Enhancing the performance of the domestic refrigerator with hot gas injection to suction line

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Abstract. The purpose of this study was to determine the increase in performance of a domestic refrigerator that uses hot gas injection (IHG) to the suction line. The experiment was conducted by flowing refrigerant from the discharge line to the suction line. To get performance data, measurements performed on the liquid brine as cooling load with various temperatures (range from 3°C to -3°C). The working fluid is used as a cooling medium is R-134a. The experimental results showed that the injection of hot gas to the suction line generates an increase in the coefficient of performance systems (COPs) of 7% and is able to lower the discharge temperature, causing the compressor to work lighter/easier, saving electric power needed by the refrigerator.

1. Introduction
The use of refrigerators in households increases every year. It is because people increasingly do their activities outside their houses; they prefer to purchase their needs at one time and store them in refrigerators. The role of refrigerators in today’s modern era occupies a primary position in people’s lives [1]. In general, refrigerators use a vapour compression cycle that requires energy input from the outside in the form of electrical energy to drive the compressor motor. The energy required by refrigerators is quite big [2], as the refrigerators work for 24 hours. Therefore, energy saving measures are necessary as it would significantly impact on energy conservation efforts in the world [3][4].

In order to solve the problem of energy saving of refrigerators, some researchers have implemented various ways to reduce energy consumption and improve the efficiency of the refrigeration system, including: (i) replacing the synthetic refrigerant with natural refrigerants [5][6][7][8]; and (ii) installing suction-liquid heat exchangers (SLHX) [9][10]. However, some problems are still found. The natural refrigerants that are made from hydrocarbons have flammable properties and the advantages of SLHX installation rely on the combination of operating conditions and the properties of the fluid [10].

In general, the technique of hot gas injection is used to defrosting process on the evaporator [11][12][13]. Difference with other report, the technique of hot gas injection in this study is used to increase the cooling capacity and lowering the discharge temperature of the refrigerant. When the refrigeration system off cycling, the pressure of both low side and high side will be the same. However, when the refrigeration system starts running both pressure values will differ significantly. Therefore, the technique of hot gas injection to the suction line is needed to reduce the pressure difference on both sides.

The purpose of this study was to determine the increase in performance of a refrigerator utilizing hot gas refrigerant from the compressor’s discharge which was injected into the suction line. This method is adopted from the heat pump cycle [14][15], which useful to maintain the balance of the capacity of the evaporator and compressor when the pressure and temperature of refrigerant at the suction channel are low. Therefore, the application of this engineering method to domestic refrigerators is expected to reduce the load of the compressor when doing compression work; this will have an impact on the...
increased value of coefficient of performance systems (COPs) and the decrease of energy/power required as the driving force.

2. Materials and Experimental method

Figure 1 shows the layout of a domestic refrigerator used for the experiment. The test unit was a Sanyo refrigerator and designed to work with R-134a refrigerant. The main components of the domestic refrigerator consist of evaporator, compressor, condenser and refrigerant control. Components of the hot gas injection line consist of a 2 m capillary tube and a check valve. Two pressure gauges (Robin Air, USA) and two temperature sensors (Lutron, Taiwan) were placed on the inlet and outlet of the compressor to measure the suction and discharge pressures. On the inside of the refrigerator, a container of brine (salt water) weighing 500g was kept, serving as cooling load. A thermometer was placed in the brine container to determine changes in temperature every 1°C.

At the beginning of the research, the system was operated under a normal condition to obtain baseline data of the performance of the refrigerator. After that, hot gas injection line was installed to the suction line. Before the second data retrieval, the system was flushed using nitrogen to eliminate dirt, moisture and other substances in the system which might affect its performance. Then, the system was filled with R-134a weighing 100g in accordance with the recommendation of the manufacturer. Data capture started when the temperature of the brine was 3°C, with the assumption that the system was steady. Next, changes were observed until the temperature of the brine reached -3°C. During the study, the temperature of the environment was kept at 28°C ± 2°C. The research procedure was implemented 3 times to obtain the average value.

3. Results and Discussions

The results were obtained from the performance testing of the domestic refrigerator in two operating conditions: normal and hot gas injection. Tests were carried out at an ambient temperature of 28°C in the refrigeration cycle operating mode under load conditions of 3°C to -3°C.
3.1. Work of compression

Figure 2 shows the results of the compression works of the domestic refrigerator under two testing conditions. In general, the compression work generated by the system using hot gas injection has a lower value than that of the normal system. In the normal system, the compression generated when the brine was 3°C was 26.27 Btu/lb. Then, this increased gradually to 26.57 Btu/lb when the temperature of the brine was -1°C. After that, it fell back to 26.48 Btu/lb when the temperature of the brine was -3°C. On the other hand, in the system which used hot gas injection, the compression work generated when the brine was 3°C was 25.25 Btu/lb. Further, this gradually decreased to 25.12 Btu/lb when the temperature of the brine was -3°C. Based on the results, there had been a 5% decrease of compression work in the system using hot gas injection. The effects of the use of the hot gas injection on the domestic refrigerator result in a smaller ratio of discharge and suction pressures, causing the compression work which compresses vapour from condensing pressure to evaporating pressure becomes shorter. Such results/values will contribute to the energy consumption of the compressor, which becomes smaller.

Figure 2. The work of compression based on temperature changes of the brine

3.2. Coefficient of performance

Figure 3 presents coefficient of performance data (Cop) of two conditions of the domestic refrigerator testing. In the normal system, the Cop decreased along with the decreasing temperature of the brine. At first, the obtained Cop was 2.15 when the temperature of the brine was 3°C; the Cop of 2.12 was obtained when the brine temperature was -3°C.

Figure 3. Acquisition Cop value based on changes in temperature brine
Further, when the system employed hot gas injection, Cop increased significantly. When the temperature of the brine was 30°C, the obtained Cop was 2.27. Then, the value fluctuated to 2.29 when the brine temperature was -30°C. These results indicate that the use of hot gas injection on the refrigeration system results in the increase value of Cop, which is 7%. The great value of Cop indicates that the system worked properly. The value of Cop is influenced by the amount of heat which can be absorbed by the refrigerant flowing in the evaporator (refrigeration effect), and the compression work performed by the compressor when it compressed the low temperature-pressured refrigerant vapour to high temperature-pressured refrigerant vapour. If the value of the refrigeration effect is big and the value of compression work are small, the Cop obtained will be large. The bigger the value of the refrigeration effect and the smaller the value of the compression work, the value of Cop obtained will be better.

4. Conclusions
Research on the use of hot gas injection to improve the performance of domestic refrigerators has been conducted. To demonstrate the performance improvement of refrigerators, we tested the refrigeration system in two different conditions. The results indicate that hot gas injection to the suction line generates an increased value of coefficient of performance (Cop) and lowers the temperature discharge. This has a significant implication for the lighter work of the compressor and low electrical power needed by the refrigerator.

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