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Search for Eco-friendly Alternatives Refrigerants in Vapor Compression Refrigeration Systems for Reducing Global Warming and Ozone Depletion

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ABSTRACT

In the Make India and Green India Program, the use of eco-friendly refrigerants is well demonstrated due to global warming and ozone depletion. This paper highlights the use of R-290 refrigerant is the best alternative and second alternative is R600a. and third is R-152a. Due to flammable nature of these eco-friendly refrigerants, these refrigerants can only be used by using safety measures, otherwise R134a and R410a and R404a are easily available in the markets can be used. The performance of R134a gives better than using R410a and R404a, however for larger Industrial applications R 717 and R744 can be used. Even in mixing of nano-particles mixed with R718 in the secondary circuit and R1234yf for low temperature applications gives better first law and second law performance as compared to R134arefrigerant To replace, R134a, R1234yf (of zero ODP and 4 GWP) and R1234ze (GWP=6, and Zero ODP) are recommended, although these refrigerants gives 5 to 10% less performance than using R134a. Although the performance of R134a is better than R134a using nano particles mixing in R718 but R1234ze can replace R134a for higher temperature applications. The best first law and second law performances have been found using copper nano materials mixed with R718 in secondary evaporator circuit as compared to TiO2 nano particles.

Keywords *Sustainable Technologies; Green Technologies; Sustainable Development; Alternative Refrigerants; Eco Friendly Refrigerants; Reduction in Global Warming; Reduction in Ozone Depletion*.

1.0 Introduction

Sustainable development is a process in which development can be sustained for generations. It also focuses attention on inter generational fairness in the exploitation of development opportunities while social development is a function of technological advancement, and also the technological advancement, in turn is a function of scientific know how for a streamlined development of the society. Technology is one of the crucial determinants of sustainable development.

Technological import through collaborations has been one of the most important sources of technological inputs for Indian conditions.

The use of technologies originating in rich countries often ten to create many social, ecological and resource problems in poor countries.

The exploitation of the vast natural resources through progressive development of science, engineering and technology that has brought about the vast changes in the civilization and society from the stone age to the present high technology era. In facts, the mad race for industrialization and economic development has resulted in over exploitation of natural resources, leading to a situation where the two worlds of mankind- the biosphere, lithosphere and hydrosphere of his inheritance and the techno sphere of his creation, are out of balance with each other, indeed on a collision path.

To facilitate optimal utilization of finite natural resources for ensuring a sustainable benefit steam for better quality of life on the one hand and to simultaneously keep in mind the conservation of natural resources on the other hand, it is essential that the technology conservation process must be made as efficient as possible.

Therefore sustainable economic development depends on the careful choice of technologies and judicious management of resources for productive

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activities to satisfy the changing human needs without degrading the environment or depleting the natural resources base.

2.0 Vapor Compression Refrigeration Systems

Refrigeration is a technology which absorbs heat at low temperature and provides temperature below the surrounding by rejecting heat to the surrounding at higher temperature. Simple vapor compression system which consists of four major components compressor, expansion valve, condenser and evaporator in which total cooling load is carried at one temperature by single evaporator but in many applications like large hotels, food storage and food processing plants, food items are stored in different compartment and at different temperatures. Therefore there is need of multi evaporator vapor compression refrigeration system. The systems under vapor compression technology consume huge amount of electricity, this problem can be solved by improving first law and second law performances of system.

Performance of systems based on vapor compression refrigeration technology can be improved by following

- The performance of refrigerator is evaluated in term of COP which is the ratio of refrigeration effect to the net work input given to the system. The COP of vapor compression refrigeration system can be improved either by increasing refrigeration effect or by reducing work input given to the system.
- It is well known that throttling process in VCR is an irreversible expansion process. Expansion process is one of the main factors responsible for exergy loss in cycle performance because of entering the portion of the
- Refrigerant flashing to vapor in evaporator which will not only reduce the cooling capacity but also increase the size of evaporator. This problem can be eliminated by adopting multi-stage expansion with flash chamber where the flash vapors is removed after each stage of expansion as a consequence there will be increase in cooling capacity and reduce the size of the evaporator.
- Work input can also be reduced by replacing multi-stage compression or compound compression with single stage compression.
- Refrigeration effect can also be increased by passing the refrigerant through sub cooler after condenser to evaporator.
- Use of nano particles mixed with R718 in the secondary evaporator circuit
- Use of nano particles directly mixed with eco-friendly
- refrigerants in the primary circuit
- Use of nano particles coating in the VCR condenser tubes.

3.0 Appropriate Refrigeration Technologies for Sustainable Development

The efforts under the Montreal protocol to protest the Ozone layer, the alternative refrigerants have been proposed as substitutes for ozone depleting substances. HFCs (Hydro-fluoro carbons) PFCs (Perfluro carbons) have zero ODP potential but they are producer of green house gases and are subjected to limitation and reduction commitments under UNFCC (United Nations Framework Convention on Climate change). With the entry into force of Kyoto protocol on 16th February 2005 developed countries have already planning and implementing rational measures intended to contribute towards meeting green house gas reduction targets during the first commitment period of Kyoto protocol (2008-2012). The countries have also started together with developing countries to size up projects that qualify under Kyoto clean development mechanism. In the developing countries the conversion of CFCs to alternate is still a major issue. In this paper the first law and second law analysis of various eco friendly refrigerants have been carried out which will help in deciding about the path to be followed to satisfy Montreal and Kyoto protocol. R-22 is the refrigerant used for window type air conditioning systems long back.

4.0 Use of Eco-Friendly Refrigerants

Due to Montreal protocol and Kyoto protocol and the provision of 1990 clean air act specifying phasing out the use of R-22 by the year 2030 due to ozone depleting potential around 0.055 as compared to the alternate refrigerants which have zero ozone depleting potential (ODP) and zero global warming potential (GWP) and some other alternate refrigerants which have less ODP & GWP. The energy (first law) analysis and second law (exergy) analysis of vapor compression refrigeration systems have been carried out for reducing irreversibility's occurring in the various components in the vapor compression refrigeration systems in terms of performance parameters such as COP, EDR, Exegetic efficiency, percentage of exergy destruction in components (i.e. condenser, compressor, throttle valve and evaporator) to total exergy destruction in the system for air conditioning system of 1.5 ton capacity for seven eco-friendly refrigerants such as (R-134a, R-404a, R-407C, R-502, propane (R-290), isobutene (R-600a), butane (R-600)) .

These performance parameters have been evaluated for varying condenser temperatures in the range from 303 K to 333K and evaporator temperatures in the range from 253 to 278K of 1.5 ton capacity of vapor refrigeration systems by using eco friendly refrigerants.

It was observed that R-290 (zero ODP & zero GWP) and R-600 (butane of zero ODP and zero GWP) and R-600a (isobutene of zero ODP and zero GWP) are best alternatives if its flammable problem will mitigate and the next option are R-134a (of zero ODP and 1300 GWP), R-407c(of zero ODP and 1530), R-404a (zero ODP and 3260 GWP)and R-410a (of zero ODP & 1730 GWP), R507a, R125, R227ea, and R236ef for replacing R-11, R12, R22 and R502 with minor modification in the existing design of vapor refrigeration systems (i.e. larger size of compressors in case of R-134a , which increases the cost of the vapor compression refrigeration system.

5.0 Methods for Improving First and Second Law Performance of Vapor Compression Refrigeration Systems Using Eco-Friendly Nano Refrigerants

Mishra[1] Simple VCR with liquid vapor heat exchanger , flash intercooler, flash chamber, water intercooler, liquid subcooler and stages in compression(double stage and triple stage) Mishra [2] conducted detailed analysis of vapor compression refrigeration systems using thirteen eco-friendly refrigerants Mishra [3] observed that there is a 12% to 19% improvement in the first law efficiency using nano particles mixed with R718 in the secondary evaporator circuit of VCR and suggested that higher improvement occurs using copper particles mixed with R718 and low improvement occurs using TiO2 in R134a Mishra [2] also observed the improvement in the second law thermal performance of vapor compression refrigeration system by mixing Al2O3 in R718 in secondary evaporator circuit and various eco-friendly refrigerants in the primary evaporator circuit.

The lowest performance was observed by using R410a in the primary evaporator circuit Based on the literature it was observed that researchers have gone through detailed first law analysis in terms of coefficient of performance and second law analysis in term of exergetic efficiency of simple vapor compression refrigeration system with single evaporator.

Researchers did not go through the nano mixed eco-friendly refrigerant in the secondary evaporator and R1234yf and R1234ze used in the primary circuit of evaporator in terms of improving first and second law efficiency of vapor compression refrigeration systems.

6.0 Results and Discussions

Table 1 to 3 gives the variation of first law efficiency in terms of coefficient of performance and second law efficiency using R1234ze refrigerant in the primary circuit and R-718 with nano mixed refrigerant in the evaporator circuit. It was observed that performance of R1234yf and R1234ze is acceptable as compared with R1234a. Even then mixing circuit, the performance of R1234yf gives better performance than R1234ze and R1234a. The worst performance is observed using R410a

Table 1: Performance Evaluation of Vapor Compression Refrigeration System Using R1234ze Eco-Friendly Refrigerants in Primary Circuit and Following Nano Materials Mixed with R718 in the Secondary Circuit

Nano materials	COP	EDR	ETA_II
Copper	5.093	0.5199	0.4801
Al oxide	4.34	0.6239	0.3761
TiO2	3.823	0.644	0.356

Table 2: Performance Evaluation of Vapor Compression Refrigeration System Using R1234 Yf Eco-Friendly Refrigerants in Primary Circuit and Following Nano Materials Mixed with R718 in the Secondary Circuit

Nano materials	COP	EDR	ETA_II
Copper	5.293	0.5071	0.4929
Al oxide	4.36	0.5666	0.4334
TiO2	3.832	0.6721	0.3279

Table 3: Performance Evaluation of Vapor Compression Refrigeration System Using R134 a Eco-Friendly Refrigerants in Primary Circuit and Following Nano Materials Mixed with R718 in the Secondary Circuit

Nano materials	COP	EDR	ETA_II
Copper	5.193	0.5194	0.4806
Al oxide	4.35	0.6239	0.3761
TiO2	3.82	0.654	0.346

Similarly the effect of nucleate heat transfer in terms of enhancement factor is showing the percentage improvement in the first law efficiency as shown in Table 4 and 5 respectively**.**

The effect of computed nano refrigerant property for enhancement factor and first law efficiency is shown in Table-5. It was observed the best performance is achieved using R1234yf which can replace R134a for low temperature and R1234ze for higher temperature applications

Table 4: Nucleate Heat Transfer Coefficient Enhancement Factor and First Law Improvement (COP Enhancement) Based on Nano-Particle Used in R718 and Eco-Friendly Refrigerants in Primary Circuit

Refrigerant	Enhancement factor	COP enhancement
R1234yf	3.54	23 %
R1234ze	2.38	18%
R134a	2.3	19%

Table 5: Effect of Computed Nano-Refrigerents Property in Terms of Enhancement Factor on First Law Improvement

Refrigerant	Enhancement factor	COP Enhance ment
R1234 yf	2.04	23 %
R 1234ze	1.7	19%
R134a	2.24	21

7.0 Conclusions & Recommendations

On the basis of theoretical computational analysis, and five test rigs developed by author with extensive experimentation have been conducted in the RAC lab of DTU, it was observed that R-290 refrigerant is the best alternative and second alternative is R600a. And third is R-152a. available in the markets can be used.

The performance of R134a gives better than using R410a however for larger Industrial applications R 717 and R744 can be used. To replace, R134a , R1234yf (of zero ODP and 4 GWP) and R1234ze (GWP=6, and Zero ODP) are recommended, although these refrigerants gives less 10% performance than R134a.

The use of nano particles mixed in the eco-friendly refrigerants and then used gives 8% to 35% improvement in the first law efficiency while using nano particles mixed with water in the secondary circuit and eco-friendly refrigerants in the primary circuit gives 7% to 22% improvement and better performance was observed with mixing copper nano particles.

Due to flammable aspect, these refrigerants can only be used by using safety measures, otherwise R134a and R410a are easily

The following recommendations have been made

(i) Even in mixing of nano particles mixed with R718 in the secondary circuit and R1234yf for low temperature applications gives better first law and second law performance as compared to R134arefrigerant

(ii) Although the performance of R134a is better than R134a using nano particles mixing in R718 but R1234ze can replace R134a for higher temperature applications.

(iii) The best first law and second law performances have been found using copper nano materials mixed with R718 in secondary evaporator circuit as compared to TiO2 nano particles

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