HCFC-22 Retrofits

A CLOSE LOOK AT THE REFRIGERANT/LUBRICANT INTERACTIONS.

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There has been increased emphasis on retrofitting R-22 systems; this applies to both air-conditioning and refrigeration systems. Some end-users are performing retrofits without considering all the effects of the refrigerant change. Of particular concern are the blends of HFC with small amounts of hydrocarbons (HFC/HC blends). Some of these blends claim to be the best match to R-22 even when used with the existing mineral oil. There are differences between the performance of these refrigerants and the original R-22.

In short, the systems under consideration for retrofit were designed to operate with R-22 and mineral-based oil. The HFC/hydrocarbon blend R-422A includes a small amount of hydrocarbon (isobutane), which is added to a mixture of HFC refrigerants (R-125, R-134a). Hydrocarbons that are miscible with mineral oils thin the mineral oil, helping its return back to the compressor. However, the small amount of HC included in R-422A does not make the blend itself miscible with mineral oils. Furthermore, the amount of hydrocarbon that can be added is typically limited to a few % to maintain an A1 (non-flammable) ASHRAE rating.

Fundamentals definitions

Solubility—When applied to refrigerants and lubricant oils used in refrigeration systems, solubility is the property of the refrigerant (solute) to dissolve in the lubricant oil (solvent). The extent of the refrigerant solubility in the oil without seeing two phases is known as the saturation concentration.

Immiscibility/Miscibility—When the refrigerant reaches its solubility limit in the lubricant oil, adding more refrigerant results in precipitation, or phase separation, and this is typically referred to as an “immiscible” condition. On the other hand when you can keep adding refrigerant to the lubricant oil and still have a single liquid phase, it means that the refrigerant is fully “miscible” in the oil.
Practical cases of miscibility

Refrigeration systems are usually designed for refrigerant/lubricant oil pairs that are fully miscible, or that otherwise show acceptable miscibility, at least at the concentration of lubricant oil circulating in the system and in the coolest parts of the system, but preferably over the range of operating conditions (evaporating and condensing temperatures). This will ensure proper oil return to the compressor as the refrigerant is able to carry the oil through the system. As for what is found in the field, Figure 1 shows the two most common cases:

1. A typical case of “full miscibility” is observed with R-22 and mineral oil. It is also observed with R-407C in POE oil.
2. On the opposite side, R-407C was found to be “immiscible” with mineral oil. This is also the case with the HFC/HC blend R-422A, which has some improved solubility due to the hydrocarbon presence. Still, it is fundamentally “immiscible” in mineral oil.

How much oil is in circulation in real systems?

What is actually happening in a refrigeration system depends on several factors, for example: 1. Working fluids (refrigerant, lubricant); 2. Hardware (compressor type and age, connecting lines, heat exchangers, oil separators); and 3. Operating conditions. All systems have lubricant in circulation and the type and amount of lubricant varies with the above-listed parameters.

Table 1 shows results of field studies performed in supermarket systems. The two supermarket systems studied used reciprocating compressors that were 10 years old on average. Samples were taken before and after the oil separators. This would allow studying systems with and without an oil separator.

These findings show the worst-case scenario being low-temperature systems where the oil circulation ratio, or OCR,
can be as high as 0.47% when no oil separator is used, and 0.36% when using an oil separator (see Table 1). It can be concluded that systems with oil separators have lower OCRs than systems with no oil separators. Nevertheless, few “old-wear” compressors where OCR values were as high as 3.5% were also observed. Such compressors should be replaced, but this hardly happens in practical applications, as detecting these high OCRs is difficult. Even higher values are also mentioned in the field (e.g. up to around 8%), but no detailed description of the compressor type and age is usually shown.

Refrigerant/oil relationship in systems
What happens in simple systems without a liquid receiver?
To investigate the effectiveness of the HFC/HC blend R-422A, an R-22 low-temperature refrigeration system that uses mineral oil was used as a baseline. Both oil retention in vertical riser and the resultant pressure drop were measured. Overall, the system performed adequately with no significant drop in oil level in the compressor.

R-422A was tested next. Figure 2 shows the additional pressure drop due to oil retention in vertical suction lines when employing this HFC/HC blend (R-422A) with the same mineral oil. The OCR simulated in this test was of 3.5% (oil in the refrigerant flow by weight). Oil retention was 30% higher than for R-22. Moreover, pressure drop was 70%

<table>
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<tr>
<th>Refrigerant</th>
<th>Horizontal Receiver</th>
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<tbody>
<tr>
<td></td>
<td>Inlet OCR (%) by weight</td>
</tr>
<tr>
<td>R-22</td>
<td>0.40%</td>
</tr>
<tr>
<td>R-407C</td>
<td>0.40%</td>
</tr>
<tr>
<td>R-422A</td>
<td>0.40%</td>
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Table 2 Oil circulation ratio measured before and after the high-side liquid receiver for R-22, R-407C and R-422A with mineral oil.
higher. In looking at these results, one could conclude that systems with no liquid receiver may be successfully retrofitted to this HFC/HC blend (R-422A) if the system is close coupled and the oil circulation rate is low enough. Still, the overall performance will be affected due to the additional pressure drop in the suction line, and also due to oil logging in the evaporator, which can negatively affect heat transfer and pressure drop.

What happens in systems with high-side liquid receivers?
As mentioned before, the small amount of hydrocarbon used in the HFC/HC blend R-422A is not enough to make it fully miscible with mineral oils. This is clearly shown in high-side liquid receivers where a significant retention of mineral oil is observed. These studies (Figure 3) show that a layer of oil will form on the surface of the liquid R-407C or HFC/HC blend R-422A. These studies were done using a horizontal liquid receiver, which was modified to add large sight glasses in the two extremes. Tests were done using oil-circulation values for a system with an oil separator (Table 2). The OCR values shown were measured by sampling before and after the liquid receiver. Looking at the imbalance of OCRs for R-407C and the HFC/HC blend R-422A (OCR at inlet higher than OCR at outlet), one can conclude that these blends are not reliable for retrofitting systems that use mineral oil as lubricant.

Performance
Some HFC blends such as R-407C come close to duplicating R-22's performance at certain operating conditions, however a closer look will show that both the system capacity and efficiency may have been impacted due to oil circulation.

Figure 4 shows how much the performance is affected because of the presence of oil in circulation. These tests were performed in a 1.8-ton refrigeration system. Three cases were considered: R-22/MO, R-407C/MO and R-422A/MO. The initial tests were performed using two very-high-efficiency oil separators so OCR was near zero. These initial points represent the performance of each fluid without any oil effects. When oil is taken into account, all the refrigerants experience some reduction of capacity and efficiency. Even R-22 would suffer some degradation when oil accumulates in the suction line for usual OCRs (1%–2%). Moreover, with the HFC/HC blend R-422A, a more dramatic degradation was observed, as more oil accumulates in the system, causing an increase of pressure drop.

General guidelines/conclusions
Giving a general recipe for R-22 retrofits is not possible, but general recommendations are possible, from the results of these studies, and other in-house technical knowledge:

Air-conditioners and refrigeration systems without liquid receiver—According to these studies, the least demanding system would be a typical air-conditioner without a liquid receiver where the main effects would be on the connecting lines. In general, the effects would not be as dramatic due to the relatively high evaporating temperatures (example: 45°F SST). At these conditions, any solubility of the refrigerant like R-422A in the oil will be reasonable.

Next, refrigeration systems without a liquid receiver were considered, where the additional challenge is the fact that the evaporating temperatures can be significantly lower (example:
Giving a general recipe for R-22 retrofits is not possible, but general recommendations are possible, from the results of these studies, and other in-house technical knowledge.

-25°F SST). In these systems, the HFC/HC blend R-422A can be used, because the compressor will get the desired oil return. Still, the user will experience some performance degradation as shown in the previous section (see Figure 3).

**Refrigeration systems with high-side liquid receiver**—Next in the degree of difficulty are systems with a high-side liquid receiver. These systems will need a greater degree of solubility in the oil, which could not be provided by the HFC/HC blend R-422A that were studied. In these cases, based on this work, adding some amount of POE oil would help to increase solubility to the point to get the oil through the liquid receiver. Tests indicated that at least 20% of the oil system needs to be of the POE type.

**Heat pumps with low-side suction accumulator**—Even more difficult are the systems with a low-side suction accumulator where the liquid accumulation occurs at low temperatures and pressures. At these conditions, any solubility of the refrigerant in the oil will be reduced. For these types of systems, a greater degree of solubility is needed. Based on this work, a full change to POE oil would advisable for refrigerants such as R-407C and R-422A.

In conclusion, there is no perfect replacement for R-22. These findings indicate that the performance of certain HFC and HFC/HC blends, namely R-407C and R-422A, can be impacted by the type and amount of oil in circulation (OCR). If economically feasible, a change to POE oil will result in the best system performance, durability and trouble-free operation for refrigerants such as R-407C and R-422A. As for the HFC/HC blend R-422A, some specific A/C and refrigeration systems (no liquid receivers or suction accumulators) have been identified where they can be cautiously used. Still users should be aware of some system performance impact coming from this choice.

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