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Tomoya Matsumoto
Idemitsu Kosan Co.,Ltd., Lubricants Research Laboratory, Japan, tomoya.matsumoto@idemitsu.com

Masato Kaneko
Idemitsu Kosan Co.,Ltd., Lubricants Research Laboratory, Japan, masato.kaneko@idemitsu.com

Yasuhiro Kawaguchi
Idemitsu Kosan Co.,Ltd., Lubricants Department, Japan, yasuhiro.kawaguchi@idemitsu.com

Evaluation of Friction and Wear on PVE Refrigeration Lubricants for HFC Refrigerants

Tomoya MATSUMOTO [1], Masato KANEKO [1] and Yasuhiro KAWAGUCHI [2]

[1]Idemitsu Kosan Co.,Ltd., Lubricants Research Laboratory
24-4 Anesakikaigan, Ichihara-shi, Chiba, 299-0107, JAPAN
Phone: +81-436-61-2504
Fax: +81-436-61-2017

[2]Idemitsu Kosan Co.,Ltd., Lubricants Department
3-1-1 Marunouchi, Chiyoda-ku, Tokyo, 100-8321, JAPAN
Phone: +81-3-3213-3146
Fax: +81-3-3211-5343

ABSTRACT

For the prevention of global warming, it is important for home electric appliance to improve the energy saving performance. Air-conditioner is one of home electric appliances, and the improvement of energy consumption efficiency is being performed by various ways. Lubricant for air-conditioner is used to protect sliding surfaces of a compressor. The low friction coefficient lubricant is considered to improve the friction coefficient between rotor and vane of the rotary-type compressor. We evaluated the friction and the wear on PVE refrigeration lubricants for HFC refrigerants. The friction coefficient and wear were measured by using the hermetic type block-on-ring tester. The evaluation items were physical properties (miscibility, solubility, mixture viscosity and volumetric resistivity) and thermal stability.

1. INTRODUCTION

Carbon dioxide emission control is regulated as a global warming countermeasure. An air conditioner is one of the products with the high electric power consumption in home electronics. Therefore, the energy conservation of an air conditioner is requested. Energy-saving technique has been developed variously by an air conditioner equipment manufacturer. [1, 2] Improvement of refrigeration lubricant could be asked from one of energy saving measures. The demand performance of the refrigeration lubricant is reduction of sliding loss for a compressor.

In this report, we evaluate the performance of the low friction coefficient lubricant for physical properties (miscibility, solubility, mixture viscosity and volumetric resistivity) and thermal stability.

2. EXPERIMENTAL

2.1 Lubricants and Refrigerants

The evaluated lubricants were PVEs. In the chemical structure of PVE shown in Figure 1, the difference between PVE-A and PVE-B is the ratio of R_1 to R_2 of a side chain. “PVE-A” was the current PVE for R410A. “PVE-B” was the current PVE for R32. The specifications of PVEs are shown in Table 1. PVE-A1 and PVE-B1 were included the antiwear, the antioxidant and the acid catcher. PVE-A2 and PVE-B2 were added the new antiwear and the new stabilizer.

Table 2 shows the evaluated refrigerants and properties of refrigerants. In addition, the difference between PVE-A1 and PVE-A2 was evaluated in terms of lubricity, miscibility, solubility, electric property, stability and energy saving test. The evaluation was performed by the method shown in the sub-sections 2.2~2.7 below.

2.2 Lubricity

Figure 2 shows the hermetic type Block-on-Ring tester and the lubricating evaluation test conditions. The evaluation was performed by comparison of the friction coefficient and the wear volume.

2.3 Miscibility

Figure 3 shows miscibility test apparatus and method [3]. The test tube is made of the sapphire and it was filled up with lubricant/refrigerant mixture. A photo-sensor is set up to detect light through the tube. The bath temperature is gradually increased (or decreased). Initially the lubricant and refrigerant mixture is clear. As the temperature increased (or decreased), the mixture becomes cloudy appearance which indicate lubricant/refrigerant separation. The two-phase separation temperature of that mixture is determined by the light transmittance of the photo-sensor. The temperature representing the center of this curve is the critical separation temperature (CST).

2.4 Solubility

Figure 4 shows the hermetic type viscometer. This apparatus measures both the solubility and mixture viscosity of lubricant/refrigerant mixtures [4]. To measure the viscosity, a capillary-type viscometer in a pressure tight case is used. Solubility was determined by the calculating formula in Figure 4. The Daniel Chart was drawn on measurement data.

2.5 Electric property

Figure 5 shows the hermetic type volumetric resistivity tester. [5] The volumetric resistivity indicates electrical insulation properties of refrigeration lubricant. Volumetric resistivity is a ratio of electrostatic strength to the current density when the direct electric field is impressed to electrode that fills the sample. The volumetric resistivity was measured at varied refrigerant contents (wt%) under the below test condition*.

*Application voltage = 250V and temperature = 20℃

2.6 Stability

Stability was evaluated with the autoclave. Table 3 shows the testing conditions. The influence of air and moisture is also examined. The evaluated analysis item was the acid value.

2.7 Energy saving test

Figure 6 shows the energy saving test apparatus and the test condition. The energy saving test were estimated by PVE-A1 and PVE-A2 for R410A application. The electric power was measured after arrival in the test condition. The electric power consumption reduction rate was determined by the calculating formula in Figure 6.

3. RESULTS AND DISCUSSIONS

3.1 Lubricity

Figure 7(a, b) show the lubricity of PVEs with refrigerants. The friction coefficient of PVE-A2/R410A and PVE-B2/R32 were reduction compared with PVE-A1/R410A and PVE-B1/R32. The friction coefficient of PVE-A2/R410A and PVE-B2/R32 were in order of 0.05. On the other hand, the friction coefficient of PVE-A1/R410A and PVE-B1/R32 were in order of 0.07. Moreover, all samples were little ring wear volume. There was no influence by the difference in the oil and refrigerant combinations, and lubricity was good under the examination conditions.

3.2 Miscibility

Figure 8(a, b) show the miscibility of PVEs/refrigerants. At 15wt% of oil content, two-phase separation temperature of PVE-A1/ R410A and PVE-A2/R410A at low temperature were -50℃> and -47℃. The dissolution region of the PVE-A2/R410A became narrow compared with PVE-A1/R410A. The relation between PVE-B2/R32 and PVE-B1/R32 was the same as PVE with R410A. It was also explained that the dissolution region of those became narrow with new additive.

3.3 Solubility and mixture viscosity

Figure 9(a, b, c, d) are the Daniel Chart of PVE with refrigerants. As an example, solubility and mixture viscosity of the condition (60℃, 1.6MPa) are shown in Table 4. It was found that PVE-A2/R410A and PVE-B2/R32 solubility and mixture viscosity were equivalent to PVE-A1/R410A and PVE-B1/R32.

3.4 Electric property
Figure 10(a, b) show the volumetric resistivities of PVEs/refrigerants. The volumetric resistivity of PVE-A1 and PVE-B1 were in order of $10^{11}\Omega\cdot$ m. In addition, the volumetric resistivity of PVE-A2 and PVE-B2 were in order of $10^{10}\Omega\cdot$ m. It turned out that there is influence by the new additive. On the other hand, the volumetric resistivities of R410A and R32 were $1.4\times10^{7}\Omega\cdot$ m and $3.7\times10^{7}\Omega\cdot$ m, respectively. The volumetric resistivity of PVEs/refrigerants decreased with increasing refrigerant content. They were slope downward with single logarithmic plot. An order of volumetric resistivity of refrigerants and refrigerant mixture by a constant fraction were the same tendency.

3.5 Stability
Tables 5 and 6 show the autoclave test results of PVEs/refrigerants. The influence on stability was not seen on two test conditions. It was understood that PVE-A2 and PVE-B2 stability are equivalent to PVE-A1 and PVE-B1.

3.6 Energy saving test
Figure 11 shows the electric power of PVE-A1/R410A and PVE-A2/R410A. The electric power of PVE-A1/R410A and PVE-A2/R410A were 153W and 145W. This was the electric power consumption reduction of the 5.2%. The lubricant of low friction coefficient was effective to electric power reduction.

4. CONCLUSION

The development of PVE-A2 and PVE-B2 added the new antiwear for the improvement in friction coefficient with R410A and R32. In addition, PVE-A2 and PVE-B2 were good to the miscibility, solubility, mixture viscosity, volumetric resistivity and stability. Furthermore, PVE-A2 showed better electric power than PVE-A1.

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(1) H. Hara and M. Oono, I. Iwata: *2010 International Symposium on Next-generation Air Conditioning and Refrigeration Technology*, NS26 (2010)
(2) T. Tokiai and Kaneko: Proc. 2007 JSRAE Annual conf., JSRAE, E310 (2007). (in Japanese)
(3) JP2823123
(4) JP3711303
(5) JP5624782

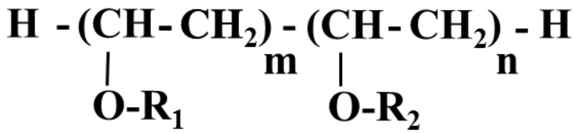


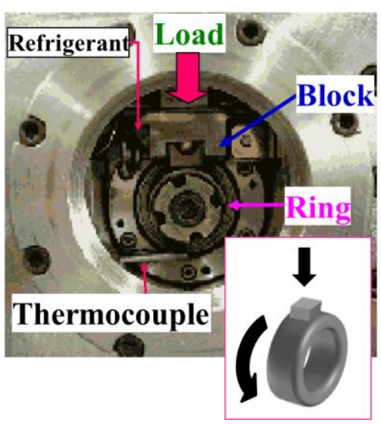
Figure 1: Chemical structure of PVE

Table 1: Specifications of PVE

Lubricant		PVE-A1	PVE-A2	PVE-B1	PVE-B2
Apprication		R410A	R410A	R32	R32
Viscosity @40℃ (mm^2/s)		66.57	67.13	68.41	66.74
Viscosity @100℃ (mm^2/s)		8.037	8.122	8.316	8.133
Viscosity Index		84	87	88	87
Density @15℃ (g/cm^3)		0.937	0.935	0.944	0.943
Acid Number (mgKOH/g)		0.01>	0.01>	0.01>	0.01>
additive	antiwear	include	-	include	-
	New antiwear	-	include	-	include
	antioxidant	include	include	include	include
	acid catcher	include	include	include	include
	New stabilizer	-	include	-	include

Table 2: Properties of refrigerants

Refrigerant	Molecular structure	MW	GWP
R410A	CH_2F_2 / CF_3CHF_2 = 50 / 50	73	2090
R32	CH_2F_2	52	675



Conditions	Test
Ring material	JIS FC250
Block material	JIS SKH51
Temperature (℃)	80
Test time (min)	30
Oil amount (g)	100
Refrigerant pressure(MPa)	0.4
Load (N)	500
Speed (m/s)	1.8

Figure 2: Hermetic type block-on-ring tester and wear test condition

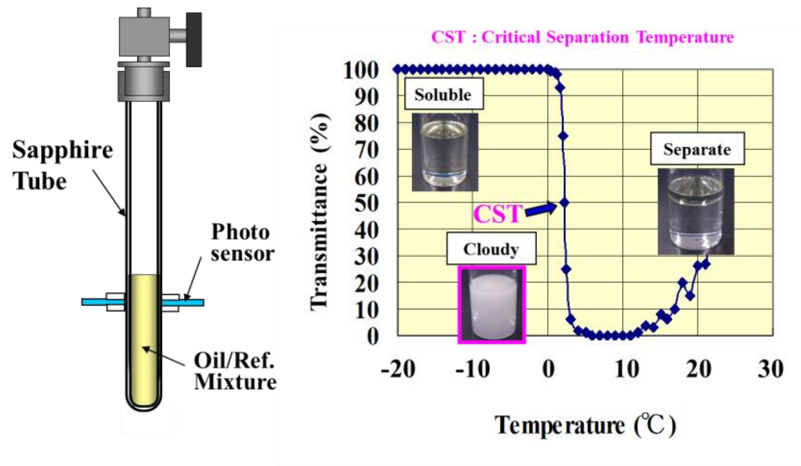


Figure 3: Miscibility test apparatus and method

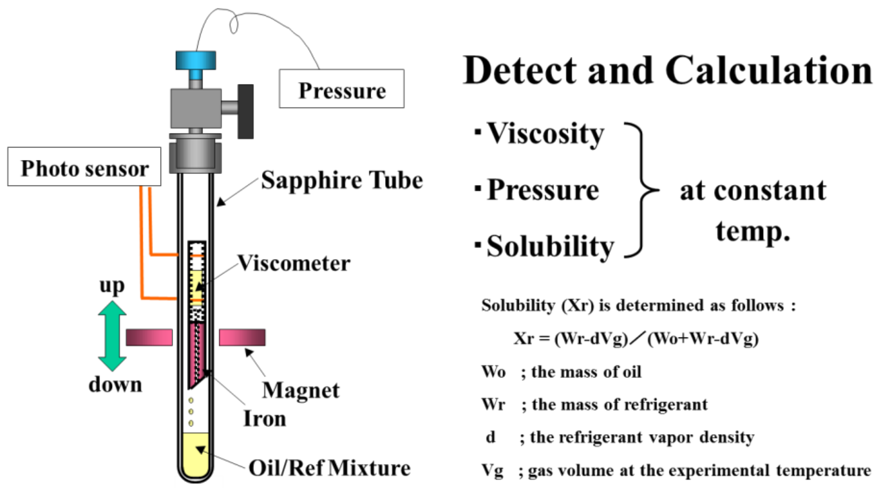


Figure 4: Hermetic type viscometer

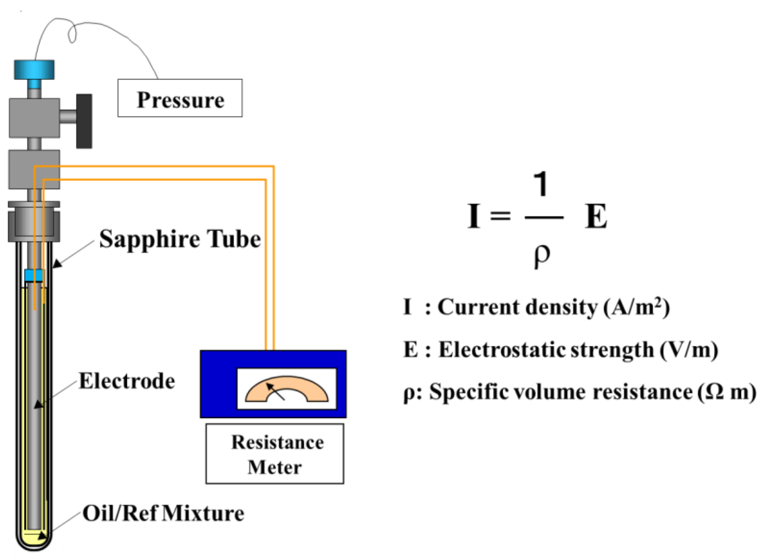
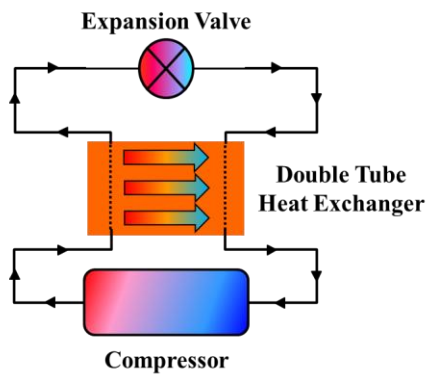


Figure 5: Hermetic type volumetric resistivity tester

Table 3: Stability test conditions

Conditions	Test 1	Test 2
Temperature (℃)	175	175
Test time (h)	336	336
Oil amount (g)	30	30
Refrigerant amount (g)	30	30
Water content (ppm)	50>	500
Air pressure (kPa)	0.7>	13
Catalysts	Fe / Cu / Al	Fe / Cu / Al



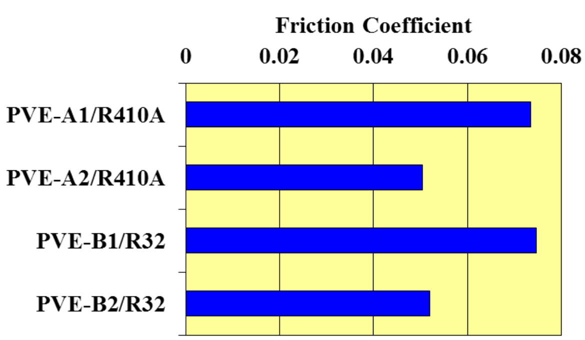
Conditions	Test
Compressor type	Rotary (R410A)
Pd / Ps (MPa)	1.6 / 0.6
Td / Ts (℃)	60 / 28
Frequency (Hz)	20
Oil amount (g)	150
Refrigerant amount (g)	150
Power meter	WT1600 (Yokogawa)

$$X = \frac{W(PVE{-}A1) - W(PVE{-}A2)}{W(PVE{-}A1)} \times 100$$

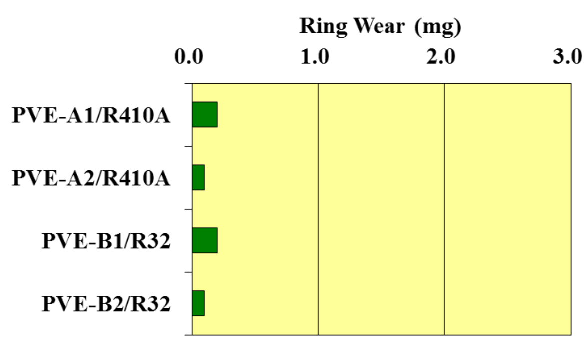
X : Electric power consumption reduction (%)

W : Electric power (W)

Figure 6: Energy saving test apparatus and the test condition

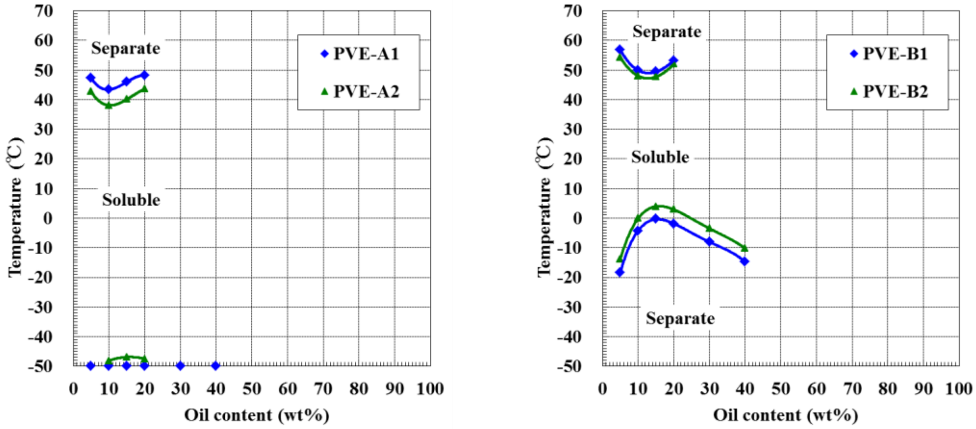


(a) Friction coefficient



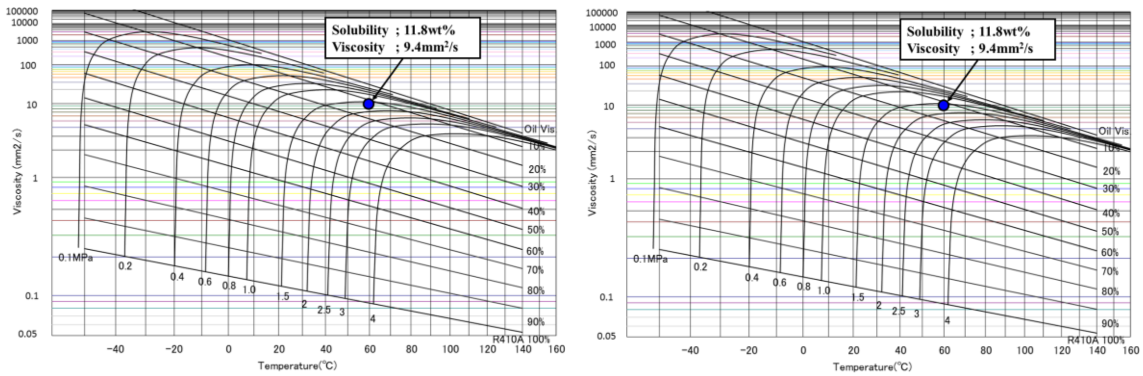
(b) Ring wear volume

Figure 7: Lubricity of PVEs with refrigerants

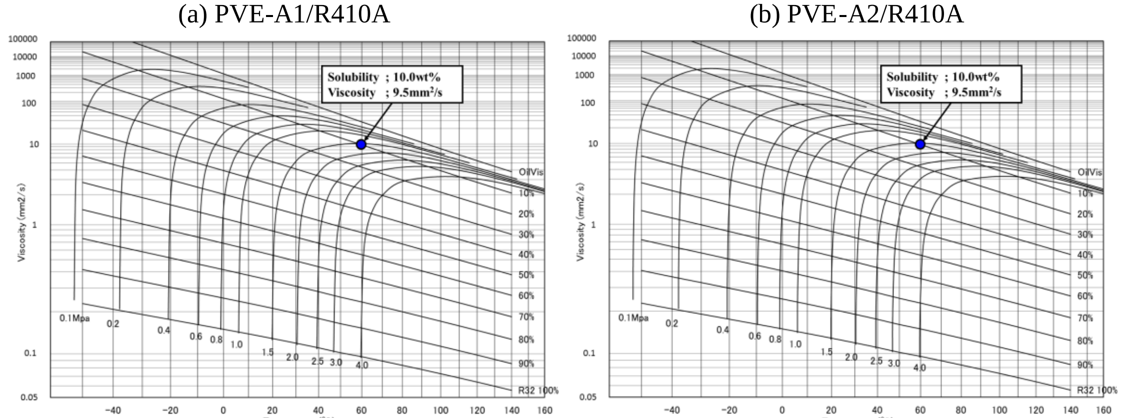


(a) PVE with R410A (b) PVE with R32

Figure 8: Miscibility of PVEs with refrigerants



(a) PVE-A1/R410A (b) PVE-A2/R410A

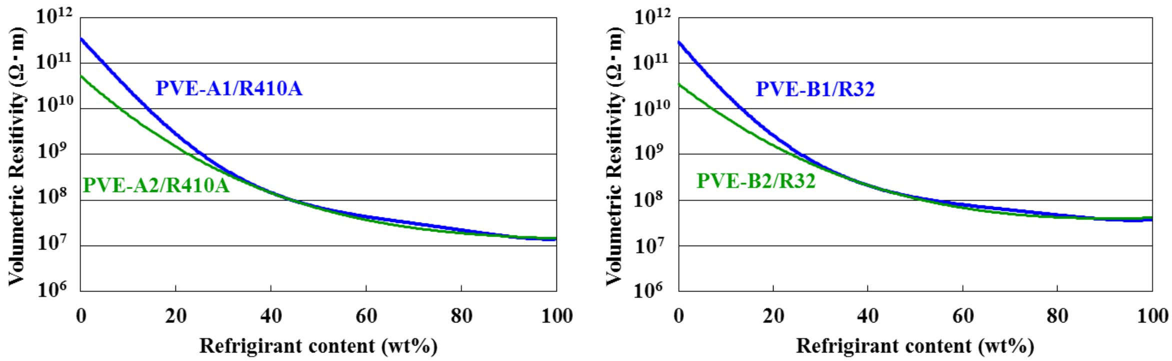


(c) PVE-B1/R32 (d) PVE-B2/R32

Figure 9: Daniel chart of PVEs with refrigerants

Table 4: Solubility and mixture viscosity of PVEs with refrigerants (60℃, 1.6MPa)

Lubricants	Refrigerants	Solubility (wt%)	Viscosity (mm^2/s)
PVE-A1	R410A	11.8	9.4
PVE-A2	R410A	11.8	9.4
PVE-B1	R32	10.0	9.5
PVE-B2	R32	10.0	9.5



(a) PVE with R410A (b) PVE with R32

Figure 10: Volumetric resistivity of PVEs with refrigerants

Table 5: Test 1 thermal stability of PVEs/refrigerants

Lubricants	Refrigerants	Oil Appearance	Catalysts Appearance	Acid Number (mgKOH/g)
PVE-A1	R410A	Good	Good	0.01
PVE-A2	R410A	Good	Good	0.01
PVE-B1	R32	Good	Good	0.01
PVE-B2	R32	Good	Good	0.01

Table 6: Test 2 hydrolytic and oxidation stability of PVEs/refrigerants

Lubricants	Refrigerants	Oil Appearance	Catalysts Appearance	Acid Number (mgKOH/g)
PVE-A1	R410A	Good	Good	0.03
PVE-A2	R410A	Good	Good	0.03
PVE-B1	R32	Good	Good	0.03
PVE-B2	R32	Good	Good	0.03

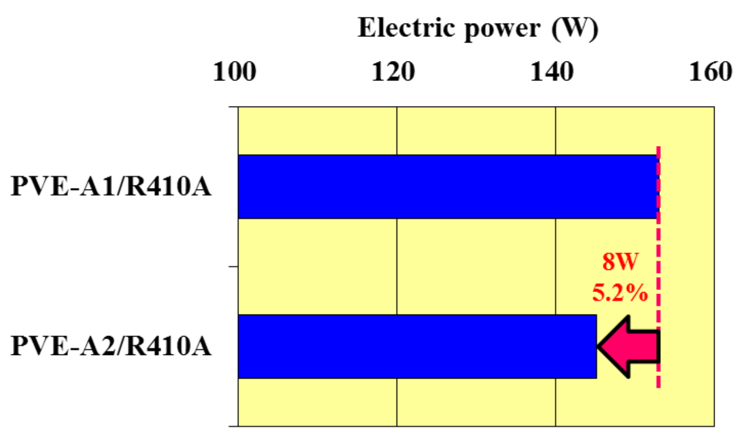


Figure 11: Electric power of PVE-A1/R410A and PVE-A2/R410A