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Extending the capillary tube of a propane air-conditioner to reduce the refrigerant charge

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Abstract

Hydrocarbon refrigerants are employed to replace synthetic refrigerants due totheir low global warming and ozone depletion potentials; however, these refrigerants are flammable; therefore, their mass in the system should be minimized to reduce the associated risks. This study deals with the novelidea of extending the capillary tube of a portable air-conditioner in orderto decrease the amount of refrigerant charge in the system. Extending the length of the capillary tube will shorten thelength of the liquid line in applications in which the distance between theoutlet of the condenser and the inlet of the evaporator cannot be reduced. A script was developed and its accuracywas experimentally assessed.It was then used to estimate the amount of charge for the existing design and the extended capillary tube. The results show a significant reduction (63.9%) in the amount of propane in the capillary tubeand liquid line, and a reasonable decrease (8.3%) in the maximumspeed of refrigerant for the airconditioner used in this work.

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*Keywords:*capillary tube; liquid line; charge.

1. Introduction

Synthetic refrigerants are being phased out, and their production will be banned entirely by 2030 due to their global warming and ozone depletion impacts [1]. Hydrocarbons such as propane are used as replacement of synthetic refrigerants due to their negligible global warming, near zero ozone depletion potentials, and their similar thermodynamic properties. However, the amount of propane in the system should be limited due to its flammability.

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In regard to the use of hydrocarbon refrigerants, several technical committees, which are responsible for standards development, have been trying to include the additional safety measures in recent years. The maximum allowable amount of hydrocarbon refrigerants in a system is specified according to room floor area, installation height and lower flammability limit of the refrigerant. A formula that is well accepted by most standards suggests a maximum of approximately 300 grams hydrocarbon refrigerants for portable factory sealed single package air conditioners [2].Recently, some amendments have been proposed for more restrictive regulations [3].

Most previous research focused on decreasing the amount of charges in components with the maximum charge of the system. The results show that a significant mass reduction can be achieved by (a) using miniature heat exchangers [4], (b) increasing the condensing temperature [5]. The length of the capillary tube is expected to have only a negligible impact on the required charge of the system, as capillary tubes contain only a small fraction of the refrigerant charge [6].For this reason, the research in this area has been very limited.

In a previous work [6], it has been shown that reducing the inside diameter of capillary tubes significantly reduces the refrigerant charge in the tube; however, this technique has a negative impact on the overall life of the capillary tube and the noise level by increasing the maximum velocity of the refrigerant. An alternative approach isto use a shorter and helical capillary tube to lower the maximum velocity. This method is effective but not practical if the distance between the outlet of the condenser and the inlet of the evaporator cannot be reduced. Here, shortening the length of capillary tubes extends the length of the tube between the outlet of the capillary tube and the inlet of the evaporator (liquid line). The liquid line has a larger diameter compared to the capillary tube; consequently, this arrangement may actually increase the overall refrigerant charge of the system. In such cases, it is suggested to both extend the capillary tube and eliminate or shorten the liquid line.

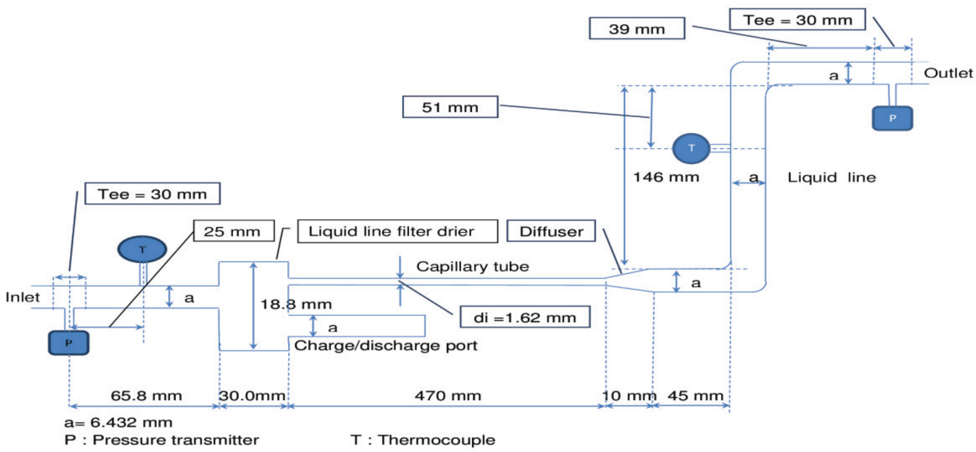

Fig. 1. Schematic of the original capillary tube and instrumentation (not to be scaled)

In the proposed technique, the length of the new capillary tube equals the sum of the length of the original capillary tube and the length of the liquid line. However, in this work, the length of the new capillary tube equals the sum of the original capillary tube and the part of the liquid line which is located between the diffuser and downstream pressure transducer (see Fig.1).This provides an opportunity to compare the computational results with the experimental data. The diameter of the proposed capillary tube is chosen in such a way that the pressure loss remains unchanged in the two cases. This is necessary because increasing the pressure loss can increase the size of the required compressor, which may lead to an increase in the overall refrigerant charge of the system.

2. Methodology

The approach in this study incorporates computational and experimental methods. First, a script was developed to model the capillary tube and liquid line, and then its accuracy was assessed by comparing the computational results with those of experiments. At the next step, the model was used to estimate the mass of propane in the capillary tube