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DETERMINATION OF TIME-TEMPERARATURE RESPONSE OF R134A USING THEORY PROVING SYSTEM

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ABSTRACT

In this work, refrigerant (R-134a) operating temperatures at various phases in each component of air-conditioning unit using Theory Proving System (TPS) was investigated based on time variation. The system worked for 30 minutes during which operating temperatures of the refrigerant at various stages were determined. T1, T2, T3, T4, T5 and T6 denote refrigerant inlet and outlet temperatures for compressor, condenser and evaporator respectively. The results showed that T1 dropped sharply from the refrigerant initial temperature of 29°C to 16°C and steadily to 14°C where it maintained balance. T2 increased steadily with time till optimum temperature of 29°C to 35°C and T4 remained unchanged as a result of condensation process for the initial temperature of 29°C was maintained. T5 reduced steadily to 15°C due to throttling process while T6 reduces steadily to 10°C due to evaporation process within 30 minutes.

Keywords: Refrigerant, Temperature, Refrigeration, Air-conditioning, and Theory Proving System (TPS).

INTRODUCTION

A refrigerant is a substance used in heat engine cycle usually, including, for enhance efficiency, a reversible phase transition from a liquid to a gas. The term refrigerant refers to the liquid used in a refrigerating system to produce "cold" by removing heat from the refrigerated area. The refrigerant absorbs heat during evaporation at low temperature and pressure, and releases heat during condensation at a higher temperature and pressure. Traditionally, fluorocarbons especially chlorofluorocarbons were used as refrigerants, but they are being phased out because of their ozone depletion effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as propane (Siegfried and Hemut, 2002).

Many refrigerants are important ozone depleting and global warming inducing compounds that are the focus of worldwide scrutiny. The ideal refrigerant has favorable thermodynamic properties, is non-corrosive to mechanical components and is safe (including non-toxic, nonflammable and environmentally friendly). The desired thermodynamic properties are a boiling point somewhat below the target temperature, a high heat of vaporization, a moderate density in liquid form, a relatively high density in gaseous form, and a high critical temperature. Since boiling point and gas density are affected by pressure refrigerants may be made more suitable for a particular application by choice of operating temperatures (Eckels and Pate 1990, Handy and Pham 2001)

The inert nature of many Halons, Chlorofluorocarbons (CFC) and Hydrochlorofluorocarbon (HCFC) with the benefits of them being non-flammable and nontoxic, made them good choices as refrigerants, but their stability in the atmosphere and their corresponding global warming potential and ozone depletion potential raised concerns about their usage. In order from the highest to the lowest potential of ozone depletion are Bromochlorofluorocarbon, CFC then HCFC. Though HFC and PFC are non-ozone depleting, many have global warming potentials that are thousands of times greater than carbon dioxide(CO₂). Other refrigerants such as propane and ammonia are not inert, and are flammable or toxic if released. New refrigerants have been developed that are safe to humans and to the environment, but their applications had been held up by regulatory hurdles (Dincer 2003, Dossat and Horan 2002)

Tetrafluoroethane, R-134a, is a haloakane refrigerant with thermodynamic properties similar to R-12 (dichlorofluoromethane) but with zero ozone depletion potential. It has the formular CH_2FCF_3 and a boiling point of $-26.3^{\circ}C$ at atmospheric pressure, R-134a cylinders are coloured light blue (Corr Stuart, 2005). R-134a is an inert gas that has molar mass of 102.03g/mol, density of 0.00425 g/cm3, melting point of $-103.3^{\circ}C$ and 0.15wt% soluble in water. It first appeared in the early 1990s as a replacement for R-12 which has high ozone depleting potential.R-134a is primarily used as a "high-temperature" refrigerant for domestic

refrigeration and automobile air conditioners. These devices began using R-134a in the early 1990s as a replacement for more environmentally harmful R-12 and retrofit kits are available to convert units that were originally R-12 equipped. Other uses include plastic foam blowing as a cleaning solvent, a propellant for the delivery of pharmaceuticals, wine cork removers and gas dusters in air driers for removing the moisture from compressed air. R-134a has also been used to cool computers in some overclocking attempts. It is also commonly used as a propellant for airsoft air guns (Harris 2008, EPA, 2010).

Wattelet et al(1993) researched into evaporative characteristics of R-134a, MP-39 and R-12 at low mass fluxes. Tests were conducted using a single tube evaporator facility. The test section used was a 2.43m and 7.04mm inside diameter, horizontal smooth, copper tube. Heat was applied to the test section using electric resistance heaters. The heat coefficients for R-134a were higher than those of R-12 using equivalent mass flux and cooling capacity bases.

Brandon (2004) researched into the use of water as a refrigerant, its impact of cycle modification on commercial feasibility. He investigated the economic feasibility of water-based vapour compression chiller with a nominal capacity of 1000 tons. More detailed component level models were developed to accurately size equipment and predict system performance for the most attractive cycle configuration. These components addressed issues that are particularly crucial in water as refrigerant cycles such as compressor discharge superheat and refrigerant side pressure drop. Where possible, these components models were verified through comparison against the current state-of-the-art technology for large chillers using R-134a as a refrigerant. Other issues that may have an economic impact on the feasibility of water as viable alternative to R-134a were direct contact heat exchangers, purging issues and condensation.

Ali and Norber 2005 carried out a comparative study of water as refrigerant with some current refrigerants. Water as refrigerant (R718) was compared with some current natural (R717 and R290) and synthetic refrigerants (R134a,R12, R22, and R152a) regarding environmental issues including ozone depletion potential (ODP) and global warming potential (GWP). A computer code simulating a simple vapour compression cycle was developed to calculate Coefficient of Performance (COP), pressure ratio, outlet temperature of the refrigerants from compressor and evaporator temperatures above which water theoretically yields better COPs than the other refrigerant investigated. It is found that for evaporator temperature above 20^oC and small temperature lift (5K). R718 gives the highest COP assuming exactly the same cycle parameter for medium temperature (20-25K), this evaporator temperature was above 35^oC whereas for even greater lifts it decreases again.

THEORECTICAL BACKGROUND

The purpose of the compressor is to: Circulate the refrigerant in the circuit.Compress the refrigerant that leaves the evaporator and thus raising its temperature in order to create a temperature difference that will enable heat transfer from the cooled area, toward the outside. The purpose of the condenser is to receive the high-pressure and temperature gas from the compressor and convert this gas into liquid, while emitting heat to the surroundings. The expansion valve fulfills in the cooling circuit a triple function: It releases the pressure from the refrigerant that is in liquid state, on its way to the evaporator. That enables its expansion while reducing its temperature to the lowest value in the cooling circuit, a degree that enables efficient temperature exchange with the air in the refrigerated area. It determines the refrigerant flow intensity through the cooling circuit, according to the momentary cooling request in the refrigerant flow.

The evaporator function is the opposite of the condenser function. In the evaporator, the refrigerant turns into gas at low pressure, while absorbing heat. The cooling down is done by the evaporator blower, which sucks the air from the refrigerated area and blows it through the evaporator fines. When the air has passed through the evaporator fines and gave up its heat, it returns to the refrigerated area much cooler and drier.

In the basic refrigerant cycle, the refrigerant, which enters, into the compressor as a lowpressure gas, compresses and moves out of the compressor as a high-pressure and high temperature gas. At the second stage, the gas flows into the **Condenser**. Here the gas condenses into a liquid, giving off its heat to the outside air. The liquid then flows under high pressure, to the **Expansion valve**. This valve restricts the flow of the liquid, thus lowering its pressure as it leaves the expansion valve. The low-pressure liquid moves then to the **Evaporator**, where heat from the inside air is absorbed by the liquid changing its state from liquid into gas. As a hot low-pressure gas, the refrigerant moves back to the compressor where the entire cycle is repeated.

MATERIAL AND METHOD

A Theory Proving System (TPS) consisting of Air-conditioning unit was employed to determine the responses of operating temperatures of Refrigerant (R-134a) with time. The high-pressure refrigerant is sent from the compressor to the condenser, where the heat is dissipated and gaseous refrigerant condensed into a liquid. The high-pressure liquid refrigerant flow to the expansion valve, where it is metered and its pressure is reduces. At the evaporator, the liquid refrigerant absorbs heat from the air and evaporates to gas. The cycle then repeated, starting at the compressor. The air-conditioning unit consists of the following major components viz; Compressor, Condenser, Expansion device and Evaporator housed by the cooling compartment. Thermometers were placed at each of refrigerant inlet and outlet to each of these components to take the operating temperatures of the refrigerant as it circulates the refrigeration cycle. The time interval were set by the aid of stopwatch through which accurate time were set for the determination of operating temperatures of the refrigerant at the inlet and outlet of each of the major components of the air conditioning unit. The Compressor size is 0.5 horse power and the cooling compartment was made of plastic glass which increases the total cooling load through insolation. The system was made to run for 30 minutes during which operating temperatures of Refrigerant (R-134a) at compressor inlet and outlet, T3 and T4 denote operating temperatures of refrigerant at evaporator inlet and outlet. Thus T6 is the prevailing temperature at the cooling compartment. Table 1.0 shows the various operating temperatures at various stages and phases within 30minutes.

RESULT AND DISCUSSION

Time (min)	T1	T2	Т3	T4	T5	Т6
0	29	29	29	29	29	29
2	16	38	34	29	19	21
4	15	40	34	29	18	20
6	15	41	34	29	17	18
8	15	42	34	29	16	17
10	15	42	35	29	16	16
12	14	41	35	29	16	15
14	14	41	34	29	16	15
16	14	41	34	29	16	14
18	14	41	34	29	15	13
20	14	41	35	29	15	12
22	14	41	35	29	16	12
24	14	41	35	29	16	11
26	14	41	35	29	15	10
28	14	41	35	29	15	10
30	14	41	35	29	15	10

Table 1.0. Time and operating temperatures

Table 1.0 shows the operating temperatures with time and Figure 1.0 shows the refrigerant (R-134a) responses to time variation. The initial temperature T1 of the refrigerant was 29^oC which

decreased sharply to 16[°]C and later to 14[°]C hence maintained a balance within 12 minutes. It is evidenced that refrigerant `leaves the compressor at high temperature cools as it recirculates. At the exit of the compressor, the refrigerant temperature T2 increases from 29°C to 41°C where it maintains a balance within 10 minutes and this increase resulted from compression process as the refrigerant leaves compressor under high pressure and temperature. In figure 1.0 as time increases the refrigerant temperature T3 at the inlet of the condenser increased steadily to optimum temperature of 35°C within 10 minutes and maintained a balance. The refrigerant temperature T4 remains unchanged with increases time, the constancy of the temperature is as a result of condensation effect through atmospheric cooling at the condenser. Refrigerant temperature T5 having lost heat as a result of condensation turn to liquid and flow to the evaporator. As time increases the refrigerant temperature drop sharply within few minutes and steadily reduce to 14⁰C where it maintains a balance. Refrigerant temperature T6is the prevailing temperature in the cooling compartment. Within 30 minutes the temperature drops 10 degree Celsius. T6 illustrates the cooling effect of refrigeration cycle where refrigerant 134a evaporates into process gaseous state through evaporation and gain heat from the surrounding (cooling compartment) to turn into low pressure liquid refrigerant and back to compressor.

CONCLUSION

The time-temperature response of refrigerant R-134a has been investigated. R-134a being environmentally friendly is universally accepted to replace R-12 which has high ozone depleting potential (ODP) and global warming potential (GWP). Since the compressor works on-stopped for 30 minutes, operating temperatures of R-134a were determined with the aid of Theory Proving System (see plate 1). The operating temperature of the refrigerant in each stages is time dependent though attain optimum and then maintain balance except the operating temperature at the outlet of the condenser that remain constant due to environmental impact on the condensing unit. Thus Time-Temperature response of other synthetic refrigerant can also be determined using the same equipment.

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Plate 1.0: Theory Proving System for Air conditioning Unit