1992

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PROPERTY AND PERFORMANCE EVALUATION OF "SUVA" HP REFRIGERANTS AS R-502 ALTERNATIVES

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Wilmington, DE

ABSTRACT

Impending reductions in chlorofluorocarbon production, with an accelerated phase-out by January 1, 1996, made it necessary to develop alternatives for R-502. A family of R-502 alternatives ("SUVA" HP Refrigerants) have been developed providing significant reductions in ozone depletion and global warming potential, plus cooling performance essentially the same as R-502.

INTRODUCTION

A commonly used refrigerant for low temperature applications has been refrigerant 502 (R-502). R-502 is a binary minimum boiling azeotrope composed of HCFC-22 (chlorodifluoromethane) and CFC-115 (chloropentafluoroethane). R-502 has a low boiling point of -45.6 C (-50.1 F) which makes it the refrigerant of choice in many applications such as supermarket frozen food cases and transport refrigeration. Because of the large installed investment in low temperature refrigeration systems operating with R-502, an alternative with similar properties was needed to permit continued use of this equipment.

Near-azeotropic refrigerant mixtures of HFC-125 (pentafluoroethane), HC-290 (propane), and HCFC-22, have thermophysical properties and refrigeration performance parameters very similar to R-502. These mixtures have been designated as the "SUVA" HP80 series and are commercially available.

As regulations tighten and controls are put into place for HCFC-22 containing products, the need for non-ozone depleting refrigerants will increase. Therefore, we are developing a HFC-based refrigerant, "SUVA" HP62 which has zero-ozone depletion potential.

REFRIGERATION CYCLE PERFORMANCE

To allow customers and OEMs a choice of refrigerant performance, two formulations of the HP80 series have been developed (see figure I).

Several developmental partners have tested "SUVA" HP81 and HP80 and found these compositions provide optimum performance over a broad application range.
SUVA HP80 SERIES FORMULATIONS

Refrigerant | Composition (weight%) | HFC-125 | HC-290 | HCFC-22
--- | --- | --- | --- | ---
SUVA HP80 | 60 | 2 | 38
SUVA HP81 | 38 | 2 | 60

Figure I

For applications where energy efficiency is critical, "SUVA" HP81 provides the same to 2% higher energy efficiency with a 4 to 7% increase in refrigeration capacity. The compressor discharge temperature is 5 to 15°C (9 to 27°F) higher than R-502.

For applications where compressor discharge temperature is critical, "SUVA" HP80 provides the same compressor discharge temperature with a 6 to 11% increase in capacity and 3 to 5% lower energy efficiency.

"SUVA" HP62 will offer a 4 to 5% increase in refrigeration capacity with the same to 2% higher energy efficiency and has as much as 8°C (14°F) lower compressor discharge temperature compared with R-502 which is often related to longer compressor life (see figures II-IV).

![Graph showing the capacity (relative to R-502) for different refrigerants](Image)

Figure II
Figure III

Figure VI
ENVIRONMENTAL PROPERTIES

"SUVA" HP refrigerants are environmentally acceptable solutions to R-502. "SUVA" HP81 and HP80 reduce both ozone depletion and global warming potentials by nearly 90% with an ozone depletion potential of 0.03 to 0.02 and global warming potential of 0.52 to 0.63. "SUVA" HP62 has zero ozone depletion and a global warming potential of 0.94 (see figure V) /Ref. 1/.

<table>
<thead>
<tr>
<th>Refrigerants</th>
<th>ODP</th>
<th>HGWP</th>
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</thead>
<tbody>
<tr>
<td>R-502</td>
<td>0.23</td>
<td>3.75</td>
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<tr>
<td>SUVA HP81</td>
<td>0.03</td>
<td>0.52</td>
</tr>
<tr>
<td>SUVA HP80</td>
<td>0.02</td>
<td>0.63</td>
</tr>
<tr>
<td>SUVA HP62</td>
<td>0</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Figure V

NEAR-AZETROPIC REFRIGERANTS

"SUVA" HP refrigerants are near-azeotropes. Laboratory leakage experiments show that composition changes are small even after a large vapor leak occurs. If a liquid leak occurs, the composition does not change measurably. For example, samples of "SUVA" HP81 and HP80 were evaporated at room temperature and the remaining composition of the vapor and liquid phases were analyzed. A graph of composition versus percent weight loss for "SUVA" HP81 is shown in figure VI. The HCFC-22 and HFC-125 compositions for "SUVA" HP81 change about 7 weight% and "SUVA" HP80 about 5 weight% after a 50% leak. Importantly, the propane concentration in both the liquid and vapor phases decreases during a vapor leak; therefore, "SUVA" HP81 and HP80 will always remain nonflammable (see figure VII). The nonflammable concentrations were determined according to the ASTM E681-85 test method /Ref. 2/.

The same experiment for measuring how the composition of "SUVA" HP81 and HP80 changes with a vapor leak was performed with R-502 and "SUVA" HP62. The azeotrope composition of R-502 changes as a function of temperature. The composition commercially available (48.8 wt% HCFC-22 and 51.2 wt% CFC-115) is an azeotrope at the R-502 normal boiling point of -45.6 C (-50.1 F) /Ref. 3/. A sample of R-502 was evaporated at a constant temperature of about 50 C (122 F), and the composition of the vapor and liquid phases changed by about 3 weight% after 50% of the sample had evaporated. "SUVA" HP62 changed by about 3 weight% as well and is essentially no different in leakage behavior than R-502.

The results of these experiments show that near-azeotropic mixtures have small composition changes and even azeotropes can change composition if the vapor leakage occurs at a temperature different from the azeotrope point. System tests described below verify that the performance of "SUVA" HP refrigerants will not deteriorate if leakage occurs in an operating system.
"SUVA" HP81 was tested in several commercial ice machines ranging in capacity from 45 to 365 kgs (100 to 800 lbs) of ice per day. The cube type ice machines were designed for R-502. Each had a hermetic compressor charged with mineral oil and an air-cooled condenser with a capillary tube or expansion valve. A standard test method was followed for evaluating the performance of ice machines. /Ref. 4/ The optimum refrigerant charge was determined in the first set of experiments. The conclusion was the ice machines required approximately the same to 2% less charge by weight with "SUVA" HP81 compared with R-502.
The ice production was measured at a variety of air and water temperatures. "SUVA" HP81 provided the same to 7% more ice per day compared with R-502 (see figure VIII).

![Ice Production vs Ambient Temperature Graph](image)

**Figure VIII**

Total power consumption per 45 kgs of ice produced was measured at the same conditions and varied within +/- 3% of R-502 (see figure IX).

![Energy Usage vs Ambient Temperature Graph](image)

**Figure IX**

In addition to measuring the refrigeration capacity and energy efficiency, the compressor discharge temperature was measured six inches from the compressor shell. "SUVA" HP81 had a 5 to 10 C (9 to 18 F) higher compressor discharge temperature compared with R-502 (see figure X). However, in this application slightly higher discharge temperatures are not a problem.
To determine how leaks and recharging affect the performance of mixtures, leakage tests were performed with these ice machines.

If a leak occurs where only one phase is present such as in the liquid line from the condenser or discharge vapor line from the compressor, no fractionation will occur. For the composition to change, the vapor leak must occur from a point where both the liquid and vapor phases are present such as in the condenser or evaporator, but only vapor escapes. Therefore, a leak was established in the midpoint of the condenser where both refrigerant phases were present.

"SUVA" HP81 was allowed to leak out of a running machine at a slow rate (approximately 30 cc of vapor/minute) until 30 weight% of the initial charge had escaped. With this amount of refrigerant loss the ice machine will not function properly. The ice machine was then recharged with "SUVA" HP81 to the original charge size. The leakage and recharging were repeated four times. The circulating composition in the condenser liquid line was sampled and measured with a gas chromatograph initially and after the 3rd and 4th recharges. Within the accuracy of the analytical method (+/- 0.5 wt%), no change was detected. Therefore, in this experiment there was no change in the circulating composition or ice machine performance after four leaks and recharges had occurred (see figure XI).

The same leakage experiment was repeated with the ice machine not running and the composition was remeasured. In this case the composition did change in agreement with the laboratory tests (see figure VI). We concluded that if a system is running with a near-azeotropic refrigerant that the composition will not measurably change during a vapor leak unless the system is shut down.
Using our leakage simulation data as a worst case, calculations show that after a series of leaks and recharges the "SUVA" HPB1 or HPB0 capacity will only decrease 2% (see figure XII). Most refrigeration equipment runs 50% of the time, therefore the capacity may decrease 1% to 2% after 5 leaks and recharges. Since the composition of "SUVA" HPB2 varies only 3 weight% with a vapor leak, a change in capacity would probably be undetectable.

A model has been developed for estimating heat transfer coefficients and pressure drop for multicomponent refrigerants. In the two phase region of the evaporator, the overall heat transfer coefficients for the "SUVA" HP refrigerants are similar to R-502 at an evaporator temperature of -40 C (-40 F). The pressure drop for the "SUVA" HP refrigerants are less than R-502.
In the two phase region of the condenser, the overall heat transfer coefficients for "SUVA" HP80 and HP81 are similar to R-502 and "SUVA" HP62 may provide about a 20% increase in the overall heat transfer coefficient at a condenser temperature of 48.9°C (120°F). The pressure drops for the "SUVA" HP refrigerants were similar to R-502 in the condenser (see Figure XIII).

The performance data in the ice machine experiments support the calculated heat transfer coefficients for "SUVA" HP81, as no changes had to be made to either the evaporator or condenser heat exchangers to maintain performance.

Evaporator
Two-Phase Region:

<table>
<thead>
<tr>
<th></th>
<th>R-502</th>
<th>HP81</th>
<th>HP80</th>
<th>HP62</th>
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<tbody>
<tr>
<td>HTC</td>
<td>2400</td>
<td>2500</td>
<td>2600</td>
<td>2400</td>
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<tr>
<td>Pressure (kPa)</td>
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<td>140</td>
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<tr>
<td>Pressure Drop (kPa)</td>
<td>22</td>
<td>19</td>
<td>22</td>
<td>21</td>
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</table>

Condenser
Two-Phase Region:

<table>
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<th>1600</th>
<th>1600</th>
<th>1700</th>
<th>1900</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure XIII

MATERIALS COMPATIBILITY AND LUBRICANTS

Lubricant compatibility should always be confirmed with compressor and equipment manufacturers. As a general guide, however, we have operated medium temperature equipment using "SUVA" HP81 and mineral oil, with excellent results in terms of compatibility with system materials and general wear characteristics.

For "SUVA" HP80, containing a higher ratio of HFC-125, we have limited operating data in commercial equipment to validate the use of mineral oils. It is uncertain whether there is sufficient solubility between the oil and "SUVA" HP80 to provide adequate oil return in all systems. Different manufacturers will reach different conclusions about the suitability of mineral oils or alkylbenzenes with "SUVA" HP80.

One compressor manufacturer has conducted miscibility studies with different hydrocarbon and polyol ester lubricants and determined that "SUVA" HP81 and HP80 offer acceptable and flexible solutions based on compressor and system requirements. /5/

For "SUVA" HP62, we anticipate the use of polyol esters to provide required miscibility (equivalent to R-502/mineral oil), and recommendations will be issuing from compressor manufacturers as they complete their evaluations thru the next year or more. As in all cases when considering the use of alternative refrigerants or lubricants, consult your equipment manufacturers for more information.
Materials of construction, particularly elastomeric and motor materials, will continue to be tested well into 1992. Early data do not show any unexpected differences between R-502 and "SUVA" HP81 or HP62 in reactions of the refrigerants alone, or refrigerants with suitable lubricants, in most cases.

COMMERCIAL AVAILABILITY

Commercial quantities of "SUVA" HP81 and HP80 will be available by mid-year 1992.

Toxicity assessment of the HFC-125 component will continue through PAFT.

Commercial quantities of "SUVA" HP62 will be available in late 1993 following additional process development and toxicity testing.

SUMMARY

"SUVA" HP refrigerants offer an excellent choice of properties as alternatives to R-502. "SUVA" HP81 matches or exceeds R-502 refrigeration capacity and energy efficiency with slightly higher compressor discharge temperatures. "SUVA" HP80 matches compressor discharge temperature with an even higher refrigeration capacity and slightly lower energy efficiency. "SUVA" HP62 will offer an increase in capacity and energy efficiency with a lower compressor discharge temperature than R-502. "SUVA" HP81 and HP80 contain no CFCs and have almost a 90% reduction in both ozone depletion and global warming potentials compared with R-502. "SUVA" HP62 (an all-HFC based refrigerant) will have zero ozone depletion potential compared with R-502.

"SUVA" HP refrigerants are near-azeotropes and leakage/recharge experiments show little to no effect on system performance. "SUVA" HP refrigerants are nonflammable and remain nonflammable during a vapor leak. "SUVA" HP refrigerants offer the same and possibly improvements in the two-phase overall heat transfer coefficients and pressure drops compared with R-502.

Lubricant compatibility should be confirmed with compressor and equipment manufacturers. Early data do not show any unexpected differences between R-502 and "SUVA" HP refrigerants in material compatibility studies.

REFERENCES

1. International Panel on Climate Change Working Group I Report and 1991 updated results from NOAA, Aeronomy Laboratory


