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Performance Investigation of Two VCR Circuits Connected In Parallel with R134a and HC Blends

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Abstract: Early mechanical refrigeration systems employed sulphur dioxide gas or anhydrous ammonia, with small home refrigerators primarily using the former. Being toxic, sulphur dioxide rapidly disappeared from the market with the introduction of CFCs. Refrigerant R12 is one of the most widely used refrigerants used for different applications.R-12 is a CFC and it has unusually high potential to cause the depletion of the ozone layer. Hence it is being replaced by R134a and certain blends. Although R134a is considered as an alternative refrigerant for R12, it has high global warming potential as per the Kyoto protocol it has to be decreased. At present natural refrigerant which is being used is a blend of propane and iso-butane. It operates at similar saturation pressures to R12 or R134A. It is also compatible with most common refrigeration materials and lubricants. HC's are having excellent thermophysical properties, only drawback is the flammability. HC's are not suitable for large cooling capacity plants as it demands more charge of the refrigerant. The present work eliminates the risk of flammable issues of HC refrigerant. Experiments were conducted on two VCR circuits in parallel connection one operating with R134a and the other with HC mixture. Therefore total quantity of the HC charge decreases.

I. Introduction:

The present work aimed to take the advantages of hydrocarbon mixtures to meet the Montreal Protocol and Kyoto Protocol. Various alterative refrigerants are available for the conventional system, but each one has its own merits and limitations. Many experimental and theoretical studies have been reported regarding the performance of various alternative refrigerants and their mixtures. The role of chlorofluorocarbons (CFCs) in the process of ozone depletion is now widely accepted, though in other respects CFCs have proved to be ideal refrigerants. The search for alternatives has been focused on chemically similar compounds which could be used as direct substitutes. Notable amongst these is the R134a as a replacement for R12. While this can now attain efficiencies comparable with that of RI2, it is considerably more expensive and has a relatively high GWP [1]. Hydrocarbon refrigerants have the advantages of low cost, local availability and environmental acceptability when compared to CFCs and HCFC substitutes. The absence of chlorine results in zero ODP and has a negligible GWP [2]. R.S.Agarwal et. al., have developed retrofit refrigerant to existing R12 with MP-39(R22/R124 and R152a) and mixtures of R290 and R600a[3].

P.Srinivas et.al.[4] investigated on replacement of R134a with LPG and calculate the performance parameterslike Compressor Work, Coefficient of Performance, Refrigerating Effect are evaluated at various operatingconditions and compared with R134a. Coefficient of Performance for LPG is higher than R134a by 34.6 %.T.S.Ravikumar et. al. [5], reported that R134a can be used in place of R12. However, to avoid synthetic oil they used the conventional mineral oil as lubricant, R134a is mixed with the commercially available hydrocarbon blend, (45.2% R290 and 56.8% R600a) in the proportion of 91% and 9%, respectively by mass.

M.A.Sattar et. al. [6], investigated and compared the performance of the refrigerator using R600a, R600 and a ternary mixture of mixture of R290/R600a/R600 as refrigerants with the R134a. The effects of evaporator and condenser temperatures on COP, refrigerating effect, compressor power and heat rejection ratio were investigated. The results show that the compressor consumed 3% and 2% less energy than that of R134a at 28°C ambient temperature when R600a and R600 was used as refrigerants respectively. D.Colbourne [7], discussed the various safety considerations with respect to the application of flammable refrigerants.

From the literature it was observed that there are limitations to use hydrocarbon refrigerant due to its flammability. Many of the advanced countries are not preferring HC's for large capacity plants. In the present work two VCR circuits are connected in parallel, performance analysis are carried out using R134a and HC mixture separately in each circuit. So that total flammable refrigerant requirement decreases, also no need to take any safety measurements.

II.Experimental setup:

The experimentation, performance tests are done on a Visi Cooler setup with a compressor, a cooling fan, five thermocouples, temperature and pressure indicators along with a wattmeter and a mass flow rate indicator. As shown in the figure, there are two similar circuits which have separate compressors, condensers and expansion devices (capillaries), but a common heat sink and cold sink. Each circuit has 4 capillaries of different lengths. All the capillaries are attached to the condenser as well as the five thermocouples which are located at compressor inlet, condenser inlet, expansion inlet, evaporator inlet and in the brine solution. However, the experimentation was carried out in both the circuits taking a constant capillary length for each, i.e., 6.3m capillary length for one circuit and 3.3m length for the other. A temperature indicator is also used to show the temperatures sensed by the various thermocouples when the compressor is in operation.

Figure 1: Experimental setup

Experimental Procedure: Tests were performed with R134a and HC mixture in both the circuits separately. The obtained results were compared with the combined system by operating both the circuits simultaneously with the similar operating conditions.

Optimization of the mass of R-134a refrigerant:

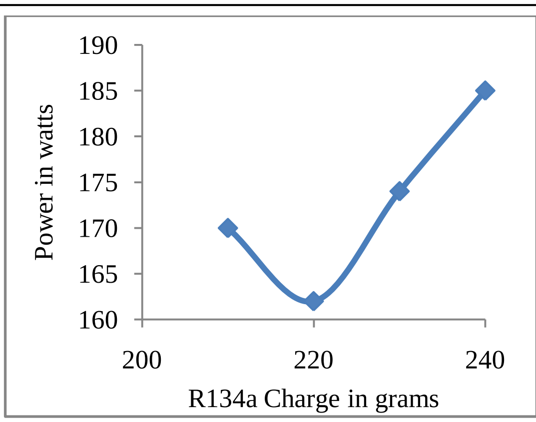

Figure 2: Optimization of R134a charge

From figure 2, initially the power remains high during undercharged condition and drops down when it is charged with the optimum amount. This is because the evaporation rate and super heating of refrigerant increases, intern compressor power increases. For overchargedcondition, due to high evaporative pressures, the power developed is higher than the power at optimum charge.

A similar trend can be observed even for the Hydrocarbon refrigerant as shown in figure 3. Minimum energy consumption is obtained at 104grams of HC mixture, which is 50% of the optimized mass of R134a.

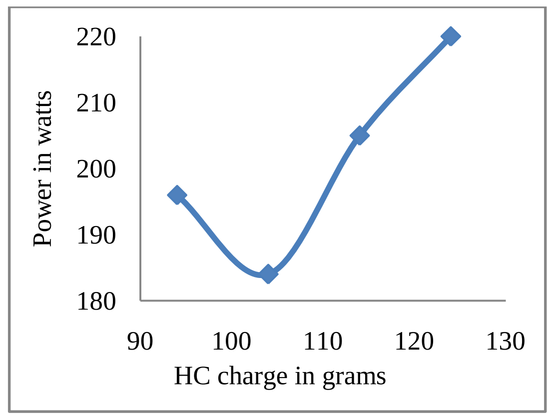

Figure 3: Optimization of HC mix charge

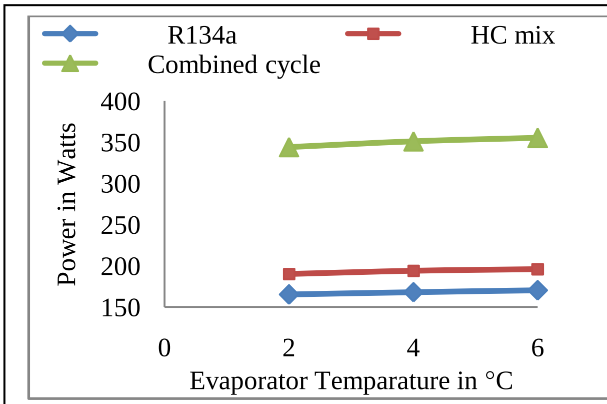

Figure 4: Variation of Power with evaporator temperature

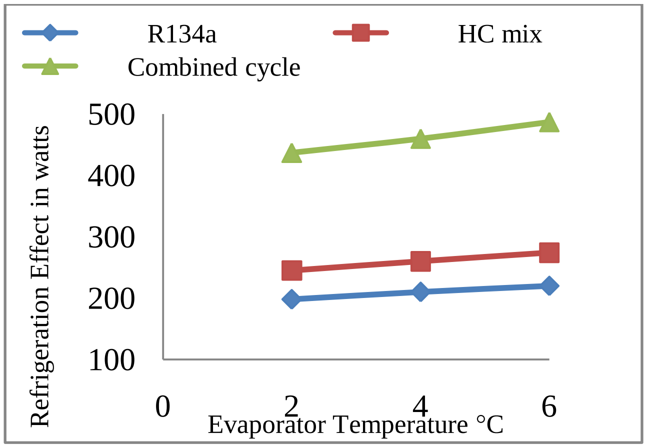

Figure 5: Variation of refrigeration effect with evaporator

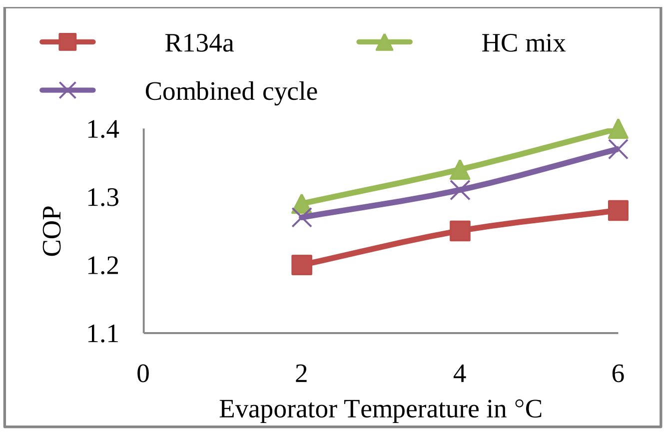

Figure 6: Variation of COP with evaporator temperature

From figure 5 it was observed that the refrigeration effect is more for the combined cycle at all the range of evaporator temperatures. Both the circuits take away the heat from the evaporator simultaneously. Cooling capacity of R134a is less than that of the HC mixture. From figure 4 energy consumption of R134a is less than HC mixture and combined cycle due to its lower specific volume. COP of the HC mixture is found to be higher than that of the R134aas shown in figure 6. Even though the power consumed and cooling capacity at the optimum charge is more for the HC mixture than R134. The rate of increase of power is less than rate of increase of cooling capacity thus COP of HC mixture is better than R134a as shown in figure 6. The COP of the combined system is slightly less than HC mixture.

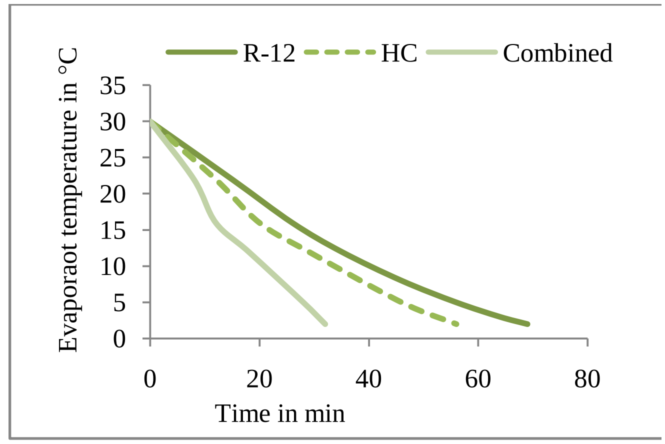

Figure 7: Pull down test

changing the brine temperature from 30°C to the desired final temperature 2°C. This test decides the cooling rate of the system. The temperature drop of the brine solution in the refrigerated space during pull down time is plotted in figure 7. The pull down time for HC mixture is 56minutes and combined system is 32 minutes, whereas it is 69 minutes in the case of R134a. The cooling speed for HC mixture refrigerant is less than R134a due to because of its high latent heat of vaporization.

Conclusions

On the basis of experimental investigation the following conclusions have been drawn

- The COP of the combined system is slightly less than HC mixture, which permits to take the advantages of HC mixture for large capacity plants.
- The pull down time for the combines cycle is 53.6% greater than that if the R134a
- Total mass of the HC refrigerant is under safe limit therefore no need to take any safety precautions.
- According to the load requirements either one or both the circuits can be operated, thereby reducing the power consumption.

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