HFO-1336mzz(Z) – Opteon™ MZ
Low GWP refrigerant for High Temperature Heat Pump

April 1, 2021
• **INTRODUCTION**
  • Regulatory drivers
  • Refrigerant Properties:
    • Thermo-Physical Properties and Thermodynamic Cycle Performance, \( \text{COP}_H \) and \( \text{CAP}_H \) comparison (30°C and 50°C uplift)

• **COMPATIBILITY AND VISCOSITY STUDIES**
  • Elastomers and lubricants selection
  • Conclusions
F-Gas Regulation and Kigali amendment Transition to Low GWP

GWP phase-down to reduce global warming GHG

Criteria:
- Low GWP lifetime
- zero/low ODP
- Low flammability
- high efficiency
- high Tcrit

Opteon™ MZ - HFO-1336mzz(Z)

Retrofit High GWP (R-245fa)
Lower GWP (e.g. Opteon™ MZ)
**Product Characteristics**

**BASIC PROPERTIES**

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>HFO-1336mzz(Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Formula</td>
<td>$\text{CF}_3\text{CH=CHCF}_3(Z)$</td>
</tr>
<tr>
<td>OEL [ppm]</td>
<td>500</td>
</tr>
<tr>
<td>Flammability</td>
<td>Non-Flam</td>
</tr>
<tr>
<td>ODP</td>
<td>None</td>
</tr>
<tr>
<td>$GWP_{100}$</td>
<td>2</td>
</tr>
<tr>
<td>$T_{cr}$ [$^\circ$C]</td>
<td>171.3</td>
</tr>
<tr>
<td>$P_{cr}$ [MPa]</td>
<td>2.90</td>
</tr>
<tr>
<td>$T_b$ [$^\circ$C]</td>
<td>33.4</td>
</tr>
</tbody>
</table>

**HFO-1336mzz(Z)**

- Opteon™ MZ

- **R-1336mzz(Z) classified as A1** (low toxicity, No flammability)
- Very low GWP
HFO-1336mzz(Z) Vapor Pressure compared with HFC-245fa

<table>
<thead>
<tr>
<th>Temperature, °C</th>
<th>HFC-245fa</th>
<th>HFO-1336mzz(Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T&lt;sub&gt;cr&lt;/sub&gt;</td>
<td>154.0</td>
<td>171.3</td>
</tr>
</tbody>
</table>

Set of properties now set in latest version of NIST Database (REFPROP)
HFO-1336mzz(Z) High Temperature stability

High Chemical Stability up to at 250 C in the presence of air, moisture, carbon steel, copper and aluminum.
Visual inspections of the tubes and coupons after aging showed no liquid or metal discoloration, insoluble residues or other signs of degradation.

HFO-1336mzz(Z) (Opteon™ MZ) as stable as HFC-245fa

Test method ASHRAE-97 was applied (Sealed Glass Tube Method to Test the Chemical Stability of Materials for Use within Refrigerant Systems). Sealed glass tubes are prepared and charged with refrigerant, lubricant, other materials to be tested, or combinations of these. Tubes are exposed to elevated temperatures for two weeks to simulate aging.
Theoretical Coefficient of Performance (COP)

- COP of the heat pump for an application envelope of 90 °C evaporation temperature and 160 °C condensation temperature could result in a good COP >3.5 but with some operating limits (Temp. lift)
- R1336mzz-Z exceeds other material alternative in application temperatures above 140oC
Theoretical Heating Capacity (CAP$_{H}$)

- R1336mzz-Z also has a very good CAPH which is approximately the same as R245fa, and still exceeds incumbent alternatives in application temperatures above 140°C
Lubricant Selection: Lubricity

Viscosity of various lubricants (POE and PAG) evaluated compatibility with the refrigerant to determine whether they have enough viscosity at high temperature to lubricate the compressors.

Miscibility of various lubricants (POE and PAG) evaluated thru vapour-liquid-equilibrium (VLE) and liquid-liquid-equilibrium (LLE) predictions and mutual solubility curves were calculated.

Daniel plot generated to map the viscosity as a function of temperature, pressure and mixing ratio.

Figure 9: Mutual solubility curve for refrigerant and POE VG 520
Stability tests with refrigerant and lubricants

- Visual observations: Before and after the ageing the test of the refrigerant and the lubricant
- Help to determine the lubricant compatibility
Elastomers and other Compatibility

Weight and Hardness Changes tested with Various Elastomers and Plastics with HFO-1336mzz(Z) at 120°C with FUCHS POE Oil

<table>
<thead>
<tr>
<th>Elastomers after 0 hrs</th>
<th>0 hr Rating</th>
<th>0 hr % Weight Change</th>
<th>0 hr % Linear Swell</th>
<th>0 hr Hardness Change, Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>POE 211 + DR2</td>
<td>1</td>
<td>11</td>
<td>3</td>
<td>-7</td>
</tr>
<tr>
<td>POE 211 + DR2</td>
<td>1</td>
<td>11</td>
<td>3</td>
<td>-6</td>
</tr>
<tr>
<td>POE 212 + DR2</td>
<td>1</td>
<td>12</td>
<td>4</td>
<td>-6</td>
</tr>
<tr>
<td>POE 212 + DR2</td>
<td>1</td>
<td>13</td>
<td>4</td>
<td>-7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elastomers after 24 hrs</th>
<th>24 hr Rating</th>
<th>24 hr % Weight Change</th>
<th>24 hr % Linear Swell</th>
<th>24 hr Hardness Change, Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>POE 211 + DR2</td>
<td>0</td>
<td>8</td>
<td>2</td>
<td>-5</td>
</tr>
<tr>
<td>POE 211 + DR2</td>
<td>0</td>
<td>8</td>
<td>2</td>
<td>-5</td>
</tr>
<tr>
<td>POE 212 + DR2</td>
<td>0</td>
<td>10</td>
<td>3</td>
<td>-5</td>
</tr>
<tr>
<td>POE 212 + DR2</td>
<td>0</td>
<td>10</td>
<td>2</td>
<td>-7</td>
</tr>
</tbody>
</table>

* EPDM exhibits good resistance with HF)-1336mzz(Z)

Conclusions

The HFO-1336mzz(Z) have all of the characteristics (Low GWP, Class A1 refrigerant, Excellent Chemical & Material Compatibility, High Critical Temperature, Exhibiting favorable toxicity profile) to be a viable working fluid in Waste Heat Recovery applications which include both high temperature heat pumps (and low temperature ORC applications).

The HFO-1336mzz(Z) allow higher condensing temperatures than R134a and have a lower GWP than R245fa. It could enable development of industrial high temperature heat pump for

- Drying / dehydration
- Process heating
- Food manufacturing industry
THANK YOU
Questions?

for additional questions, contact:
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