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# **A NEW SYNTHETIC HYBRID REFRIGERATION OIL FOR R410A AND R407C**

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## **ABSTRACT**

There is a need to improve conventional polyolester lubricants that are currently being evaluated as the optimal refrigeration base oil for the alternative refrigerants R410A and R407C, which are expected to be designated as the replacement of HCFC 22. Prior studies show that the conventional polyolesters and other lubricants have poor hydrolysis and solubility.

This paper is an introduction to a new hybrid polyolester made by a simple synthesis of alcohols, olefins and carbon monoxide as raw materials, and its evaluation process as a refrigeration oil as compared to conventional lubricants. Having a 100% alpha branched structure with a wide temperature miscibility range, research on this hybrid polyolester shows excellent hydrolytical, oxidation and chemical stability and lubricity not seen in esters introduced in the past.

## **INTRODUCTION**

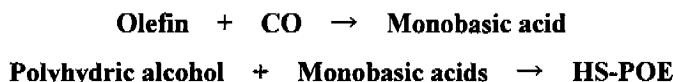
The production of air conditioners using either R407C or R410A as a replacement refrigerant to HCFC-22 has now begun. In the majority of cases, HS-POE (High Stability-Polyol Ester) is used as a refrigeration oil where HFC type refrigerants are used in refrigerators and air conditioning units. However, the current HS-POE is not necessarily satisfying the quality or cost requirements, so an oil with higher quality and lower cost is being researched.

We have focused on the synthesizing procedures of POE. As a result, using a different synthesizing procedure from the normal process, HB-SL (Hybrid Synthetic Lubricant) having a 100% alpha branched structure (quaternary carbon atom) was successfully developed.

## ESTERIFICATION METHODS & MOLECULAR STRUCTURE

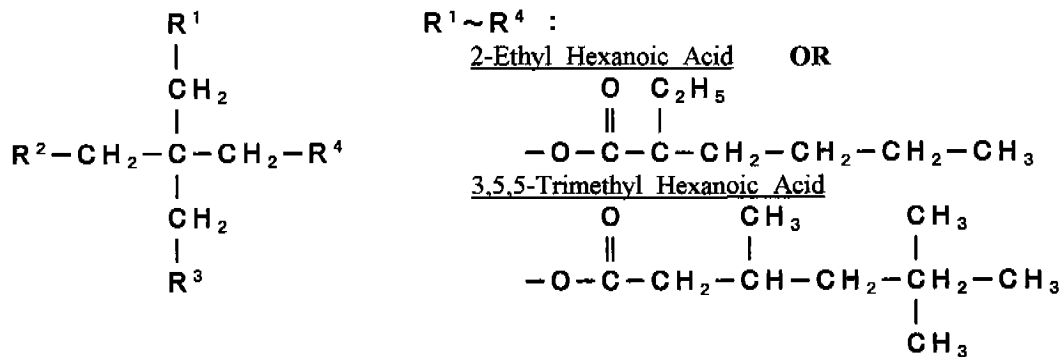
In general, POE is synthesized by an internal dehydration of polyhydric alcohols and monobasic acid(Eq.1). Currently in Japan, a high viscosity HS-POE (VG68) for HFC air conditioners is synthesized by PE(pentaerythritol) with i-C<sub>8</sub> acid(2-ethyl hexanoic acid) and i-C<sub>9</sub> acid(3,5,5-tri methyl hexanoic acid). After the two different types of fatty acid are synthesized, the esterification process follows.

### Eq. 1: HS-POE Process



The molecular structure of a high viscosity HS-POE (VG68) is shown in Eq. 2. The alpha carbon atom is attached to an ethyl group and hydrogen atom or in some cases, two hydrogen atoms are bonded. This HS-POE results into mixtures of five different types of molecules.

### Eq. 2: HS-POE molecular structure



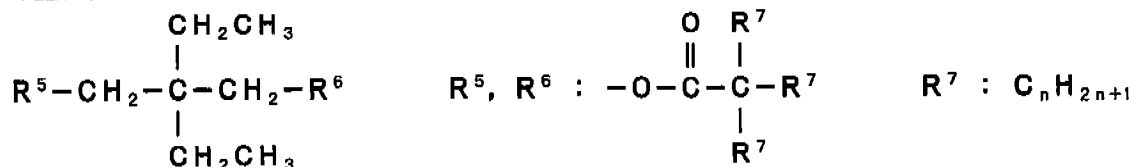
As in contrast, HB-SL is synthesized from alcohol, olefin and CO (carbon monoxide) (Eq.3) by a single process. In addition, since fatty acids are not used as a raw material, there are no supply limitations as in the case of HS-POE. As a result, a stable HB-SL of a 100% alpha branched structure is made and when compared to HS-POE, the HB-SL is improved in hydrolytic stability and mutual miscibility with HFC refrigerants.

### Eq. 3: HB-SL Process(Reference:1)



HB-SL has a structure of tertiary fatty acid bonding to NPG (neopentyl glycol)(Eq.4). From this advanced synthetic method, HB-SL has mixtures of over 10 different types of molecules and has a wide range in molecular weight as seen also in mineral oils.

### Eq. 4: HB-SL Molecular Structure



## PERFORMANCE

Refrigeration oil requires good chemical stability (especially in POE for hydrolytic stability), lubricity, material compatibility and other various characteristics. In order to meet these requirements, oils especially for HFC type applications, must have not only a better quality base oil, but also an effective additive formulation. Taking into consideration of the above required qualities, this paper presents the data on solubility with refrigerants, chemical stability and lubricity of HB-SL.

### Solubility:

In the first place, the reason why POEs were used as a synthetic refrigeration oil for HFC refrigerant, was that mineral oils were not soluble with HFC. In other words, solubility with refrigerants was the first characteristic to clear for the refrigeration oil to be considered.

In Fig.1 and Fig.2, the solubility data of HB-SL for R407C and R410A is shown. The solubility of refrigeration oil in refrigerants is dependent on the characteristic of the base oil and may be not adjusted by additive formulation. In the case of HFC refrigerant and POE, the solubility depends of the molecular structure of alcohol and fatty acids. The lower side critical solution temperature (L-CST) of HS-POE (VG68) with R410A is poor at +10°C. In comparison to this, L-CST of HB-SL with R410A is better at -17°C. Therefore, HB-SL has the advantage in oil return from the low side of the refrigeration cycle and heat pump application in cold weather.

HB-SL is very soluble in R407C as shown.

Fig. 1: Mutual solubility of R410A

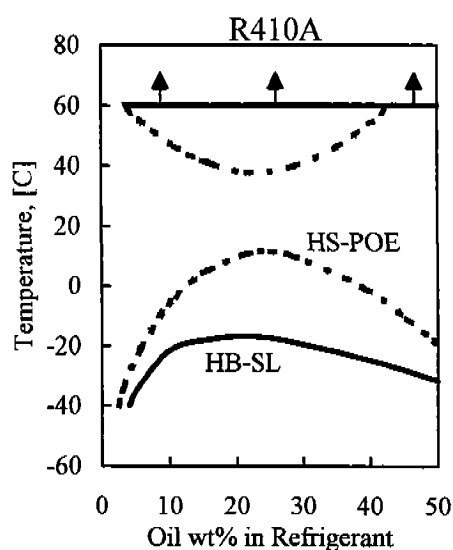
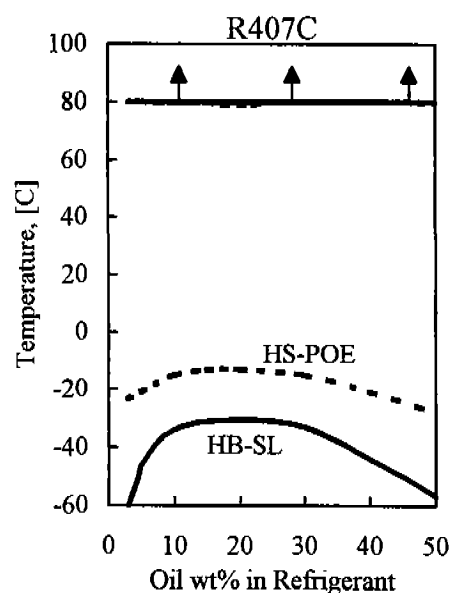


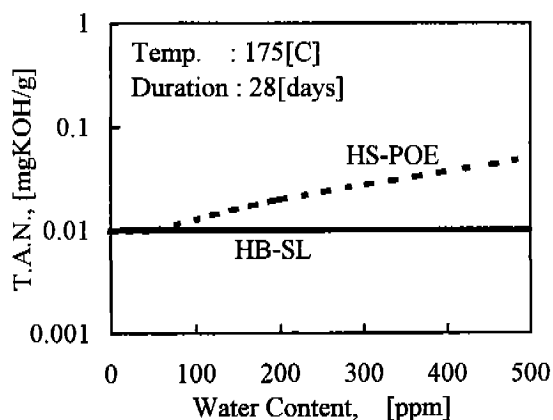
Fig. 2: Mutual solubility of R407C



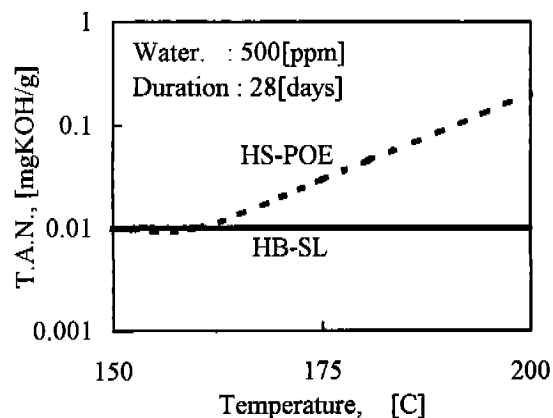
### Hydrolytical Stability:

Hydrolytic stability is a very important characteristic. Hydrolysis of POE results in fatty acids, which are harmful to the refrigeration system. Hydrolytical stability as measured by the sealed tube method is shown on Fig.3 to Fig.5. Having a partial alpha branched structure, it is easy for water to attack the ester group of HS-POE. As a result, the total acid number increases rapidly and in order to prevent this, HS-POE is dependent on the use of an epoxy type additive.

**Fig. 3: Hydrolytical Stability-Effect of water**



**Fig. 4: Hydrolytical Stability-Effect of temperature**

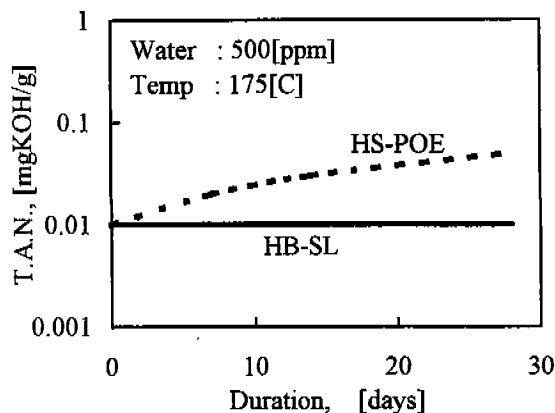


On the other hand, HB-SL has alpha carbon atom bonding with two alkyl groups which makes it a highly steric hindrance for ester group. As a result, the hydrolytic stability is excellent as compared to the HS-POE, the total acid number does not increase.

### Lubricity:

To promote proper lubrication in the system, the chloride atom in the refrigerant is beneficial for adequate lubrication. Therefore, if a chloride free HFC refrigerant is used, a higher level of lubricity is required in the oil than in the past.

**Fig. 5: Hydrolytical Stability-Effect of time**



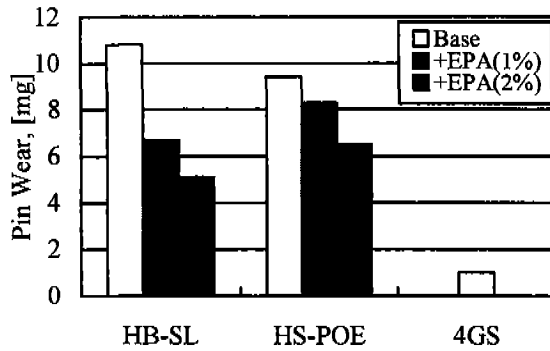
The Falex test is normally used to measure lubricity by failure load and pin wear as data results shown in Table 1. In general, synthetic refrigeration oils like POE for HFC refrigerants as compared to naphthenic oils, the failure load is high but pin wear rate is slightly poor. Especially, with the refrigerant, pin wear rate of the naphthenic oil 4GS(VG56) is lower than that of POE.

**Table 1. Falex test results (Failure Load)**

| Failure Load, lbs | HB-SL | HS-POE | 4GS(VG56) |
|-------------------|-------|--------|-----------|
| Base Oil          | 1,000 | 1,000  | 530       |
| + EPA*(1%)        | 1,050 | 1,050  | 780       |
| + EPA*(2%)        | 1,100 | 1,050  | 900       |

\*Extreme Pressure Additive

**Fig.6 : Falex test results (Pin Wear Test)**



At this point, we have conducted compressor endurance tests with two kinds of refrigerants(R407C and R410A) and analyzed the parameters. The test results are as shown in Table 2A and Table 2B.

**Table 2A. Compressor Endurance Test Results-R410A/HB-SL**

|                              |      |      |      |      |      |      |
|------------------------------|------|------|------|------|------|------|
| Compressor Type              | RO   | RO   | RO   | RO   | RO   | RO   |
| Application                  | RAC  | RAC  | RAC  | RAC  | RAC  | RAC  |
| Modification of compressor   | Yes  | Yes  | Yes  | Yes  | Yes  | No   |
| EPA                          | Yes  | No   | Yes  | No   | Yes  | No   |
| Test Condition               | HSC  | HSC  | HSC  | HSC  | HLC  | HLC  |
| Duration, [hrs]              | 700  | 700  | 2000 | 4000 | 2000 | 2000 |
| Wear                         | Pass | Pass | Pass | Pass | Pass | Pass |
| Copper Plating               | No   | No   | No   | No   | No   | No   |
| Deterioration of oil         | No   | No   | No   | No   | No   | No   |
| Decomposition of refrigerant | No   | No   | No   | No   | No   | No   |

**Table 2B. Compressor Endurance Test Results-R407C/HB-SL**

|                              |      |      |      |      |      |      |
|------------------------------|------|------|------|------|------|------|
| Compressor Type              | RO   | RO   | RO   | RO   | RO   | RO   |
| Application                  | RAC  | RAC  | RAC  | RAC  | RAC  | RAC  |
| Modification of compressor   | No   | No   | No   | No   | No   | No   |
| EPA                          | Yes  | No   | Yes  | No   | No   | Yes  |
| Test Condition               | HSL  | HSL  | HSL  | HLC  | HLC  | HLC  |
| Duration, [hrs]              | 1000 | 1000 | 2000 | 2000 | 2000 | 2000 |
| Wear                         | Pass | Pass | Pass | Pass | Pass | Pass |
| Copper Plating               | No   | No   | No   | No   | No   | No   |
| Deterioration of oil         | No   | No   | No   | No   | No   | No   |
| Decomposition of refrigerant | No   | No   | No   | No   | No   | No   |

Test Condition    HSL    : High Speed High Load Continuous  
                           HSC    : High Speed Continuous  
                           HLC    : High Load Continuous  
 Compressor Type   RO    : Rotary Compressor  
 Application         RAC    : Room Air Conditioner

The above tables show satisfactory results on lubricity and passing range levels for the wear and other items. Although not shown in figures, we have found that the test for HB-SL with extreme pressure additive shows significantly better results. Although the Falex pin wear test results of Fig. 6 do not reflect positive results, actual compressor endurance test runs are more reliable for data purposes. The tested oil analysis showed that the oil has not deteriorated and copper plating or sludge did not occur.

### CONCLUSION

1. A 100% alpha branched structure HB-SL was developed by advanced and unique synthesis method.
2. HB-SL has significantly better solubility with R407C and R410A as compared to HS-POE.
3. HB-SL has the most advantage in hydrolytic stability.
4. The actual compressor endurance test is a more reliable test method which shows HB-SL passing the lubricity requirements as opposed to the Falex test method.
5. HB-SL production process, when compared to HS-POE production stages, is a cost savings process.

### REFERENCES

- (1)Technology of Mitsubishi Gas Chemical, Inc