# Experimental Investigation Of One Ton Vapour Compression Refrigeration R-12 Refrigerate with Alternative ECO Friendly Refrigerants R410. R-413a and R-423a

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## Abstract

*The Montreal Protocol has sealed the use of Halogenated Hydrocarbons; Keeping in view they affect the environment in the form of Ozone layer depletion and Global warming. Thus one of the major thrust areas is to identify substitute of Halogenated Hydrocarbons, especially CFCs. The substitute refrigerant should be eco-friendly, chemically stable and compatible with existing refrigeration systems with transport and thermal properties similar to or better than CFCs. Since the refrigeration system use CFC- 12 as refrigerant universally, the search for a suitable alternative for CFC-12 is inevitable.HFC-134a is currently the leading alternative to CFC-12. Other promising substitutes are R-423as a binary mixture of R-227ea & R- 413a ternary mixture of R-134a, R-218 andR-600a. In this thesis, performance evaluation of eco-friendly alternate refrigerant R-134a, R-413a & R-423a for replacing CFC12 has been done and a suitable alternative refrigerant for retrofitting has been identified.*

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**Introduction**

the search for a suitable alternative for CFC-12 is inevitable.HFC-134a is currently the leading alternative to CFC-12. Other promising substitutes are R-423a a binary mixture of R-227ea & R-413a ternary mixture of R-134a, R-218 and R-600a. The present work aims to analysis suitability of two newly discovered mixtures R-423a & R-413a for replacement of CFC-12 in existing refrigeration units. For this purpose it is necessary to evaluate the performance of refrigeration system. This requires thermodynamic and transport properties of the mixture, most of which have already computed. A cycle analysis has been carried out to predict the performance of system under various operation conditions.

The aim of this project is to propose a suitable design of a vapor Compression Refrigeration System using eco-friendly refrigerants such as R-423a and R-413a. The design changes of the components of refrigerating system will be based on the similarities in the desirable properties of the refrigerants with that of R-12.

**1.1 Classification of refrigerants**

Most of the existing refrigerants belong to halocarbon group which is classified into three categories:-

1. Chlorinated hydrocarbons
2. Fluorinated hydrocarbons
3. Bromines

In the present usages halogenated hydrocarbons are divided into three groups:-

1. CFCs (Chloro Flouro Carbon compounds)
2. HCFCs (Hydro Chloro Flouro Carbons)
3. HFCs (Hydro Flouro Carbons)

**1.2 Need of alternative refrigerants**

Recent studies have established that CFCs are depleting the Ozone layer and also contributed towards global warming. As due to favorable thermo dynamical and transport properties CFCs are used in the refrigeration system so there must be some alternative refrigerant, which is eco-friendly and having properties which are suited for refrigeration purpose.

**1.3 Required properties of refrigerants**

**1.3. a Thermodynamic**

- The boiling temperature at atmospheric pressure should be low.
- The freezing temperature should be well below the operating evaporator temperature.
- Critical point and freezing point far away from the application range of temperature to be maintained.
- High enthalpy of evaporation.
- Pressure in evaporator and condenser should be positive but not too high than atmosphere.

**1.3.b Physical**

- Low specific volume.
- Low specific latent heat of liquid refrigerant and high specific heat of vapor refrigerant.
- High thermal conductivity in both the states.
- Low viscosity for better heat transfer and pumping power.

**1.3.c Chemical**

- Stable and inert.
- Non-toxic and nonflammable.

**1.3.d Other properties**

- Easy leak detection
- Satisfactory oil solubility.
- Odorless.
- High dielectric strength.

**1.4 CFCs and ozone layer**

The ozone layer prevents harmful ultra-violet radiations form reach. The ozone layer consists of ozone at very low concentration in the stratosphere form 12 to 13 km up in the altitude. Large hole in ozone can cause skin disease. A hole was detected in the ozone layer for first time in 1956. Recent study shows that this hole is expanded. Therefore it is necessary to take precautions to prevent further depletion.

**1.5 Mechanism of ozone layer depletion (Rowland theory)**

Ozone is formed by the interaction of the ultraviolet radiations from the sum with oxygen. Both chemical processes are in equilibrium absorbing adsorbing the ultraviolet rays. CFCs. reach the stratosphere through the process of diffusion and are attacked by ultraviolet radiations forming chlorine. This free Chlorine (C1) converts ozone into oxygen by shifting the equilibrium towards oxygen formation. The equations are :-

$CC1_2F_2$ ....................> $CClF_2$ +Cl

CI +$O_3$ .....................> C1O +$O_2$

O+C1O .....................> Cl+$O_2$

O+$O_3$ ....................> $2O_2$

**1.6 Global warming & CFCS**

Problem of global warming is due to greenhouse effect. The green house effect refers to the trapping of infra-red radiation of sun by the atmosphere and subsequent warming of earth. Although the greenhouse effect is primarily due to $CO_2$ and the concentration of CFCs are very low compared to $CO_2$. CFCs absorb strongly the I-R region particularly in the wavelength between 7-13 microns where the atmosphere is largely transparent. The absorption is due to the C-Cl and C-F bonds present are the CFCs. If the greenhouse gases keep on emitting at present rate, the average temperature of earth will increase which will cause many problems like submerging of coastal areas and also lead to ecological unbalance.

**Literature Review:**

**Ciro Aprea et al.** investigate through an experiment global environmental impact of the R22 retrofits with R422D (11)**.** In recent years a new refrigerant, R422D, has been introduced as substitute of R22 for refrigeration systems. This new fluid is an easy-to-use, non-ozone-depleting HFC refrigerant and, differently from its predecessor (R407C), it is compatible with mineral oil. However, R422D has a very high GWP, and it tends to worsen the efficiency of retrofitted R22 systems. Consequently, even if R422D respects the limits of Montreal Protocol, its global environmental impact could be high. In this paper, we report an experimental analysis in terms of TEWI aimed to identify the global environmental impact of R22 systems retrofitted with R422D. For this purpose, we considered a direct expansion refrigerator for commercial applications and we investigated energy consumption with the temperature of the cold reservoir set to 5, 0, 5, 10 $^{0}$C. The experimental investigation confirmed that the system, when retrofitted with R422D, leads to an increase of TEWI. Therefore an optimization analysis aimed to eco-friendly scenarios was performed.

**Ciro Aprea et al**. investigate an experimental analysis for a vapor compression refrigeration plant for a walk-in cooler for change in energy performance as a result of a R422D retrofit (12). In this paper, the energy performance of a walk-in cooler working with R22 and its substitute R422D are experimentally studied. The experimental investigation was carried out considering three different operating conditions; in particular, the AHRI standard has been used as reference for operating conditions. All tests were run at steady state conditions and keeping the external air temperature at 35$^{0}$C. The experimental analysis allowed the determination of cooling capacity, the electrical power absorbed, the COP and other variables characterizing the working of the plant. The results demonstrated that the cooling capacity for R422D was lower than for R22, while the electrical power absorbed with R422D was higher than that with R22. As consequence, the COP of R422D was lower than that of R22 furthermore; technical proposals are introduced with the aim of improving the overall performances of those plants, which could be retrofitted with R422D.

**A.N. Leiper et al.** investigate energy conservation in ice slurry applications (13). Significant improvements in coefficient of performance (COP) can be made when the evaporating temperature of a vapour compression cycle is raised. Producing the ice slurries used in cooling applications and ice pigging by crushing blocks of ice made from pure water and mixing the particles with a solution of freezing point depressant (FPD) later enables higher evaporator temperatures than if the solution itself is frozen in a scraped surface ice maker. Predictions of the possible improvements to COP can be made in Cool Pack, a refrigeration cycle simulation program, over a range of evaporator temperature series of experiments designed to verify these predictions were carried out where the operating conditions of a scraped surface ice maker were altered by retrofitting compressor speed control to a scraped surface ice maker. Following verification of the Cool Pack results, further experiments were conducted that evaluated the energy required for two stage combinations of large ice blocks into fine particles. Two theoretical slurry production systems were then compared: mixing crushed ice with an FPD solution and a scraped surface ice maker with FPD solution feedstock. Although energy conservation was shown with combination the proposed method introduces a number of challenges that require careful consideration.

**R. Llopis et al.** investigate HCFC-22 replacement with drop-in and retrofit HFC refrigerants in a two-stage refrigeration plant for low temperature (14). The world community has committed to eliminate the HCFC-22 refrigerant to a series of deadlines according to the agreements taken during the 19th Montreal Protocol meeting in September 2007. This phase-out, which is already in progress in European Countries, has been accelerated in Article 5 countries. Refrigerant manufactures offer different drop-in refrigerants to replace R22 in existing equipment by non-ozone depleting substances in order to be able to make full use of the remaining life of the plants or different retrofit refrigerants, the use of which implies modifications to the existing systems. This work aims to contribute to the understanding of the implications of the process of R22 substitution, either with drop-in or retrofitting processes, by presenting a theoretical and experimental analysis of the performance of R22, of two drop-in fluids (R422A, R417B) and a retrofit refrigerant (R404A), in a two-stage vapour compression plant over a wide range of evaporating temperatures for a fixed condensing temperature of 40$^{0}$C. In this communication the main energy parameters, such as cooling capacity and COP are analyzed and discussed.

**Bukola Olalekan Bolaji et al.** Investigate on Performance of ozone-friendly R404A and R507 refrigerants as alternatives to R22 in a window air-conditioner (15). In this study, experimental research was carried out to investigate the performance of R22 and its ozone-friendly alternative refrigerants (R404A and R507) in a window air-conditioner. The performance parameters of the system using R22 were considered as benchmarks and those obtained using alternative refrigerants were compared. Experimental results showed that R22 had the lowest pressure ratio and discharge temperature closely followed by R507. The average discharge temperature obtained using R507 and R404A were 4.2% and 15.3% higher than that of R22, respectively. The lowest compressor power and energy consumption were obtained from R507 retrofitted system. Also, the highest refrigeration capacity and coefficient of performance (COP) were obtained using R507 in the system. The average refrigeration capacities of R507 and R404A were 4.7% higher and 8.4% lower than that of R22, respectively, while the average COP of R507 increased by 10.6% and that of R404A reduced by 16.0% with respect to that of R22. Generally, the investigation has revealed that R507 can be used successfully as a retrofitting refrigerant in existing window air-conditioners originally designed to use R22 in the event of HCFC phased out.

**Bilal Ahmed Qureshi et al.** investigate The effect of refrigerant combinations on performance of a vapour compression refrigeration system with dedicated mechanical sub-cooling (16). Performance characteristics due to use of different refrigerant combinations in vapour compression cycles with dedicated mechanical sub-cooling are investigated. For scratch designs, R134a used in both cycles produced the best results in terms of COP, COP gain and relative compressor sizing. In retrofit cases, considering the high sensitivity of COP to the relative size of heat exchangers in the sub-cooler cycle and the low gain in COP obtained due to installation of a dedicated sub-cooling cycle when R717 is the main cycle refrigerant, it seems that dedicated mechanical sub-cooling may be more suited to cycles using R134a as the main cycle refrigerant rather than R717. With R134a as the main cycle refrigerant, no major difference was noted, by changing the sub-cooler cycle refrigerant, in the degradation of the performance parameters such as COP and cooling capacity, due to equal fouling of the heat exchangers.

**Chiaki Yokoyama et al.** invesgigate viscosity of gaseous mixtures of HFC-125 (pentafluoroethane) HFC-134a (1,1,1,2-tetrafluoroethane) under pressure (17). He reports experimental results for the viscosity of gaseous mixtures of HFC-125 (pentafluoroethane) HFC-134a (1,1,1,2-tetrafluoroethane) under pressure. The measurements were carried out with an oscillating-disk viscometer of the Maxwell type at temperatures from 298.15 to 423.15 K. The viscosity was measured for three mixtures (mole fraction of HFC-125 is 0.7510, 0.5001 or 0.2508). The viscosity at normal pressure was analyzed with the extended law of corresponding states developed by Kestin et al. and the scaling parameters were obtained for unlike-pair interactions between HFC-125 and HFC-134a. The modified Enskog theory developed by Vesovic and Wakeham was applied to predict the viscosity for the binary gaseous mixtures under pressure.

## PROBLEM FORMULATION AND PROPERTY CORRELATION

In this chapter the aim of the present work is briefly describes the plan to complete the work successfully.

### Problem formulation

The objectives of the present work are as follows.

1. To study various alternatives to CFC-12 for refrigeration system. This involves the study of various aspects including the thermodynamic as well as operating and maintenance aspects.
2. To develop properties and property correlation for R-423a & R-413a, which are not available in literature.
3. To evaluate the performance of 1 ton refrigeration system using HFC-134a, R-423a & R-413a at various conditions and to compare them with CFC -12.
4. To carry out the thermodynamic design of refrigeration system and identify the design changes required, for each component of the system.
5. To study the feasibility of the design modification of various components and modify some of the components, if necessary.
6. To identify the design changes with respect to R-12 and to suggest modification (if any) in each system component.

This chapter deals with the cycle analysis of the refrigeration system using R-423a (binary) and R- 413a (ternary) mixture. Performance of system using CFC-12 and R-134a also studied for comparison. The first portion of this chapter is devoted to property correlation and second portion is devoted to identify the design changes required.

**Property correlation**

Analysis of vapor compression refrigeration system can be carried out using thermodynamic properties of the working fluid. Prediction of the performance of compression refrigeration system at design and off design conditions needs repeated calculations.

This necessitates the development of correlation for various properties such as vapor pressure, specific volume, saturated vapor and saturated vapor enthalpy as a function of temperature and pressure.

For thermodynamic properties correlation have already been developed. The reference state for liquid phase enthalpy and entropy is taken at temperature of $0^oC$.

**Href= 200kJ/kg,        Sref. = 1.0 kJ/kg**

For design of vapor compression refrigeration system in addition to thermodynamic properties, transport properties of the working fluid are also required. These have been developed in the present work, taking data mainly from TPRC handbooks. The data is available for R-423a and R -413 a separately.

All the correlations have been developed using Regression method

**METHDOLOGY**

**The Refrigeration system**

The refrigeration system of 1-ton cooling capacity has been chosen for the study. The system consists of the four usual components i.e. the compressor, condenser, evaporator and capillary tube (throttling device). The design conditions for the refrigeration unit in Indian conditions are as follows.

| S.No | | Case-1 | Case-2 |
|---|---|---|---|
| 1. | Condensing Temperature | $45^0C$, $50^0C$ and $55^0C$ | 450C,500C and 550C |
| 2 | Evaporator Temperature | $-10^0C$,$-5^0C$, $0^0C$, $5^0C$, $10^0C$ | $-10^0C$, $-5^0C$, $0^0C$,$5^0C$,$10^0C$ |
| 3. | Superheating | $0^oC$ | $10^0C$ |
| 4 | Sub-cooling | $0^oC$ | $5^0C$ |

**Analysis of the Refrigeration system**

The aim of the performance analysis is to compare the refrigerant R-134a, R-423a and R-413a with R-12. The simple vapor compression refrigeration cycle considering no losses is shown in figure 3.1. T-s diagrams are shown in figure 3.1.a and 3 .1.b for case - 1 and Case 2 respectively.

The various processes in the cycle are as follows (fig. 3.1.b)

1-2 Compression process in compressor
2-3 Condensation of vapor in condenser
3-4 Throttling (expansion) in the expansion device
4-1 Evaporation in the evaporator
1'-1 Superheating before compression
2-2' Superheating after compression

3-3’ Sub-cooling during condensation

**RESULT AND DISCUSSION**

**Result of the performance investigation :**

**Performance Analysis of Refrigeration system**: The performance analysis has been carried out by manual calculations for evaporatortemperatures -10$^0$c,-5$^0$c, 0$^0$c, 5$^0$c,and 10$^0$c, and condenser temperatures 45$^0$c, 50$^0$c and 55$^0$c. The following parameters have been calculated by considering case1 & case2 separately, as discussed below.

Case 1: Without sub-cooling

Case 2: Superheating.

Case 3: With sub-cooling of 5$^0$c &

Case 4: Superheating of 10$^0$c.

**Conclusion**

Same type of construction can be used.

Making an overall comparison, both refrigerants R-423a and R-413a are attractive alternatives to CFC-12. Research results are favorable,

**REFERENCES**


1 "Montreal protocol on substances that deplete the Ozone Layer" UNEP 2006 Report of the refrigeration, air conditioning and heat pumps technical options committee, 2006 Assessment.

2 Suva@DupontTM Corporation , USA for thermodynamic tables of R-423a and R- 413a (www. refrigerants.dupont.com).

3 "Thermodynamic study of a ternary Azeotropic mixture for Vapor Compression systems", Bansal V K, Mechanical Engineering Department, IIT Delhi 1990.

4 R.S. Khurmi, "Refrigeration and Air-conditioning", S. Chand publication.

5 Arora C.P., "Refrigeration and Air-conditioning", TMH publication.

6 Stocker and Jones, "Refrigeration and Air-Conditioning", McGraw Hill publication.

7 UNEP. Decisions adopted by the nineteenth meeting of the parties to the Montreal protocol on substances that deplete the ozone layer. United Nations Environment Programme (UNEP) Ozone Secretariat; 2007.

8 Kadam Sanjay V et al. Retrofitting of refrigeration Bench Test Rig - Replacing R-12 refrigerant by R134a refrigerant. IOSR Journal of Engineering May. 2012, Vol. 2(5) pp: 952-955 ISSN.