Low GWP Refrigerants For Chiller Systems

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Abstract- *In present paper, various low GWP refrigerants available for the all type of chiller systems working on the low pressure, medium pressure, and high pressure refrigerants like conventional centrifugal chiller, screw and oil-free centrifugal chiller and scroll chiller system are studied and selected the best suitable one on the basis of global warming potential value and properties of refrigerants. The existing refrigerants are studied and replaceable like R-1233zd instead of R-123, R-1234ze(E), R-1234yf, R-450A, R-513a instead of R-134a and R-32 instead of R-410A. Most of the existing refrigerants used in the chiller system cause the environmental problem like ozone depletion potential (ODP) and global warming potential (GWP) leads to an effect on the living organisms and environment. So an attempt is made to replace the existing refrigerant with new low GWP refrigerant which will suitable for that system and gives the less environmental impact with optimum performance.*

Keywords- Chiller system, Global Warming Potential (GWP), Ozone Depletion Potential (ODP), Refrigerant.

I. INTRODUCTION

Chiller is the machine that removes the heat from a liquid via a vapor compression refrigeration cycle. This liquid is then circulated through a heat exchanger to cool equipment or air. But the refrigerants used in this chiller system also cause an environmental impact. Montreal and Kyoto Protocol are restricting the use of hazardous and harmful gases. So it is necessary to search for alternative options available for the existing refrigerants used in the chiller system [1].

Hydrofluoro Olefins (HFO) and HFO blends are the future refrigerants that are going to use instead of all HFC refrigerants. Lots of paper represent the theoretical as well as practical performance values of HFO refrigerants. So we have to select the refrigerant which is having low GWP value with compatibility with the system, cost criterion, safety of human and environment with optimum performance of the chiller system [8].

II. ENVIRONMENTAL IMPACT

A. ODP

The ozone layer protects the all living organisms from the harmful ultraviolet rays coming from the sun which can damage the life on the earth. The chlorine-based refrigerant is mainly responsible for the depletion of the ozone layer. After the Montreal Protocol, these refrigerants are banned. The reference for the measuring of ODP value is refrigerant R-11. So the ODP value of R-11 is considered as 1 [1].

B. GWP

Global warming potential is also responsible for environmental damage. GWP value is used to measure the greenhouse effect of the refrigerant based on its radiative properties. As per the Kyoto Protocol, those refrigerants having a high value of GWP are going to ban in the next few years. The reference for the measuring of GWP value is CO_2. So the GWP value of CO_2 is considered as 1 [1].

III. FUTURE REFRIGERANTS

CFC and HCFC refrigerants showing the adverse effect on the ozone layer, so they are banned. Then after HFC refrigerants are coming in to picture. But these HFC refrigerants are also showing the global warming potential. So today's need is to move towards Hydrofluoro Olefins (HFO) and HFO blends. Hydrofluoro olefins contain the carbon-carbon double bond, which is chemically weaker. So the atmospheric life of this HFO refrigerant is less and shows the lesser global warming potential value.

For high-pressure refrigeration system and scroll chiller system, we can use R-32 instead of R-410A. For medium pressure refrigeration system and screw or oil-free centrifugal chiller system we can use R-1234ze(E), R-1234yf, R-450A, R-513a instead of R-134a. And for low-pressure refrigeration system and conventional centrifugal chiller system, we can use R-1233zd instead of R-123.

TABLE 1. Properties of Refrigerants [3]

Refrigerant	Refrigerant Type	Composition	Mass %	ASHRAE Safety Class	GWP Value*	Boiling Temp. (C)	Critical Temp. (C)	Critical Pressure (MPa)
R-134a	HFC	R-134a	100	A1	1300	-26.07	101.06	4.06
R-1234ze(E)	HFO	R-1234ze	100	A2L	1	-18.97	109.36	3.63
R-1234yf	HFO	R-1234yf	100	A2L	1	-29.45	94.70	3.38
R-450A	HFO Blend	R-134a/R-R-1234ze/R-1234yf	42/40/18	A1	547	-25.60	100.18	3.74
R-513a	HFO Blend	R-134a/R-1234ze	44/56	A1	573	-27.9	97.51	3.67
R-123	HCFC	R-123	100	B1	77	27.85	183.68	3.66
R-1233zd	HFO	R-1233zd	100	A1	1	18.31	165.5	3.57
R-410A	HFC	R-32/R-125	50/50	A1	2088	-51.40	71.34	4.90
R-32	HFC	R-32	100	A1	675	-51.65	78.11	5.78

A1: Non-flammable
A2L: Mildly-flammable
*As per IPCC AR5 [3].

While selecting the required refrigerant for the chiller system we have to optimize between various parameters. The major selection criterion is the GWP value. Figure 1 shows the comparison between various refrigerant GWP values as per IPCC AR5 [3].

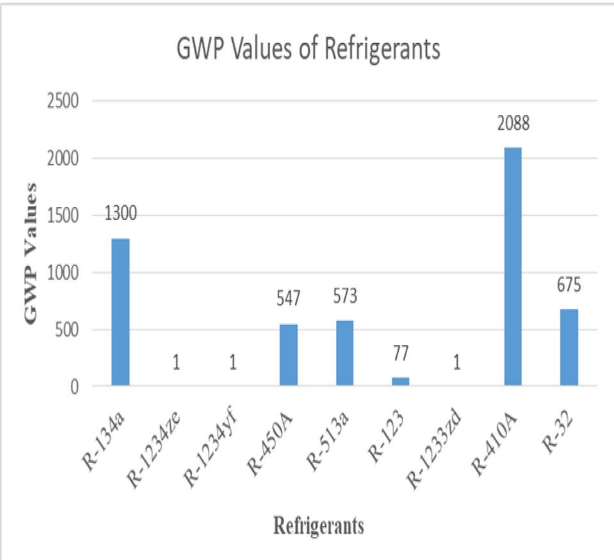


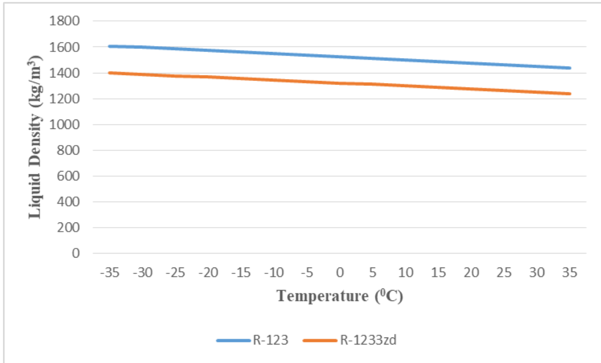
Fig.1 GWP values of Refrigerants [2]

IV. RESULT

If we consider the low-pressure refrigeration system and conventional centrifugal chiller system, R-1233zd is best suitable refrigerant for replacement of the refrigerant R-123. The refrigerant R-1233zd comes under ASHRAE safety class A1 and shows the GWP values as 1.

If we consider the medium pressure refrigeration system and screw or oil-free centrifugal chiller system, R-513a is best suitable refrigerant for replacement of the refrigerant R-134a. R-1234ze(E) and R-1234yf are though showing GWP value of 1, but they are mildly flammable and comes under the ASHRAE safety class A2L. Whereas R-513a is an A1 class refrigerant with lower GWP than R-134a refrigerant.

If we consider the high-pressure refrigeration system and scroll chiller system, R-32 is best suitable refrigerant for replacement of the refrigerant R-410A. The refrigerant R-32 comes under ASHRAE safety class A1 and shows a GWP value of 675.



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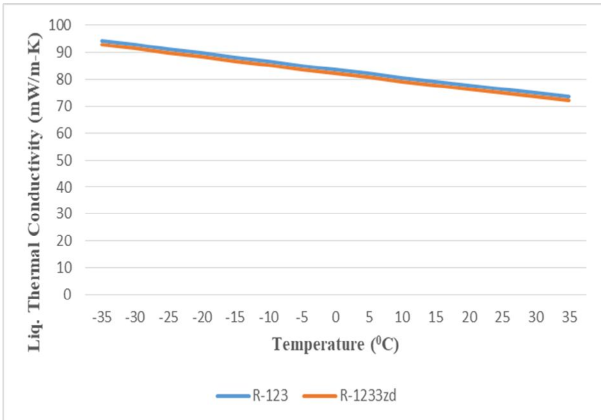

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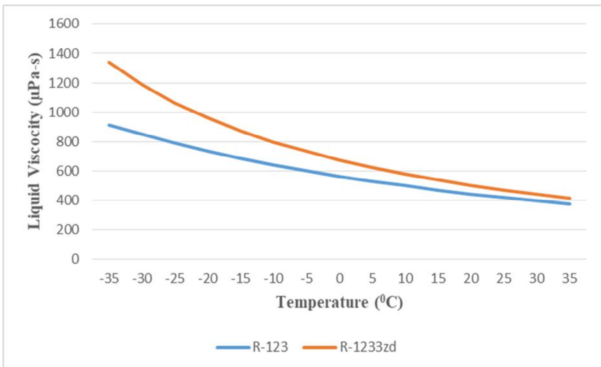

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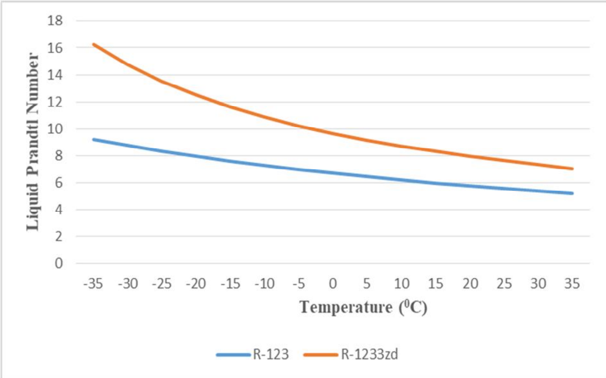

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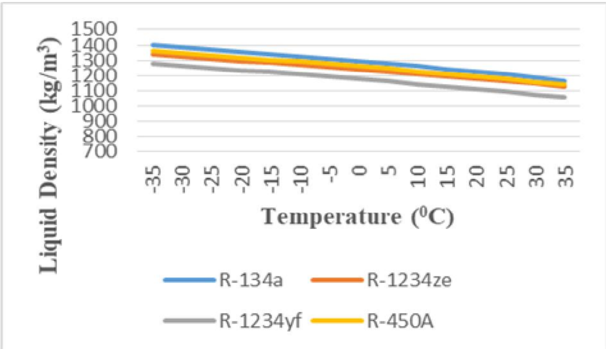
Fig. 2 Variation of a) Liquid density b) Liquid thermal conductivity c) Liquid viscosity d) Liquid Prandtl number with Temperature of the R-123 alternative



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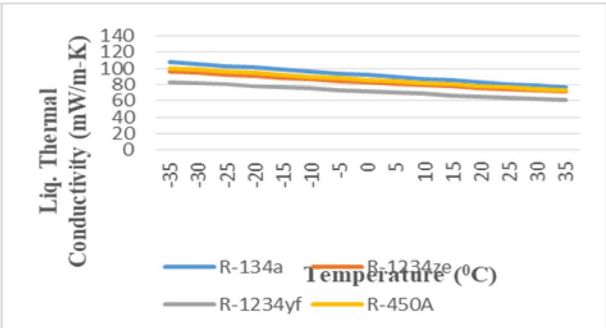

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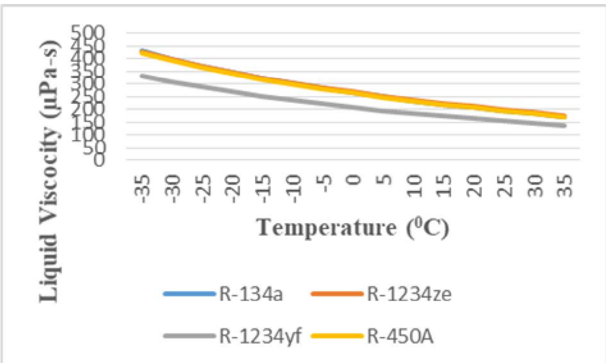

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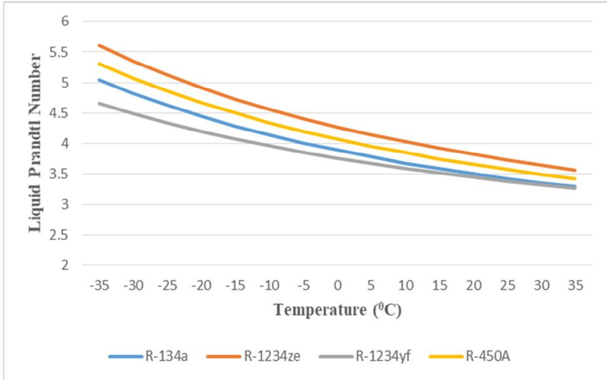

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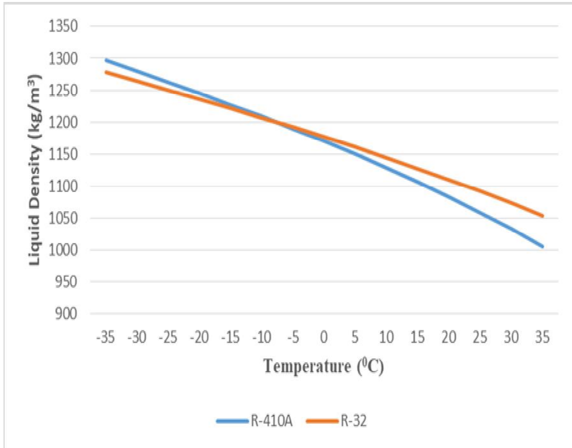
Fig. 3 Variation of a) Liquid density b) Liquid thermal conductivity c) Liquid viscosity d) Liquid Prandtl number with Temperature of the R-134a alternatives



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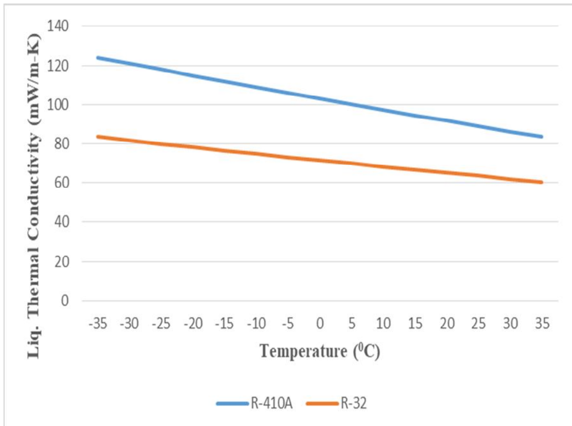

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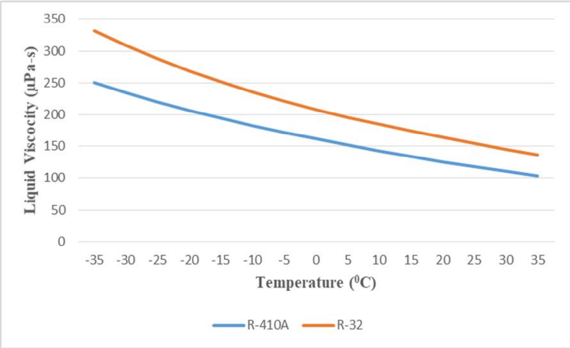

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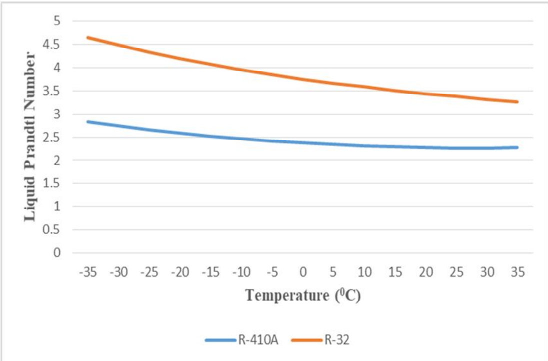

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Fig. Variation of a) Liquid density b) Liquid thermal conductivity c) Liquid viscosity d) Liquid Prandtl number with Temperature of the R-410A alternative

V. CONCLUSION

In the selection of refrigerant for the required chiller system, in addition to low GWP consideration, refrigerants with better energy characteristics should be preferred. The study represents all alternative refrigerants stated are better as per their low GWP values. By considering the energy and performance with the safety of human and environment, R-513a is used instead of R-134a in medium pressure refrigeration system and screw chiller system. R-1233zd is used instead of R-123 in low-pressure refrigeration systems and conventional centrifugal chiller system. R-32 is used instead of R-410A in high-pressure refrigeration systems and scroll chiller systems.

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