Performance analysis of R290 as a substitute for R404A on 12,000 Btu.h cold storage capacity

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Abstract. Cold Storage is a machine that has a very low temperature: -30°C which is used for the freezing process. Cold storage used for this research has a capacity of 18,000 Btu.h with R404A. This refrigerant does not contain ODP but still contains a very high GWP: 3940 compared to R290. R290 (propane) is GWP: 4 and ODP: 0. But this refrigerant has flammable properties between LFL - UFL: 2 - 10%. The cold room dimensions: 3 x 1.5 x 2.5:11.25 m^3. The testing methodology by comparing the performance of R404A with R290 cold storage conditions was tested without using a cooling load with a room temperature setting of -29°C, room temperature of 35°C and RH: 70%. Time Testing is carried out for 90 minutes. From the test results obtained data: evaporator temperature: -29°C with a time of 68 minutes for R290 and 95 minutes for R404A, LP: R404A / R290: 12/6 Psig, discharge pressure: 215 / 175 Psig and the amount of refrigerant entered in the system: 3500/1800 grams and electric current: 4.1/2.9 Amperes. From the data analysis, it can be concluded that R290 has better performance, energy-saving, and environment friendly compared to R404A.

1. Introduction

Cold storage is a cooling machine with cold room temperatures reaching -29°C. This cold room is usually used to store fish, meat, and other ingredients with a view to freezing. The purpose of this freezing is to maintain the quality of the goods stored in the refrigerator. The main components of this cold storage machine consist of the cold room, evaporator, outer unit, control panel, thermostat, ventilator, and other accessories. R404A is a mixed type refrigerant consisting of R125 / R143a / R134a (44/52/4%) content with ODP: 0 and GWP: 3922 while R290 is a hydrocarbon refrigerant with ODP: 0 and GWP: 3 content. R290 refrigerant or called propane has a density of 30% lower compared to R404a and has a flammable nature with an LFL / UFL threshold: 2-10% [1,2]. The purpose of this research is to compare the performance of R290 with R404A especially in cooling speed, compression work, COP and savings in electricity consumption.

1.1. Safety aspect hydrocarbons refrigerant

The sole disadvantage of using HCs is their flammability and the risk of explosion. It is recommended that small refrigerators with refrigerant charges of less than 150 gram should be preferentially purchased where an option to do so exists. Larger charges can be used, provided safety conditions are met. The limiting factor associated with the use of HC refrigerants is the refrigerant charge size, the occupancy category, and the room size. Systems with charge sizes of 0.15 kg or less may be installed in a room of any size. However, for systems with a charge size of more than 0.15 kg and up to 1.5 kg, the room size
should be such that a sudden loss of refrigerant does not raise the mean gas concentration in the room above the practical limit 0.008 kg/m³. If it is proposed to use even large charges of HC, this is permitted although it is strongly recommended that European Norm (standard) EN 378 on the safety of refrigerants be consulted for safety recommendations [3,4].

1.2. Consideration of using hydrocarbons refrigerant
Hydrocarbons (HCs) HC refrigerants are natural compounds that are generally available at a low cost and have excellent thermodynamic properties. HCs have been widely used in petrochemical applications, where the use of flammable substances is well understood. They are chemically stable and their application outside the petrochemical area is rapidly growing [5]. Domestic refrigeration is an obvious application; here, safe systems are easy to achieve because the system charges are small (smaller than contained in a cigarette lighter, in many cases). Many small and medium commercial applications are also feasible for various HC refrigerants, where safety requirements are adhered to (28) Article 5 countries and in some non-Article.

Cold Storage consists of two main parts, namely cold room cold room which includes an evaporator, thermostat, ventilator and timer. And the outdoor unit which includes a condenser, compressor, HP and LP control neaple for charging refrigerant. Below is figure 1 diagram of cold storage [6]:

![Cold Storage Diagram](image_url)

**Figure 1.** Diagram cold storage system.

2. Methodology
The method used in this research is to refer to previous research by testing the next cold storage unit after stable data collection is performed. This test refers to the data written on the nameplate. Furthermore, the cold storage unit is tested using Refrigerant R290 refers to the weight of the refrigerant entered into the system a maximum of 50% of the total amount of refrigerant written on the nameplate [7]. In the same way, data retrieval is carried out after the conditions are stable. Cold storage unit testing only with a load of an empty room with a volume: 11.25 m³. Test chamber temperature 33°C and RH: 80%. Thermostat settings are made of two variations: temperature -25°C and -29°C. In carrying out the process of filling hydrocarbon refrigerants, they must pay attention to safety aspects in accordance with standards, use standard work equipment, and be carried out by technicians who have competency certificates. Data is collected by noting: cold room temperature, High Pressure, Low Pressure, Electric current, test chamber temperature, cooling speed, and humidity [8].

3. Data and analysis
From processing cold storage test data obtained the following results:
Below is a graph of the test results of the performance of suction and discharge pressure in cold storage using R404A refrigerant and thermostat settings in the cooling room -25°C. Suction pressure ranges from 14-25 Psig. While the discharge pressure between 220-230 Psig, in detail, can be seen in figure 2 below:
Below is the graph of the test results of the performance of suction and discharge pressure in cold storage using R404A refrigerant and the thermostat setting in the cold room -29°C. Suction pressure ranges from 12-30 Psig. While the discharge pressure between 215-235 Psig in detail, can be seen in figure 3. below:

**Figure 3.** Graph of Suction and discharge Pressure (Psig) versus time (minute) room temperature -29°C.

Below is a graph of the results of the test performance of suction and discharge pressure in cold storage using refrigerant R290 and the thermostat setting in the cooling room -25°C. Suction pressure ranges from 23-30 Psig. While the discharge pressure between 180-210 Psig, in detail, can be seen in figure 4. below:

**Figure 4.** Graph of Suction and discharge Pressure (Psig) versus time (minute) room temperature setting -25°C R290.
Below is a graph of the results of the test performance of suction and discharge pressure in cold storage using refrigerant R290 and thermostat settings in the cooling room -29°C. Suction pressure ranges from 6-30 Psig. While the discharge pressure between 175-210 Psig, in detail, can be seen in figure 5. below:

**Figure 5.** Graph of Suction and discharge Pressure (Psig) versus time (minute) room temperature -29°C R290.

Graph Comparison of suction pressure R404A with R290, R290 has a lower suction pressure compared to R404A because it has a lower density at the time 70 minute after stabile R404: 18 Psig and R290: 6 Psig. The details, can be seen in figure 6. below:

**Figure 6.** Graph of Comparison Suction Pressure R404A Vs R290

Table 1 below shows the ratio of discharge pressure to time until it reaches a constant pressure. A fairly high-pressure difference of R290 is seen that is 40 Psig lower when compared to R404A. due to differences in density and saturated vapor pressure owned by R290.

**Table 1.** Comparison Discharge Pressure (Psig) versus time(minute).

| Refrigerant Type | Time (minute) |
|------------------|---------------|
|                  | 15 | 30 | 45 | 60 | 68 | 75 | 95 |
| R404a            | 235| 225| 222| 220| 218| 216| 215|
| R290             | 210| 200| 185| 180| 175| 175| 175|

Graphic Comparison of R404A with R290 discharge pressure, R290 has lower discharge pressure compared to R404A due to having a lower density. In the R404: 220Psig and R290: 175Psig stabile conditions in detail can be seen in figure 7 below:
Figure 7. Comparison graph discharge-pressure R404A Vs R290.

Graphic Comparison of cooling speed of R404A with R290, R290 has a faster cooling speed compared to R404A because it has lower latent heat. In a stable condition with a temperature setting of -29°C R404: it takes 90 minutes and R290: only 60 minutes in detail can be seen in figure 8 below:

Figure 8. Graph comparison graph of cooling speed cold room temperature R404A Vs R290.

Graphic Comparison of electrical current of R404A with R290, R290 has a little bit to R404A because it has lower compression work. In a stable condition with a temperature setting of -29°C R404A: it takes 90 minutes and R290: 4.2 A, R290: 2.9A, in detail can be seen in figure 8 below:

Figure 9. Graph comparison of average current R404A and R290

Calculating the performance R404A of Cold storage by using the mollierChart software by referring to the evaporator temperature (cold room) for each refrigerant the following results at figure 10 in below:
Figure 10. Performance calculation used mollier chart software R404A

Calculating the performance R404A of Cold storage by using the mollierChart software by referring to the evaporator temperature (cold room) for each refrigerant the following results at figure 11 in below:

Figure 11. Performance calculation used mollier chart software R290

From the results of calculations performed using the MollierChart software the results of cooling performance are obtained in table 2 below:

| Refrigerant Type | Refrigeration Effect(kJ/kg) | Work Compression(kJ/kg) | COP | Current (Ampere) |
|------------------|-----------------------------|------------------------|-----|-----------------|
| R404A            | 99,8                        | 63,97                  | 1,56| 4,1             |
| R290             | 260,7                       | 137,9                  | 1,89| 2,9             |

4. Conclusion
From the results of calculations and analyzes conducted, the cold storage performance results are as follows:

a. The suction pressure when using R404A is higher compared to R290: 50% increase.
b. The release pressure when using R404A is higher compared to R290 18.6% increase.
c. The speed of recovering R290 cooling is faster than R404A. 15 minutes faster.
d. By using R290 More efficient refrigerant filling: 1,700 grams (44.7%) 
e. By using R290 can reduce electricity consumption by 29.3%
f. COP (coefficient of performance) is almost the same, only the difference of 0.2, R290 is better compared to R404A.
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