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Selection of a Refrigeration Oil for R32 refrigerant and Evaluation of the Compressor Reliability

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ABSTRACT

Recently, low global warming potential (GWP) refrigerants have attracted attention as an alternative to the most commonly used refrigerants. We considered R32 as an alternative to R410A because of its low GWP and energy saving characteristics. This study focused on the selection of a suitable refrigeration oil for R32 that would not compromise compressor reliability. We found R32 to be poorly miscible with refrigeration oils used for R410A. This, combined with a higher discharge gas temperature for R32 compared to R410A, would result in lower compressor reliability. We selected a refrigeration oil suitable for R32 and confirmed compressor reliability equivalent to R410A.

1. INTRODUCTION

As seen by the destruction of the ozone layer and global warming, the effects of fluoro refrigerants on the global climate have become evident, and a new role in protecting the global environment is increasingly expected for air-conditioning technologies in addition to the conventional role of providing indoor comfort. From the perspective of protecting the ozone layer, the air-conditioning and refrigeration industry has been promoting the use of hydrofluorocarbon (HFC) refrigerants, including R134a, R407C, and R410A, as an alternative to R22. Under these circumstances, the Kyoto Protocol (United Nations 1998) aiming at preventing global warming was adopted in December 1997, which required reductions in emissions of greenhouse gases, including HFC refrigerants. It was shown that The Kyoto Protocol was agreed to the United Nations Framework Convention on Climate Change (United Nations, 1998). In response to this, specific considerations have been made to prevent global warming, such as the development of products that feature less energy consumption and lower refrigerant emissions as well as the introduction of natural refrigerants and HFC refrigerants with a lower GWP from a long-term perspective. It was shown that the low GWP was evaluated for global warming (K.Kita et al., 1998).
In this paper, we present the results of the study we conducted to select refrigeration oil and evaluate the reliability of an air-conditioning system and compressor with a focus on R32, an HFC refrigerant with a low GWP, in order to develop the R32 compressor.

2. ISSUES OF R32 REFRIGERANT

The technical issues of the R32 refrigerant air conditioning system are shown in Table 1. R32 refrigerant theoretically results in a higher discharge gas temperature compared to R410A refrigerant. Even if the maximum temperature within the system is regulated so as to have a similar temperature to the R410A system by controlling the discharge gas temperature or suction superheat degree, the weighted average temperature of discharge gas ends up increasing by a few degrees Celsius. This increase in temperature leads to decomposition of R32 refrigerant and this decomposed product causes various issues such as poor stability of the refrigeration oil, wear of the sliding parts, and corrosion of expansion valves. Moreover, poor miscibility of refrigeration oils conventionally used for HFC refrigerants, including R410A, with R32 refrigerant is also an issue.

Table 1: Technical Issues of R32 Refrigerant Air Conditioning System

Elements	**Technical Issues**
Refrigerant	Chemical Stability
Compressor	Wear (Corrosive Wear)
Lubricant	Miscibility with R32 Refrigerant Chemical Stability Mixture Viscosity
Motor Materials	Compatibility with R32 Refrigerant & Lubricant Thermal Stability
Refrigeration Cycle	Corrosive Expansion Valve Capillary Tube Clogging Influence of Process Materials

3. SELECTION OF REFRIGERATION OILS FOR R32

3.1 Points in Selecting Refrigeration Oils for R32

There are three points to be considered when selecting refrigeration oils for R32: the first is the miscibility with R32 refrigerant, the second is to keep of the viscosity when R32 refrigerant is dissolved, and the third is the stability of the refrigeration oil when the stability of R32 refrigerant is reduced.

With regard to the first point, miscibility, polyol ester oil (POE) and polyvinyl ether oil (PVE) currently used for R410A have poor miscibility with R32 refrigerant, which causes the refrigeration oil discharged from the compressor along with the refrigerant to accumulate within the system, preventing it from returning to the compressor. It was shown that Current Oils was poor miscibility (T.Shibata, 2012). As a result, the refrigeration oil in the compressor decreases, which compromises the reliability of the compressor. This is why it is essential to select an oil that has higher miscibility with R32 refrigerant.

Regarding the second point, the viscosity must be kept because the viscosity of R32 refrigerant becomes lower than that of R410A. The results of the absolute viscosity comparison using the REFPROP program are shown in Figure 1. Because the absolute viscosity of R32 refrigerant became lower than that of the R410A, a reduction of the oil (fluid) viscosity, particularly during transient operation, must be taken into account when selecting refrigeration oils.

With regard to the third point, stability, R32 refrigerant has a lower GWP and is decomposed more easily compared to R410A refrigerant. When R32 is decomposed, it generates organic acids, such as hydrofluoric acid (HF) and formic acid, causing the corrosion of expansion valves, clogging of capillary tubes, and wearing of sliding parts. Therefore, it is important to have a refrigeration oil with excellent stability that is not easily affected by the organic acids generated during decomposition of refrigerant.

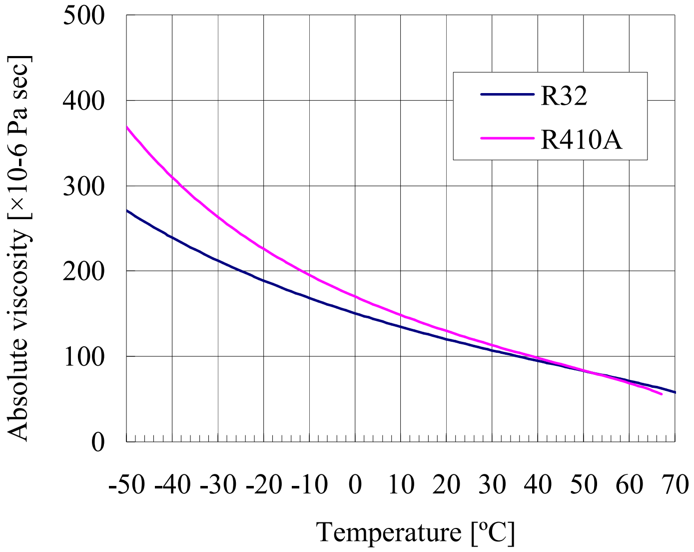

Figure 1: Comparison of Absolute viscosity between R32 and R410A

3.2 Selection of Base Oil

The base oil was selected upon placing importance on excellent miscibility with the refrigerant, stability, and lubricity.

As a refrigeration oil for R32 refrigerant air-conditioning system, miscible lubricants such as New-PVE and New-POE have been proposed. It was shown that New PVE and New POE were miscible lubricants for R32 (Matsumoto et al., 2012, Shibata, 2012, Saito et al., 2012 and Karnaz, 2012). The characteristics of these lubricants are shown in Table 2. New-PVE was selected as the base oil for the refrigeration oil because it has excellent miscibility, hydrolytic stability, lubrication, and no issues in other characteristics.

With regard to the viscosity grade, VG68 was chosen in consideration of the viscosity and separation temperature when the refrigerant is dissolved. The separation temperature of New-PVE with R32 is shown in Figure. 2 and that of New-POE with R32 is shown in Figure 3.

Table 2: Characteristics of Typical Lubricants

	New-PVE VG68	New-POE VG68	PVE VG68	POE VG68
Miscibility with R32	3	3 or 4	1	1
Thermal stability	3	4	3	4
Hydrolytic stability	4	1 or 2	4	1 or 2
Oxidation stability	2 or 3	4	2 or 3	4
Lubrication	4	2 or 3	4	2 or 3
Insulation (Resistively)	3	3	3	3

4 = Excellent, 3 = Good, 2 = Fair, 1 = Bad

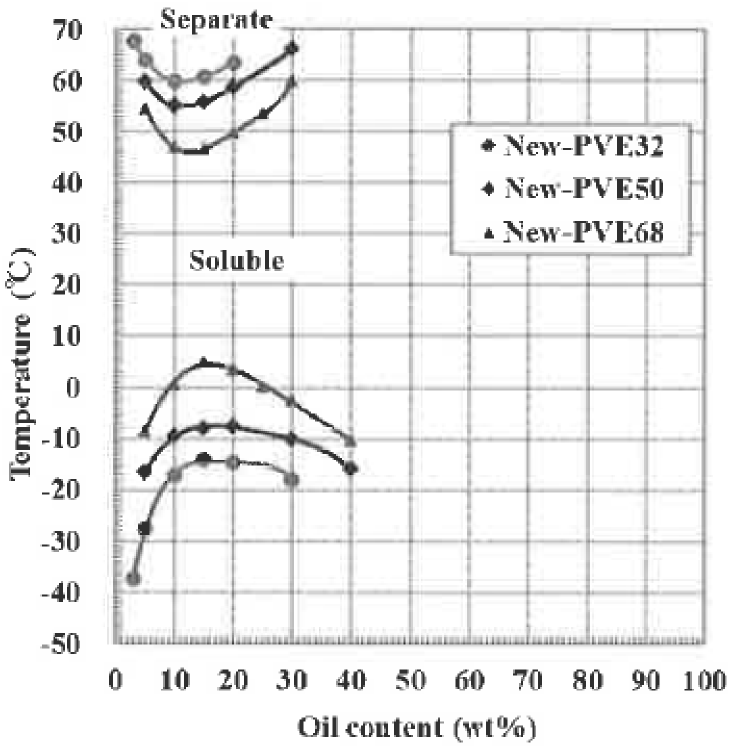

Figure 2: Separation Temperature of New-PVE with R32

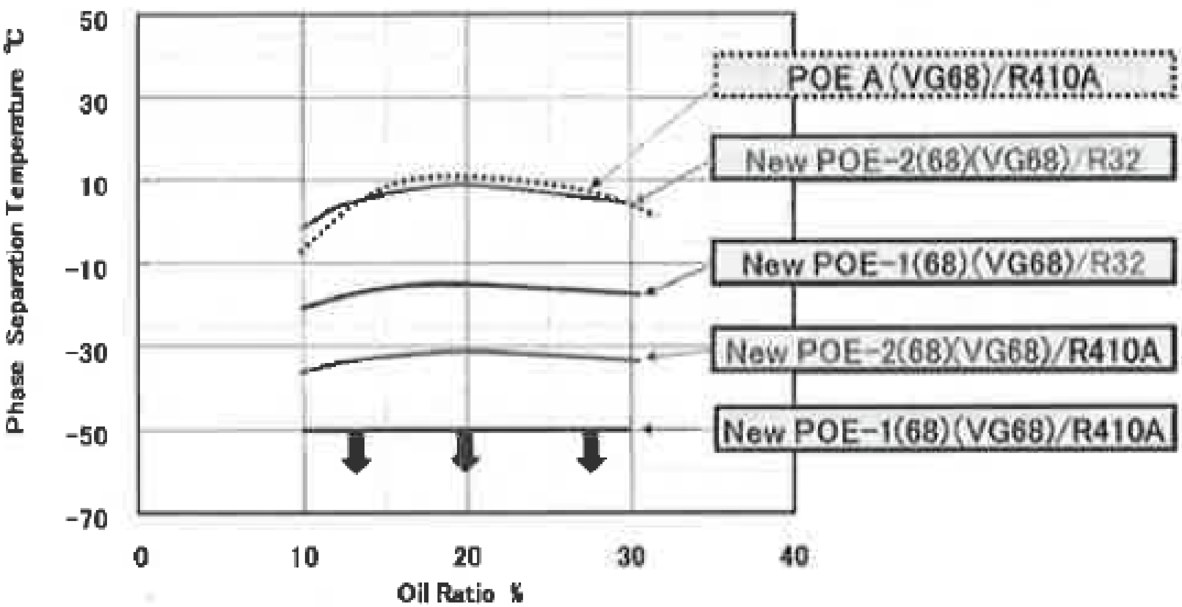

Figure 3: Separation Temperature of New-POE with R32

3.3 Specifications of Additives

The specifications of additives are shown in Table 3. As additives to the refrigeration oil for R32, the same agents as those added to the refrigeration oil for R410A were used. However, since R32 refrigerant decomposes easily, the specifications were modified by increasing the amount of the acid catcher to capture the acid generated during the decomposition of R32 refrigerant.

Table 3: Additive Treatment

	Refrigeration oil for R32
Extreme Pressure Agent	Same as that for R410A
Antioxidant Agent	Same as that for R410A
Acid Catcher Agent	Increased from that for R410A

4. RESULTS OF CONFIRMATION OF R32 REFRIGERANT CYCLE RELIABILITY BY DROP-IN TEST

4.1. Results of Confirmation of System Reliability by Drop-in Test

In order to verify the applicability of R32 refrigerant in the system, a drop-in test was conducted using a 2.8kW system for R410A refrigerant. The test conditions are shown in Table 4 and the test results are shown in Table 5 as well as Figures 4 to 6. Figures 4 and 5 show the observation results of the expansion valves. The expansion valves in the R32 refrigerant cycle showed a higher extent of thinning from corrosion compared to those in the R410A refrigerant cycle. As a result of the EPMA analysis shown in Figure 4, a large amount of fluorine, which was considered to be decomposed products of the refrigerants, were observed to attach onto the valves. Figure 6 shows the amount of acids generated and dissolved in the refrigeration oil. R32 refrigerant tends to generate a larger amount of acids compared to R410A refrigerant. Even if the discharge gas temperature is controlled in the same way, the system for R32 requires more attention to corrosion presumably caused primarily by refrigerant decomposition.

Table 4: Conditions of System Drop-in Test

Test No.	No. 1	No. 2	No. 3	No. 4	No. 5
System	2.8 kW System for R410A				
Refrigerant	R410A	R32			
Compressor Type	Swing Compressor for R410A				
Casing Pressure	High Pressure Dome Casing Type				
Rotational Speed	Variable				
Lubricant	PVE		New-PVE		
Additive	Same as an additive used in PVE for R410A				Acid Catcher Increased
Expansion Valve	Electric Expansion Valve (Material: Cu-Zn Alloy(Brass)				
Discharge Gas Temperature Control	120ºC Max.				
Operating Time	5000 hours				

Table 5: Results of System Drop-in Test

Test No.	No. 1	No. 2	No. 3	No. 4	No. 5
Expansion Valve	No Problem	Corroded	No Problem	Corroded	No Problem
Compressor		No Problem		Copper Plating Occurred on Roller Thrust Part and Roughness Worsened	No Problem (Thrust Part Material Changed)
Lubricant					
Acid Number	0.03±0.01 mgKOH/g	0.06 ±0.01 mgKOH/g	0.03 ±0.01 mgKOH/g	0.07 ±0.01 mgKOH/g	0.02 ±0.01 mgKOH/g
Fluorine ion	0±0.5mg/L	3±0.5 mg/L	0±0.5 mg/L	3±0.5 mg/L	0±0.5 mg/L
Formic acid ion	0±0.5 mg/L	2±0.5 mg/L	1±0.5 mg/L	1±0.5 mg/L	0±0.5 mg/L
Acetic acid ion	6±0.5 mg/L	13±0.5 mg/L	9±0.5 mg/L	9±0.5 mg/L	5±0.5 mg/L

No. 1 Expansion Valve in R410A Refrigerant Cycle

No. 4 Expansion Valve in R32 Refrigerant Cycle

No. 5 Expansion Valve in R32 Refrigerant Cycle when Acid Catcher Increased

Figure 4:. Expansion Needle Valves after System Drop-in Test (Needle Material:Cu-Zn Alloy(Brass))

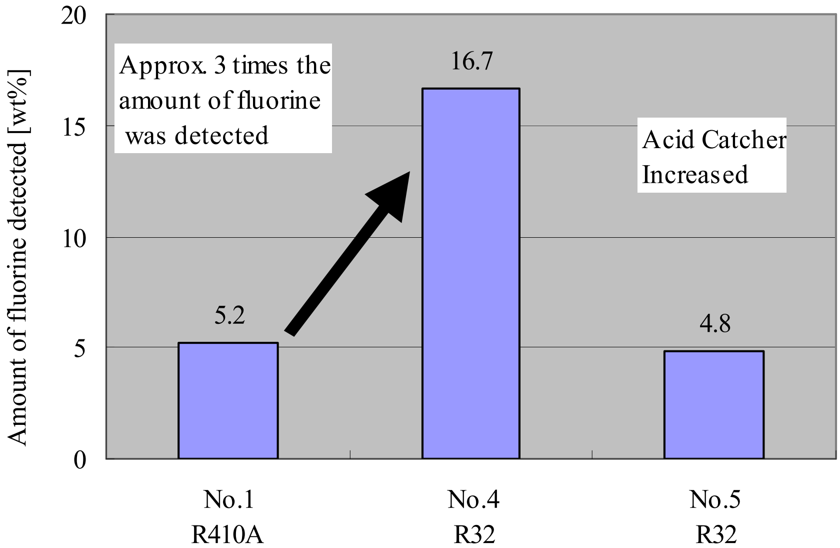

Figure 5: Amount of Fluorine Detected by EPMA on Expansion Valve

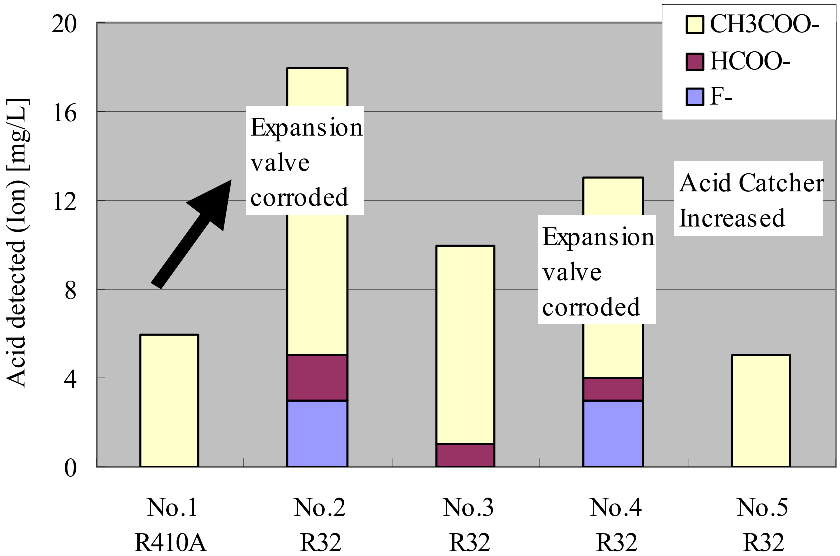

Figure 6: Difference in Amount of Acids Detected between R410A and R32

4.2. Results of Confirmation of Compressor Reliability by Drop-in Test

In order to verify the reliability of the compressor for R32 refrigerant, an endurance test was conducted upon charging R32 refrigerant into a scroll compressor for R410A. The test conditions are shown in Table 6 and the test results are partly shown in Table 7 and Figure 7.

Tests No. 1 to No. 4 were conducted using R32 refrigerant, New-PVE oil, and additives with the same specifications as for R410A. The results showed that worsening of the shaft roughness and abnormal wear of the bearing were observed under the conditions of high discharge gas temperatures. Tests No. 5 to No. 8 were conducted under the specifications with an increased amount of an additive, the acid catcher. The results showed that no worsening of the shaft roughness or abnormal wear of the bearing was observed under the conditions of high discharge gas temperatures.

Table 6: Durability Test Conditions of Scroll Compressor

Test No.	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Operating Conditions	High Compre-ssion Ratio	Max Speed, Wet	Overload Wet, On-off Action	Overload Superheat	High Compre-ssion Ratio	Max Speed, Wet	Overload Wet, On-off Action	Overload Superheat
Operating Time	400 hr	400 hr	400 hr	2000 hr	400 hr	400 hr	400 hr	2000 hr
Refrigerant	R32							
Lubricant	New-PVE							
Additive	Same as PVE for R410A				Acid Catcher Dosage Increased			
Discharge Gas Tenmperature	120 ºC	50 ºC	65 ºC	120 ºC	120 ºC	50 ºC	65 ºC	120 ºC
Pd	High	Normal	High	High	High	Normal	High	High

Table 7: Durability Test Results of Scroll Compressor (Wear Property of Sliding Parts)

Test No.	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Shaft (Gray Cast Iron)	Rough -ness Worsened	Same as R410A	Same as R410A	Rough -ness Worsened	Same as R410A			
Bearing (PTFE Coating Bronze)	Wear Increased	Same as R410A	Same as R410A	Wear Increased	Same as R410A			
Oldham (Al)	Same as R410A				Same as R410A			

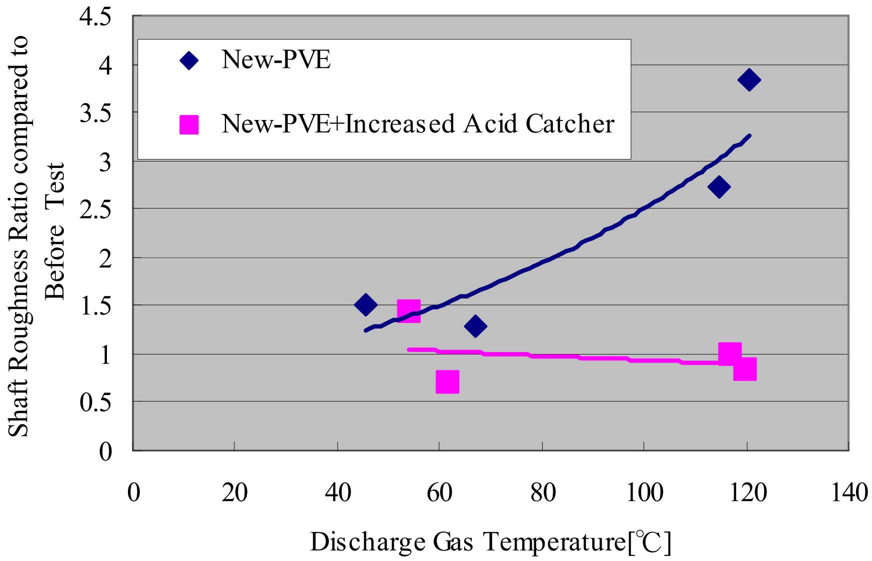

Figure 7:. Relationship between Shaft Roughness and Discharge Gas Temperature

5. LUBRICITY

Due to the results of the system and compressor reliability evaluations that showed the abnormal wear and worsened shaft roughness in the compressor, the lubricity test was conducted using a hermetic block-on-ring (Falex LFW-1) test machine. The test conditions are shown in Table 8 and the test results are shown in Figure 8 and Figure 9. In the test piece, the ring material was the compressor shaft and the block material was the bearing. The test piece was processed by forcing the deterioration under simulated degradation conditions equivalent to the reliability test. While the wear characteristics with R32/New-PVE worsened more extensively compared to R410A/PVE, R32/New-PVE with increased acid catcher demonstrated wear characteristics comparable to R410A/PVE.

Table 8: Conditions of Wear Test

Refrigerant	R32 or R410A
Atmospheric pressure	0.4 MPa
Sliding velocity	2.6 m/s
Load	200 N
Test time	60 min
Ring material	Gray Cast Iron (Forced deterioration)
Block material	PTFE Coating Bronze (Forced deterioration)

Moreover, the results of the EPMA analysis on the ring test piece after forced deterioration prior to the wear test confirmed the attachment of fluorine, presumably decomposed products of the refrigerant, on the ring for R32/New-PVE.

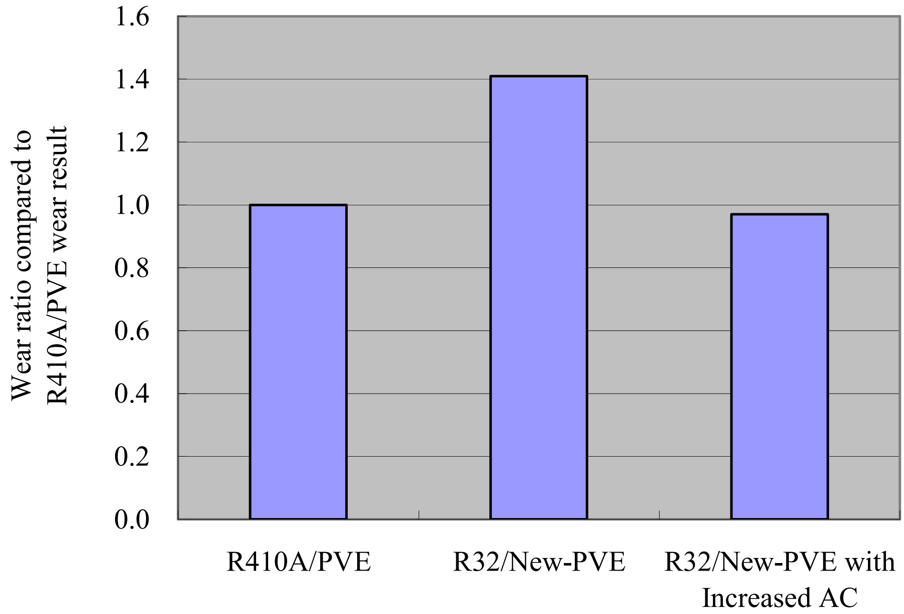

Figure 8: Results of Lubricity Confirmation

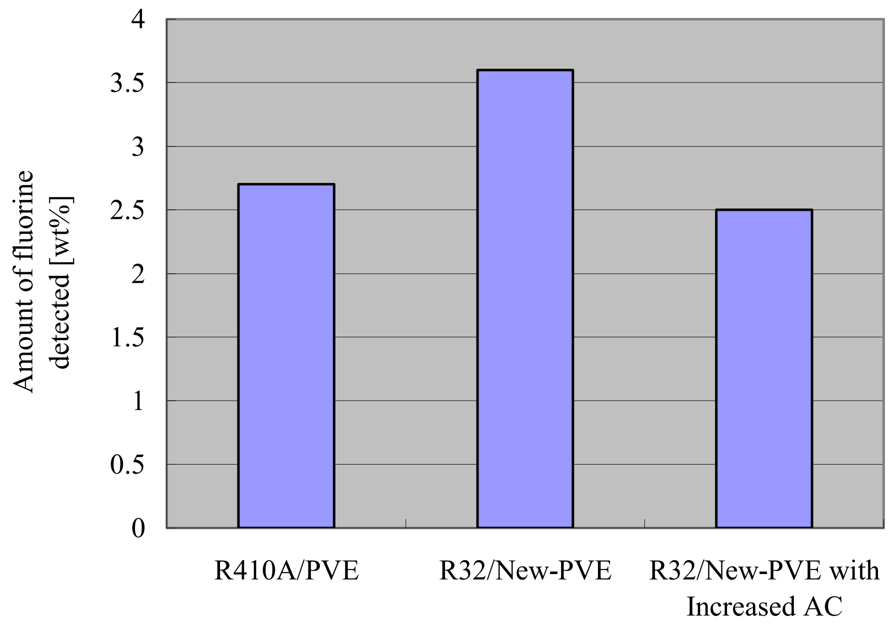

Figure 9: Results of EPMA Analysis on Forcibly Deteriorated Test Pieces (Amount of Fluorine Detected)(Prior to Wear Test)

6. CONCLUSIONS

The reliability of the product systems and compressors was evaluated by a drop-in test upon charging R32 refrigerant into the product systems and compressors for R410A refrigerant and the following results were obtained:

- R32 refrigerant has poorer stability and generates more acids compared to R410A refrigerant, and the acids generated cause corrosion of the expansion valves and abnormal wear of the compressor's sliding parts.
- Increasing the amount of acid catcher is effective in capturing the acids generated.

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