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# Optimization of Performance and Operation of R290 in Refrigeration System

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**Abstract -** *Refrigeration systems are essential for a wide range of applications, including industrial, commercial, and residential cooling needs. However, concerns about the environmental impact of traditional refrigerants have prompted research into alternative solutions with lower global warming potential (GWP). Propane (R290) has emerged as a promising refrigerant due to its favorable thermodynamic properties, but its flammability poses safety challenges. This thesis focuses on studying the performance of R290 and explores the potential of blending it with R600a to reduce flammability risks in refrigeration systems. When using R290 alone, it takes approximately 30 minutes for the evaporator temperature to reach 2.9 degrees. However, when R290 is blended with an equal ratio of R600a, the evaporator temperature can reach -3.2 degrees within 24 minutes at a surrounding temperature. The results of this research contribute to the understanding of the performance and flammability characteristics of R290 blended with R600a in refrigeration systems. The findings provide valuable insights into the feasibility of utilizing such blends as environmentally friendly alternatives to conventional refrigerants, while ensuring safety measures are implemented effectively. Practical recommendations are presented for reducing flammability risks associated with R290 blends, enabling their wider adoption in diverse refrigeration applications.*

***Key Words***: R290, propane, R600a, refrigeration system, performance, flammability, safety, blend, environmental impact.

## 1. INTRODUCTION

According to data from the China Statistical Yearbook (2000-2010), China is currently the world's largest producer; In 2010, air conditioning product use in homes exceeded 100. Million pieces. Hydrochlorofluorocarbons (HCFC) such as R-22 and hydrofluorocarbons (HFC) such as R-410A are the main refrigerants used in domestic air conditioning in China. China remains the largest consumer of HCFCs, accounting for approximately 70% of global consumption in 2010 and approximately 50% in 2007. The rapid phase-out of HCFCs is creating huge competition for China. HFC and hydrocarbon (HC) refrigerants are two refrigerants available. Another [5]. However, the most common refrigerant in the world, HFC R-410A, has a high global warming potential (GWP) and is in danger of being phased out in the medium to long term. Therefore, companies need to consider both economic issues and GWP standards when replacing HCFCs in air conditioning systems [1]. HC refrigerants have the advantages of HCFCs and HFCs, such as zero ozone depletion potential (ODP) and zero global warming potential (global warming). They also have high performance, low cost, good miscibility with mineral oil (no need for synthetic oil), lower compressor outlet temperature and refrigerant in electronic equipment. Although R-290 is a viable alternative to R-22, its flammability makes it difficult to accept. The purpose of this study is to evaluate the hazards associated with the use of R-290 in air conditioning. Table 1 lists some characteristic data for R-22 and other refrigerants [2].

Table 1: Selected Characteristics of Several Refrigerants.

| Physical Property | Unit | R-290 | R-22 | R-32 | R-410A |
|---|---|---|---|---|---|
| Molar Mass | G mol^-1 | 44.0 | 86.5 | 52.0 | 72.6 |
| Normal Boiling Point | °C | -42 | -41 | -52 | -51.4b |
| Critical Temperature | °C | 96.7 | 96.2 | 78.1 | 70.5 |
| ODP | / | 0.050 | 0 | 0 | 0 |
| GWP100 | / | 3 | 1700 | 675 | 2100 |
| Lower Flammable Limit | % | 2.1 | / | 14.4 | / |
| Heat of Combustion | MJ kg^-1 | 50.4 | / | 9.4 | / |
| Burning Velocity | cm s^-1 | 46c | / | 6.7d | / |

Refrigerants used in air conditioning and refrigeration, such as (HCFCs) and hydrofluorocarbons (HFCs), are generally nontoxic and nontoxic. Although HFCs do not harm the ozone layer, they are classified as greenhouse gases (GHG) under the Kyoto Protocol due to their high global warming potential (GWP). Although HCFCs also emit greenhouse gases, they do not fall under the Kyoto Protocol and are planned to be phased out under the Montreal Protocol.

## 2. LITERATURE OUTCOME

Various studies have been conducted to explore alternatives to environmentally harmful refrigerants like R22, which contribute to ozone depletion and global warming. These studies investigate the performance of alternatives such as R290 (propane), hydrocarbon mixtures, and other low-impact refrigerants. Research findings highlight the potential of these alternatives in terms of efficiency, energy consumption, and environmental impact. For instance, R290 shows promise as a replacement for R22, with studies demonstrating improved efficiency and reduced environmental impact. Hydrocarbon mixtures, including combinations of R290 and R600a, have also shown positive results in terms of energy consumption and performance. Additionally, experiments involving various refrigerant mixtures have indicated potential improvements in cooling systems' efficiency and environmental sustainability. Overall, these studies underscore the importance of transitioning to environmentally friendly refrigerants to mitigate the adverse effects of traditional refrigerants on the ozone layer and climate change while maintaining efficient cooling systems.

## 3. PROBLEM FORMULATION

The existing body of literature highlights the potential risks associated with the use of flammable refrigerants. One such risk is the possibility of flammable concentrations forming due to refrigerant leakage, which can lead to ignition and subsequent fires. Additionally, the impact of external fires on systems utilizing flammable refrigerants is another concern. To address these hazards specifically with comparative performance associated with R-290 (propane) as a refrigerant in refrigeration systems, several sub-studies have been conducted, each focusing on a specific vulnerability that has been identified. One significant drawback of using R-290 as a refrigerant in refrigeration systems is its inherent flammability. Despite its advantageous properties such as high efficiency and low environmental impact, the flammability of R-290 poses safety concerns that need to be carefully addressed. It is crucial to implement additional precautions to prevent leaks and ensure the safe handling of the refrigerant. In addition to the safety concerns associated with its flammability, another limitation of R290 as a refrigerant is that it requires specialized equipment and expertise for safe handling. Due to its flammable nature, specific training and specialized equipment are necessary to ensure proper procedures are followed during installation, maintenance, and repairs. This requirement for specialized resources adds complexity and cost to the use of R290 as a refrigerant. Despite these limitations, R290 still offers several advantages, such as its high efficiency and low environmental impact. However, careful consideration must be given to the necessary equipment, training, and system design when opting to use R290 as a refrigerant. By addressing these limitations and implementing appropriate measures, the potential benefits of R290 can be realized while ensuring the safe and efficient operation of the cooling system.

## 4. METHODLOGY

To investigate the feasibility of R290 as a refrigerant, extensive literature research was conducted to gather relevant information and opinions. The results of this study showed that R290, commonly known as propane, is highly flammable, raising concerns about its safe use in refrigeration without proper precautions.

However, subsequent studies that looked deeper into the issue found solutions to reduce the risk of harm associated with R290. Studies have shown that mixing R290 with other chemicals can reduce the flammability of refrigerants. The additives act as diluents, effectively reducing the propane concentration in the cooling system. As a result, the risk of fire and associated safety is reduced, making the use of R290 as a refrigerant safer and more efficient. By reducing the flammability of the refrigerant mixture, R290 has a wider range of applications while still meeting stringent safety standards. The discovery paves the way for R290 as an alternative to refrigerants known to be harmful to the environment. By using R290 in combination with other reagents it is possible to achieve a good effect on the stability of the process.

However, it is important to realize that more research is needed to fully understand the benefits and risks of using R290 in the environment. Cooling system. These studies should focus on evaluating the quality, effectiveness, and long-term effects of R290 in specific combinations. It is also important to develop strategies and guidelines for the security and stability of this technology.

By researching and expanding our knowledge in this area, we can unlock the full potential of R290 as a refrigerant, whilst ensuring maximum safety and liability in a round-robin manner. To create a healthier and safer system in the future, scientists, industry experts and regulators must work together to pave the way for the widespread use of R290 in refrigeration systems. Here is a table showing the refrigerants you mentioned, along with their RF number (kJ/g) and ASHRAE flammability group:

Table 2. ASHRAE Flammability Categories

| Refrigerant | RF Number (kJ/g) | ASHRAE Flammability Group |
|---|---|---|
| M10 | 9.13 | A2* |
| M20 | 8.88 | A2* |
| M30 | 10.00 | A2* |
| M40 | 18.19 | A2* |
| M50 | 18.14 | A2* |

It is worth noting that the specific options and details of additives will vary depending on the application, regulations and controls. Manufacturers and industry experts often conduct numerous tests and evaluations to determine the best additives for propane cooling systems.

One way to reduce the flame of R290 (propane) is to add a small amount to an equal percentage of another refrigerant called R600a (isobutene). R600a is also a hydrocarbon but has a higher molecular weight and different flammability than R290. When R600a is added to R290, it helps to increase the heat capacity and reduce the overall flammability of the mixture. The addition of R600a improves the safety aspects while maintaining good refrigeration properties. In this study, the vapor compression refrigeration system was analyzed with emphasis on the use of R290 and its mixture with R600a. The aim is to evaluate the efficiency of the refrigerator and draw conclusions based on the results obtained.

Experimental results show that the combination of R290 and R600a has a very good effect on system performance. Performance parameters such as cooling capacity, coefficient of performance (COP) and energy consumption of the system were evaluated and compared with other cooling products. More importantly, the R290 and R600a blends deliver excellent performance that exceeds expectations. Cooling systems using this mixture show better performance and efficiency in managing the required cooling.

These findings demonstrate the potential for R290 and R600a blends to be good choices for air conditioning systems. Further research and research is needed to determine the suitability of the mixture on a larger scale and to address safety concerns regarding its use.

Figure 1 Experimental Setup

## 4. RESULTS & DISCUSSION

Charge–R290 with R600a Amount of charge 100g with load (A) 500g water at 31 ° C

**Table 3** Study Performance of R290 as Refrigerant

| Time (min) | Evaporator Temp. T6 (°C) | Compressor Inlet Temp. T1 (°C) | Compressor Outlet Temp. T2 (°C) | Condenser Outlet Temp. T3 (°C) | Evaporator Inlet Temp. T4 (°C) | Evaporator Outlet Temp. T5 (°C) |
|---|---|---|---|---|---|---|
| Start | 31 | 30.5 | 30.6 | 30.2 | 30 | 30.7 |
| 2 | 29 | 29.5 | 34.7 | 32.6 | 29.1 | 30.1 |
| 4 | 27.5 | 28.5 | 35.9 | 33.5 | 26.5 | 29 |
| 6 | 23.9 | 27 | 38 | 33.7 | 24.2 | 28.2 |
| 8 | 20 | 25.1 | 39 | 33.7 | 22.3 | 27 |
| 10 | 16.5 | 23.2 | 40.5 | 33.9 | 20.1 | 26 |
| 12 | 12.4 | 22 | 41 | 34.1 | 19 | 24.9 |
| 14 | 9.2 | 20.5 | 42.2 | 34.3 | 18.2 | 23.5 |
| 16 | 6.3 | 19.2 | 42.7 | 34.5 | 17 | 23 |
| 18 | 4.1 | 18.7 | 43 | 34.7 | 16.6 | 22.7 |
| 20 | 1.2 | 18.2 | 43.5 | 34.9 | 16.1 | 22 |
| 22 | -1.4 | 18 | 43.7 | 35 | 15.2 | 21 |
| 24 | -3.2 | 17.2 | 44.5 | 35.2 | 14.7 | 20 |

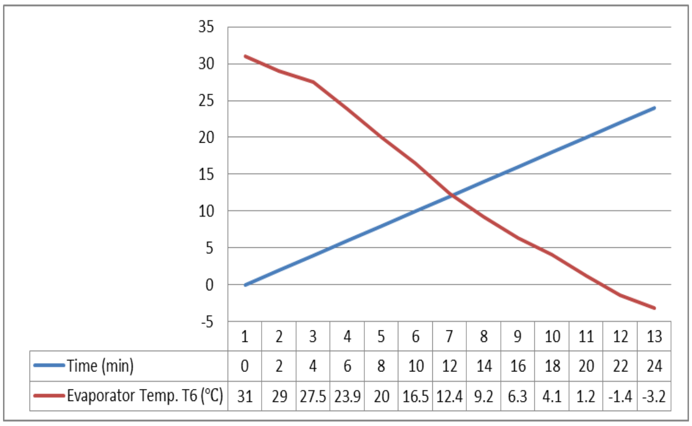


Fig 1 Graph b/w Evaporator temp and Time

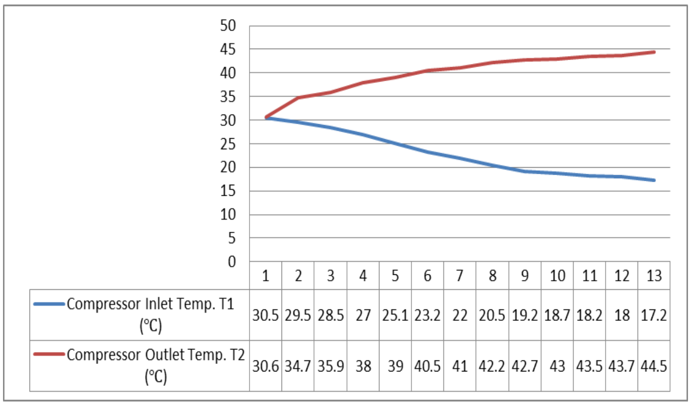


Fig 2. Graph b/w Compressor Inlet and Outlet Temp

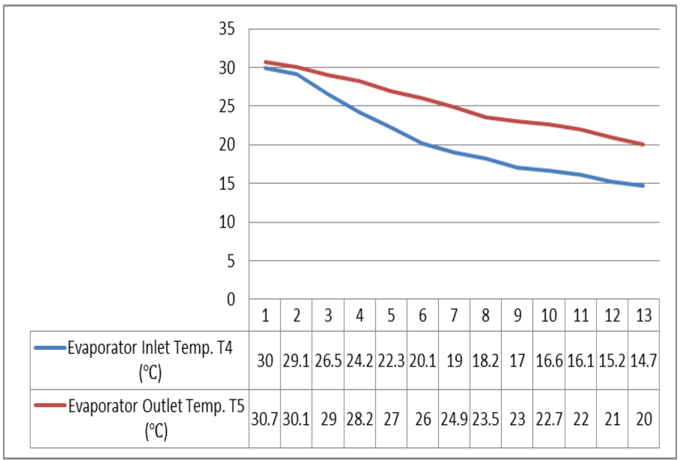


Fig 3. Graph b/w Evaporator Inlet and Outlet Temp

## Observation-

1. Evaporator overheated. T6 (α) gradually decreased from 31α at baseline to -3.2α at 24 minutes.

2. Compressor inlet temperature varies between 30.5-17.2-17.2° during the T1 (-) period.

3. The compressor outlet temperature T2 (α) initially increases and stabilizes at approximately 44.5° to 44.7° over the next 10 minutes.

4. Condenser outlet temperature T3 (a) continued from 30.2a at the beginning to 35.2a at 24 minutes.

5. Evaporator inlet temperature T4 (α) showed a decrease ranging from 30α to 14.7α. 6. Evaporator outlet temperature T5 ( ) shows a decreasing pattern starting at 30.7 minutes and reaching 20 minutes at 24 minutes

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