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# HFC/POE LUBRICITY EVALUATION ON THE ROTARY COMPRESSOR IN SYSTEM OPERATION

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**ABSTRACT**

As R22 alternative refrigerant/oils, R407/POE/polyolester) and R410A/POE lubricating conditions on the rotary compressor journal bearings are eva1uated, using electrica1 detection for the contact at sliding parts, in comparison with R22/MO (mineral oil) as the current refrigerant/oil.
The evaluation is made with the 0.75kW class 2-cylinder rotary compressor, mounted in a split type inverter driven heat pump system, and under system operation simulating the heat pump system in actual use.
The results are:
The R407C/VG68POE's lubricating conditions the bearings is a little better than that for the current R22/MO's condition, the R407C/VG32POE's condition is roughly at the same level as for the currant R22/MO's.
The R410/VG68POE's lubricating condition on the bearing, is better than that for the current R22/MO's condition, the R410A/VG32POE's condition is roughly at the same level as for the current R22/MO's.

## INTRODUCTION

CFCs are already regulated for ozone layer protection, and now HCFCs' regulation is about to be carried out. *As* for HCFC22 (R22) mainly used as the air conditioner refrigerant, several alternative refrigerant candidates axe proposed and their applicabilities are now widely evaluated.
Among the candidates, the HFC binary or tertiary refrigerant blends are considered most likely. For the Air conditioner application, R407C (R32/125/134a, 23/52wt%) and R41OA (R32F125, 50/50wt%) are the most likely candidates. On the other hand, as the lubricating oil, mineral oil (MO) has been most applicable for R22, however, MO has poor miscibility with HFCs, so polyolester (POE), that is miscible with HFCs, is the most likely alternative oil.
On selecting the proper lubricating oil, the viscosity grade (VG), the miscibility level with the refrigerant etc. are important properties. However, good selection is hardly possible with only these static property data. Because, under a dynamic situation, such as inside the compressor during system operation, many factors may be different from those for current R22/MO; such as the temperature distribution or ambient pressure, and their changing way for example, so the refrigerant and oil behavior cannot always be the same as that for the current R22/MO. The rotary compressor bearing is designed as a journal bearing to be lubricated by the hydrodynamic lubricating oil film formation; so the lubricity on the bearing is governed by the oil film forming condition, which depends on both the oil viscosity behavior and the load influenced by pressure and rotating frequency.
This paper describes a new experimental approach to determining the lubricating condition level on the rotary compressor bearings during system operation for better selection of proper lubricating oil. In the evaluation, the lubricating condition, i.e. the contact condition between sliding parts, is monitored electrically during operation, so that the oil film breakdown can be detected instantly. The compressor operation was the air conditioner system operation that imitates actual use. 'The test results obtained for of different refrigerant/oils are afterwards compared with the R22/MO result.

## Experiment

<u>Compressor</u>

Figure 1 shows a cross-sectional view of the tested compressor. It is 0.75kW-class 2-cylinder rotary compressor (twin rotary compressor). For R407C, the same compressor *as* for R22 is used, because the R407C properties are similar to those for R22. For R41OA, the compressor displacement volume is adjusted so that the cooling capacity *is* the same as for the *R22* compressor, because the capacity derived from the refrigerant property is about 14 times as much as that for R22. The 4 electrodes are fitted in the bearings to detect the contact. The positions are as shown in Fig. 1. The angular position of the electrodes is at about 170 degree, from the vane along the crankshaft rotating direction around the crankshaft center. The position is decided on the basis of the system dynamic analysis (2) and several reliability test results. A viscosity sensor is fitted at the bottom of the shell to monitor the oil viscosity. The vane motion is monitored with a gap sensor as the rotation-timing signal (not shown in Fig. 1).

**Lubricant**

For both R407C and R410A, 2 kinds of POE oil (VG68, 32) were evaluated and the results are compared with those for the current R22 with MO (VG56). The properties of these lubricating oils are listed in Table 1.

**Lubricating condition monitoring --- electrical contact detection**

There are presently several reports that referred to the electrical contact detection for the observation of the lubricating condition (3). In this evaluation, the electrical resistance change between sliding parts is monitored as the potential drop. Figure 2 explains the method. The electrode is a metallic pin, fitted in the bearing while insulated from the bearing around it. The surface inside the bearing is finished after the electrode is fitted in. With the circuit as shown in the Figure, some voltage is applied between it and the other compressor parts. When the lubricating condition is good enough, there is hydrodynamic lubricating oil (insulator, see Table 1) film that can insulate between the bearing and the crankshaft, i.e. between the electrode and the crankshaft. However, as the condition becomes worse and the oil film is broken, the electrode and the crankshaft make direct contact, and the potential of the electrode becomes the same as that for other parts. So, by monitoring the electrode potential as the voltage output, the lubricating condition changes during the operation can be monitored instantly. The actual signal shape, when the contact occurred, was like a group of pulses, which appeared periodically at certain rotating angles for the compressor rotation. This may indicate that the actual contact between the two surfaces that have certain roughness might occur intermittently. The amount of contact signal, that is, the ares dthe voltage drop (see Fig. 2), per 1 revolution cycle time, can be regarded as the index of the lubricating condition. In this paper, this amount is called "signal intensity".

**Compressor operating method — air conditioner system operation**

In this evaluation, the compressor was mounted in an air conditioner system and operated under the system's control in order to imitate the actual air conditioner use. The air conditioner is a split type inverter driven heat pump type RAC (room air conditioner). The expansion device is a capillary tube. For R407C test, refrigerant weight is adjusted. For R410A, capillary tube length is adjusted. The operation mode is heating. This is because, during heating operation, It may well be considered that compressor frequency, temperature, and pressure change more widely than during cooling operation. The system operation was made in the manner shown in Figure 3. That is, the system is settled in the test room and both indoor & outdoor area is kept at 273K(OT) for 24 hours. Then indoor temperature controller of the teat room is switched off (outdoor is still kept at 273K(0C$^{o}$) and RAC system operation is started with RAC's controller temperature set at 303K(30$^{o}$C). The operation continues until the indoor room temperature goes up to 303K(30$^{o}$C) and compressor frequency goes down and finally stops. In this method, the test operating thus was about 4 to 6 hours.

## RESULTS

**Operation transition**

Figure 4 shows an example of the operation transition on this evaluation. The transitions in different refrigerant/oils were all similar except for the operating time. Discharge pressure (Pd), suction pressure. (Ps), inverter frequency, indoor room temperature, oil viscosity in the compressor, and compressor shell bottom temperature (close to oil temperature) are plotted against operating time.

From starting while the indoor temperature is rather low, the operation is in high capacity mode with high inverter frequency and the discharge pressure goes higher along with the indoor temperature rise. The oil viscosity falls immediately after starting, and recovers after a while. This may indicate that, on starting the flood-back occurs and the oil is diluted with the liquid refrigerant and viscosity falls. Then, after a while, oil temperature (see compressor bottom temperature) rises and dissolved refrigerant is released. Afterwards, the

viscosity falls slightly. This may indicate that, after must of refrigerant *is* released, viscosity is mainly influenced by temperature.
After indoor temperature comes close to the set value, the inverter frequency is gradually lowered to control capacity, and finally the compressor stops. During this period, the discharge pressure and the shell bottom temperature also fall gradually, and oil viscosity rises little by little.
In this operating method, the lubricity in various operating modes and the changes mentioned above, are evaluated

**Contact signals in operation**

The contact signal intensity changes (see the paragraph on "Lubricating condition monitoring") for different refrigerant/oils during this system operation are shown in figs. 5&6. The intensity shown in the figures is the total of the 4 electrode signals.

**Comparison between R407C/POE and R22/MO**

The contact signal intensity changes during test operations of R407C/VG88POE, R407C/VG32POE, and R22/VG56M0, are shown in Fig. 5. Operating times vary, because of experimental unevenness (see the paragraph on "Operation transition"). To compare signal intensities all through the operation, the R407C/VG32POE signal is roughly the same as for current R22/VG56M0, and the R407C/VG68POE signal is rather less than these 2 cases. This may indicate that the R407C/VG68POE's lubricating oil film condition on the bearing is a little better than current R22/VG56MO's, the R407C/VG32POE's condition is roughly at the same level as for current R22/VG56MO's.

**Comparison between R410A/POE and R22/MO**

The contact signal intensity changes during test operations of R410A/VG68POE, R410A/VG32POE, and R22/VG56MO, are shown in Fig. 6. In the case of Fig. 6, not only the data for R410A's but also the data for R22/VG56MO's are newly measured. The reason is that it *was* not possible to avoid some influence due to the difference in the seasons when the test was made, on the transition of the operation (the system operating method needs test room's temperature controller off). To compare the signal intensities all through the operation, the R410A/VG32POE signal is roughly the same as that for current R22/VG56MO, and the R410A/VG68POE signal is less than these 2 cases. This may indicate that the R410A/VG68POE's lubricating oil film condition on the bearing is better than that far current R22/VG56MO's, the R410A/VG32POE'e condition is roughly at the same level as for current R22/VG56MO's.

## CONCLUSION

HFC/POE lubricating condition on the rotary compressor bearing in RAC system operation was experimentally evaluated in comparison with current B22~MO. R407C and R4IOA as HFC, and 2 kinds of POE (VG68, 32) were tested. The lubricating conditions were monitored by the electrical contact detection.
From the experimental results, the following conclusions are obtained.

1. The R407C/VGOSPOE'e lubricating condition on the bearings Is a little better than that for the current R22/MO'sondition, the R4O7C/VG32POE's condition is roughly at the same level as far the current R22/MO's.

2. The R410/VG68POE's lubricating condition on the bearings is better than that for the current R22 (MO's condition, the R410A/VG32POE's a condition is roughly at the same level as for the current R22/MO's.

In the future, more extensive tests carried out under various operating conditions, and examination of the relation *to* reliability tests, will be implemented, so as to select proper lubricating oil and to develop highly reliable products.

1. Refrigerant Property Calculating Program REFPROP Var. 4" by NIST

2. Hattori H. Kawashima, N., “Dynamic Analysis of a Rotor-Journal Bearing System for Twin Compressors”, Proceedings of the 1990 International Compressor Engineering Conference at pp.750-760, 1990.
3. For example, Ozu, M., Itami, T., “Some Electrical Observations of Metallic Contact Between Lubricated Surfaces under Dynamic Conditions of Rotary Compressor”, Proceedings of the 1980 International Compressor Engineering Conference at Purdue, pp.105-111, 1980.

| Property | | POE-1 | | POE-2 | | MO |
|---|---|---|---|---|---|---|
| Viscosity Grade | | 68 | | 32 | | 56 |
| Density (g/cm³) @288K (15°C) | | 0.968 | | 0.974 | | 0.915 |
| Kinematic Viscosity | @313K (40°C) | 65.6 | | 31.4 | | 54.6 |
| (mm²/s) | @373K (100°C) | 8.15 | | 5.25 | | 6.06 |
| Viscosity Index | | 90 | | 85 | | 22 |
| Lower Separation Temp. (Refrigerant Kind) | | 260K (−13°C) (R407C) | 284K (+11°C) (R410A) | 238K (−35°C) (R407C) | 243K (−30°C) (R410A) | 278K (+5°C) (R22) |
| Volume Resistivity (Ω·cm) | | $>10^{13}$ | | $>10^{13}$ | | $>10^{14}$ |

**Table 1. Physical properties of evaluated oils**

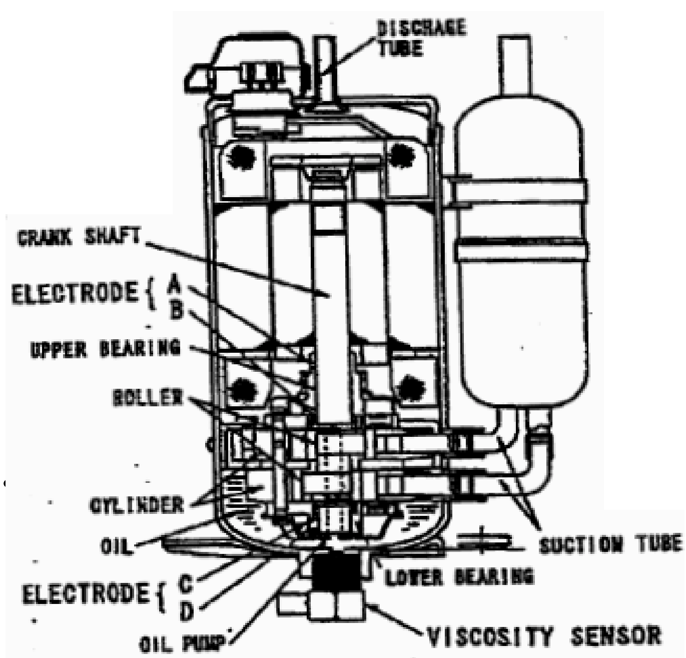



**Figure 1. Cross-sectional view of test compressor**

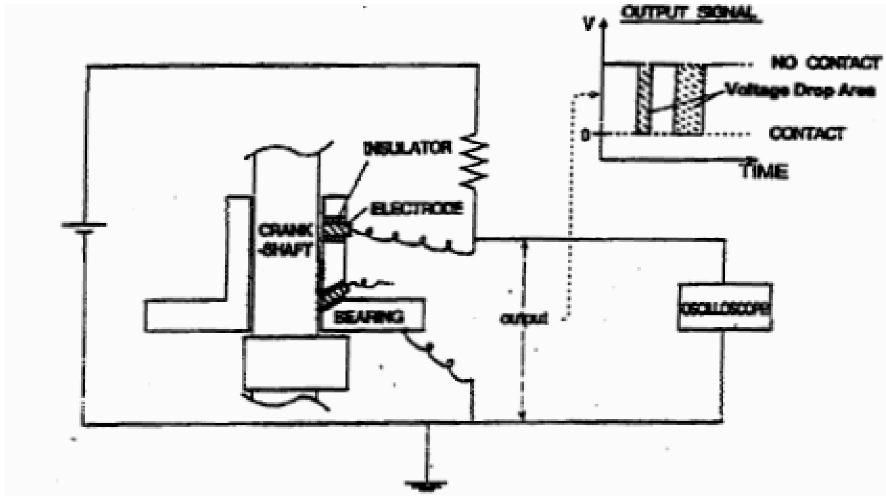



**Figure 2. E1ectrica1 contact detection system**

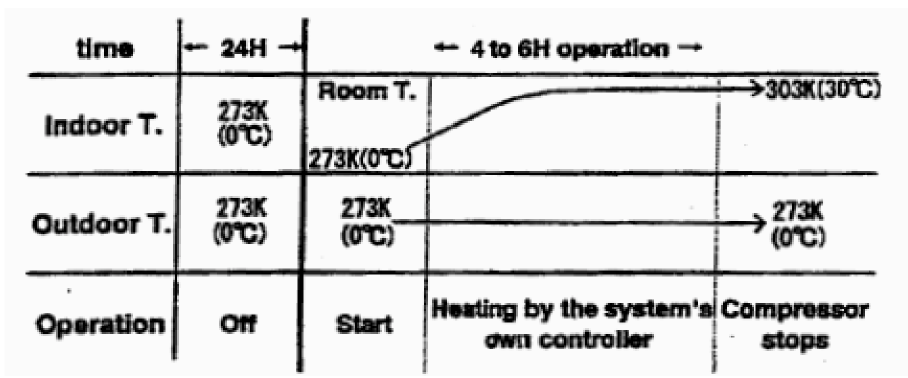
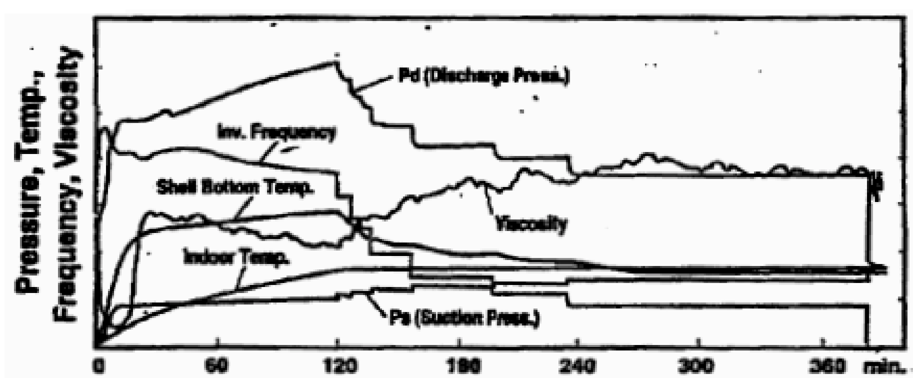



**Figure 3. Operating procedure diagram**




**Operating Time**

**Figure 4. An example of operation transition**

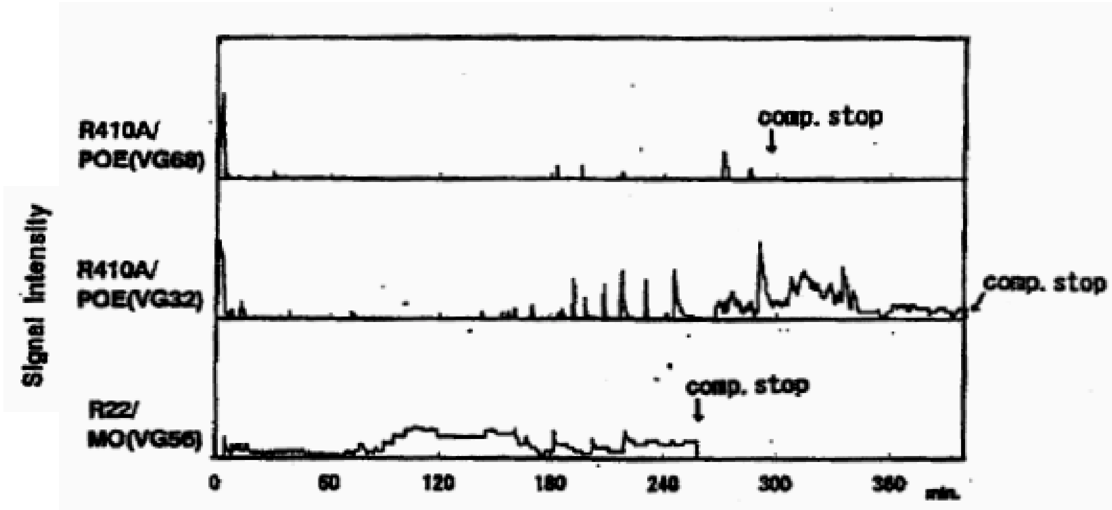



**Figure 5. Contact signal comparison between R4O7C/POE and R22/MO**

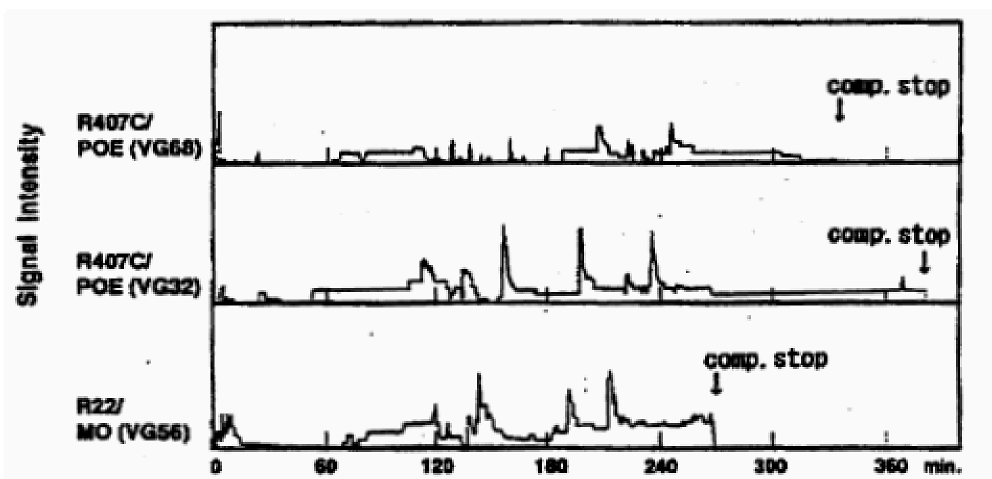



**Figure 6. Contact signal comparison between R410A/POE and R22/MO**