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EVALUATION OF HFC ROTARY COMPRESSOR AND SYSTEM
(Improvement of Lubricating Ability and Capillary Tube Clogging)

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ABSTRACT

In the process of developing refrigerating systems for alternative refrigerants, two problems
must be solved. First, chlorine-free refrigerants cause a decrease in lubricating ability. Second,
impurities and decomposition of refrigerant oils cause capillary tube clogging.

Among all types of compressors, rotary compressors face the most serious problems.
Therefore, the sliding parts must be reinforced to reduce lubricating capacity. Also, either the
impurity content must be decreased, or refrigerant oil, which does not clog easily, must be
selected.

In this paper, the authors investigated using ether as the refrigerant oil, and a swing
compressor instead of a rotary compressor. As a result, the problems were solved.

1. INTRODUCTION

Today, environmental protection and energy efficiency issues have led to regulations
related to air conditioning systems and low temperature equipment. As a result of such issues,
the ozone-deleting refrigerants, CFC's and HCFC's, which include chlorine, the ozone-depleting
factor, are now regulated. CFC's were phased out on January 1, 1996. HCFC's will
be banned by the year 2030.

HCFC22 refrigerant has been used mainly for air conditioning systems. At first, for its
alternative, various chlorine-free refrigerants were developed. Today, the possible
replacements have been narrowed down to two: a binary mixture composed of HFC32/125,
and a ternary mixture composed of HFC32/125/134a. The alternative refrigerants are shown
in Table-1.

These candidate alternative refrigerants do not include chlorine atoms in the molecule. Therefore,
these refrigerants have a problem of deteriorating lubricating ability in conditions of mixed lubrication.

<table>
<thead>
<tr>
<th></th>
<th>R22</th>
<th>R407C</th>
<th>R410A</th>
<th>R32/125/134a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23/25/52</td>
<td>50/60</td>
<td>30/70</td>
<td></td>
</tr>
<tr>
<td>ODP</td>
<td>0.22</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GWP</td>
<td>0.37</td>
<td>0.38</td>
<td>0.46</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 1. The candidate alternative refrigerants for replacing R22
Furthermore, they do not dissolve in mineral oil, which is widely used. Accordingly, it is necessary to investigate new synthetic oils. At present, ester oils have been effective candidates. This paper discusses the improvement of lubricating ability and capillary tube clogging, which are important for the reliability of rotary compressors and air conditioning systems.

2. TECHNICAL PROBLEMS FOR COMPRESSOR AND SYSTEM

The outline of a refrigerator system is shown in Fig.-1. When HFC134a replaced CFC12, there were a number of papers\(^1\),\(^2\),\(^3\) that discussed the reliability of component parts of refrigerator systems. Those papers considered two main points: improvement of lubricating ability for compressors and capillary tube clogging.

Among all types of compressors, rotary compressors face the most critical loss in their lubricating capacity. Because rotary compressors have a compression mechanism in which the sliding vane presses against the roller, the vane and the roller contact each other, under the condition of mixed lubrication. Therefore, it is necessary that the sliding parts be changed or chemically-treated\(^4\). In addition, an additive agent for the abrasion inhibitor of refrigerant oil is being developed\(^5\),\(^6\).

At first, it was observed that the wax of processing oils used during manufacturing causes capillary tube clogging\(^7\). Afterward, it was guessed that the metallic soap and polymerized oil resulting from the decomposition of refrigerant oil cause clogging\(^8\). Fig.-2 shows the mechanism of clogged capillary tubes. We considered these factors, and we investigated the main reasons for the clogging in order to reduce it.

3. IMPROVEMENT OF LUBRICATING ABILITY

One of the two major problems in developing rotary compressors for alternative refrigerants is selecting sliding vane and roller under the conditions of boundary and mixed lubrication. Shortly we will discuss the other major problem, clogging.
We tested the compressor by changing the vane and keeping the same roller. We tested with a device for compressor durability, and evaluated the results by scuffing, wear amount and surface roughness of the roller. However, it is difficult to be quantitative about scuffing appearance. It is the case that scuffing is not equal to the surface roughness of sliding parts. Therefore, though the results were not precise, we judged the scuffing by eye. Table-2 shows the result. It is possible to improve the reliability of rotary compressors regarding lubricating ability, by selecting compatible sliding parts.

4.CLOGGING OF CAPILLARY TUBE

As noted in Fig.-2, it is guessed that the factors causing capillary tube clogging are the decomposition of refrigerant oil, the decomposition of additive agents, the mixing of processing oil, the extraction of oligomer from the organic materials, and the wearing of sliding parts. Next, we analyzed the clogging materials to determine the actual main factors.

4-1.Analysis of clogging materials

We removed the clogging materials from the capillary tube, and separated insoluble and soluble compounds with chloroform. The analysis of the insoluble materials in chloroform by means of electron probe X-ray microanalysis (EPMA) is shown in Table-3.

Next, we analyzed the dissolved materials in chloroform by infrared spectroscopy (IR). We detected hydrocarbon, metallic soap and phosphate, but not refrigerant oil.

In addition, we tried to determine the formation by mass spectrometric analysis. We supposed that the hydrocarbon was wax like polybutene, and that the phosphate was iron compound.

As a result, we determined that the main factor of clogging was the decomposition of refrigerant oil and additive agents, and the processing oil used during manufacturing. Then, we narrowed our focus to these two points, and evaluated their influence in detail.
4-2. Influence of refrigerant oil decomposition

It is well-known that ester oil decomposes due to such impurities as moisture, oxygen, chloride, and several others. We controlled moisture, oxygen, and chloride, and investigated under conditions without the influence of impurities. Therefore we considered that the heat of friction increased decomposition of ester oil.

We investigated the clogged capillary tube using a compressor device shown in Fig.-3. However, because it was difficult to measure the temperature due to friction, we substituted the value of the contact force between the vane and roller for that.

Because the rotary compressor is a structure in which the vane presses against the roller, making use of discharge pressure, the result is large differential pressure, large contact force, and high temperature.

As a result, we supposed that refrigerant oil decomposes, that the decomposed matter accumulates in the capillary tube, and that the flow rate decreases.

4-3. Influence of processing oil used during manufacturing

Next, we investigated the influence of processing oil content. We chose 9 processing oils which were most frequently left in the compressor and system and performed our tests with them. The result is shown in Fig.-5.

The drop in flow rate increased slowly with the gain of processing oil content, and it increased suddenly when the processing oil content exceeded 1%. Separation and deposition of insoluble content of refrigerant caused clogging. We were not able to discover the reason.

Then, we investigated the influence of operating times. The result is shown in Fig.-6. The clogging (rate of flow drop) is almost proportional to operating time at the early stage. In the later stage the clogging tends to saturate.

4-4 Influence of different refrigerant oils
We would like to briefly describe polyether oil. The previous polyether was polyalkyleneglycol (PAG); its saturated moisture content is large and electric resistivity is low. But new polyether does not have these weak points of PAG, and has many of the characteristics of mineral oil, because the structure of the main chain is hydrocarbon, and the side chain has an ether combination. In addition, the lubricating ability of new polyether is close to that of mineral oil. The pressure viscosity coefficient of polyether is much larger than that of ester oil.

Our results show that the lubricating capacity of ether oil is higher than that of ester oil according to rotary compressor tests.

Next, we investigated refrigerant oils which had different structure. Their typical characteristics are shown in Table-4. The result is shown in Fig.-7, and is composed of three groups. The clogging of the ester group was largest, and that of ether oil was smallest. The currently used mineral oil/refrigerant mixture behaves the same as ether oil. We suppose that this result is caused by the solution capacity of the refrigerant oils dissolving the clogging materials.

4.5 Influence of compressor types

We investigated the influence of compressor types. Our testing compressors were a one-cylinder rotary compressor, a two-cylinder rotary compressor, and a swing compressor with unified vane and roller. The structure of a swing compressor is shown in Fig.-8. The swing structure eliminated seizure and wear at the point of contact between vane and roller.

The results of testing compressor types are shown in Fig.-9. As stated, these results signify that clogging amount (rate of flow drop) correlates with temperature rise at the point of contact between vane and roller. We found that the clogging amount was smallest with a swing compressor.

5. CONCLUSION

Regarding the lubricating ability of a rotary compressor, it is possible to improve lubricating conditions by changing sliding parts, but the clogging problem remains.
Therefore, it is necessary to strictly control the processing oil content.

On the other hand, we suppose that using a swing compressor and adopting ether oil improve the situation. In addition, R410A refrigerant will work under more difficult conditions regarding lubricating ability and clogging than R407C, because the differential pressure is larger when using R410A.

6. REFERENCES