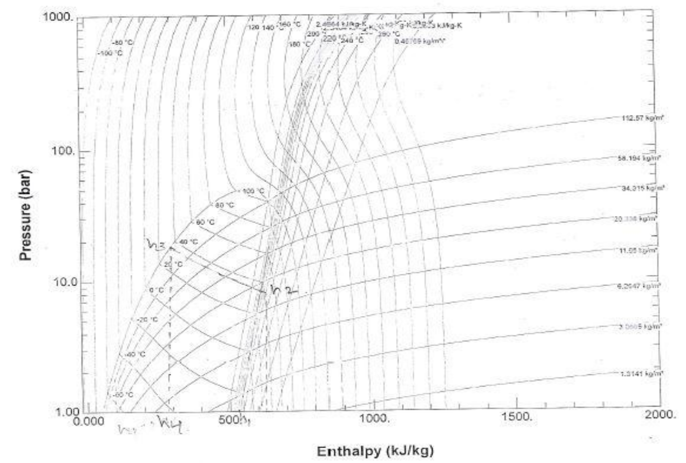

Figure 3. Pressure vs. enthalpy plot: propane/ isobutene /ethane

From the above graph we got the values of enthalpies as follows:

h_1 = 537.5
h_2 = 625
$h_3 = h_4$ = 287.5
$(COP)_{th}$ = $(h_1 - h_4)/(h_2 - h_1)$
= (537.5 – 287.5)/ (625 – 537.5)
= 250/87.5
$(COP)_{th}$ = **2.85**

2.3 Calculation of GWP:

Values of GWPof refrigerants R290, R600a and R170 were taken from Internet.
GWP of R290 = 4
GWP of R600a = 5
GWP of R170 = 6
and the theoretical calculation of GWP of the mixture giving us the lowest liquid phase temperature was calculated by following formula.

GWP of Blend = (Proportion by % mass of component A) x (GWP of A) +(Proportion by % mass of component B) x (GWP of B) + (Proportion by % mass of component C) x (GWP of C)

GWP of R170/R600a/R290 = 0.24*6 + 0.60*5+0.16*4
= 4.6

2.4 comparing COP and GWP of refrigerants:

2.4.1 Comparing COP's:

COP of R290 = 1.76
COP of R600a = 2.43
COP of R290/R600a/R170 = 2.85

Now, comparing the theoretical COP of above refrigerants with the obtained theoretical COP of the azeotropic mixture. We get,

COP of R170/R600a/R290 > COP of R600a > COP of R290.

From above expression it can be concluded that the azeotropic blend of R170/R600a/R290 in proportion 16:60:24 by masscan be use as replacement for R290 and R600a as far as the COP is concerned.

2.4.2 Comparing GWP's:

GWP of R290 = 4
GWP of R600a = 5
GWP of R170 = 6
GWP Of R170/R600a/R290 = 4.6

Now, Comparing the theoretical GWP of above refrigerants with the obtained theoretical GWP of the azeotropic mixture. We get,

GWP of R170/R600a/R290 < GWP of R600a < GWP of R170

Lower GWP refrigerant will be more environmentally friendly. Thus, from above expression it can be concluded that the azeotropic blend of R170/R600a/R290 in proportion 16:60:24 by mass can be use as replacement for R170 and R600a as far as the GWP is concerned.

3. RESULTS

Following are the results are drawn from the above calculations.

1. Lowest liquid phase temperature at 1 bar for each refrigerant pair is as follows:

Table -1: Liquid phase temperature

Sr No.	Group	Proportion	Liquid Phase Temperature
1	R290/ R600a	48:52	-32.594
2	R290/ R170/ R600a	16:60:24	-82.547
3	R600a/R1234yf	05:95	-28.495
4	R290/ R134a	16:84	-46.559
5	R290/R600a/ R134a	50:04:46	-45.538

2. The theoretical values of COP of R290, R600a and the azeotrope mixture of R290/ R170/ R600a are as follows:

Table -2: Coefficient of performance

Sr No.	Group	COP
1	R290	1.76
2	R600a	2.43
3	R290/ R170/ R600a	2.85

3. The theoretical values of GWP of R290, R600a and the azeotrope mixture of R290/ R170/ R600a are as follows:

Table -3: Global warming potential

Sr. No.	Group	GWP
1.	R290	4
2.	R600a	5
3.	R170	6
4.	R170/R600a/R290	4.6

4. CONCLUSION

Following are the conclusions that can be drawn from the above results.

1. Pair R290/ R170/ R600a in proportion 16:60:24 by mass which produces lowest liquid phase temperature of -82.547 at 1 bar pressure.

2. COP of R290/ R170/ R600a is 2.85 which is better than COP of R290 (1.76) and R600a (2.43).

3. GWP of R290/ R170/ R600a is 4.6 which is better than GWP of R170 (6) and R600a (5).

4. From above conclusions we can conclude that azeotrope mixture of R290/ R170/ R600a in proportion 16:60:24 by mass can be used as alternate refrigerant for R600a.

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