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Performance Investigation of Domestic Refrigerator Using Pure Hydrocarbons

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ABSTRACT**:** *A domestic refrigerator designed to work with R-134a was used as a test unit to asses the possibility of using hydrocarbons and their blends as refrigerants. Pure butane, isobutene and mixture of propane, butane and isobutene were used as refrigerants. The performance of the refrigerator using hydrocarbons as refrigerants was investigated and compared with the performance of refrigerator when R-134a was used as refrigerant. The effect of condenser temperature and evaporator temperature on COP, refrigerating effect, condenser duty, work of compression and heat rejection ratio wereinvestigated. The energy consumption of the refrigerator during experiment with hydrocarbons and R-134a was measured. The results show that the compressor consumed 3% and 2% less energy than that of HFC-134a at 28°C ambient temperature when iso-butane and butane was used as refrigerants respectively. The energy consumption and COP of hydrocarbons and their blends shows thathydrocarbon can be used as refrigerant in the domestic refrigerator. The COP and other result obtained in this experiment show a positive indication of using HC as refrigerants in domestic refrigerator.*

Keywords: *Hydrocarbons, Butane, Iso-butane, Heat rejectionratio, Energy consumption.*

I. INTRODUCTION

Natural ice was harvested, distributed and used in bothcommercial and home applications in the mid-1800s torefrigerate food. The idea that cold could be produced by theforced evaporation of a volatile liquid under reduced pressurehad been previously pursued by Willam Cullen in theeighteenth century. These same volatile liquids could becondensed from a vapor state by application of cooling andcompression was also known by the 1800s. Combining thesetwo ideas led to the development of what would ultimatelybecome the dominant means of cooling, the vaporcompression refrigerating system. Since the invention of thevapor compression refrigeration system in the middle of the 18th century and its commercial application at the end of the18th century, the application of refrigeration has entered manyfields. The application includes the preservation of food andmedicine, air-conditioning for comfort and industrialprocessing (Donald and Nagengast, 1994).Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons(HCFCs) have many suitable properties, forexample, nonflammability, low toxicity and materialcompatibility that have led to their common widespread useby both consumers and industries around the world, especiallyas refrigerants in air conditioning and refrigerating systems.Results from many researches show that this ozone layer is being depleted. The general consensus for the cause of thisevent is that free chlorine radicals remove ozone from theatmosphere, and later, chlorine atoms continue to convertmore ozone to oxygen. The presence of chlorine in thestratosphere is the result of the migration of chlorinecontaining chemicals. The chlorofluorocarbons (CFCs) andhydrochloro-fluorocarbons (HCFCs) are a large class ofchemicals that behave in this manner. (Radermacher and Kim,

1996, Akash and Said, 2003).Since the discovery of the depletion of the earth's ozonelayer caused mainly by CFC and HCFC and as a result of the1992 United Nations Environment Program meeting, thephase out of CFC-11 and CFC-12, used mainly innconventional refrigeration and air conditioning equipment,was expected by 1996 (Lee and Su, 2002). The thermophysical properties of HFC-134a are very similar to those ofCFC-12 and are also non-toxic environmentally saferefrigerant; the American Household AppliancesManufacturers have recommended HFC-134a as a potentialreplacement for CFC-12 in domestic refrigerators. However,while the ozone depletion potentials (ODPs) of HFC-134arelative to CFC-11 are very low (<5.10-4), the global warmingpotentials (GWPs) are extremely high (GWP 1300) and alsoexpensive. For this reason, the production and use of HFC-134a will be terminated in the near future (Tashtoush *et al.*,2002, Sekhar *et al.*, 2005, Somchai and Nares, 2005).

II. EXPERIMENTAL SETUP AND TEST PROCEDURE

This section provides a description of the facilities developed for conducting experimental work on a domesticrefrigerator. The technique of charging and evacuation of the system is also discussed here.

Experimental data collection was carried out at ECL (Energy Conservations Laboratory), Mechanical Engineering Department, University of Malaya (UM). The schematic diagram of the test unit and apparatus is shown in the Fig. 1.

A. Experimental Methodology

The temperature of the refrigerant inlet/outlet of each component of the refrigerator was measured with copperconstantan thermocouples (T type). The thermocouple sensors fitted at inlet and outlet of the compressor, condenser, and evaporator are shown in Fig. 1.

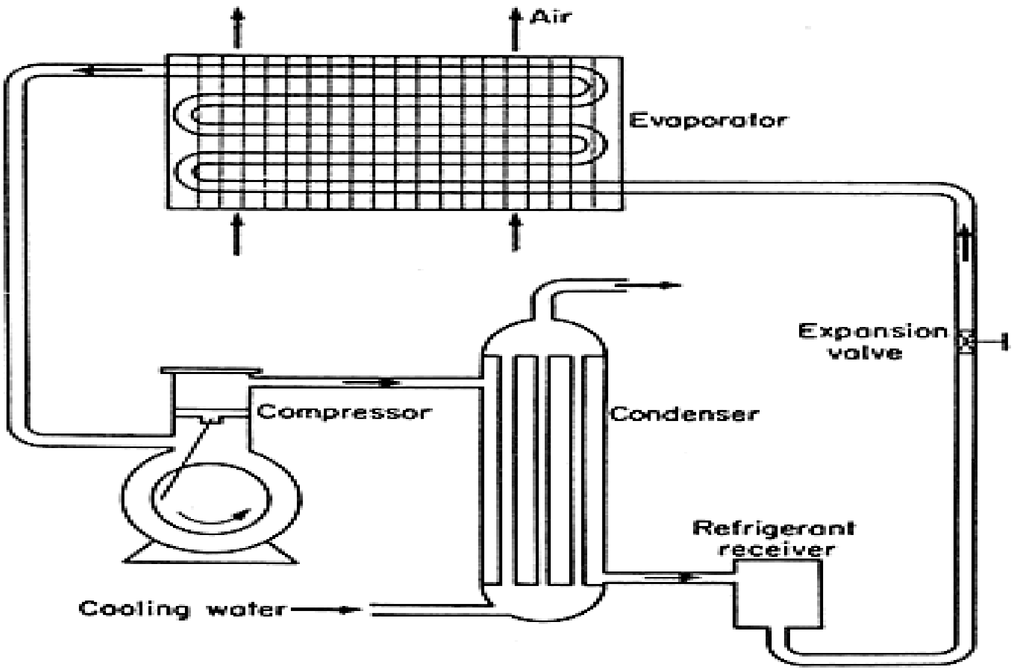

Fig. 1 Schematic diagram of the test unit and apparatus

Thermocouples/Temperature sensors were interfaced with a HP data logger via a PC through the GPIB cable for data storage. Temperature measurement is necessary to find out the enthalpy in and out of each component of the system to investigate the performance. The inlet and outlet pressure of refrigerant for each of the component is also necessary to findout their enthalpy at corresponding state. The pressure transducer was fitted at the inlet and outlet of the compressor and expansion valve as shown in Fig. 1.The pressure transducers were fitted with the T-joint and then brazed with the tube to measure the pressure at desired position. The range of the pressure transducer is -1 to + 39 bars. The pressure transducers have also been interfaced with computer via data logger to store data. A service port was installed at the inlet of expansion valve and compressor for charging and recovering the refrigerant. The location of the service port is shown in Fig. 1. The evacuation has also been carried out through this service port. A power meter was connected with compressor to measure the power and energy consumption.

B. System Evacuation

Moisture combines in varying degree with most of the commonly used refrigerants and reacts with the lubricating oil and with other materials in the system, producing highly corrosive compound. The resulting chemical reaction often produces pitting and other damage on the valves seals, bearing journal, cylinder wall and other polished surface of the system. It may cause the deterioration of the lubricating oil and the formation of sludge that can gum up valves, clog oil passages, score bearing surface and produce other effect that reduce the life of the system. Moisture in the system may exist in solution or as free water. Free water can freeze into the ice crystals inside the metering device and in the evaporator tubes of system that operate below the freezing point of the water. This reaction is called freeze up. When freeze up occurs, the formation of ice within the orifice of the metering device temporarily stops the flow of the liquid refrigerant (Dossat and Horan, 2002). To get rid of the detrimental effect of moisture Yellow jacket 4cfm vacuum pump was used to evacuate the system.

This supervac system evacuates the system fast and better which is deep enough to get rid of contaminant that could cause system failure. The evacuation system which is shown in the Fig. 2 consists of a vacuum pump, a pressure gauge and hoses. The hoses were connected with the service port to remove the moisture from the system as shown in the Fig. 2. When the pump is turned on the internal the pressure gauge shows the pressure inside the refrigerator system

C. System Charging

Yellow jacket digital electronic charging scale has been used to charge HCs, their blends and HFC-134a into the
system. This is an automatic digital charging system that can charge the desired amount accurately and automatically. The charging system consists of a platform, an LCD, an electronic controlled valve and charging hose. The refrigerantcylinder was placed on the platform which measures theweight of the cylinder. The LCD displays the weight and also acts as a control panel. One charging hose was connected withthe outlet of the cylinder and inlet of the electronic valve andanother one was connected with the outlet of electronic valveand inlet of the service port. Using this charging systemrefrigerants were charged into the system according to desiredamount.

D. Test Unit

The test unit was a Samsung refrigerator and designed towork with R-134a refrigerant. The refrigerator's performance with no load and closed door condition has been investigated.The specification of the refrigerator is shown in Table I.

TABLE I
TECHNICAL SPECIFICA
TIONS OF REFRIGERATOR FREEZER TEST UNIT

SPECIFICATIONS	
Freezer Capacity (liter)	80
Fresh Food Compartment Capacity (liter)	220
Power Rating (W)	160
Current rating (A)	0.9
Voltage (V)	220
Frequency (Hz)	50
No of door	2
Refrigerant type	134a(CF3CH2F)
Defrost system	Auto Defrost

E. Test Procedure

The system was evacuated with the help of vacuum pumpto remove the moisture and charged with the help of charging system. The pressure transducers and thermocouples fittedwith the system were connected with the data logger. The datalogger was interfaced with the computer and software hasbeen installed to operate the data logger from the computerand to store the data. The data logger was set to scan the datafrom the temperature sensor and pressure sensor at an intervalof 15 minutes within 24 hours. A power meter was connectedwith the refrigerator and interfaced with the computer andpower meter software was installed. The power meter storesthe instantaneous power and cumulative energy consumptionof the refrigerator at an interval of one minute within 24 hoursin the computer. The pressures and temperatures of therefrigerants from the data logger were used to determine theenthalpy of the refrigerant with the help of REFPROP7software. All equipments and test unit was installed inside theenvironment control chamber where the temperature andhumidity was controlled. The dehumidifier has been used tomaintain desired level of humidity at the control chamber. Theunit can maintain humidity from 60% to 90% with anaccuracy of ±5%. The humidity has been maintained at 60%RH for all experimental work. The temperature inside thechamber was maintained at 25°C and 28°C. When thetemperature and humidity inside the chamber was at steady
state, the experiments were started. The experiment has beenconducted on the domestic refrigerator at no load and closeddoor conditions

III. CONCLUSION

This project invested an ozone friendly, energy efficient, user friendly, safe and cost-effective alternative refrigerant forHFC134a in domestic refrigeration systems. After thesuccessful investigation on the performance of HCs andblends of HCs as refrigerants the following conclusions can bedrawn based on the results obtained.• The co-efficient of performance for the HCs and blends of HCs is comparable with the co-efficient ofperformance of HFC134a.

• The energy consumption of the pure HCs and blendsof HCs is about similar to the energy consumption ofrefrigerator when HFC134a is used as refrigerant.The compressor consumes 2% and 3% less energywhen Butane and Iso-butane was used than that ofHFC-134a at 28°C ambient temperature.

• HCs and mixture of HCs offer lowest inlet refrigeranttemperature of evaporator. So for the lowtemperature application HCs and blends of HCs isbetter than HFC-134a.

• The domestic refrigerator was charged with 140g ofHFC134a and 70g of HCs and blends of HCs. This isan indication of better performance of HCs asrefrigerants.

• The experiment was performed on the domesticrefrigerator purchased from the market, the components of the refrigerator was not changed ormodified. This indicates the possibility of using HCsas an alternative of HFc-134a in the existingrefrigerator system.Chemical and thermodynamics properties of hydrocarbonmeet the requirement of a good refrigerant. Some standardsallow the use HCs as refrigerant if small amount of refrigerantis used. The final conclusion is that butane and isobutene canbe used in the existing refrigerator-freezer withoutmodification of the components.

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