Performances of New PVE Lubricants for Air Conditioning system with the low Global Warming Potential Refrigerants

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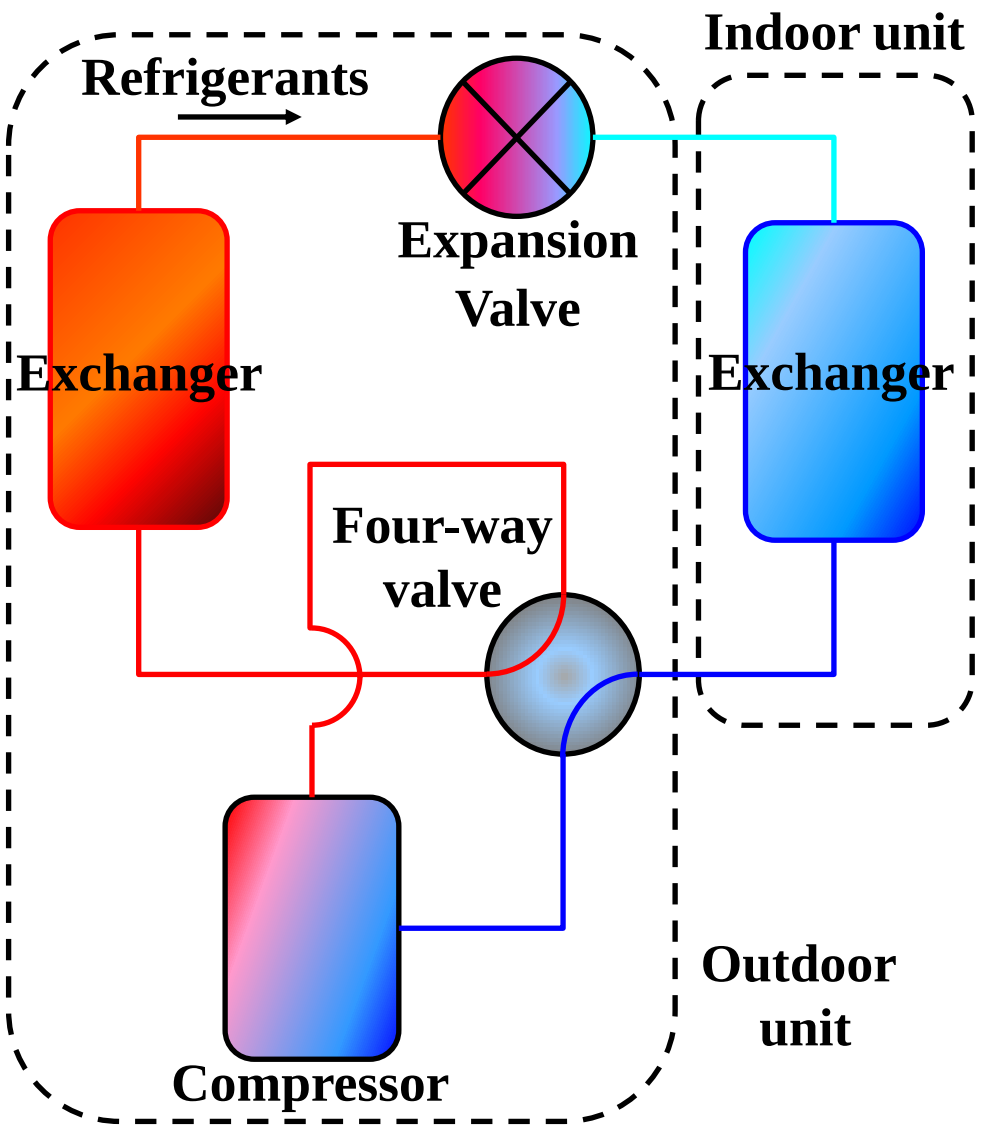
Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Transition of Refrigerants and Lubricants

		Montreal Protocol		Kyoto Protocol
Air-Conditioner (PAC, RAC)	Ref. Oil	R22 MO	R410A PVE, POE	R32, R1234yf PVE, POE
Vender Machine (VM)	Ref. Oil	R22 MO	R407C PVE, POE	CO_2 PAG
Showcase (SC)	Ref. Oil	R22/R502 MO	R404A PVE, POE	
HP-Water Heater (HPWH)	Ref. Oil			
Refrigerator	Ref. Oil	R12 MO	R134a POE	R600a MO
Car-A/C	Ref. Oil	R12 MO	R134a PAG	R1234yf PAG

Requirement for Refrigeration Oil



1.Miscibility
2.Solubility
3.Mixture Viscosity
4.Lubricity
5.Volumetric Resistivity
6.Stability

Properties of Refrigerants

	R410A	R32	R1234yf
Molecular structure	CH_2F_2 / CF_3CHF_2 50 / 50	CH_2F_2	$CF_3CF=CH_2$
ODP	0	0	0
GWP	2088	675	4
M.W. (g/mol)	52 / 120	52	114
Tc (℃)	72.0	78.1	94.7
Pc (MPa)	5.0	5.8	3.4

Specification of PVEs for R410A and R32

Lubricant		PVE-1A	PVE-2A
Refrigerant		R410A	R32
Viscosity @40℃ (mm^2/s)		66.57	68.41
Viscosity @100℃ (mm^2/s)		8.037	8.316
Viscosity Index		84	88
Density @15℃ (g/cm^3)		0.9369	0.9440
Acid Number (mgKOH/g)		0.01>	0.01>
PVE type		PVE1	PVE2
additive	antiwear	include	include
	antioxidant	include	include
	acid catcher	include	include

⇒A

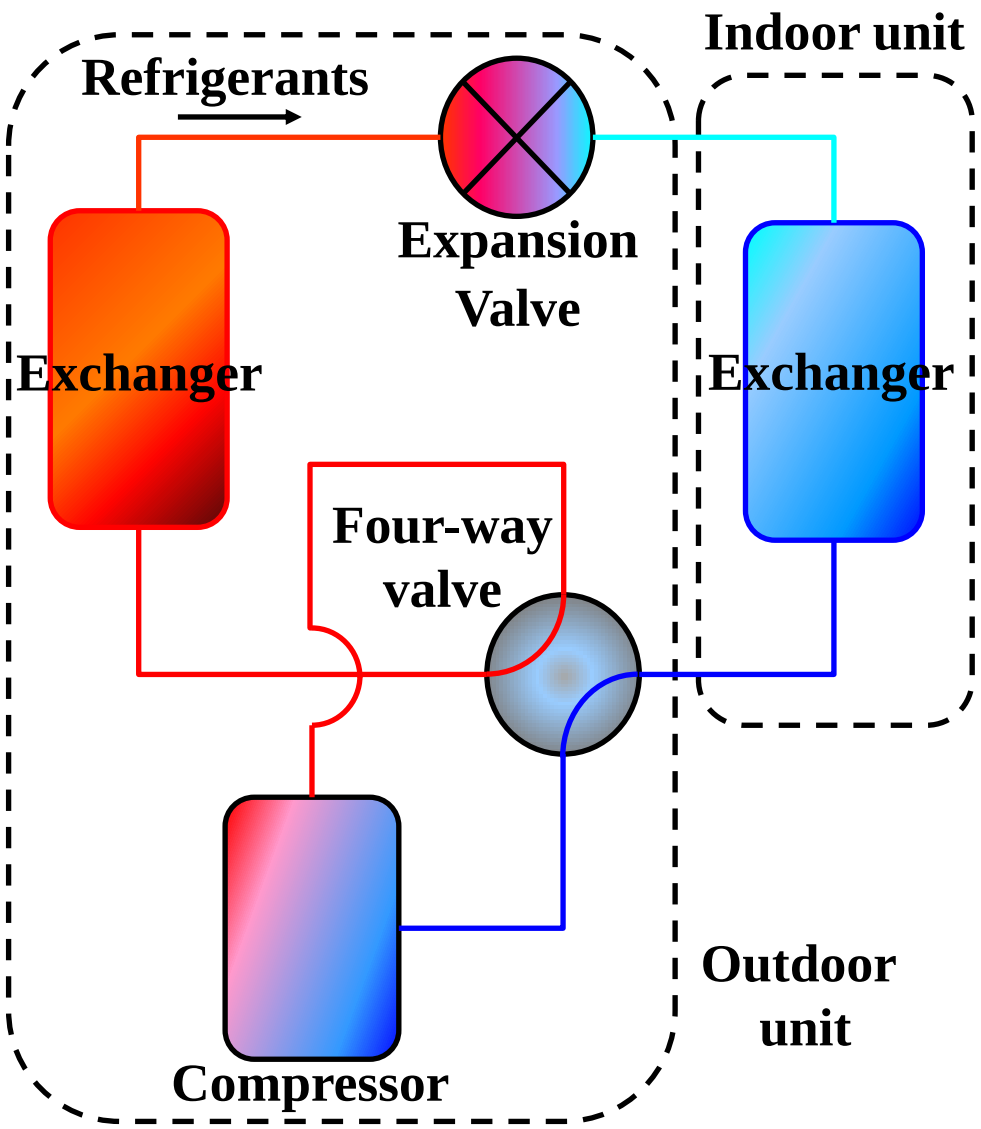
$$H\text{-}(CH\text{-}CH_2)_m - (CH\text{-}CH_2)_n\text{-}H$$

$$O\text{-}R_1 \qquad O\text{-}R_2$$

m/n=a'/b'

Chemical Structure of PVE2 was modified

Miscibility of PVEs for R32



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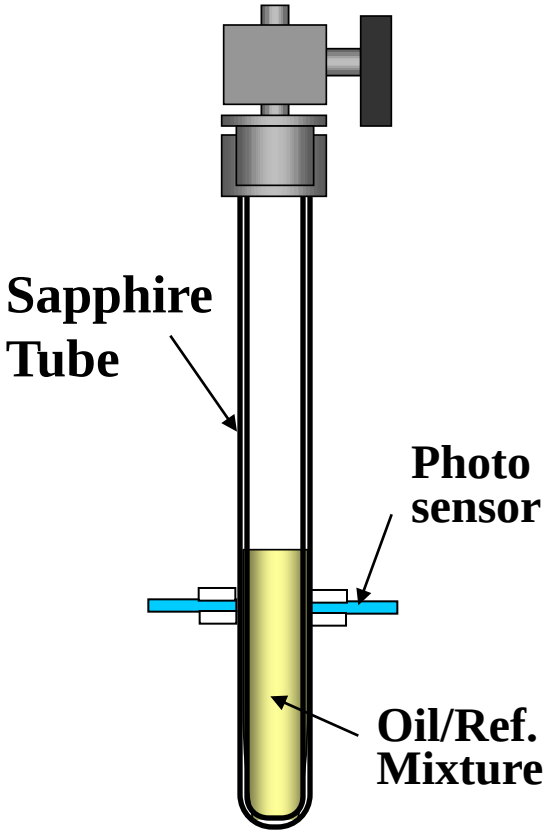
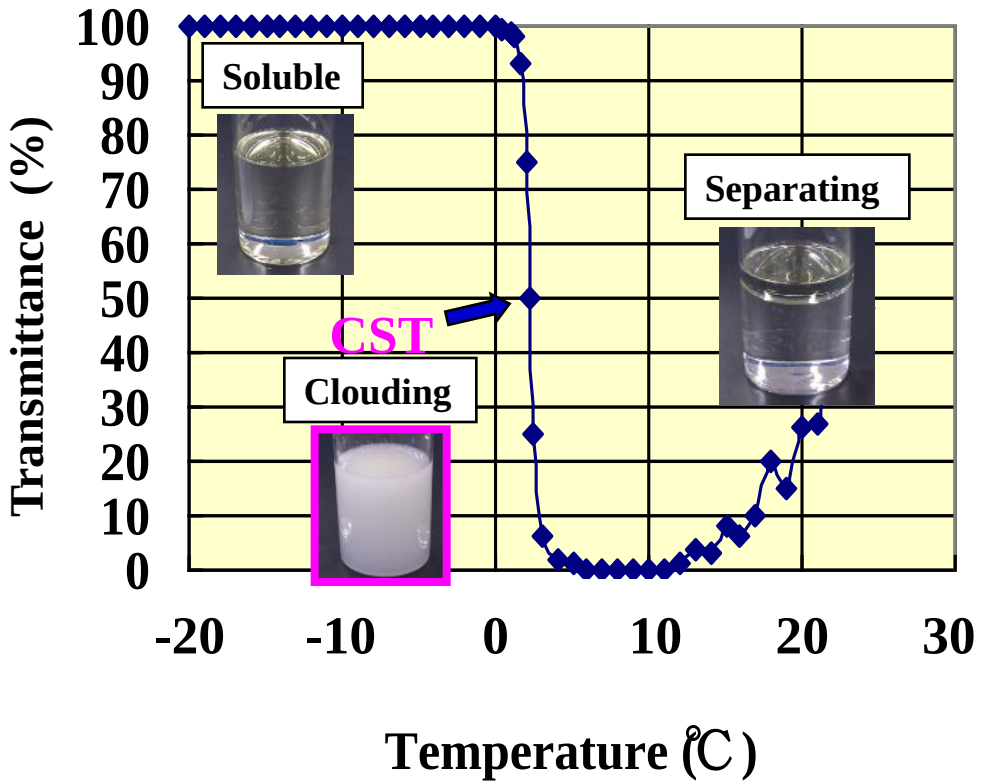
Miscibility

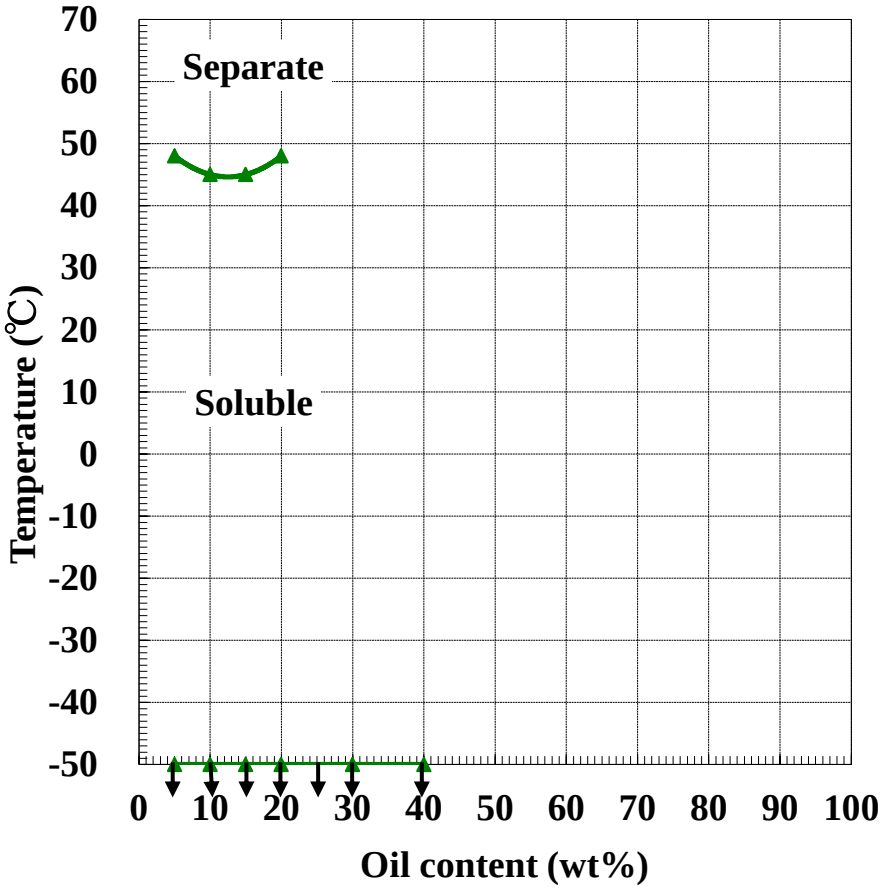


CST : Critical Separation Temperature

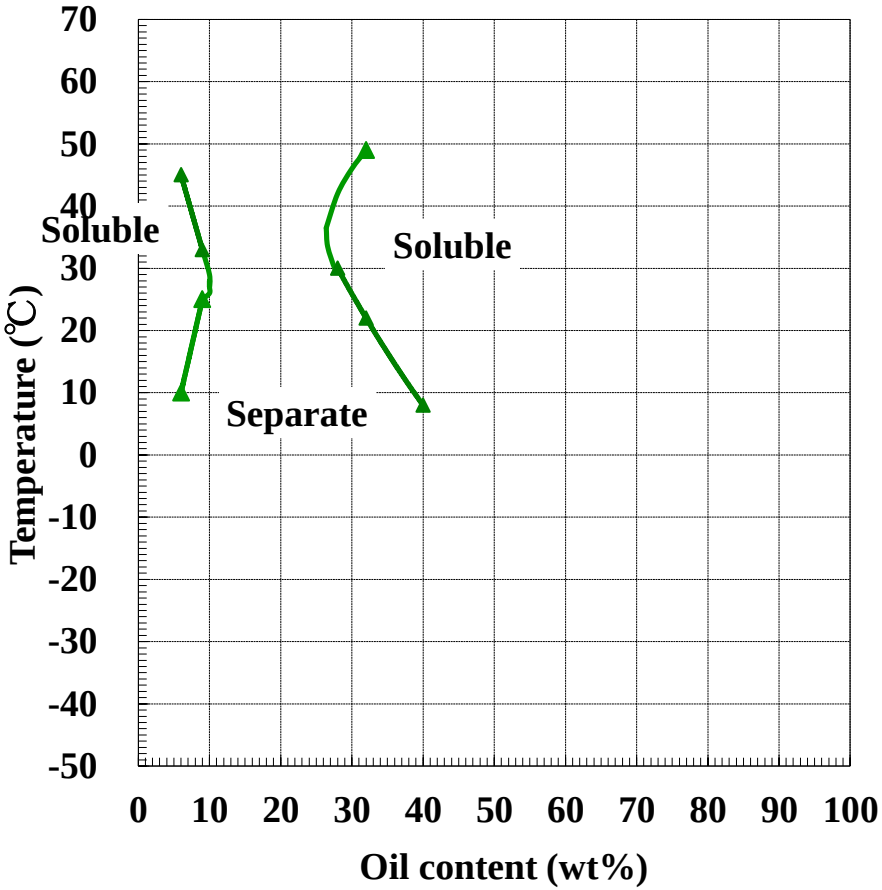


Miscibility of PVE-1A with R410A, R32

R410A



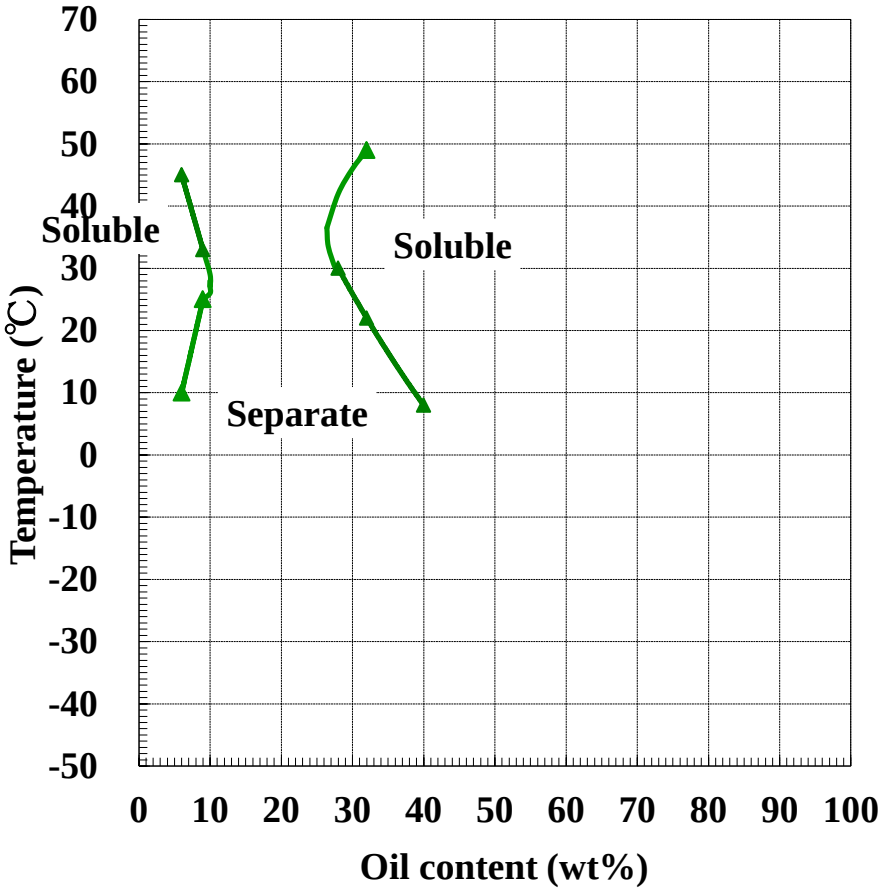
R32



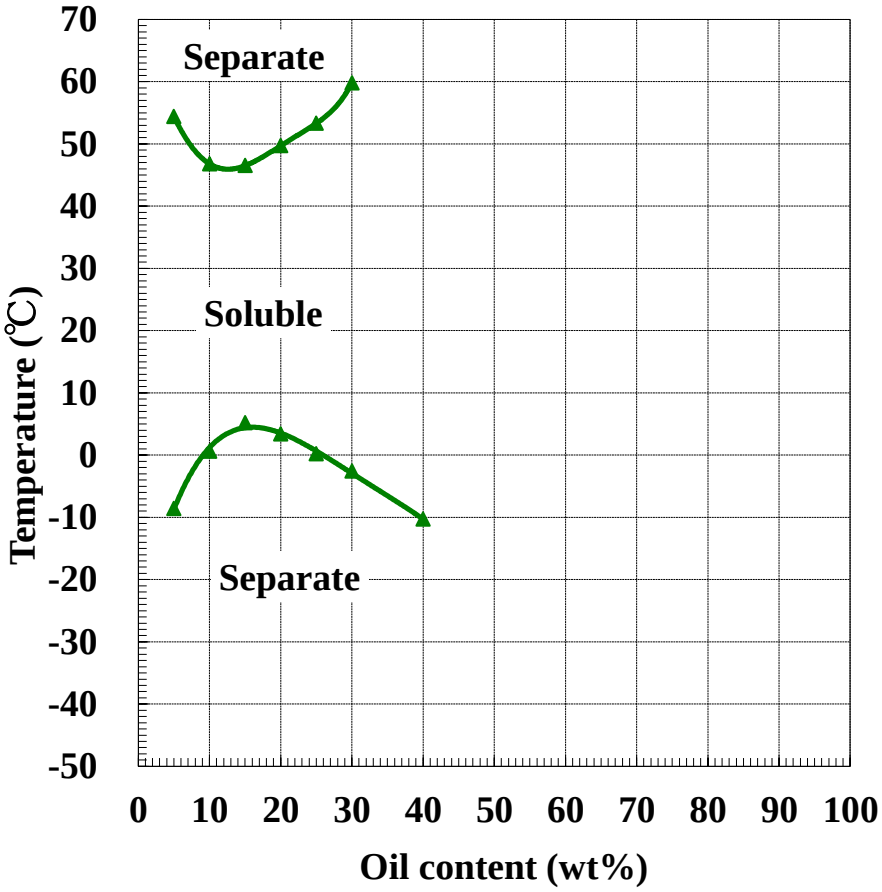
PVE-1A/R32 was less miscible than that of PVE-1A/R410A.

Miscibility of PVE-2A with R32

PVE-1A

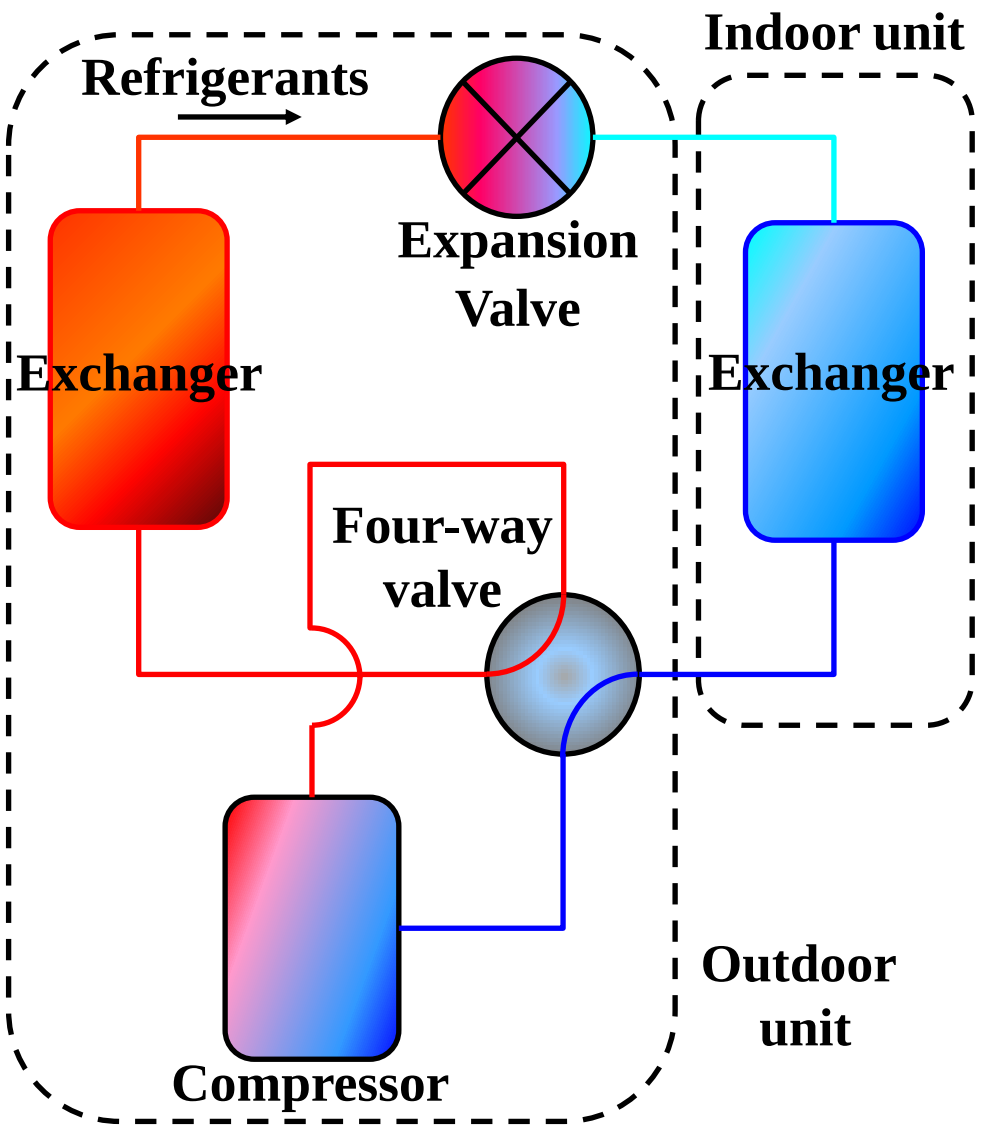


PVE-2A



Miscibility of PVE-2A/R32 was improved.

Solubility and Mixture Viscosity of PVEs for R32



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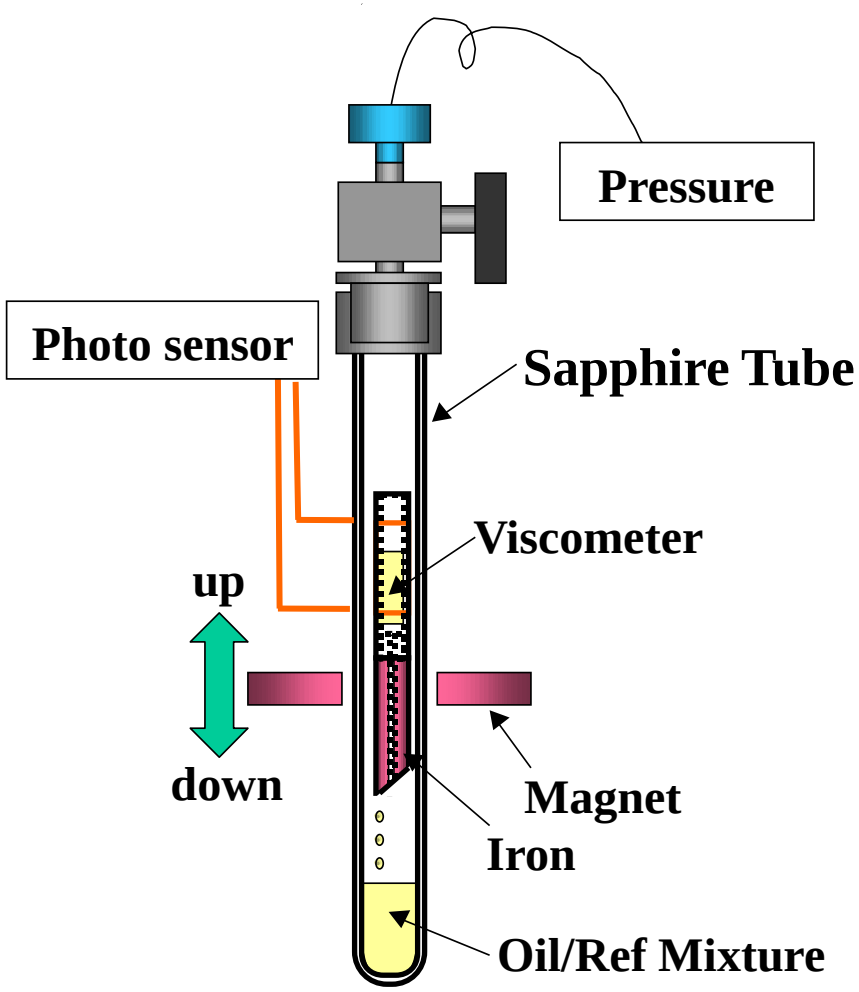
Solubility & Mixture Viscosity



Detect and Calculation

- Viscosity
- Pressure
- Solubility

} at constant Temp.

Solubility (Xr) is determined as follows :

$$Xr = (Wr - dVg) / (Wo + Wr - dVg)$$

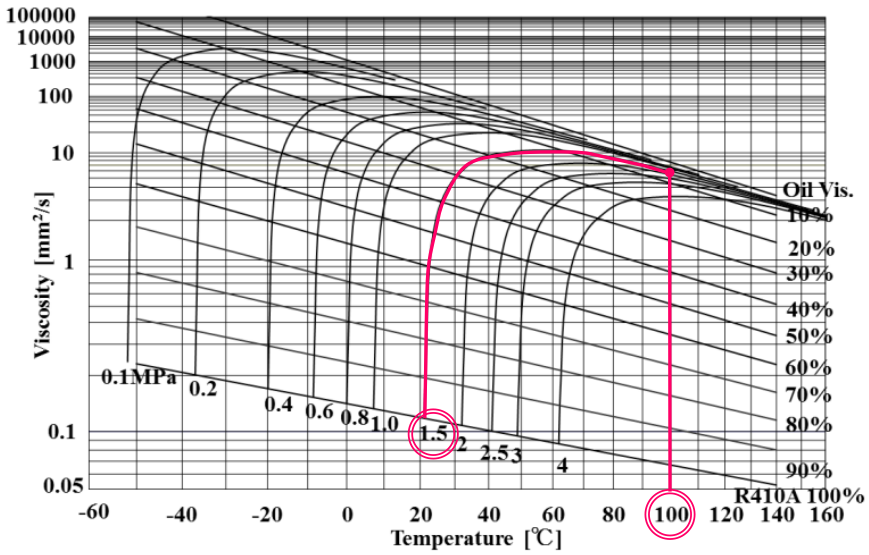
Wo ; the mass of oil

Wr ; the mass of refrigerant

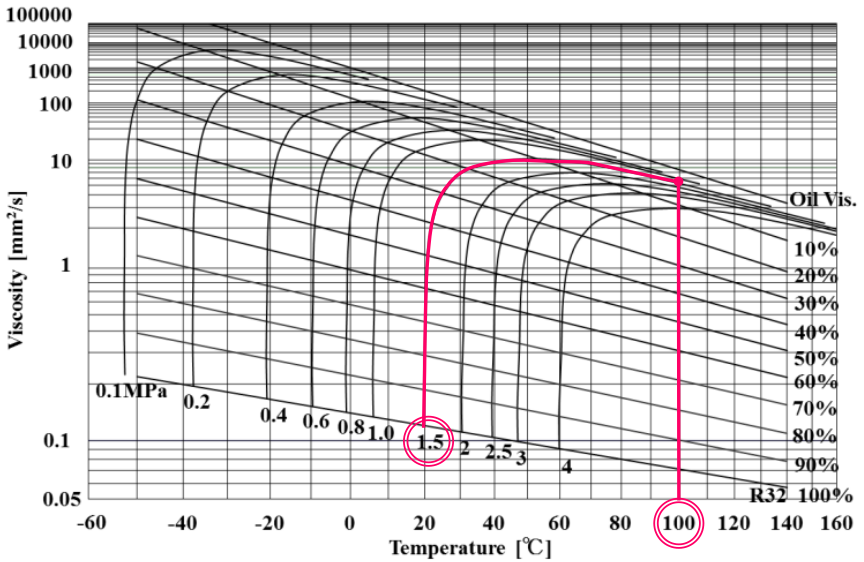
d ; the refrigerant vapor density

Vg ; gas volume at the experimental temperature

Daniel Chart of PVE-2A



PVE-1A/R410A

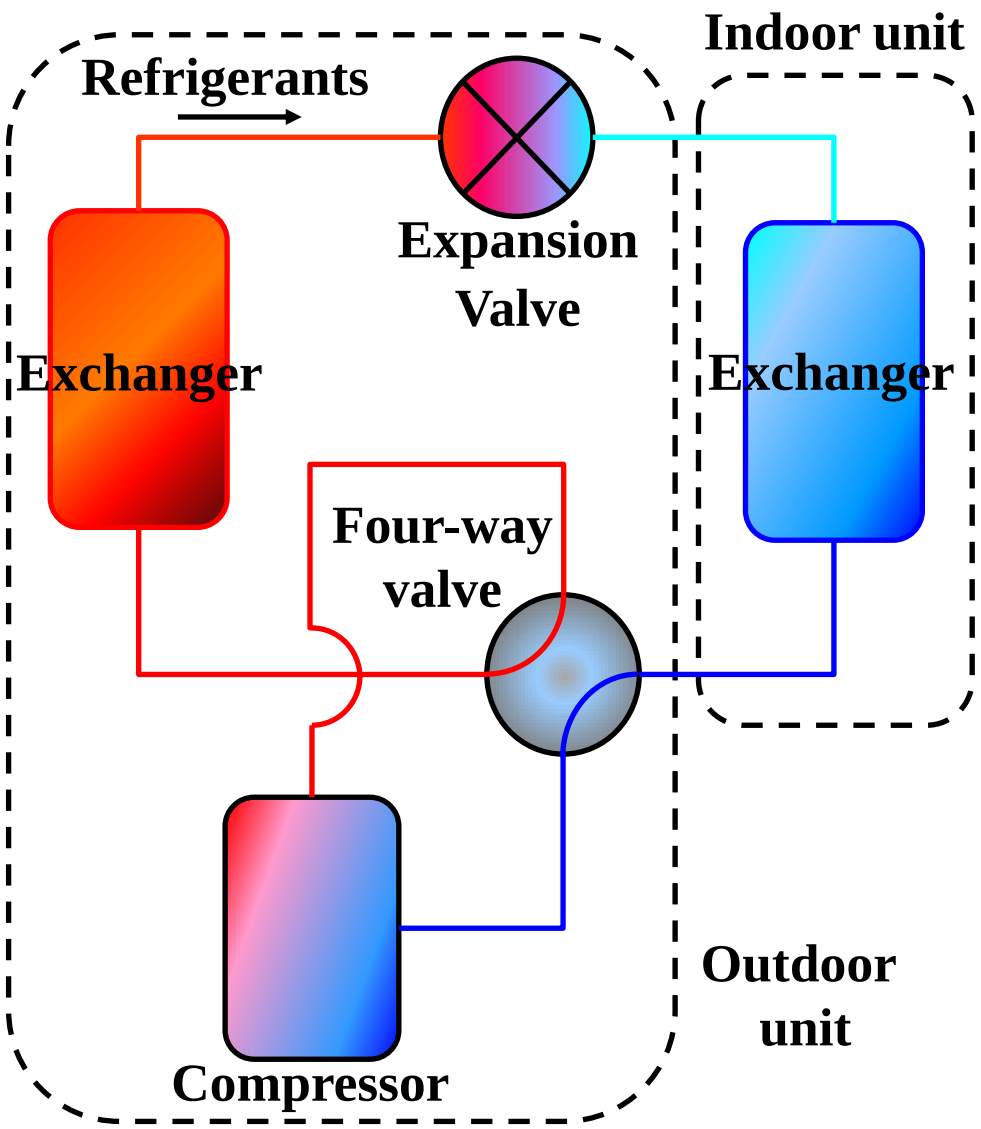


PVE-2A/R32

100℃, 1.5MPa

Lubricants	Refrigerants	Solubility (wt%)	Viscosity (mm^2/s)
PVE-1A	R410A	4.6	5.7
PVE-2A	R32	3.5	5.2

Lubricity of PVEs for R32



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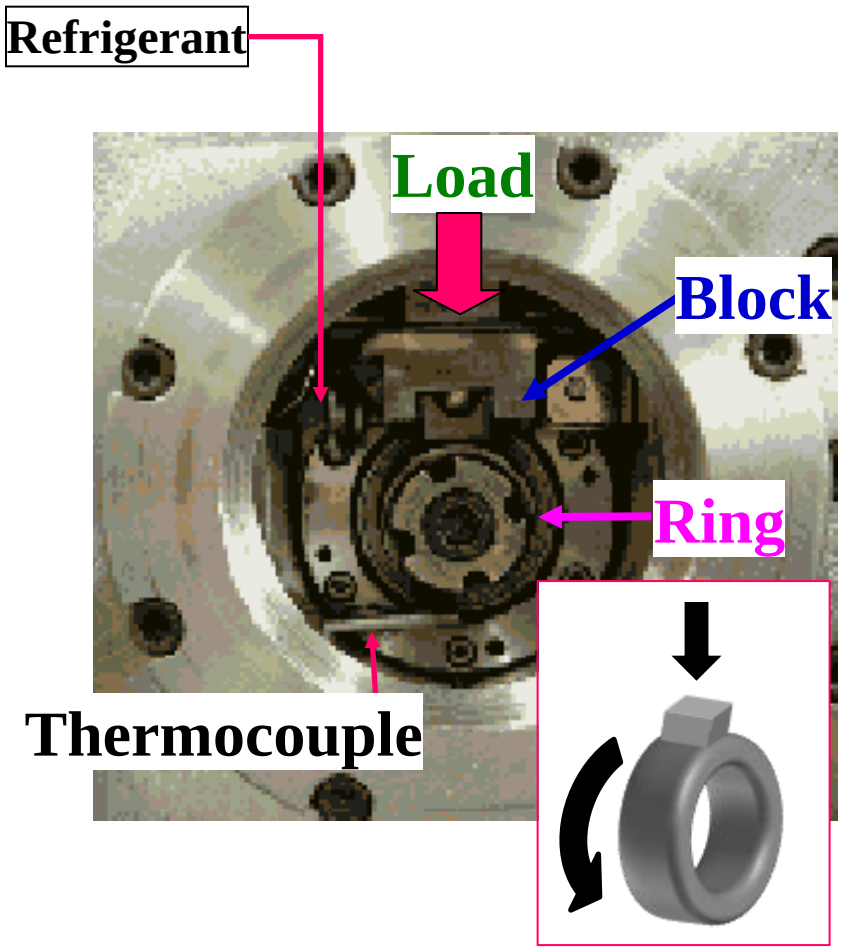
Lubricity

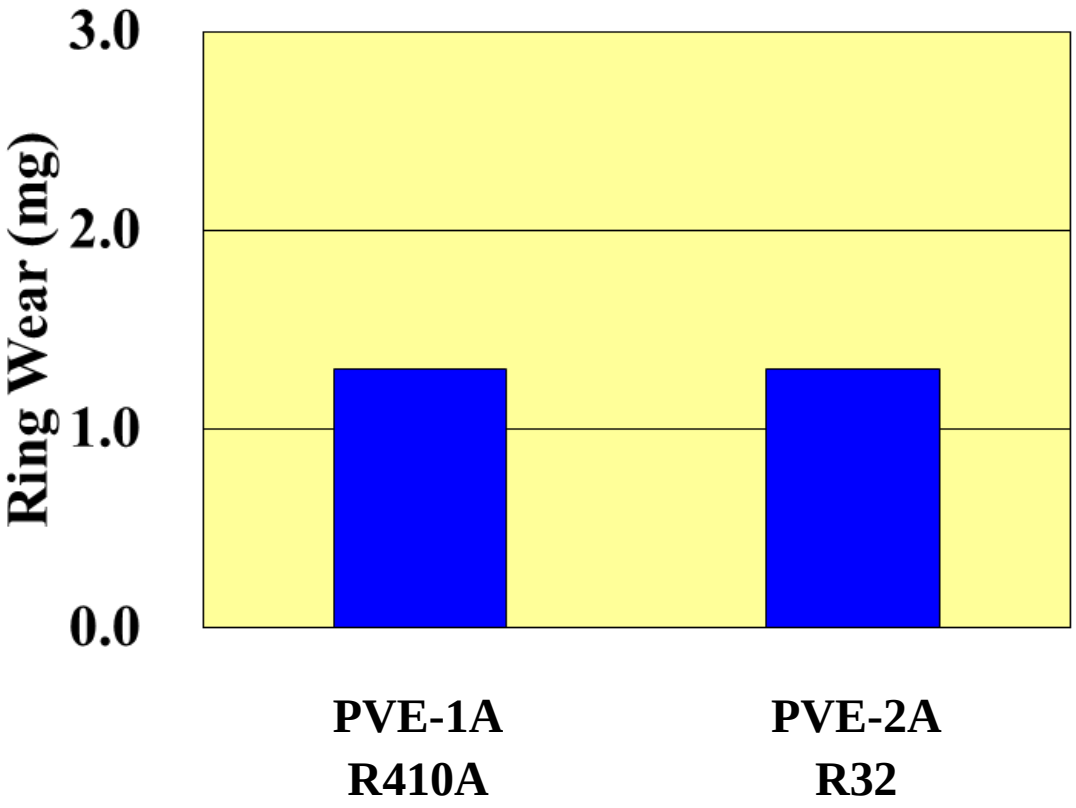


Hermetic Type Block-on-Ring Tester

Lubricity Test Condition

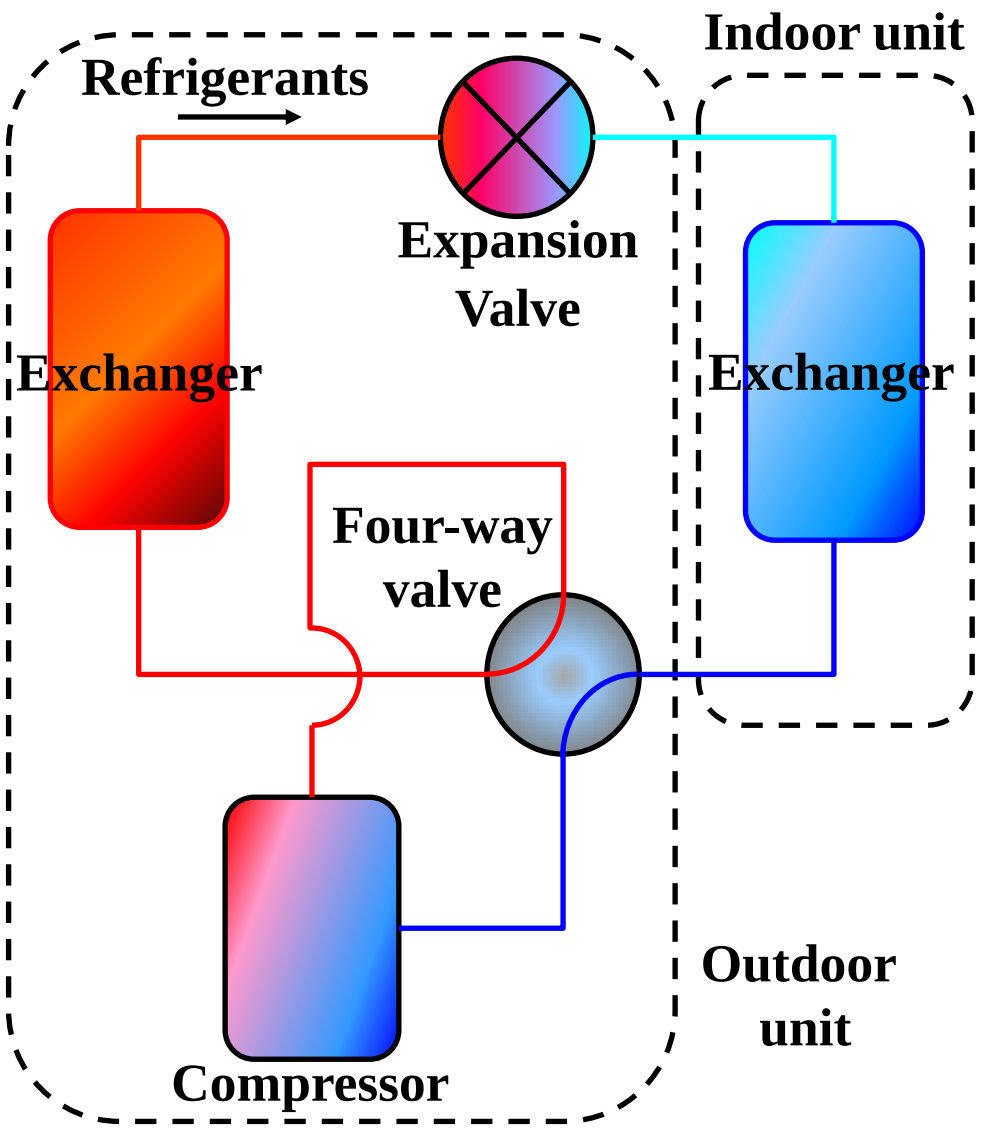
Condition	Test
Temperature (℃)	100
Test Time (min)	60
Oil (g)	250
Refrigerant (MPa)	1.5
Test Piece (Ring)	FC250
Test Piece (Block)	SKH51
Load (N)	1400
Speed (rpm)	1400

Lubricity of PVE-2A



Lubricity is good.

Volumetric Resistivity of PVEs for R32



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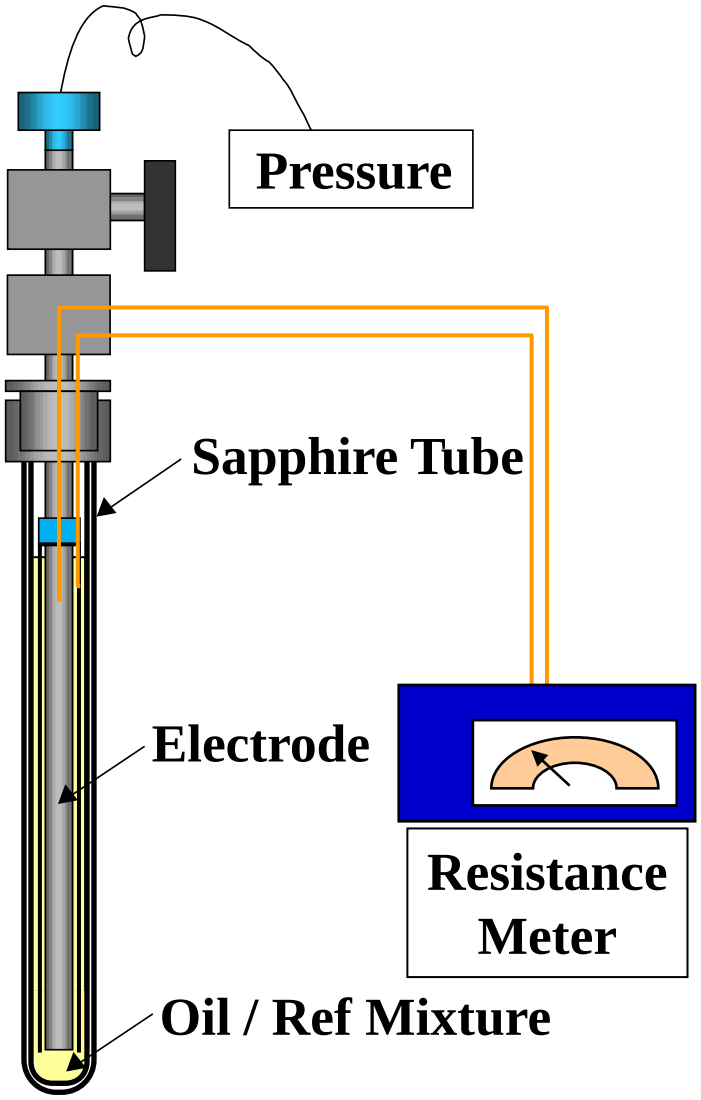
Volumetric Resistivity



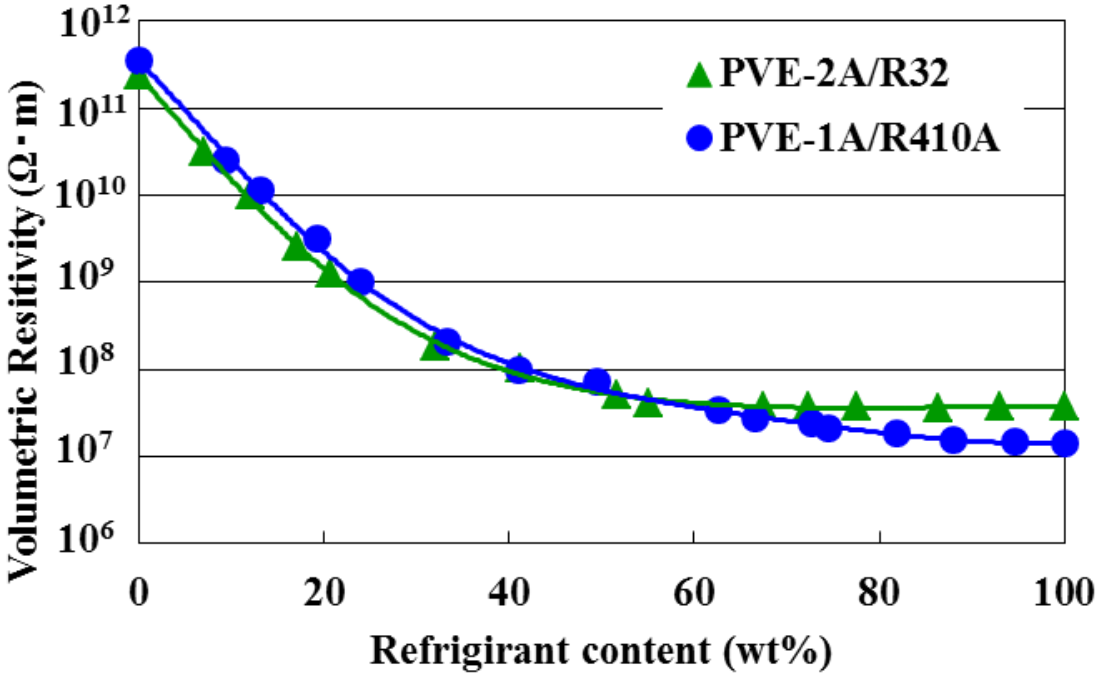
$$I = \frac{1}{\rho} E$$

I : Current density (A / m^2)

E : Electrostatic strength (V / m)

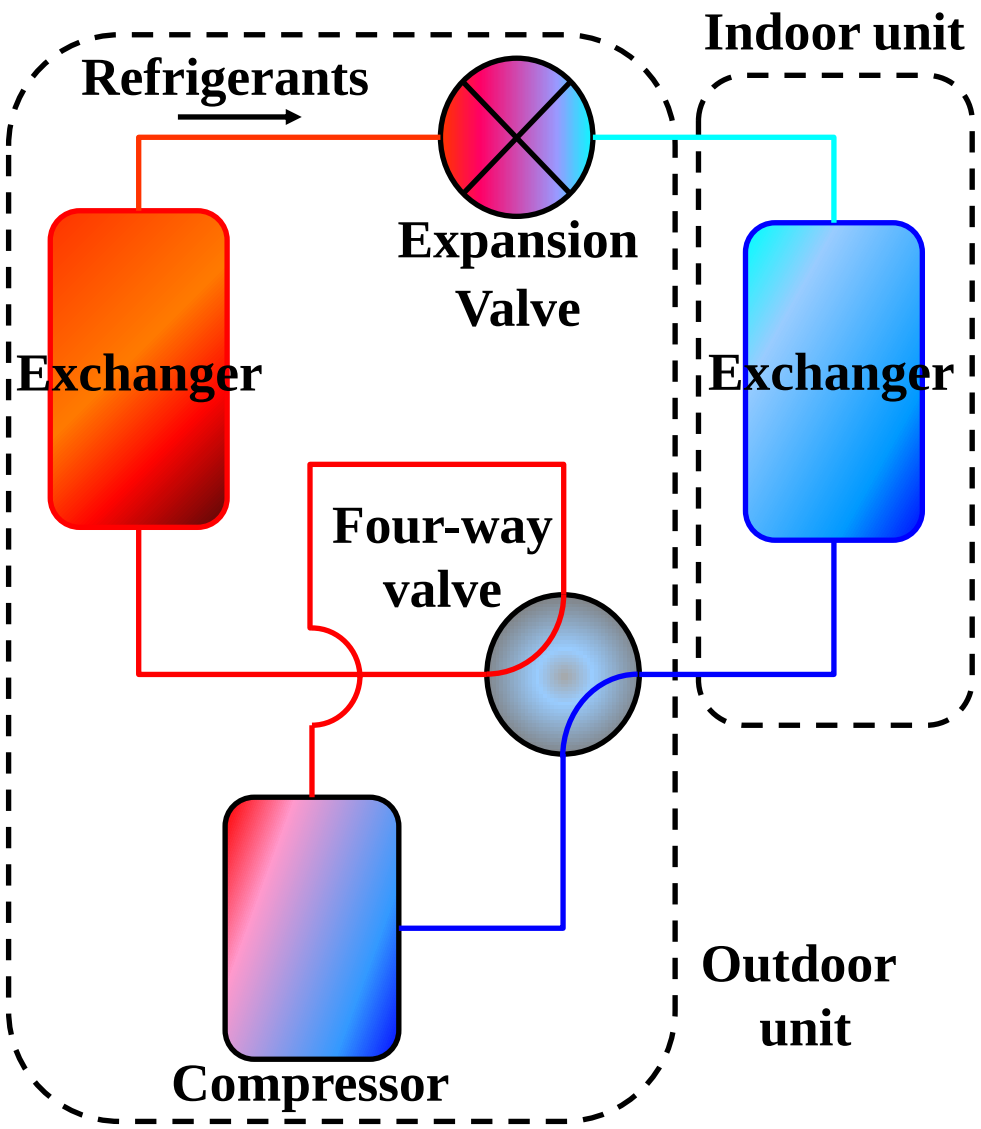
ρ : Volumetric Resistivity ($\Omega \cdot$m)

Volumetric Resistivity of PVE-2A



Volumetric Resistivity is good.

Stability of PVEs for R32



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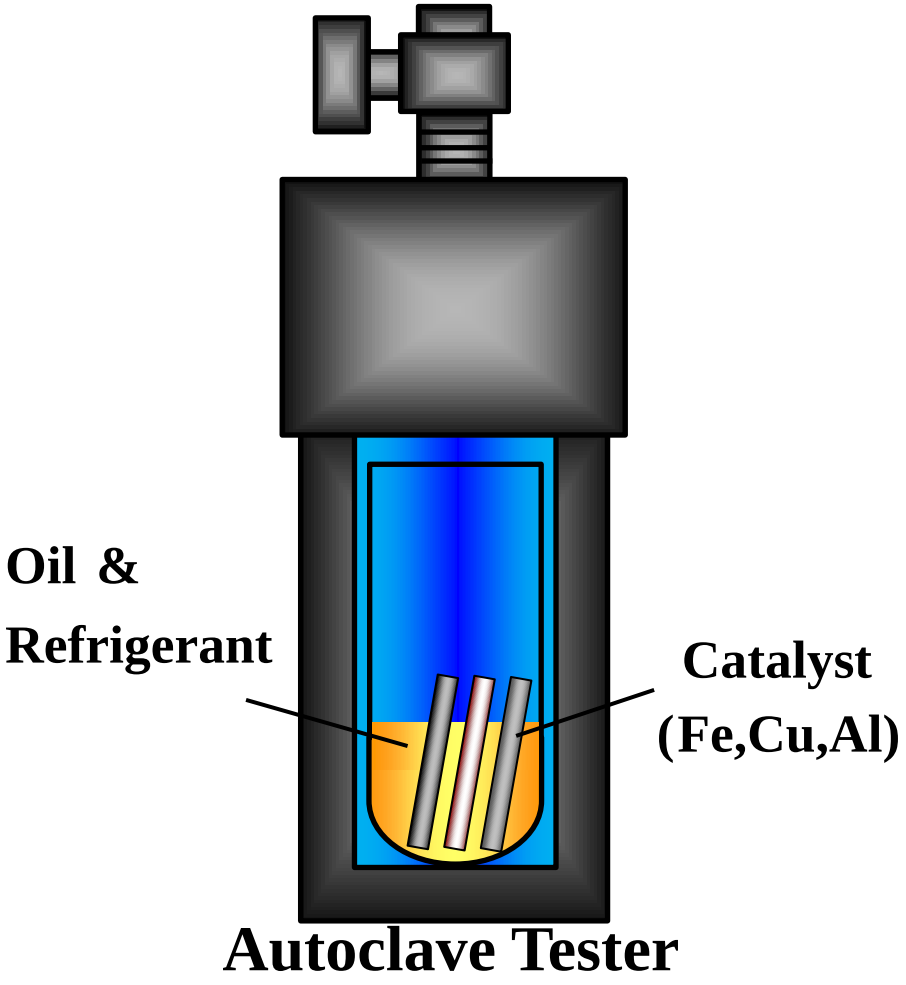
Stability

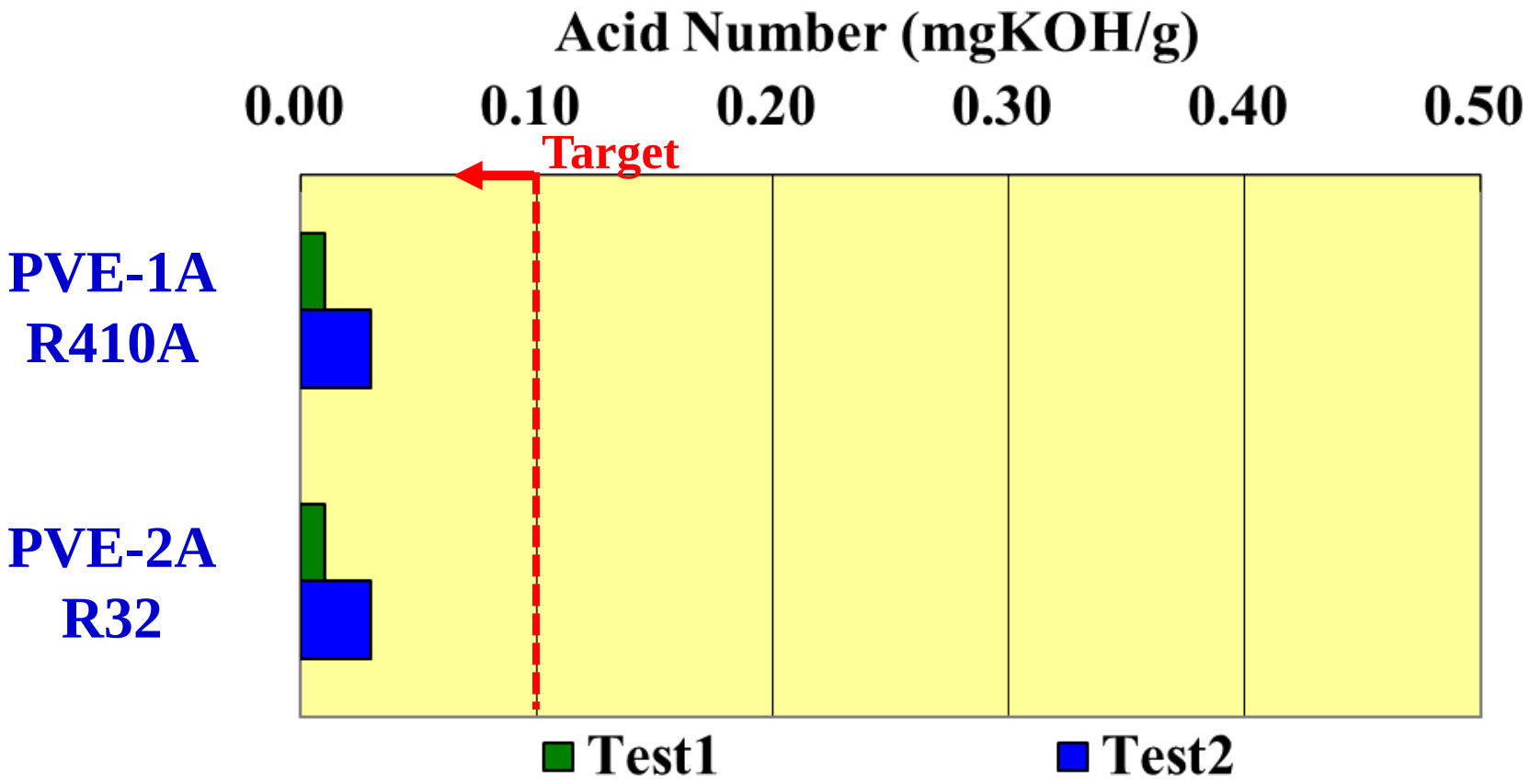


Stability Test Condition

Condition	Test 1	Test 2
Temperature (℃)	175	175
Test Time (day)	14	14
Oil (g)	30	30
Refrigerant (g)	30	30
Water (ppm)	50>	500
Air (Torr)	5>	140
Catalyst	Fe / Cu / Al	Fe / Cu / Al

Condition of Test 1 is for Thermal Stability
Condition of Test 2 is for Hydrolytic & Oxidation Stability

Stability of PVE-2A



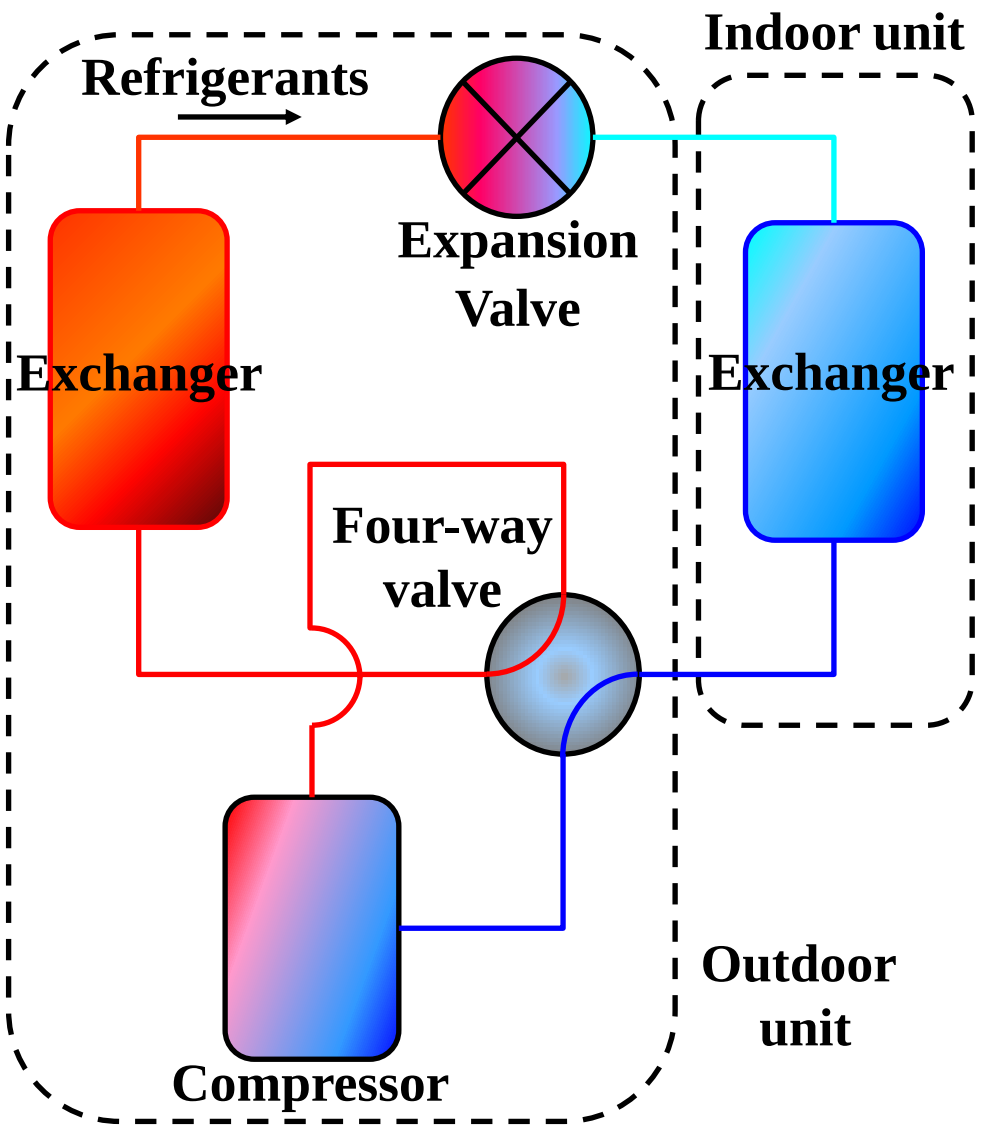
Stability is good.

Good Lubricants with R32

Refrigerants	R32	
Lubricants	PVE-1A	PVE-2A
Miscibility	Poor	Good
Volumetric Resistivity	Good	Good
Stability	Good	Good

PVE-2A was selected.

Stability of PVEs for R1234yf



Refrigerants

(1) R1234yf

(2) R1234yf / R32 (50wt% / 50wt%)

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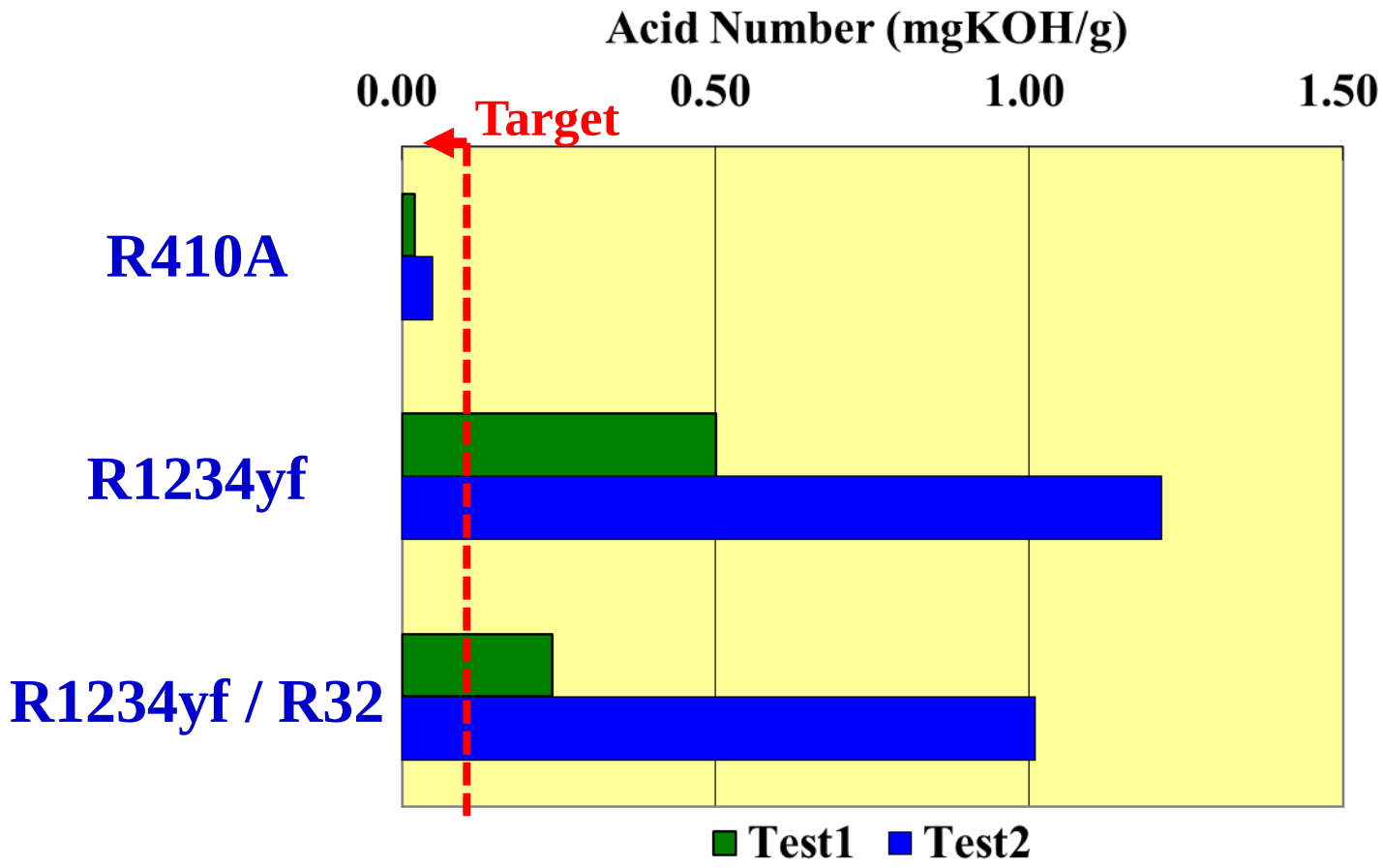
6.Stability

Stability of PVE-1A



R1234yf and R1234yf / R32 showed higher AN.

⇒ Stability of R1234yf was less than that of R410A.

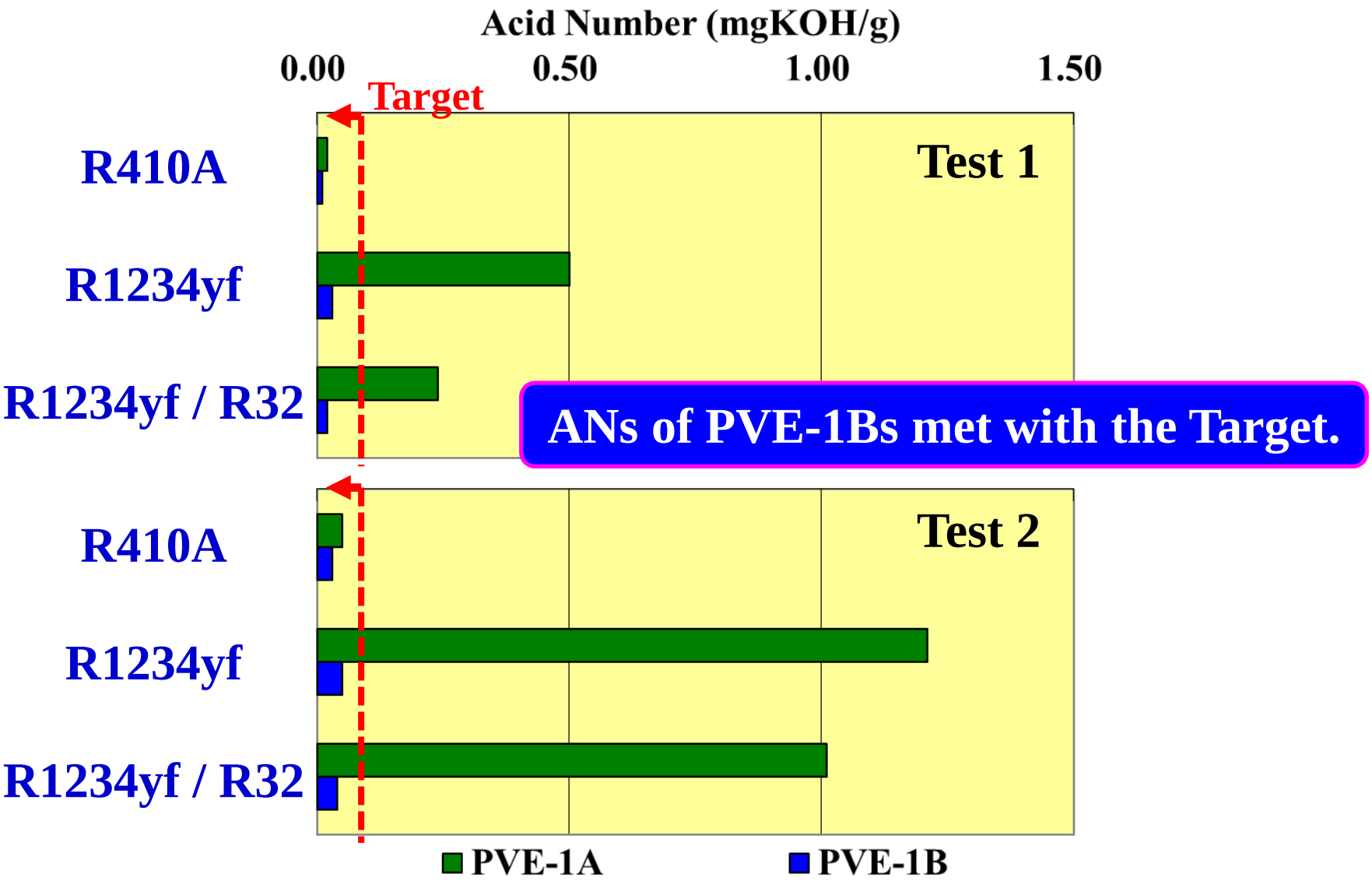
Specification of PVE-1B

Lubricant		PVE-1A	PVE-1B
Refrigerant		R410A	R1234yf
Viscosity @40℃ (mm^2/s)		66.57	66.86
Viscosity @100℃ (mm^2/s)		8.037	8.073
Viscosity Index		84	84
Density @15℃ (g/cm^3)		0.9369	0.9370
Acid Number (mgKOH/g)		0.01>	0.01>
PVE type		PVE1	PVE1
additive	antiwear	include	include
	antioxidant	include	include
	acid catcher	include	include
	New compound	-	**include**

⇒**B**

PVE-1B was included additive of the New compound.

Stability of PVE-1B



Conclusion(1)

The development of PVE-2A for R32
changed the monomer ratio of the PVE side chain.

$$\mathrm{H\text{-}(\underset{\displaystyle |\atop \displaystyle O\text{-}R_1}{CH}\text{-}CH_2)_m - (\underset{\displaystyle |\atop \displaystyle O\text{-}R_2}{CH}\text{-}CH_2)_n\text{-}H}$$

$m/n = a'/b'$

&

PVE-2A for A/C System with R32

Good Miscibility

Good Stability

Good Lubricity

Good Volumetric Resistivity

Conclusion(2)

The development of PVE-1B
for R1234yf, R1234yf / R32

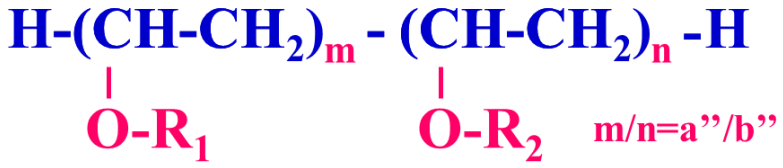
included additive of the New-Compound.

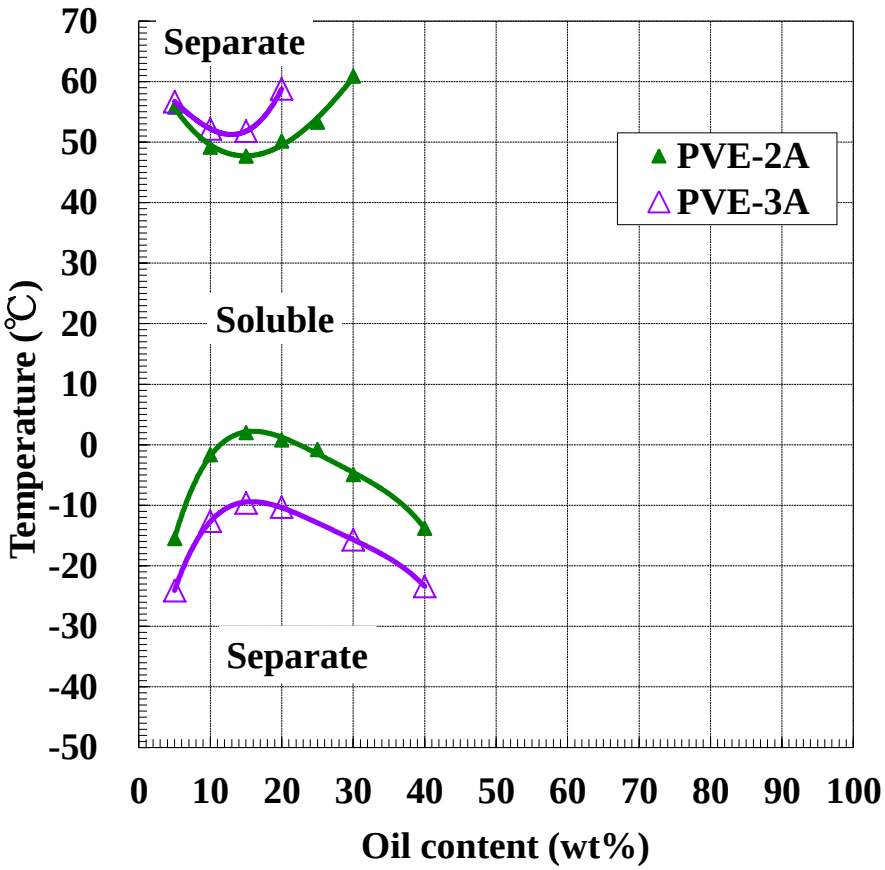
&

PVE-1B for A/C System
with R1234yf, R1234yf / R32
Good Miscibility
Good Stability
Good Lubricity
Good Volumetric Resistivity

Specification of PVE-3A
For cold area with R32

Lubricant		PVE-2A	PVE-3A
Refrigerant		R32	R32
Viscosity @40℃ (mm^2/s)		68.41	65.01
Viscosity @100℃ (mm^2/s)		8.316	8.030
Viscosity Index		88	88
Density @15℃ (g/cm^3)		0.9440	0.9542
Acid Number (mgKOH/g)		0.01>	0.01>
PVE type		PVE2	PVE3
additive	antiwear	include	include
	antioxidant	include	include
	acid catcher	include	include





Chemical Structure of PVE3 was modified

Miscibility of PVE-3A was improved.

Thank you !

Questions ?

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