Review Paper on Compressor Oil Used in Refrigeration System

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Abstract: *This review examines the stability of PAG, POE, and PVE oils used in refrigeration system compressors, along with their interactions with low- and ultra-low-GWP refrigerants. Key findings reveal minimal degradation and strong compatibility under standard conditions. Following ASHRAE 97 standards, the study highlights the necessity of long-term stability evaluations and advocates for further research into lubricant additives, refrigerant interactions, and metal components to improve system reliability.*

Keywords: *Refrigerant, Refrigeration system, PAG Oil, POE Oil, PVE Oil, Compressor Desiccant.*

1.0 Introduction

The refrigeration industry is moving towards low and ultra-low GWP refrigerants as a result of the growing emphasis on environmental sustainability. This change, however, calls for a thorough comprehension of the stability and performance of compressor oils—specifically PAG, POE, and PVE oils—when combined with these novel refrigerants. In order to address the potential and challenges related to this transition, this review assesses the existing understanding of these oils' compatibility and stability.

1.1 Oil used in refrigeration system compressor

A. PAG Oil: PAG Lubricant Because of their exceptional miscibility with specific refrigerants and strong thermal stability, PAG oils are utilised extensively. Their hygroscopic nature, however, may make it difficult to control the system's moisture levels.

B. POE Oil: POE oils are prized for their ability to work with low-GWP refrigerants and hydrofluorocarbons (HFCs). For many applications, they are the preferable option due to their comparatively reduced hygroscopicity as compared to PAG oils.

C. PVE Oil: PVE oils are appropriate for ultra-low-GWP refrigerants due to their remarkable chemical and thermal stability. System dependability is increased by their low affinity for moisture.

1.2 Chemical Stability and Compatibility of Desiccants

Chemical stability refers to the resistance of refrigeration oils to chemical reactions, such as oxidation and hydrolysis, during operation. PAG, POE, and PVE oils exhibit varying degrees of chemical stability influenced by their molecular structures. PAG oils are prone to hydrolysis in the presence of moisture, while POE oils offer better resistance but can still degrade under high moisture and temperature conditions. PVE oils, with their robust chemical structure, exhibit the highest resistance to chemical degradation.

Compatibility focuses on the interaction between oils and system components, including refrigerants, seals, and metals. All three oils demonstrate compatibility with most low- and ultra-low-GWP refrigerants, though specific refrigerant-oil pairings may require further testing to prevent issues such as phase separation, material swelling, or corrosion. Ensuring chemical stability and compatibility is essential to maintaining the reliability and efficiency of refrigeration systems.

2.0 Literature Reviews

2.1 Chemical Stability Investigations of Low-GWP Refrigerants (2022) - AHRTI Project 9016

This study conducted by Kujak et al. explores the chemical stability of six low-GWP refrigerants—R-1234ze(E), R-450A, R-515B, R-1234yf, R-513A, and R-516A—when paired with various lubricants, including polyalkylene glycol (PAG), polyolester (POE), and polyvinyl ether (PVE) [1]. Using highly accelerated life tests (HALT) based on ASHRAE Standard 97, the study assessed breakdown products and lubricant-metal interactions at elevated temperatures (175°C). Key findings include:

- Minimal reactivity between the refrigerants and materials under typical HVACR conditions.

- Differences in total acid number (TAN) and dissolved metals depending on the lubricant type.

2.2 Chemical Stability Investigations of Ultra-Low GWP Refrigerants (2022)

This follow-up study by the same authors examines ultra-low GWP refrigerants like R-1336mzz(Z), R-1336mzz(E), R-514A, R-1233zd(E), and R-1224yd(Z). It highlights the unique stability challenges posed by olefin refrigerants due to their double-bond chemistry [2]. Findings include:

- R-1336mzz variants showed high stability with no significant polymerization under test conditions.
- Reduction and nucleophilic substitution reactions were minimal but highlighted the importance of material compatibility.

2.3 Miscibility of POE and PVE Oils with Low-GWP Refrigerant R-1234ze(E) (2016)

Lee et al. focused on the miscibility of POE and PVE oils with R-1234ze(E). Miscibility was tested across a wide range of temperatures (-35°C to 80°C) and oil concentrations [3]. Findings include:

- POE exhibited better miscibility with R-1234ze(E) than PVE, especially at oil mass fractions below 20%.
- Phase separation in certain conditions could pose operational challenges for HVAC systems.

2.4 Tribological Study Comparing PAG and POE Lubricants Under CO2 (2008)

Nunez et al. compared PAG and POE lubricants in compressors operating with CO2 as a refrigerant. Using a high-pressure tribometer [4], the study observed:

- PAG outperformed POE in scuffing and wear resistance due to the formation of protective carbonate layers.
- POE's miscibility with CO2 resulted in a viscosity drop, adversely affecting its tribological performance.

2.5 Performance of PVE Lubricants with HFC Refrigerants (2002)

Tominaga et al. examined the application of PVE lubricants with HFC refrigerants. PVE demonstrated superior performance compared to POE due to [5]:

1. Higher pressure-viscosity coefficients, indicating stronger oil films under high pressure.

2. Resistance to hydrolysis, reducing system failures related to moisture exposure.
3. Improved prevention of capillary tube blockage, attributed to reduced sludge and corrosion formation.

3.0 Summary and Key Insights

Chemical Stability: Both low- and ultra-low-GWP refrigerants show promising stability with minimal degradation under test conditions, but material compatibility remains crucial.

Lubricant Properties: PAG and PVE offer advantages over POE in specific scenarios, such as resistance to hydrolysis and better performance under high pressures.

Operational Challenges: Miscibility and phase separation need careful consideration when selecting lubricant-refrigerant pairs for HVAC systems.

4.0 ASHRAE 97 Standards

ASHRAE 97 provides a structured approach to evaluating material compatibility and stability in refrigeration systems. The study adheres to ASHRAE 97 by evaluating the performance of activated alumina and molecular sieves in contact with PAG, PVE, and POE oils. The mechanical degradation and pH changes of desiccants under different conditions were observed. HVAC equipment, which typically lasts 15-25 years, requires long-term refrigerant stability, which is further influenced by the interactions between lubricants and desiccants.

5.0 Final Recommendations

Given the findings of this study, future research should focus on:

1. Long-term stability and performance under varying operational conditions.
2. The impact of lubricant additives on chemical stability and refrigerant compatibility.
3. Understanding the interactions between HFO refrigerants and lubricants, especially in the presence of desiccants.
4. The role of metal components, especially zinc, in accelerating the degradation of refrigerants and lubricants.

6.0 Conclusion

In his review highlights the stability and compatibility of PAG, POE, and PVE oils with low- and ultra-low-GWP refrigerants. While current studies indicate minimal degradation and favourable interactions under standard conditions, the need for comprehensive long-term stability assessments remains critical. Future research should focus on developing advanced lubricant formulations, exploring refrigerant-oil-metal interactions, and optimizing system designs to ensure the reliability and sustainability of refrigeration systems.

Abbreviations

ASHRAE - American Society of Heating, Refrigerating & Air Conditioning Engineers

HALT - Highly Accelerated Life Tests

HVAC - Heating Ventilation Air Conditioning

HVACR - Heating Ventilation Air Conditioning & Refrigeration

HFO - Hydrofluoroolefins

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