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ABSTRACT

PVE (Polyvinyl ether) has been developed as a lubricant for air conditioning systems which use an alternative refrigerant such as HFC407C and HFC410A instead of HCFC22.

Because HCFC22 will no longer be used as a refrigerant in Japan after 2020, Japanese OEMs have started to convert their existing HCFC22 systems to an alternative refrigerant system, either HFC410A or HFC407C. During the conversion process, it is inevitable that the PVE will be mixed with the residual Mineral oil (MO) which was used in the HCFC22 system. Because of this, extensive evaluation has been conducted on the oil mixture between PVE and Mineral oil to determine it's suitability in a converted system.

The evaluations that were conducted include: Solubility, Thermal stability, Lubricity, Compatibility with system materials and the analysis data of used oil in a converted system. The evaluation results support that PVE is a very suitable refrigeration lubricant for air conditioning systems converting from HCFC22 to either HFC410A or HFC407C refrigerant.

1. INTRODUCTION

In 1974, Dr. Roland of the University of California indicated the destruction of ozone layer by CFCs and HCFC. This was reiterated during the Vienna Convention in 1985. In 1995 a ban was placed on CFCs by the Montreal Protocol.

Today, because of the increasingly strict environmental standards and pending termination of HCFCs in 2020, many HCFCs are being replaced by more environmentally friendly refrigerants. In the commercial air conditioning industry, HCFCs are being replaced by HFC, Hydrocarbon and natural refrigerants. In Japan, HFC Air conditioning systems were introduced to the commercial market in 2001. By the end of 2002, the transition to HFC was completed in the majority of new systems.

Older unitary A/C systems still using HCFC refrigerant (especially in multi systems for building) are now starting to require either total system replacement or refrigerant conversion to meet current environmental standards. With the conversion, installation cost and environmental waste can be reduced by using existing piping.

Although this is an advantage, there are several concerns to be evaluated before the system conversion.

First of all, compatibility between Mineral oil for HCFC systems and synthetic oil for HFC systems should be evaluated. This is because some Mineral oil will remain in the system and mixed with new installed synthetic oil. Secondly, the effect of air or water contamination during the conversion process should also be considered. This is because it is difficult to completely remove the contaminants during the conversion period.

In this report, the chemical and the practical evaluations have been conducted with Polyvinyl Ether (PVE) as a HFC A/C system lubricant, such as a miscibility/solubility with HFC[(1)], chemical/ thermal stability[(2)], lubricity [(3)(4)], and durability in actual systems[(5)].

2. TEST METHOD AND CONDITIONS

Table 1 shows the general specification of PVE and commercial Mineral oil (MO) for the HCFC22 system used in this report. A mixture of PVE and MO was prepared for each test (Table 2). Fig. 1 shows the apparatus used to measure the miscibility and solubility of the PVE/MO mixture with refrigerant. Fig. 2 shows auto clave equipment used to evaluate chemical and thermal stability of the mixture. This test was conducted under the condition of 175 degree C x 30 days. Fig. 3 shows the hermetic type block on ring lubricity test apparatus. The test condition for this is shown in Table 3.

Durability testing was conducted using a converted HCFC system. This included its original piping. During the testing, oil samples were taken and measured on a regular basis for total acid number and additive content.

3. TEST RESULTS AND ANALYSIS

3.1 Miscibility Test Results of PVE/MO Mixture

Fig. 4 and Table 4 show the CST and miscibility data for the PVE/MO oil mixture. Fig. 4 shows that two phase separation was found at both high and low temperature conditions with less than 3% MO in the PVE/MO mixture. With more than 3% MO in the mixture, it was found that the mineral oil was always separated to upper phase at any temperature.

Table 4 shows the miscibility of a PVE/MO mixture with HFC410A refrigerant at increasing levels of MO (5-20%) and at various temperatures (30-46 degree C). A 20% MO content in the PVE/MO mixture at 30 degree C showed a clear MO rich upper phase and PVE/HFC410A rich lower phase. The same mixture (20% MO) at 33 degree C showed the lower phase starting to get cloudy due to the immiscibility of MO in the PVE/HFC410A mixture. Finally at temperatures above 46 degree C, a definite cloudiness indicated the PVE was separating from the lower phase. These test results indicate a correlation between increasing temperatures and a 2 step oil separation with the PVE/MO and HFC410A mixture

In summary the test result indicate that excess amount of residual mineral oil left in a converted system can result in continuous oil separation through out the system. This may cause less efficient heat transfer performance at the condenser and evaporator. Furthermore, in the case of an inner low pressure compressor, oil separation in the compressor may cause liquid implosion. This information emphasizes the importance of system cleaning and the elimination of mineral oil to less than 2% in the conversion system.

3.2 Thermal Stability Test Results of PVE/MO Mixture

Table 5 shows the thermal stability test results of PVE/MO mixture by auto clave test equipment. In all PVE/MO mixture ratios, the mixture appearance remained clear and good. Also, the oils TAV did not significantly increase, and residue was not observed after testing.

These results indicate that contamination of mineral oil will not affect the thermal stability of the PVE.

3.3 Hydrolytic & Oxidative Stability Test Results of PVE/MO Mixture

During the conversion process, both internal and external heat exchangers must be replaced with new ones which meet the HFC system specification. It is possible that some air and/or water contamination will occur during the conversion process. Therefore, it is necessary to evaluate the system oil chemical stability because of the possible contamination.

Table 6 and 7 show the thermal stability test result of the oil mixture conducted by auto clave test equipment with air and water contamination. Dramatic increase of TAV was founded with 0.5% of water contamination, and with 760torr of air contamination (we supposed no vacuum process during the conversion process). These test result show the requirement of stringent air/water contamination control during the conversion process.

3.4 Lubricity Test Results of PVE/MO Mixture

Fig. 5 shows the lubricity test results of the PVE/MO mixture by a hermetic Block on Ring lubricity test equipment. There was no significant difference of wear on the block parts when comparing pure PVE and the PVE/MO mixture.

The wear on ring tends to increase by increasing the mineral oil ratio in the mixture. However, we could not find any scuffing on the surface. Because of this, we believe there would not be any severe wear problem in actual operation.

3.5 Endurance Test Results of PVE/MO Mixture

Durability test was conducted with the PVE/MO mixture (80/20 ratio) in a converted HCFC22 system using existing piping. Table 8 shows the Viscosity/TAV change, and Fig 6 shows the additive content in the mixture during the durability test.

At the start of the test, both antioxidant and acid catcher additives decreased slightly, then stabilized with no further reduction. This initial slight reduction is due to the additives reacting with the contaminants (acid and water) which remain in the converted systems. TAV did not increase during the durability test, and there was no reduction of anti-wear additive.

In summary, the durability test confirmed that PVE can be successfully used as a lubricant in a converted system as a system.

4. CONCLUSION

Various evaluations were conducted using PVE/MO mixture for a converted system.
The results indicated:

4.1 Oil separation: Excess amount of residual mineral oil in conversion systems will cause continuous oil separation through the systems, and may cause the less efficient heat transfer performance in the condenser and evaporator. It is important to clean the system during the conversion process, and to eliminate the mineral oil to less than 2%.
4.2 Thermal stability: Contamination by mineral oil will not affect the thermal stability of the PVE, however it will be necessary to remove the air/water contamination during the conversion process.
4.3 Lubricity: PVE/Mineral oil mixture show natural wear performance indicating that the contamination of mineral oil did not significantly affect the lubricity of PVE.
4.4 Durability: During durability test (using a converted system), initial reduction of antioxidant and acid catcher agent were found but quickly stabilized without any further reduction. The durability test also confirmed that PVE can be successfully used as a system lubricant in a converted HCFC system.

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Table1 General Specification of PVE & MO

		PVE68	MO56
Viscosity(@ 40℃)	mm^2/s	66.57	54.24
Viscosity(@100℃)	mm^2/s	8.037	5.986
Viscosity Index	-	84	12
Density(@15℃)	g/cm^3	0.9369	0.918
Pour Point	℃	-37.5	-35
Acid Number	mgKOH/g	0.01>	0.01>
Additives		Antioxidant	Antioxidant
		Antiwear	Antiwear
		Acid Catcher	—
Purposes & Refrigerant		A/C	A/C
		R410A/R407C	R22

Table2 General Specification of PVE/MO Mixture

MO		3%	10%	20%	50%
Viscosity(@ 40℃)	mm^2/s	66.15	65.19	63.85	60.02
Viscosity(@100℃)	mm^2/s	7.963	7.793	7.558	6.909
Viscosity Index	-	83	79	74	55
Density(@15℃)	g/cm^3	0.9363	0.9350	0.9331	0.9275
Pour Point	℃	-37.5	-37.5	-37.5	-37.5

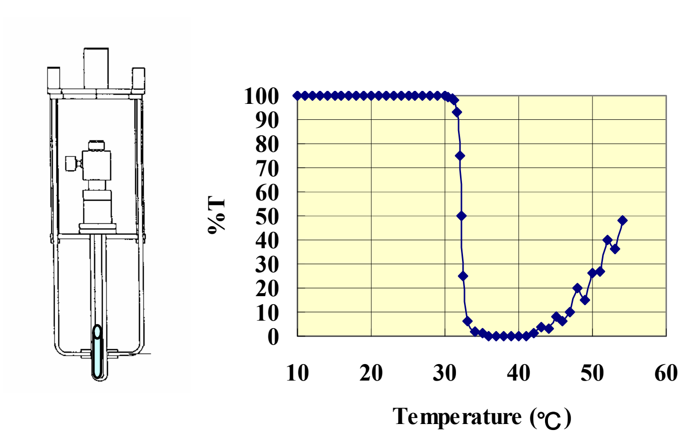
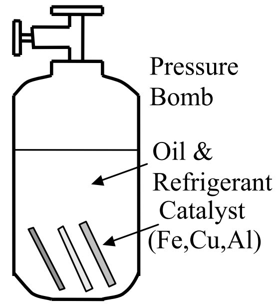


Fig.1 Miscibility Test apparatus and Method



Autocleave Test Condition
Duration: 30days at 175℃
Mixed Oil:50g
Refrigerant:30g
Catalyst :Fe, Cu, Al

Fig. 2 Autoclave Test

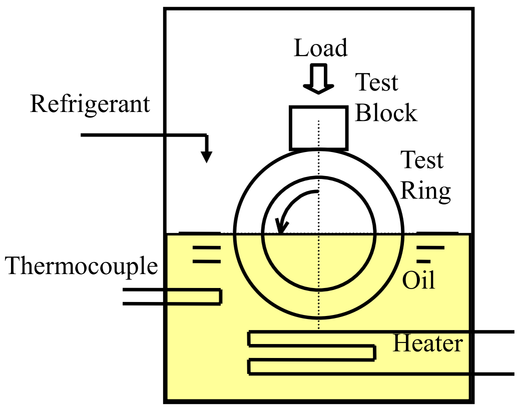


Fig. 3 Hermetic Type Brock on Ring Test Apparatus

Table 3 Lubricity Test Condition

Oil Temperature	100℃
HFC410A Pressure	1MPa
Revolution	500rpm
Load	980N(100kgf)
Test Time	60min.
Block	Steel (SKH51)

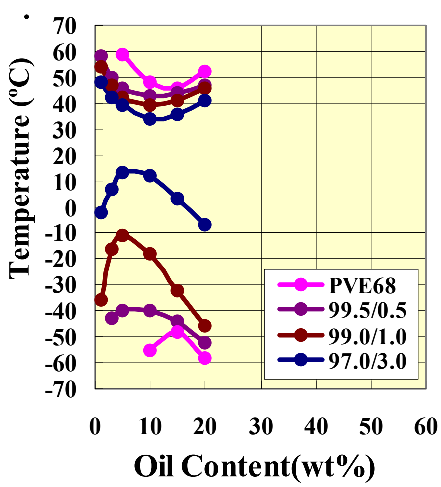


Fig. 4 CST Curves of PVE/MO Mixture

Table 4 Miscibility of PVE/MO (80/20) Mixture in HFC410A

Temp.	Layer(*1)	Oil Ratio			
		5%	10%	15%	20%
30℃	Upper	Clear	Clear	Clear	Clear
	Lower	Clear	Clear	Clear	Clear
33℃	Upper	Clear	Clear	Clear	Clear
	Lower	Clear	Clear	Cloudy	Cloudy
46℃	Upper	Clear	Clear	Clear	Clear
	Lower	Clear	Cloudy	Cloudy	Cloudy

(*1)Upper Layer(MO Rich) ,
Lower Layer(Refrigeration & PVE Rich)

Table 5 Thermal Stability Test Results of PVE/MO Mixture

MO (%)	0	3	10	20	50
Oil Form	Clear	Clear	Clear	Clear	Clear
AV（mgKOH/g)	0.01	0.01	0.01	0.01	0.01
Cat.Fe	Good	Good	Good	Good	Good
Cat.Cu	Good	Good	Good	Good	Good
Cat.AL	Good	Good	Good	Good	Good
Sludge	Non	Non	Non	Non	Non

Table 6 Hydrolitic Stability Test Results of PVE/MO Mixture
(@ PVE/MO=90/10)

Water content（ppm)	100	200	500	1000	5000
Oil Form	Clear	Clear	Clear	Clear	Clear
AV（mgKOH/g)	0.01	0.01	0.01	0.1	2.25
Cat.Fe	Good	Good	Good	Good	Good
Cat.Cu	Good	Good	Good	Good	Good
Cat.AL	Good	Good	Good	Good	Good
Sludge	Non	Non	Non	Non	Non

Table 7 Oxidative Stability Test Results of PVE/MO Mixture
(@ PVE/MO=90/10)

Air content（Torr)	10>	100	200	300	760
Oil Form	Clear	Clear	Clear	Clear	Clear
AV（mgKOH/g)	0.01	0.01	0.01	0.03	0.14
Cat.Fe	Good	Good	Good	Good	Good
Cat.Cu	Good	Good	Good	Good	Good
Cat.AL	Good	Good	Good	Good	Good
Sludge	Non	Non	Non	Non	Non

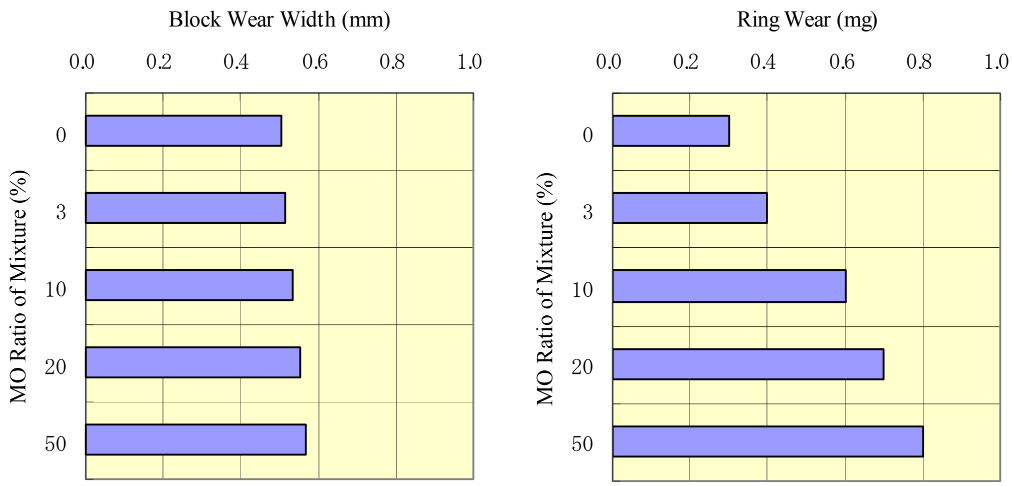


Fig.5 Block on Ring Test Results

Table 8 Endurance Test Results of PVE/MO Mixture

	7000h	10000h	18000h
Viscosity(@ 40℃) mm^2/s	60.54	61.75	61.98
Viscosity(@100℃) mm^2/s	7.41	7.42	7.45
Viscosity Index	78	74	75
Acid Number(mgKOH/g)	0.01	0.01	0.01

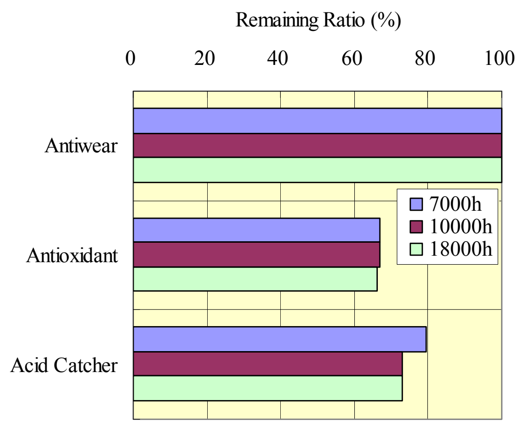


Fig. 6 Additive Contents after Endurance Tests