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COMPATIBILITY OF MOTOR MATERIALS WITH POLYOLESTER LUBRICANTS:

EFFECT OF MOISTURE AND WEAK ACIDS

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ABSTRACT

This paper discusses the effects of various levels of acid and moisture in a Polyol Ester(POE) lubricant on the compatibility of motor insulation materials. Thirteen motor insulation materials were exposed to R-134a/POE lubricant combinations with four levels of acid and moisture for 500 hours at 127°C(260°F). The moisture levels were <50 ppm to 500 ppm and the weak acid levels were <0.05 to 2.0 mg KOH/g. The acid levels of the lubricant were raised by the addition of organic acids that would be produced by hydrolysis of the POE lubricants. The results were compared to a R-22/mineral oil exposure with the mineral oil containing a moisture level of <30 ppm and acid level of <0.01 mg KOH/g.

Results indicated that a 500 ppm moisture level in the polyolester lubricant had a greater effect on the motor materials than a high acid level. However exposure to R-134a/polyolester lubricant with a high moisture level had less effect than exposure to R-22 /mineral lubricant with a low moisture level.

INTRODUCTION

POE lubricants appear to be the lubricants of choice for air-conditioning and refrigeration equipment operated with HFC refrigerants. However, actual field experience with POE lubricants is limited to the equipment using R-134a sold within about the past 2 years

POE lubricants are known to be hydroscopic and do absorb greater amounts of water than compared to mineral oils. Secondly, POE's can hydrolyze in the presence of water to form weak acids and alcohols. Both effects could degrade materials used in hermetic motors and affect the reliability of air-conditioning and refrigeration equipment.

The purpose of this study was to determine the effects of moisture and/or weak acids in a POE lubricant with R-134a on commonly used motor materials

EXPERIMENTAL

The elevated moisture level in the POE was increased by the addition of known amounts of liquid water to the lubricant. After the addition of water, the oil was stirred vigorously for 2-4 days until a stable moisture level in solution was achieved. The weak acid levels were increased in the POE by the addition of a mixture of isonanoic and heptanoic acids that would form if the lubricant ideally hydrolyzed.

The motor insulation materials tested in this study were:

Magnet Wire Insulation(copper wire)
-Wire A was a modified polyester overcoated with a polyamide imide and epoxy saturated Dacron/glass.
-Wire B was a polyester imide overcoated with poly amide imide.

Sheet Insulation
-Nomex/Mylar/Nomex(NMN)
-Dacron/Mylar/Dacron(DMD)
-Mylar MO
-Nomex 410
-Nomex-Mica 418
-Melinex 228

Tape and Tie Cord
-Polyester

Varnish
-Proprietary 100% solid epoxy

Spiral Wrapped Sleeving
-Mylar
-Nomex

Samples of the motor materials were placed in a 2000 ml stainless steel vessel and covered with lubricant. An appropriate amount of R-134a was charged in the vessel to give a 25% refrigerant to 75% lubricant weight ratio. The vessels were then placed in a 260°F(127°C) oven for 500 hours. After the 500 hour exposure, the motor materials were removed and immediately tested. The specific tests performed were:

Varnished Magnet Wire
Bond Strength
Burnout Resistance
Dielectric Strength

Sheet Insulation
Tensile Strength
Elongation

Tapes and Tie Cords
Break Load Strength
Elongation

Varnish Disks
Weight Change
Volume Change

Spiral Wrapped Sleeving
Dielectric Strength

The lubricant used was Solest 68 from CPI Engineering. The moisture in the lubricant was measured with the Karl-Fisher method. The acid number of the lubricant was determined by the method described in ASTM D-664[7].

RESULTS AND DISCUSSION

Varnish and Varnished Magnet Wire

Table 1 shows weight and volume changes of the varnish disks after the various exposures. Visually the varnish disks appeared to be unaffected after the various exposures.

Table 1

Summary Weight and Volume Changes of Varnish Disks after Exposures.

	<50 ppm H_2O ≤0.05 Acid#	500 ppm H_2O ≤0.05 Acid#	<50 ppm H_2O 2.0 Acid#	500 ppm H_2O 2.0 Acid#
Weight Change	1.1%	3.1%	1.0%	3.2%
Volume Change	-0.1%	-1.4%	-0.1%	-1.5%

As shown in Table 1 the varnish disks exposed to a 500 ppm moisture environment had the largest weight gains. This increase in weight might be explained by the absorption of moisture from the lubricant, but analysis of the oil after the exposure indicated no significant change in the moisture content. If this increase in weight was due to moisture absorbed from the lubricant, the moisture level in the POE should have dropped by more than 50%. This data seems to indicate that R-134a and/or the POE lubricant is absorbed to a greater extent in the presence of moisture. Since all the motor materials were exposed in the same vessel, another possibility is that residual moisture in the sheet insulation samples was transferred to the POE and then to the varnish.

Table 2.

Effect of Moisture and Weak Acids on the Bond, Dielectric and Burnout Strength of Varnish Coated Magnet Wire.
% Change from Unexposed

Wire#A	Unexposed Results	<50 ppm H_2O ≤0.05 Acid#	500 ppm H_2O ≤0.05 Acid#	<50 ppm H_2O 2.0 Acid#	500 ppm H_2O 2.0 Acid#
Bond Strength	39.3 pounds	5.1%	7.5%	4.7%	9.6%
Dielectric Strength	14.2 kilovolts	33.1%	35.4%	18.1%	25.5%
Burnout Strength	764 seconds	0.0%	-0.1%	-2.4%	-0.2%
Wire#B					
Bond Strength	63.2 pounds	3.8%	-2.6%	4.8%	-3.5%
Dielectric Strength	18.5 kilovolts	-13.7%	-3.0%	-2.8%	-3.0%
Burnout Strength	333 seconds	18.3%	12.4%	-17.0%	9.6%

The bond strength of the varnish was not significantly influenced by the elevated levels of moisture and/or acid as shown in Table 2. Bond strengths showed very little change after any of the exposures. The dielectric and burnout strength of the varnish coated magnet wire also showed no significant changes. For Wire A(a glass served wire), the dielectric strength actually increased and the burnout strength remain unchanged. For Wire B(a polyester imide overcoated with poly amide imide) some variations were seen in the burnout strength, but this not considered significant. The elevated moisture and/or weak acid had no significant deleterious effects on the varnished magnet wire.

Sheet Insulation and Spiral Wrapped Sleeving

Tensile strengths and the elongations of the unexposed sheet insulation materials are given in Table 3. Table 4 and Table 5 show the effect of exposures on the tensile strengths and elongations of the sheet insulation materials. Results of exposure to R-22/mineral oil, from a previous study, are also included for comparison with results of the exposures to R-134a/POE with various water and acid levels[3].

Table 3

Unexposed Properties of Sheet Insulations.

	NMN	DMD	Mylar	Nomex	Nomex-Mica	Melinex
Tensile Strength, ksi	18.2	13.3	22.1	20.8	6.8	19.9
Elongation, %	25.7	27.7	125.0	14.1	1.8	151.8

Table 4

Effect of Moisture and Weak Acid on the Tensile Strength of Sheet Insulations.
% Change from Unexposed

	R-22/Mineral Oil	R-134a/Polyolester Oil			
	<30 ppm H_2O <0.01Acid#	<50 ppm H_2O ≤0.05 Acid#	500 ppm H_2O ≤0.05 Acid#	<50 ppm H_2O 2.0 Acid#	500 ppm H_2O 2.0 Acid#
NMN	-17.2%	-25.7%	-31.8%	-26.9%	30.9%
DMD	-10.7%	38.5%	32.5%	36.8%	35.2%
Mylar	-35.2%	0.1%	-13.9%	-0.6%	-16.2%
Nomex	-11.6%	-12.7%	-11.1%	-10.8%	-7.7%
Nomex-Mica	-25.6%	8.5%	4.0%	3.5%	11.4%
Melinex	-29.5%	-9.1%	-15.3%	-6.1%	-18.3%

Table 5

Effect of Moisture and Weak Acid on the Elongation of Sheet Insulations.
% Change from Unexposed

	R-22/Mineral Oil	R-134a/Polyolester Oil			
	<30 ppm H_2O <0.01Acid#	<50 ppm H_2O ≤0.05 Acid#	500 ppm H_2O ≤0.05 Acid#	<50 ppm H_2O 2.0 Acid#	500 ppm H_2O 2.0 Acid#
NMN	-41.9%	3.1%	1.8%	-4.5%	9.7%
DMD	-71.0%	-37.6%	-38.6%	-45.9%	-35.7%
Mylar	-87.8%	21.1%	-12.5%	16.6%	-4.6%
Nomex	-55.4%	-35.9%	-30.3%	-34.2%	-28.8%
Nomex-Mica	-79.2%	-23.6%	-23.6%	-27.8%	-27.8%
Melinex	-74.5%	-11.3%	-23.0%	-10.5%	-10.5%

Of the six sheet insulations tested, the Mylar and Melinex(PET films) materials showed some signs of moisture degradation. After the exposure to 500 ppm moisture, small losses in tensile strength and elongation were observed. These losses were not large, but were significantly greater than experienced after exposure to <50 ppm moisture. On the other hand, the tensile strengths and elongations of the PET insulations and of the other insulation materials were significantly degraded after exposure to R-22/mineral oil with <30 ppm moisture. The sheet insulations were not significantly affected by the elevated level of weak acids.

POE lubricants are much more hydrophilic(water loving) than mineral oil. Which means POEs can solvate water molecules to a much greater extent than mineral oils. Studies have shown water in mineral oils to have a great propensity to degrade PET sheet insulations[2]. Water which behaves in this manner is consider free water. The POE's ability to reduce the chemical potential of the water dissolved in it (solvated or bound water as opposed to free water) is evident in the results. Thus water concentrations normally considered to be high in mineral oils would not pose a significant concern in POE's to degrade PET sheet insulations.

The spiral wrapped sleeving material appeared to unaffected by the moisture and/or the weak acids. No significant change was observed in the dielectric strength of the sleeving material after any of the R-134a/POE exposures.

Tape and Tie Cord

Table 6

Effect of Moisture and Weak Acids on the Break Load Strength and %Elongation of Polyester Tie Materials.
% Change from Unexposed

	R-22/Mineral Oil	R-134a/Polyolester Oil			
	<30 ppm H_2O ≤0.01Acid#	<50 ppm H_2O ≤0.05 Acid#	500 ppm H_2O ≤0.05 Acid#	<50 ppm H_2O 2.0 Acid#	500 ppm H_2O 2.0 Acid#
Polyester Tape					
Breakload Strength	-60.3%	5.7%	3.9%	7.7%	0.0%
Elongation	-22.0%	-0.9%	-3.5%	2.4%	-5.6%
Polyester Tie Cord					
Breakload Strength	-61.6%	-9.6%	-9.1%	-8.6%	-8.6%
Elongation	18.9%	2.9%	9.7%	4.9%	14.9%

Unexposed breakload strength, Polyester Tape = 60.8 pounds, Polyester Tie Cord = 32.8 pounds.
Unexposed %Elongation, Polyester Tape = 18.7%, Polyester Tie Cord = 17.5%.

Table 6 summarizes the effects of exposure on the breakload strength and the elongation for the polyester tape and tie cord. The elevated moisture and/or weak acids had no deleterious effects on the tape or the tie cord. Again the exposure to R-22/mineral oil had a greater effect on the materials than the exposure to R-134a/POE.

CONCLUSIONS

1. The motor materials were not significantly degraded by exposure to R-134a/polyolester lubricant with elevated moisture levels and with elevated weak acid(carboxylic acids) contents that simulate possible hydrolysis of the polyol ester.

2. The motor materials were affected to a greater extent by the 500 ppm moisture in the POE than by the elevated weak acid content.

3. Most significant is that exposure to R-22/mineral oil with a usual moisture level of <30 ppm had a much greater effect on the motor materials compared with exposure to R-134a/POE at the highest moisture and weak acid content.

4. The results provide further confidence for the use of polyol esters lubricants in air-conditioning and refrigeration equipment.

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