Experimental study of hydrocarbon refrigerant (R-1270) to replace R-32 in residential air conditioning system

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Abstract. The purpose of this study was to test the performance of hydrocarbon refrigerant (R-1270) to replace R-32 refrigerant. The refrigerant R1270 is a propylene-base refrigerant (C3H6), while R32 is a synthetic refrigerant. Both refrigerants were tested on residential air conditioning systems with similar specifications. At pressure of 100 psig and external air temperature of 25 °C, the Coefficient of Performance (CoP) and Energy Efficiency Ratio (EER) of R32 were better than those of R32. The electrical power consumption of R1270 was 12.5 % more efficient than R32. In terms of volume used, R1270 required was 53.5 % lower than that of R32. The air temperature coming out of the evaporator of R1270 was 1 °C lower than that of R-32. This research showed that R-1270 could be used to replace R-32 effectively.

1. Introduction
Refrigerant used in air-conditioning system is often related to energy conservation, global warming, and ozone protection [1]. There are two main groups of refrigerants: synthetic refrigerants (CFC-HCFC-HFC) and natural refrigerants (HC). Synthetic refrigerants are produced chemically. It is technically good since it has high stability, it is less flammable, colorless, and odorless, and it has no toxin. However, synthetic refrigerant uses non-environmentally friendly compounds [2], such as chlorofluorocarbon (CFC), hydrochlorofluorocarbons (HCFC), and hydrofluorocarbon (HFC). The three compounds could endanger the ozone layer that may lead to global warming [3].

Natural refrigerant or hydrocarbon (HC) is a type of refrigerant that is extracted from natural gas and it has short shelf life at the atmosphere, which is less than one year [4]. Hydrocarbon refrigerant has density, viscosity, and pressure that are lower than those of the synthetic refrigerant. It does not harm the ozone layer nor cause the global warming effect. However, this refrigerant is not widely used yet. There is a concern from the consumers regarding the flammability of the hydrocarbon refrigerant. This characteristic is actually not dangerous if the refrigerant is used following the correct procedure. Hydrocarbon is flammable when it exists together with two other compounds called as the fire triangle: hydrocarbon, the air, and source of fire in certain amount. If one of the three factors is not available, thus there would be no fire incident [5].

Propylene or R-1270 is a hydrocarbon refrigerant with the chemical term C3H6. Its characteristics make it suitable to be used to replace the synthetic refrigerant for residential air conditioning system [6]. The strengths of R-1270 are: it is harmless to the ozone layer (ODP-0) and it has low effect on global warming, which is <2. The thermodynamic characteristics of R-1270 are suitable for efficient use of energy source. It has good compatibility with the components of air conditioning system, it has low cost of usage and good thermal conductivity, and it needs pipes with smaller dimensions [7]. The relative capacity index (RCI) of R-1270 is better than R-22 by 27.5 % [8]. The current types of refrigerant used...
by residential air conditioning system are R-32 and R-401a. Both types are synthetic refrigerants that are less friendly to the environment and they have high pressure [9].

Table 1. Comparison of characteristics of R-32 and R-1270 [10].

| Component                        | R-32 (HFC) | R-1270 (HC) |
|----------------------------------|------------|-------------|
| Ozon Depleting Potential (ODP)   | 0          | 0           |
| Global Warming Potential (GWP)   | 675        | <2          |
| Safety group classification      | A2L        | A3          |
| Chemical Formula                 | CH2F2      | C3H6        |
| Boiling point at 1 bar (°C)      | -52        | -47.7       |
| Critical Pressure (bar)          | 54         | 46          |
| Critical temperature (°C)        | 78         | 92          |

R-32 has been used in the new units of residential air conditioning system, while R-1270 has not [11]. In the current study, the performance of both refrigerants was tested. The tests were important to collect data needed to compare both refrigerants. The parameters measured were: inlet and outlet air temperatures of the evaporator, outlet air temperature of the condenser, the amount of refrigerant used, electrical current and voltage, CoP and EER.

The coefficient of performance (CoP) is a number that describes the effectiveness of refrigerators or air conditioners that is measured by comparing the heat released from the instrument to perform its work. The coefficient is similar to the thermal efficiency of heat engines, as they both provide data of the efficiency of the instrument as compared to the cost of operation. The higher the CoP, the lower the work of the compressor to perform equal cooling effect. Higher CoP shows that the air conditioning unit has good work performance. Meanwhile, the energy efficiency ratio (EER) measures how efficiently an air conditioner operates at a specific outdoor temperature. EER is measured by dividing the cooling rate (Btu/hr) with the power input to the compressor (watt), thus EER is presented as Btu/hr per watt. The value of EER can also be calculated by using the following formula: CoP x 3.412. The value of EER shows the power used by the compressor to provide higher cooling rate. The higher the EER value, the more efficient the work of the air conditioning unit.

2. Research methodology
The research was performed as an experiment. The materials used were R-32 and R-1270 refrigerants. The experimental unit was a residential air-conditioning unit with the capacity of 1 hp. The first experiment measured the performance of the residential air conditioning unit by using R-32. In the second experiment, the refrigerant of the residential AC was replaced with R-1270. The performance of the unit was measured and compared. The parameters collected were: inlet air temperature of the evaporator (°C), outlet air temperature of the evaporator (°C), outlet air temperature of the condenser (°C), external air temperature (°C), electrical current at the compressor (ampere), the mass of refrigerant used at each pressure (gram), the amount of total refrigerant used (gram), electrical voltage at the compressor (volt), coefficient of performance (CoP), energy efficiency ratio (Btu/hr-W), and the variation of temperature at every suction.

3. Results and discussion
The results of the experiment using both refrigerants were collected from a unit of air conditioning system. There were eight parameters that were measured and observed at variety of pressure suction [12]. The parameters represent the performance of the residential AC unit.

Table 2 shows the maximum suction pressure of R-32 was 140 psig, while the value for R-1270 was 120 psig. The different pressure values showed that both refrigerants had different characteristics. The more pressure needed, the higher the electrical power consumed. Thus, R-1270 was shown to have lower
consumption of electrical power than R-32. If the electrical power is low, then the electrical current needed is also low. Therefore, R-1270 was shown to need lower electrical current than R-32.

Table 2. Comparison of performance of R-1270 and R-32.

| No | Parameter                               | Refrigerant | Pressure (psig) |
|----|-----------------------------------------|-------------|----------------|
|    |                                         |             | 40  | 60  | 80  | 100 | 120 | 140 |
| 1  | Inlet air temperature of the evaporator | R-32        |     |     |     |     |     |     |
|    | (°C)                                    | R-1270      | 24.9| 24.2| 23.8| 23.3| 21.4| 20.5|
| 2  | Outlet air temperature of the evaporator| R-32        |     |     |     |     |     |     |
|    | (°C)                                    | R-1270      | 23.5| 23.6| 23.7| 23.3| 21.8| 21.8|
| 3  | Outlet air temperature of the condenser | R-32        |     |     |     |     |     |     |
|    | (°C)                                    | R-1270      | 24.9| 25.5| 25.0| 23.8| 30.1| 30.9|
| 4  | External air temperature (°C)           | R-32        |     | 26  | 25  | 24  | 25  | 26  |
|    |                                         | R-1270      |     | 25  | 25  | 25  | 25  | 25  |
| 5  | The amount of refrigerant used at every | R-32        |     | 149 | 149 | 149 | 149 | 149 |
|    | pressure (gram)                         | R-1270      |     | 64  | 48  | 20  | 23  | 27  |
| 6  | Total amount of refrigerant used (gram)  | R-32        |     | 149 | 149 | 149 | 149 | 149 |
|    |                                         | R-1270      |     | 64  | 112 | 132 | 155 | 182 |
| 7  | Electrical current at the compressor    | R-32        |     | 2.13| 2.19| 2.19| 2.31| 2.43|
|    |                                         | R-1270      |     | 2.10| 2.19| 2.19| 2.31| 2.43|
| 8  | Electrical voltage of the compressor    | R-32        |     | 221 | 221 | 221 | 221 | 221 |
|    |                                         | R-1270      |     | 220 | 221 | 221 | 221 | 221 |

The external temperature is the atmospheric temperature of the air that would enter the evaporator to be cooled down. The inlet temperatures at the evaporator using both types of refrigerants were similar. Meanwhile, the outlet air temperature of the evaporator is the cold air that is supplied into the room where the AC unit is installed. The outlet air temperature of the evaporator of R-1270 was lower than R-32, which shows that the air supplied by R-1270 was cooler than that of R-32. Thus, the residential AC unit that used R-1270 could produce cooler air.

How cool the air conditioning system depends on the amount of refrigerant used. The amount of refrigerant used at every increase of the pressure showed a large difference [13]. The amount of refrigerant used by R-1270 was lower than R-32. Therefore, the total amount of refrigerant needed was also different. With lower amount of R-1270, it could produce lower air temperature. This result showed that R-1270 was more efficient in terms of amount of refrigerant used [14]. The total amount of R-1270 used was lower by 53.7 % from R-32.

The electrical voltage needed by both refrigerants was equal: 220 volt 50 Hz. Table 2 shows that at every increase of suction pressure, R-1270 needed lower electrical current. Meanwhile R-32 had higher use of electrical current at every increase of suction pressure [15]. Low consumption of electrical current would affect the electrical power used. At the experiment, R-1270 showed that it consumed lower electrical power than R-32 by 12.6 %.

Table 3. Comparison of CoP and EER of R-1270 and R-32.

| No | Parameter                               | Refrigerant | Pressure (psig) |
|----|-----------------------------------------|-------------|----------------|
|    |                                         |             | 40  | 60  | 80  | 100 | 120 | 140 |
| 1  | Coefficient of Performance (CoP)        | R-32        |     |     |     |     |     |     |
|    |                                         | R-1270      | 4.49| 4.17| 3.88| 3.52| 3.19| 2.93|
| 2  | Energy Efficiency Ratio (EER)           | R-32        |     |     |     |     |     |     |
|    |                                         | R-1270      | 15.34| 14.24| 13.24| 11.99| 10.88| 9.98|

Table 3 shows the CoP and EER of R-1270 and R-32 at variety of pressure [16]. The CoP and EER of both refrigerants showed a decreasing trend at every increase of suction pressure [17]. The CoP and EER values of R-1270 were higher than those of R-32 at every increase of suction pressure. High suction pressure would bring high risk on the piping system of the air conditioning unit [18]. CoP shows the performance of an air conditioning and the highest value of CoP is 10. The higher the CoP, the better the performance of the air conditioning system [19]. Meanwhile, EER is an indicator of the efficiency of the air conditioning unit. EER is derived from the cooling rate of the input power of the compressor.
and presented as Btu/hour/watt. EER shows the use of low electrical power to result in higher cooling rate [20]. High EER shows the efficiency of the air conditioning unit.

4. Conclusion
The refrigerant R-1270 had better performance than R-32. It can replace the use of R-32 at residential air conditioning system. Air conditioning unit that used R-1270 was more efficient than R-32.

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