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Improvement of COP and Energy Efficiency Ratio of Domestic Refrigerator by using Additive in Refrigerant R134a

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Abstract: Refrigerator-freezers are one of the major energy consuming appliances in the household environment, and so more attention should be paid in improving their efficiency throughout the world. A certain additives are provided by a company Infinity HVAC, which can be used in the refrigeration and air conditioning system. These additives are a chemical solution which helps in improving the performance of the system and reducing the energy consumption of the system by removing oil fouling from the inner surface of the evaporator and condenser. The system used in this work is 165 litre domestic refrigerators with R134a as a working refrigerant. Experimental results have shown that the COP is increased by 7 % and energy consumption is increased by 4.48 %.

Keywords: Performance additive, Refrigerator, COP, Energy efficiency ratio, R134a

INTRODUCTION

Refrigeration is a process of moving heat from one location to another in controlled conditions. Refrigeration has many applications, from which one of the important is household refrigerators.
In terms of environmental protection, CFCs such as R12, as the working fluid in refrigerator compressors is being replaced by more environmental benign refrigerants such as R600a and R134a, since these have less destructive effects on the ozone layer. Hence, R134a is used as a working refrigerant in this work.
Compressor, Condenser, Evaporator and Expansion valve (capillary tubes) are four main component of the VCRS system. Evaporator is one of the most important components in VCRS system. The refrigerating or cooling effect is obtained by evaporator. Evaporators are designed in such a manner the refrigerant leaving the evaporator are superheated by a few degree so that when they enter the compressor there is no wet compression. Evaporator performance issues can be given as:

1) The cooling effect of the evaporator is governed by a) the difference in temperature between the medium being cooled and the evaporating refrigerant. The wider the temperature difference the greater the rate of heat transfer and b) the size and design of the evaporator.
2) The tubes in a shell and tube evaporators should be cleaned to prevent fouling and corrosion (water may need to be treated to reduce such problems).
3) The cooling medium flow should be maintained- pump and fan motors must work.
4) Compressor lubricating oil flows around the system with the refrigerant. It is important that this oil returns to the compressor, but it can drop out of solution with the refrigerant in the evaporator. Oil control in evaporators is, therefore an important issue. In order to maintain the evaporator performance, it is important that oil is not allowed to collect in the evaporator where it will coat the tubes and reduce heat transfer.
5) Evaporators for natural air circulation are used less and less because of the relatively poor heat transfer from the air to the cooling tubes.
6) Evaporator yield is increased significantly, if forced air circulation evaporators are used. With an increase of air velocity the heat transfer from air to tube is improved so that for a given cold yield a smaller evaporator surface than for natural circulation can be used.

Oil return in a refrigeration system usually depends on both physical factors (system design) and chemical factors (mixing of the refrigerant and lubricant). [10].
Lubricants used with refrigerant 134a are mineral oils; alkyl benzenes; dibasic, polybasic and polyol esters (POE) ; polyalkylene glycols (PAG); polyvinyl ether and fluoro chemical lubricants. [15]
Refrigeration systems typically circulate from 2% to 5% oil with the refrigerant. R-134a was found to be most miscible over the temperature range -50°C to 60°C with the following lubricants:
• polypropylene glycol diol
• penta erythritol ester mixed-acid
• penta erythritol ester branched-acid [15]

But still the refrigerant loses its miscibility with the lubricants after reaching certain temperature due to which possibilities of oil fouling increases.
Hence, a performance additive is provided by the HVAC for reducing the oil accumulation in the inner surface of the evaporator and condenser.
The purpose of this project is to reduce the oil retention and to remove the accumulated oil layer (oil fouling) from the inner surface of the tubes with the help of certain additives.

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Additives Selection:

Two types of additives are made available in the market by Infinity HVAC: Leak stopper (extreme) and Performance additive (cool shot)

A) Leak Stopper (Extreme)[16]:

It is specifically designed for the safe repair of small refrigerant gas leaks that frequently occur in Refrigeration and air conditioning system components.

Benefits:

- Permanently seals refrigerant leaks in both metal and rubber system components.
- Significantly reduces compressor noise and vibration.
- Enhance the performance of the system.

Technical benefits:

- Safe and harmless to system and recovery components.
- Non reactive to humidity and air.
- Compatible with all CFC , HCFC refrigerants.
- Does not clog system compressor or recovery machine.

Table 1: For the best results, the appropriate dose of the additive is provided by the HVAC for the size of the system

KG (refrigerant)	Automatic leak stopper
Up to 0.7 kg	12 ml
UP to 1.3 kg	30 ml
Up to 2.7 kg	42 ml
Up to 5.4 kg	60 ml
Up to 8.2 kg	84 ml
Up to 10.9 kg	120 ml

B) Performance additive (cool shot)[16]:

A powerful yet safe synthetic catalyst that improves the performance and efficiency of any refrigeration and air conditioning system by removing the oil fouling which occurs at the inner walls of evaporator and condenser coil.

Benefits:

- Enhance the performance of system.
- Especially effective with older systems.
- Minimum 29% energy savings.
- Reduces annual maintenance costs by approx. 20%.

Technical benefits:

- Increases cooling capacity.
- Improves the heat transfer.
- Reduces compressor friction, vibration and noise.
- Delivers higher lubricity to compressor oil.
- Extends life of system.

Features:

- Provides direct contact for refrigerants with internal heat transfer surfaces.
- Prevents compressor oil from creating insulating effects.
- Do not harm or chemically alter any refrigerant.

Table 2: For the best results, the appropriate dose of the additive is provided by the HVAC for the size of the system

KG (refrigerant)	Performance additive
Up to 0.3 kg	12 ml
Up to 0.45kg	24 ml
Up to 1 kg	30 ml
Up to 2 kg	42 ml
Up to 4 kg	60 ml

The additive used in this work is performance additive (cool shot) which removes the oil fouling occurs at the inner walls of evaporator and condenser.

On the basis of these doses, **5 ml** of the additive is added to the system.

Experimental set up:

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For obtaining results at load condition, the heater is provided inside the evaporator section of 75 watt.

Theoretical COP is calculated by formula:
Coefficient of performance (theoretical)

$$= \frac{\text{Refrigerant effect}}{\text{Workdone}} = \frac{RE}{Wc}$$

Actual COP is calculated by formula:
Comp power = (Nc*3600)/(tc*EMcom)
EMcom = Comp energy meter constant
= 3200 pulse/KW hr
Tc=Time for 10 Pulse of compressor energy meter in sec.
Nc = No. of compressor =1

Energy Efficiency Ratio [4]:
Energy Efficiency Ratio is can be define as the ratio of energy consumption in kWh per year to the adjusted volume in litre.

$$\textbf{EER} = \frac{\textbf{Energy Consumptio in } \frac{\textbf{kWh}}{\textbf{year}}}{\textbf{Adjusted Volume in litre}}$$

Adjusted volume = [FFV + FZV]* K * Fc
FFV = fresh food compartment volume = 0.45 x 0.40 x 0.65 = 0.117 m = 117 litre
FZV = freezer compartment volume = 0.45 x 0.38 x 0.16 = 0.028576 m3 = 27.36 litre
K = adjustment factor
Fc = frost free factor = 1.2

K = (Tr -Tff)/ (Tr – Tf)

Where, Tr = Test room temperature
Tff = Fresh food compartment temperature
Tf = Freezer compartment temperature

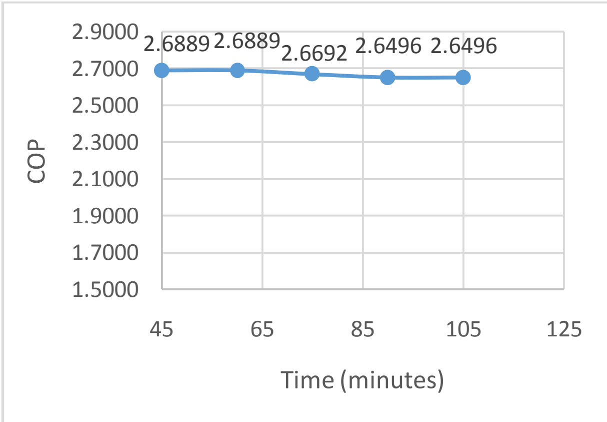
Table 3: Propose Grading System for Domestic Refrigerator [9]

Proposed Grading System (EER)	
1 Star	≥ 1.45
2 Star	$1.23 \leq \text{EER} \geq 1.44$
3 Star	$1.01 \leq \text{EER} \geq 1.22$
4 Star	$0.81 \leq \text{EER} \geq 1.00$
5 Star	$\text{EER} \leq 0.80$

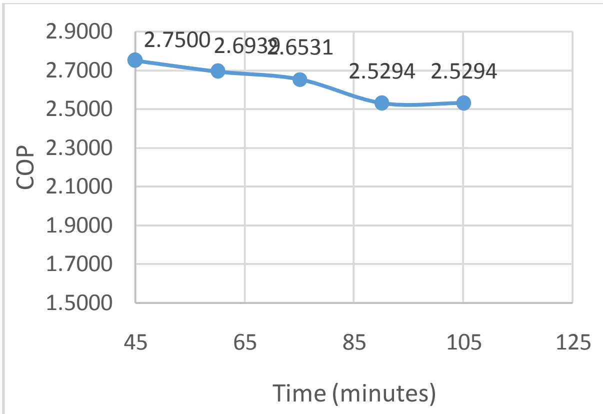
RESULTS AND DISCUSSIONS

Readings were taken for both load and no load condition using refrigerant R134a. The corresponding pressures and temperatures were measured. COP and energy efficiency ratio with and without additive is obtained at load and no load condition.

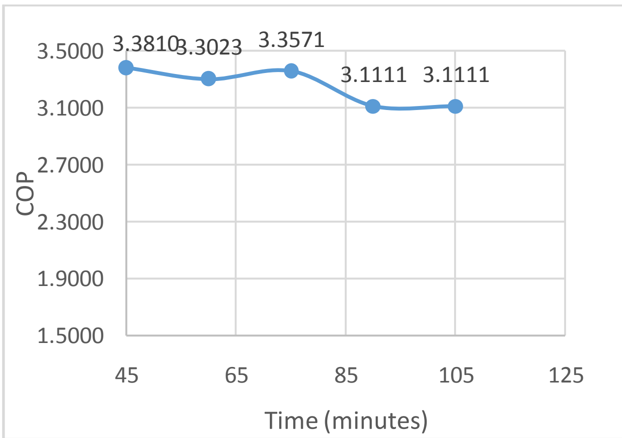
Variation COP with respect to time (minutes) without additive at no load condition:



Variation COP with respect to time (minutes) without additive at load condition:



Variation COP with respect to time (minutes) with additive at no load condition:



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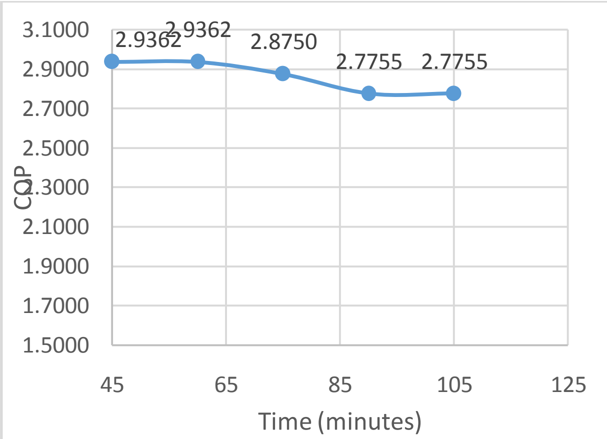
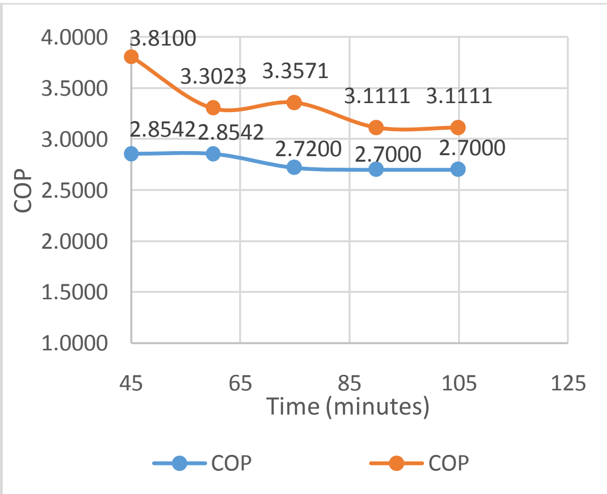
Variation COP with respect to time (minutes) with additive at load condition:

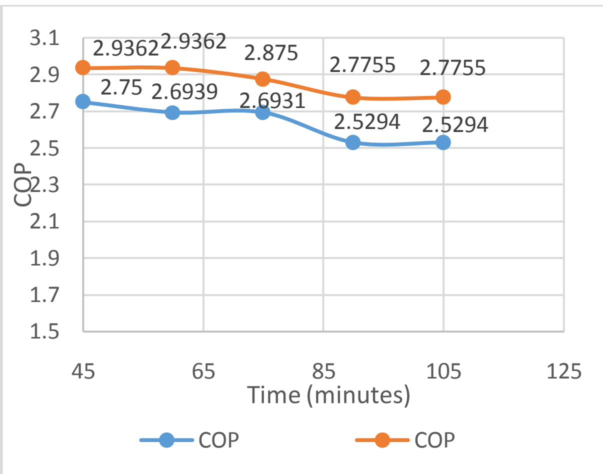


Variation of COP with respect to time is noted and it was observed that the performance of refrigerator becomes constant after 75 minutes from the starting time of the refrigerator.

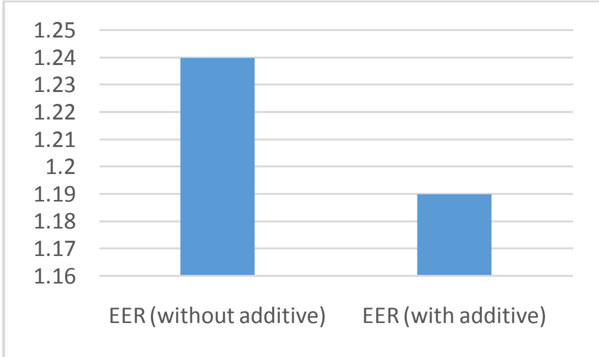
Comparison of COP at no load condition:



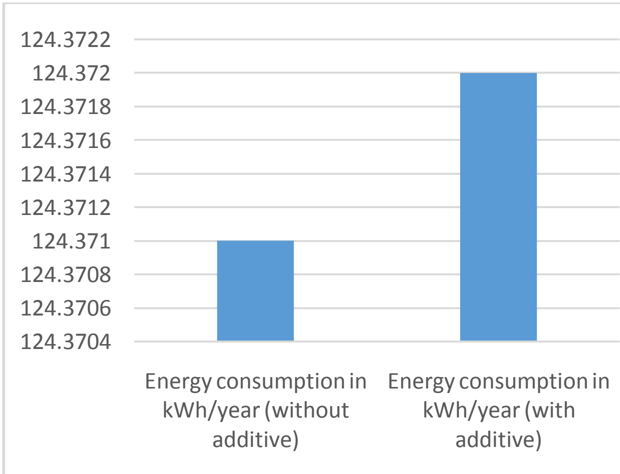
Comparison of COP at load condition:



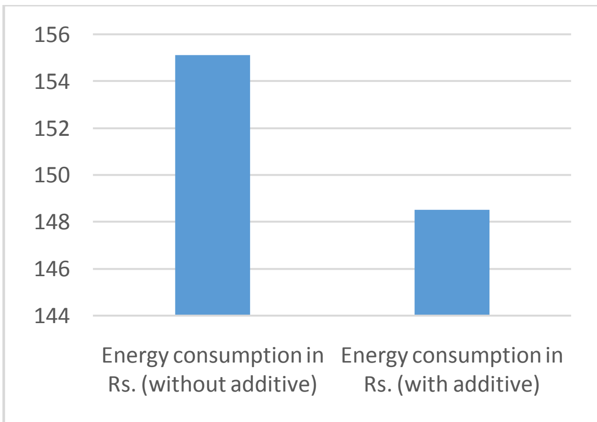
Comparison of EER at load condition:



Comparison of energy consumption in kwh/year at load condition:



Comparison of energy consumption in Rs. at load condition:



CONCLUSION:

In the overall experimentation the domestic refrigerator is injected by an additive and the performance of the refrigerator is analysed. The testing and analysis for both the conditions with and without additive has performed at variable load for variable mass flow rate of refrigerant. Thus the conclusions are listed as follows:

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- The HVAC has introduce a two types of additive which can be used in the refrigeration and air conditioning system: Leak stopper (extreme) and performance additive (cool shot). The performance additive is used in this project which helps in removing the oil layer that gets accumulated in the inner surface of the evaporator and condenser.
- With additive the COP of the system has increased between 11 - 14 % at no load condition and 5 - 7 % at load condition.
- Energy consumption is reduced by 4.48 % after adding additive into the system.
- The result has confirmed that the performance of the refrigerator is improved by injecting additive in the system. The additive do not harm the system or chemically alter the refrigerant.

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