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Experimental Investigation of A Domestic Refrigerator Having Water-Cooled Condenser Using Various Compressor Oils

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Abstract :- *The objective of this paper was to investigate experimentally the effect of different types of compressor oil in a domestic refrigerator having water cooled condenser. The experiment was done using HFC134a as the refrigerant , Polyol-ester oil (POE) oil which is used as the conventional lubricant in the domestic refrigerator and SUNISO 3GS mineral oil as the lubricant alternatively. The performance of the domestic refrigerator and HFC134a/POE oil system was compared with HFC134a/SUNISO 3GS mineral oil system for different load conditions. The result indicates that the refrigerator performance had improved when HFC134a/SUNISO 3GS mineral oil system was used instead of HFC134a/POE oil system on all load conditions. The HFC134a/SUNISO 3GS mineral oil works normally and safely in the refrigerator. HFC134a/SUNISO 3GS mineral oil system reduced the energy consumption when compared with the HFC134a/POE oil system between 8% and 11% for various load conditions. There was also an enhancement in coefficient of performance (COP) when SUNISO 3GS mineral oil was used instead of POE oil as the lubricant. The water cooled heat exchanger was designed and the system was modified by retrofitting it, instead of the conventional air-cooled condenser by making a bypass line and thus the system can be utilized as a waste heat recovery unit. The hot water obtained can be utilized for household applications like cleaning, dish washing, laundry, bathing etc. Experimental result shows that about 200 litres of hot water at a temperature of about 58ºC over a day can be generated and thus the system signifies the economic importance from the energy saving point of view.*

Keywords: *- Domestic refrigerator, HFC134a, POE oil, SUNISO 3GS mineral oil, Water-cooled condenser*

I. INTRODUCTION

A household refrigerator is a common household appliance that consists of a thermally insulated compartment and which when works, transfers heat from the inside of the compartment to its external environment so that the inside of the thermally insulated compartment is cooled to a temperature below the ambient temperature of the room. Heat rejection may occur directly to the air in the case of a conventional household refrigerator having air-cooled condenser or to water in the case of a water-cooled condenser. Tetrafluoroethane (HFC134a) refrigerant was now widely used in most of the domestic refrigerators and automobile air- conditioners and are using POE oil as the conventional lubricant.Heat can be recovered by using the water-cooled condenser and the system can work as a waste heat recovery unit. The recovered heat from the condenser can be used for bathing, cleaning, laundry, dish washing etc. The modified system can be used both as a refrigerator and also as a water heater. Therefore by retrofitting a water-cooled condenser it produce hot water and even reduce the utility bill of a small family. In this system the water-cooled condenser is designed as a tube in tube heat exchanger of overall length of 7m. It consists of an inlet for the cooling water and an exit for collecting the hot water. The hot water can be used instantly or it can be stored in a thermal storage tank for later use. The survey of the literature regarding the waste heat recovery and using of various compressor oils in the household refrigerator and air-conditioners are listed.S.S. Hu, B.J. Huang et al. **[1]** conducted an experimental investigation on a split air conditioner having water cooled condenser. They developed a simple water-cooled air conditioner utilizing a cooling tower with cellulose pad filling material to cool the water for condensing operation. The experimental investigation verified that the water-cooled condenser and cooling tower results in decreasing the power consumption of the compressor.H.I. Abu-Mulaweh **[2]** designed and developed a thermosyphon heat recovery system which can recover heat from a window air conditioner. They designed two types of heat exchangers, concentric type heat exchanger and coiled heat exchanger and then it is retrofitted in to the air conditioning system. They analysed the performance of the system with these two types of heat exchangers. The circulation of water through the heat exchanger is done with the themosyphon effect which completely eliminates the need of a pump. For having that, the heat exchangers are connected to a water storage tank and when the water in the heat exchanger get heated up by the superheated refrigerant the hot water flow upward through the connecting pipe into the top of the storage tank and at the same time the cold water from the

bottom of the tank will flow into the heat exchanger. The test results show that the concentric heat exchanger produce hot water at a temperature of 45ºC and the coil type produce d hot water having 40ºC.Douglas T. Reindl et al. **[3]** explains the Heat Recovery In Industrial Refrigeration in an article published in ASHRAE 2007. It explains that recovering heat offers potential for reducing both the direct primary energy consumption associated with refrigeration system operation as well as the consumption of primary energy used to meet heating demands directly.M. M. Rahman et al. **[4]** developed a heat recovery system which can recover heat from a split air conditioning system. In this case, the 60 litre heating tank is designed in a way that the copper tube conveying refrigerant is not submerged in water. The heating tank consists of two cylindrical chambers, the inner chamber, which is filled with water, is coiled with the hot refrigerant conveying tube at the outer surface. It was found that this heat recovery system improved the compressor efficiency and at the same time continuously supplied warm water for domestic purposes. This system rejected less heat to the environment so it is safer in environmental aspects.Sheng-shan Bi et al. **[5]** experimentally investigated the performance of a domestic refrigerator with SUNISO 3GS mineral oil and nano particles in the working fluid. The results indicated that the energy consumption of the HFC134a refrigerant using SUNISO 3GS mineral oil and 0.06% mass fraction of nano particle mixture as lubricant reduced the energy consumption by 21.2% when compared to that of HFC134a and POE oil system.Romdhane ben slama **[6]** developed a system that can recover heat from the condenser of the refrigerator. In this work the air-cooled conventional condenser is replaced by another heat exchanger to heat the water. The results show that water at a temperature of 60ºC was produced by the system. This paper also analysed the economic importance of the waste heat recovery system from the energy saving point of view.This study aims to compare the performance of a household refrigerator with water-cooled condenser and using HFC134a/POE oil and HFC134a/SUNISO 3GS mineral oil.

II. EXPERIMENTAL SETUP

2.1Experimental System

The refrigerator was of 190L capacity, single door, manufactured by Kelvinator. The system was retrofitted with a water-cooled condenser instead of the conventional air-cooled condenser by making a bypass line. Water-cooled condenser is a tube in tube heat exchanger having an inlet for the cooling water and an exit for collecting the hot water. The modified household refrigerator was properly instrumented with temperature indicators, pressure gauges and digital energymeter. The temperature at various points was noted using calibrated K-type thermocouples. The calibration of thermocouple was performed in comparison with the Standard Platinum Resistance Thermometer (SPRT). Pressure gauges used in this experiment are of bourdon tube type gauges. Dead weight pressure gauge tester using the principle of Pascal's law was used as the calibration equipment. Evaporator and condenser pressure are noted using calibrated pressure gauges. The power consumption of the domestic refrigerator was measured by using a digital energymeter. Figure 1. shows the experimental test rig. The retrofitted water-cooled condenser can also been seen. The refrigerator specification is given in Table1.

Figure 1: Experimental test rig

Table 1: Refrigerator Specifications

Gross capacity	190 L
Refrigerant	HFC134a
Charged mass	140 g
Compressor type	Hermetic

2.2 Experimental Procedure

Schematic diagram of the experimental apparatus is shown in Figure 2. After the integration of the components, the valve V 1 and V 2 was closed to make the system work only with the water cooled condenser. The system was operated at five load conditions namely, No load, 40W, 100W, 160W and 200W. At each load conditions temperature and pressure at salient points were noted down at every five minutes interval. The temperature of the water at inlet and exit was also measured. The experiment was done until steady state conditions were attained in the evaporator. The energy consumption of the system is measured using a digital energymeter. The performance of the refrigerator with water-cooled condenser was first measured using HFC134a/POE oil as the working fluid then by using HFC134a /SUNISO 3GS mineral oil as the working fluid. The test results of HFC134a/POE oil system and HFC134a/ SUNISO 3GS mineral oil system were compared.

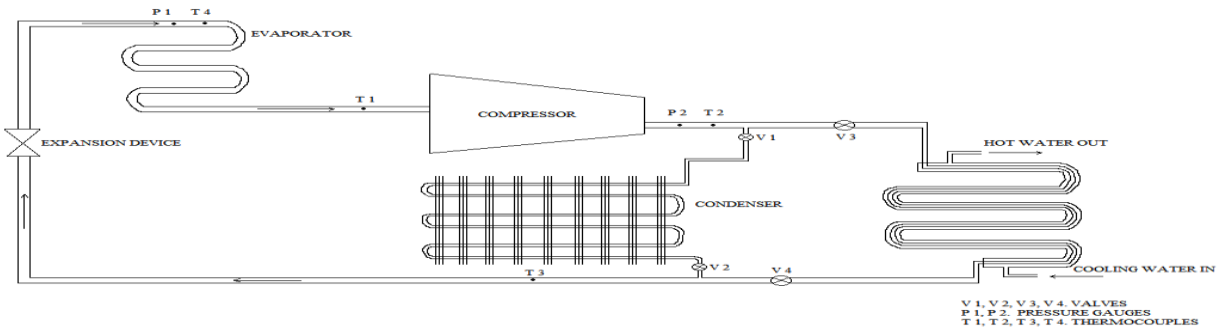

Figure 2: Schematic diagram of the experimental apparatus

III. RESULTS AND DISCUSSIONS

Figure 3. gives the comparison of the work done by the compressor with HFC134a/POE oil and HFC134a/SUNISO 3GS mineral oil. On all load conditions, the work done by the compressor was greater for the HFC134a/POE oil system than the HFC134a/SUNISO 3GS mineral oil system. This was because the condenser-evaporator pressure difference was high for the system when operating with HFC134a/POE oil than the HFC134a/SUNISO 3GS mineral oil system. As the work done by the compressor increases the power consumption also increases.

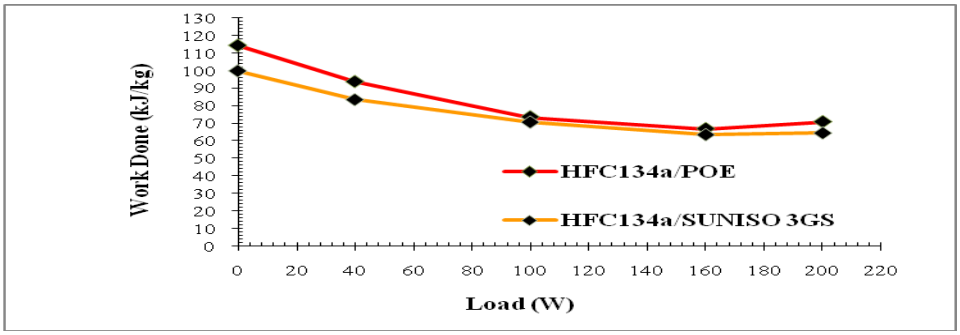

Figure 3: Variation of work done with load

Figure 4. shows the COP variation of HFC134a/POE oil and HFC134a /SUNISO 3GS mineral oil. The COP was greater for the HFC134a/SUNISO 3GS mineral oil system. This may be due to the inverse proportionality of COP to work done on all load conditions. These results confirmed that the performance of household refrigerator with water-cooled condenser and the HFC134a/SUNISO 3GS mineral oil system was better than that of the HFC134a/POE oil system.The experimental result also shows that about 200 litres of hot water at a temperature of about 58ºC over a day from the outlet of water-cooled condenser and thus analysed the economic importance of this waste heat recovery system from the energy saving point of view. Table 2. provides the energy consumption of the system at steady state for a time period of five minutes.

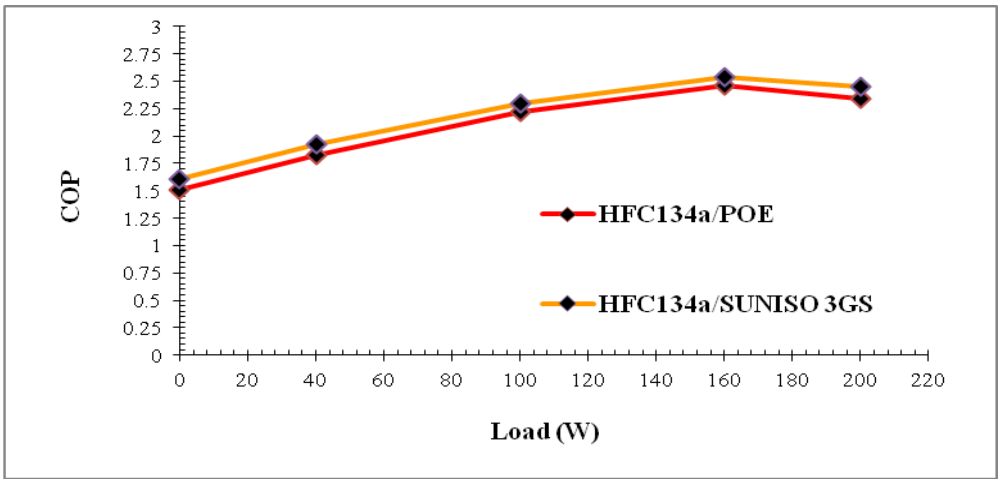

Figure 4: Variation of COP with load

Table 2: Energy Consumption of HFC134a/POE oil and HFC134a/SUNISO 3GS Mineral Oil

Load (W)	HFC134a/POE oil Energy consumption (kWh)	HFC134a/SUNISO 3GS mineral oil Energy consumption (kWh)	Energy saving (%)
No load	0.00906	0.00813	**10.26**
40	0.01125	0.01031	**8.36**
100	0.01313	0.01188	**9.52**
160	0.01406	0.01281	**8.89**
200	0.01500	0.01344	**10.40**

IV. CONCLUSIONS

The advantages of using SUNISO 3GS mineral oil as the lubricant instead of POE oil in a household refrigerator with water-cooled condenser was investigated experimentally. The main conclusions are listed as follows:

1) The HFC134a/SUNISO 3GS mineral oil system worked normally and efficiently in the household refrigerator with water-cooled condenser.

2) The energy consumption of the HFC134a refrigerator using SUNISO 3GS mineral oil as the lubricant reduced the energy consumption of the household refrigerator between 8% and 11% for different loads.

3) The results confirmed that the performance of refrigerator with the HFC134a/SUNISO 3GS mineral oil system was better than that of the HFC134a/POE oil system.
4) POE oil is known to be hydroscopic and hydrolytic, so there are many problems in refrigeration systems using POE oil such as wadding deposition, bulging equipment that chokes the flow and severe friction in the compressor. The SUNISO 3GS mineral oil completely eliminates these problems, not only this SUNISO 3GS mineral oil is having excellent chemical stability. They do not precipitate wax deposit in an extremely low temperature section of the system such as valve or evaporator. SUNISO 3GS mineral oil is having better fluidity at low temperature condition resulting good oil returning in the refrigeration systems. These outstanding features may be the reasons for the better performance of the household refrigerator with the HFC134a/SUNISO 3GS mineral oil system than that of the HFC134a/POE oil system.
5) About 200 litres of hot water at a temperature of about 58ºC over a day from the outlet of water cooled condenser and this modification made the household refrigerator to be work as both refrigerator and water heater. The hot water which was obtained from the water-cooled condenser can be utilised for household applications like cleaning, dish washing, laundry, bathing etc.

V. ACKNOWLEDGEMENT

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