

DESICCANT COMPATIBILITY TEST WITH PAG, PVE & POE COMPRESSOR OIL

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Abstract - The aim of this study is to evaluate the chemical compatibility and stability of two commonly used desiccants, activated alumina and molecular sieves, with three types of lubricants: Polyalkylene Glycol (PAG), Polyvinyl Ether (PVE), and Polyol Ester (POE) oils. Following the ASHRAE 97 standard, the study tests the chemical stability of the desiccants in each oil type to ensure optimal performance in refrigeration and air conditioning systems. The research focuses on two key objectives: assessing desiccant degradation through a crushing test and measuring pH values to identify any chemical reactions after exposure.

The experimental procedure involves placing the desiccants in sealed glass tubes with PAG, PVE, and POE oils, then subjecting them to elevated temperatures over an extended period, as outlined by ASHRAE 97. After the exposure period, the desiccants undergo a crushing test to determine any loss in mechanical strength or structural degradation. In addition, the pH of the oils is measured to identify any changes in acidity or alkalinity, which would indicate chemical reactions between the desiccants and the oils.

Initial findings suggest varying levels of compatibility between the desiccants and the oils, with both activated alumina and molecular sieves showing some degree of mechanical degradation in specific oil environments.

In conclusion, the study highlights the importance of selecting desiccants that are chemically stable and compatible with the specific oils used in refrigeration systems. These findings provide valuable insights for optimizing system longevity and performance, ensuring that the choice of desiccant minimizes chemical reactions and system failures.

Key Words: Desiccant, Filter Drier, ASHRAE, PAG Oil, PVE Oil, POE Oil

1. INTRODUCTION

Refrigeration System Moisture Management In refrigeration and air conditioning systems, managing

moisture effectively is critical to ensuring optimal performance and longevity of the equipment. Moisture can lead to several issues, such as corrosion, ice formation, and a decrease in system efficiency. If moisture is not adequately controlled, it can damage vital components, leading to expensive repairs and reduced operational reliability [15]. To address this, desiccants like activated alumina and molecular sieves are used to absorb excess moisture. These materials help maintain the system's performance by preventing water-related damage. However, desiccants can interact with lubricating oils used in refrigeration systems, including Polyalkylene Glycol (PAG), Polyvinyl Ether (PVE), and Polyol Ester (POE) [2]. Understanding how desiccants interact with these lubricants is essential because it can influence the efficiency and stability of the entire refrigeration system [7].

1.1 Components of Filter Drier

Core: The core ensures proper flow and prevents clogging or damage to other components. It holds the filter and desiccant materials securely in place.

Inner Bore: It directs the flow of refrigerant in an efficient manner to maximize the exposure to the desiccant and filter materials, ensuring effective moisture removal and filtration.

Screen: The screen prevents solid contaminants from reaching sensitive parts of the system like the compressor, valves, or expansion devices. It prolongs the life of the desiccant and keeps the system running smoothly.

Spring: The spring ensures that the components remain securely positioned, preventing movement that could cause leaks or poor filtration performance.

- **Activated Alumina & Molecular sieves:** Activated alumina plays A critical role in removing water from the system & molecular sieves act as both a filter and drying agent in the refrigeration system [10].

1.2. Chemical Stability and Compatibility of Desiccants

Chemical stability refers to a material's ability to maintain its physical and chemical properties under specific conditions over time. When desiccants are exposed to lubricating oils in a refrigeration system, chemical reactions can occur. These reactions can lead to the degradation of the desiccant, reducing its ability to absorb moisture effectively [14]. Additionally, these interactions can impact the properties of the lubricating oil, such as its viscosity and acidity, which are crucial for maintaining proper lubrication and preventing mechanical wear [9]. Lubricating oils play a vital role in refrigeration systems by reducing friction between moving parts, dissipating heat, and sealing critical components. If a desiccant interacts negatively with a lubricating oil, it can cause changes in the oil's properties, leading to poor lubrication, increased wear and tear, and a higher risk of system failure. Activated alumina and molecular sieves are commonly used desiccants in refrigeration systems. Activated alumina consists of highly porous aluminum oxide that provides excellent moisture absorption, while molecular sieves are synthetic crystalline materials with uniform pores designed for selective moisture adsorption [11]. Although both desiccants are chemically stable under normal conditions, they may degrade when exposed to high temperatures, contaminants, or incompatible lubricants.

1.3. Effects of Moisture on Refrigeration Systems

Corrosion: Moisture can react with metal components, leading to rust and deterioration. This weakens the system and can cause leaks or complete failure.

Ice Formation: In low-temperature applications, moisture can freeze and block narrow passages, disrupting refrigerant flow and reducing cooling efficiency.

Acid Formation: Moisture can interact with refrigerants and oils to form acids, which can degrade system components over time.

Oil Degradation: If moisture reacts with lubricating oils, it can change the oil's viscosity, making it less effective at reducing friction and protecting moving parts [8].

1.4. ASHRAE 97 Standards

The ASHRAE 97 standard is a widely recognized testing method used to evaluate the compatibility and chemical stability of materials in refrigeration systems.

These standards outline procedures to assess how different materials, such as desiccants and lubricants,

behave under high temperatures and operating conditions [3]. The ASHRAE 97 testing process involves exposing materials to elevated temperatures for an extended period while monitoring their physical and chemical changes. Key factors assessed in these tests include: Mechanical Degradation: How well the desiccant maintains its structure and absorption capacity under high temperatures.

pH Changes: Any changes in the acidity or alkalinity of the lubricating oil, which can affect its performance and lead to potential system damage.

Oil Stability: Whether the oil maintains its viscosity and lubricating properties after prolonged exposure to the desiccant.

By following ASHRAE 97 guidelines, researchers can determine whether activated alumina and molecular sieves are suitable for use with different lubricating oils in refrigeration systems. The goal of these tests is to ensure that desiccants and lubricants work together efficiently without causing chemical instability or reducing the system's lifespan.

1.5. Compatibility of Desiccants Refrigeration Lubricants

Understanding the interaction between desiccants and refrigeration lubricants is essential for selecting the right combination of materials to maximize system efficiency and durability [13]. Below is a breakdown of how activated alumina and molecular sieves interact with different lubricating oils.

1.5.1 Polyalkylene Glycol (PAG) Oil PAG oils are widely used in automotive air conditioning systems and some refrigeration applications. They offer excellent lubrication properties and thermal stability [12].

1.5.2 Polyvinyl Ether (PVE) Oil

PVE oils are commonly used in CO₂ refrigeration systems and are known for their excellent thermal stability and lubrication properties [7].

1.5.3 Polyol Ester (POE) Oil

POE oils are used in modern refrigeration systems, particularly those using hydrofluorocarbon (HFC) refrigerants. They offer good lubrication and chemical stability but can be sensitive to moisture. Activated Alumina with POE: Effective in moisture absorption but may contribute to slight acid formation over time.

1.5.4 Key Aspects

1. Moisture management is a crucial aspect of maintaining refrigeration and air conditioning systems.

2. Desiccants such as activated alumina and molecular sieves help remove moisture, preventing common issues like corrosion, ice formation, and oil degradation. However, their interaction with lubricating oils can impact system performance.

3. By adhering to ASHRAE 97 standards, researchers and engineers can assess the compatibility and stability of desiccants with different lubricating oils.

4. Molecular sieves generally offer better performance in maintaining oil stability and preventing chemical reactions that may compromise the system's efficiency.

5. Understanding these interactions allows for better material selection, ultimately enhancing the reliability and lifespan of refrigeration and air conditioning systems.

2. Literature Review

1. Stephen Kujak et. Al (2022) carried out Chemical Stability

Investigations of Ultra-Low GWP Refrigerants and their lubricant. They used sealed glass tube method as per

ASHRAE 97 standards and observed that lubricant chemistry on the breakdown of the various hydrofluoroolefin (HFO) refrigerants tested [1].

2. Stephen Kujak et. Al (2022) carried out Chemical Stability Investigations of Low GWP Refrigerants with lubricants. They used sealed glass tube method as per ASHRAE 97 standards and observed that potential compatibility issues and reactivity concerns that could affect the reliability and lifespan of refrigeration equipment. The research addresses a gap in existing literature regarding the interactions between these refrigerants and materials [2].

3. Morgan Herried et. Al (2022) Chemical Stability Investigations of Low GWP Refrigerants Chemical Stability Investigations of Low GWP Refrigerants R-454B, R-454C, R-455A, R-468A, R-466A with Lubricants. They used sealed glass tube method and observed lubricant chemistry involvement on the breakdown of various hydrofluoroolefin refrigerant [3].

4. S Tominaga et. Al (2002) various performance of polyvinyl ether (PVE) with HFC Refrigerant. They used Actual machine tests were conducted to evaluate PVE

performance and observed that PVE demonstrates superior lubricity and solubility with HFC refrigerants. PVE reduces capillary tube blockage compared to POE. PVE has lower precipitation temperature in practical conditions [4].

5. Nunez et. Al (2008) Tribological Study Comparing PAG and POE Lubricants used in Air-Conditioning Compressors under the Presence of CO₂. They used High pressure tribometer for tribological tests. Pin-on-disk configuration for lubricant evaluation and observed that tribological behaviour. Selecting the right lubricant is crucial for efficient, sustainable air-conditioning systems [5].

6. Günsel et. Al (1999) Elastohydrodynamic Lubrication with Polyolester Lubricants and HFC Refrigerants. They used ultrathin film EHD interferometry technique for film thickness measurement and observation is It focuses on predicting lubricant film thickness. The challenge lies in evaluating lubricant properties under varying conditions [6].

Key Findings

In order to determine degradation pathways and film-thickness behaviours, these studies use sealed glass tube tests, real-cycle system trials, and EHD interferometry to assess the chemical stability of ultra-low and low GWP refrigerants with various lubricants.

Using high-pressure pin-on-disk tribological evaluations, PAG, POE, and PVE oils are further compared, especially in CO₂ and HFC environments, to maximize wear, friction, and compatibility for low-GWP refrigeration systems.

3. Problem Statement

The compatibility of desiccants with lubricating oils is crucial for the reliable operation of refrigeration and air conditioning systems, as chemical interactions can lead to desiccant degradation and compromised system performance. This study seeks to identify the effects of activated alumina and molecular sieves on the stability of polyalkylene glycol (PAG), polyvinyl ether (PVE), and Polyol Ester (POE) oils, following ASHRAE 97 standards.

4. Methodology

4.1 Experimental Setup

ASHRAE 97 standards provide guidelines for evaluating the thermal stability and chemical compatibility of lubricants and desiccants in refrigeration and industrial applications. These standards help determine the performance of materials under specified temperature conditions over an extended period. The controlled

exposure conditions ensure that the degradation and interactions of lubricants and adsorbents are measured accurately. The standard testing procedures include [3].

4.1.1 Materials Selection:

1.Desiccant used:

a) Molecular Sieves (3A to4A): A porous material commonly used for moisture removal and gas purification. used 50g per sample

b) Activated Alumina (3 to 4 mm): a porous material used remove water moisture. Used 50g per sample

2.lubricant used: 100mL per sample

a) Polyvinyl ether (PVE): A synthetic lubricant commonly used in R-134a refrigeration and industrial applications.

b) Polyol ester (POE): A widely used lubricant in R-134a air conditioning and refrigeration systems.

c) Polyalkylene glycol (PAG): A synthetic oil with excellent thermal stability Used in automotive R-134a Refrigeration air conditioning system.

3.Beakers (250 ml): six beakers used to hold the oil and desiccant separately, ensuring no cross contamination.

4.1.2 Equipment's: To ensure accurate and reliable results, the following equipment was used

1.Hot Air Oven: Set to maintain a consistent temperature of 70°C for 14 days to simulate prolonged exposure conditions.

2.Crushing Strength Tester: It is used to measure the mechanical integrity of the adsorbents after exposure to the oils

3.pH Testing Materials: pH paper for quick qualitative assessment. o Universal Indicator for more precise pH measurement.

4.Weighing Balance: High-precision balance used to measure the adsorbents accurately (50g per sample)

5. Glassware: Beakers, stirrers, and pipettes for handling and mixing the samples.

4.2 Experimental Procedure:

1.Beakers cleaned with lab. grade soap and water.

2.Beaker Placed for drying.

3.Sample of desiccants and lubricants were prepared.

4. Each beaker is filled with 100ml oil (PAG, POE, PVE), and each oil has two samples of activated alumina and molecular sieves 50g each.

5.Mixture of activated alumina and molecular sieves were prepared for the three different oil (PAG, POE, PVE) samples.

6. beakers were sealed with filter paper.

7.The hot air oven was pre heated and set for 70°C temperature

8.Once the 70°C temperature is reached, the samples were kept into oven for 14 days.

9.After 14 days of exposure, the samples were removed from hot air oven and kept for cooling at the room temperature.

10. desiccants were separated from the oils and taken for pH measurement using Ph paper as well as universal indicator

11.After pH measurement, separated desiccants were preserved for crushing test.

12.The results obtained from the laboratory tests were evaluated and analyzed



Fig -1: sample preparation & testing

5. Results analysis:

5.1 Crushing Strength Test of Desiccants: During crushing test, we checked 15 sample each and took the average value of these samples (fresh & after exposure) for activated alumina and molecular sieves.

Table -1: Crushing strength test

Crushing Strength Test			
Desiccant	Condition	Avg. Crushing Strength (Kg)	Avg. Crushing Strength (N)
Activated Alumina	Fresh Sample	13.17	129.17
	PAG	13.53	132.76
	PVE	12.53	122.95
	POE	12.8	125.57
Molecular Sieves	Fresh Sample	20.27	198.82
	PAG	22.8	223.67
	PVE	19.53	191.62
	POE	24.23	237.73

Analysis of activated alumina

Fresh Activated Alumina shows a solid baseline crushing strength of 13.17 Kg.

PAG oil exposure slightly increases the crushing strength (13.53 Kg), possibly due to minimal chemical interaction or oil residue filling surface pores.

PVE exposure shows the lowest strength (12.53 Kg), indicating potential weakening of structure, likely due to chemical softening or pore damage.

POE oil results in a moderate value (12.80 Kg), showing some reduction but not as significant as PVE

The pie chart supports this by showing a relatively even distribution among condition.

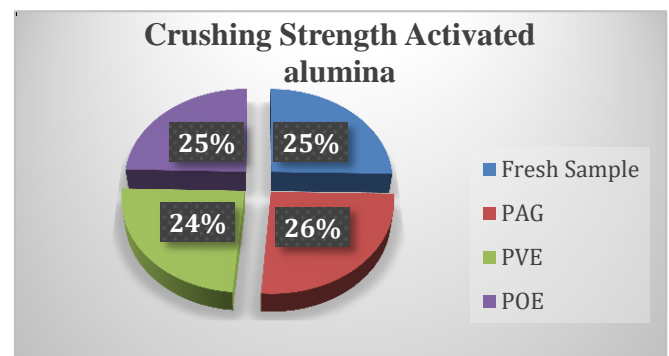


Chart -1: Crushing strength

Oil exposure does have a mild effect on Activated Alumina. The impact is most noticeable with PVE, suggesting it may compromise mechanical integrity over time.

Molecular sieve:

Fresh Molecular Sieves have a high initial strength of 20.27 Kg, already significantly stronger than Activated Alumina. PAG oil increases crushing strength (22.80 Kg), which may result from pore filling or oil-induced surface hardening.

PVE causes a slight drop (19.53 Kg), indicating a small weakening effect.

POE oil shows the highest average strength at 24.23 Kg, implying excellent stability and potential reinforcement under this condition.

The pie chart for Molecular Sieves reveals a stronger contribution from POE and PAG

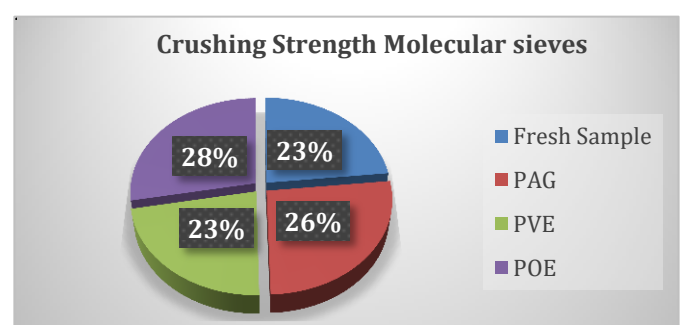


Chart -2: Crushing strength

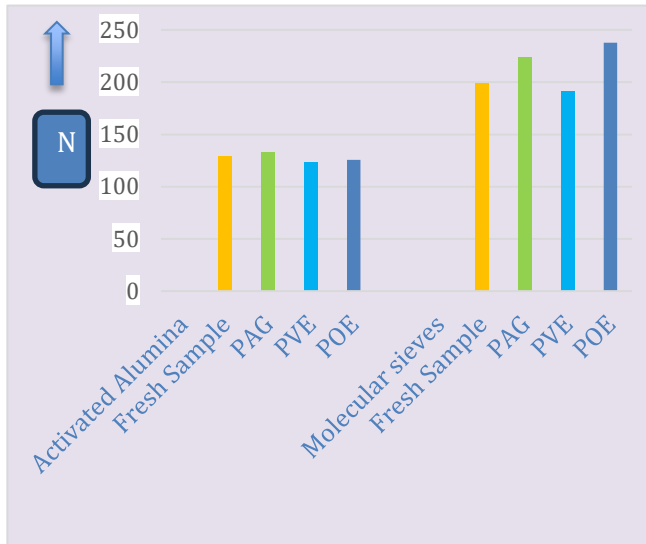
Molecular Sieves consistently outperform Activated Alumina in crushing strength. They

exhibit not only better initial strength but also greater resistance and, in some cases,

improvement when exposed to oil environments, especially POE.

Final Remark:

Molecular Sieves are more mechanically robust than Activated Alumina, across all conditions.



Graph -1: AA V/S MS

PVE tends to weaken both materials.

POE appears to stabilize or enhance strength, particularly in Molecular Sieves.

These insights are critical for selecting the right desiccant in refrigeration systems, where chemical interaction with oils is inevitable.

5.2 pH Measurement:

The experiment aimed to study the chemical stability (via pH check) of two desiccants Molecular Sieves and Activated Alumina after being exposed to synthetic refrigerant oils (PVE, POE, and PAG) at 70°C for 14 days in a controlled oven environment.

All samples (1 to 6) were subjected to both pH Paper and Universal Indicator testing methods before and after oil exposure.

The pH remained neutral (~7) in every case before and after the 14-day exposure, indicating no significant acidic or basic degradation occurred in any oil-desiccant combination.

The consistency across both pH testing methods (pH paper and universal indicator) further confirms the accuracy and repeatability of the results.

Table -2: pH Measurements

Results and Records						
Sample No.	Oil Type	Desiccant	pH Test Method	pH (Before Exposure)	pH (After Exposure)	Observation Summary
1	PVE	MS	pH-P	≈ 7	≈ 7	✗
	PVE	MS	UI	≈ 7	≈ 7	✓
2	PVE	AA	pH-P	≈ 7	≈ 7	✗
	PVE	AA	UI	≈ 7	≈ 7	✓
3	POE	MS	pH-P	≈ 7	≈ 7	✗
	POE	MS	UI	≈ 7	≈ 7	✓
4	POE	AA	pH-P	≈ 7	≈ 7	✗
	POE	AA	UI	≈ 7	≈ 7	✓
5	PAG	MS	pH-P	≈ 7	≈ 7	✗
	PAG	MS	UI	≈ 7	≈ 7	✓
6	PAG	AA	pH-P	≈ 7	≈ 7	✗
	PAG	AA	UI	≈ 7	≈ 7	✓

Symbolic Representation			
pH-P	pH Paper	MS	Molecular Sieves
UI	Universal Indicator	AA	Activated Alumina
✗	No change observed	≈ 7	Neutral
✓	Confirmed no change		

The results indicate chemical stability and compatibility of both Molecular Sieves and Activated Alumina with PVE, POE, and PAG oils, even after prolonged exposure to elevated temperatures. This reinforces their suitability as desiccants in systems using these synthetic oils, with no adverse effect on oil pH or degradation.

6. CONCLUSIONS:

The experiment results showed that POE refrigeration compressor oil was highly compatible with Molecular Sieves. In comparison, PVE compressor oil demonstrated poor compatibility with both desiccants. In case of PAG refrigeration compressor oil shows increasing crushing strength with both desiccants.

There was no change in pH before and after testing, proving both desiccants are chemically stable. pH tests confirmed that all samples stayed neutral (~7) even after 14 days at 70°C. This means both desiccants are safe and stable in use.

Molecular Sieves with POE oil are the best choice for reliable performance of refrigeration system.

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