Chemours™

HFO-1336mzz(Z) – Opteon™ MZ

Low GWP refrigerant for High Temperature Heat Pump

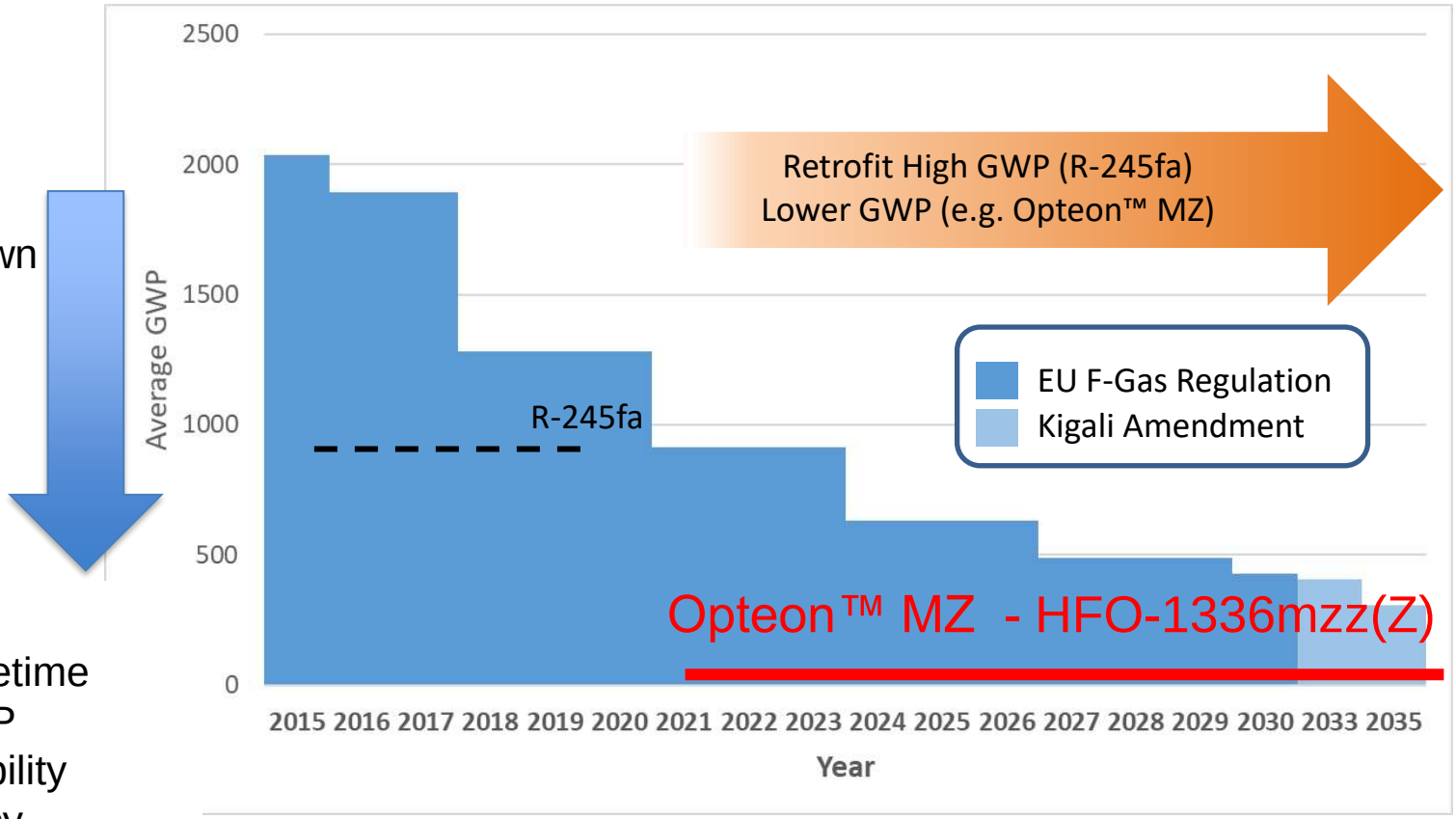
April 1, 2021

Outline

- **INTRODUCTION**
  - Regulatory drivers
  - Refrigerant Properties:
    - Thermo-Physical Properties and Thermodynamic Cycle Performance, COP_H and CAP_H comparison (30^{o}C and 50^{o}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

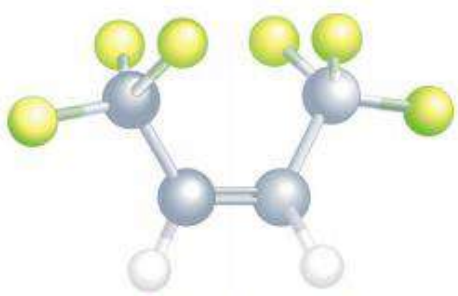
Product Characteristics

BASIC PROPERTIES

Chemical Name	HFO-1336mzz(Z)
Chemical Formula	$CF_3CH=CHCF_3(Z)$
OEL [ppm]	500
Flammabilty	Non-Flam
ODP	None
GWP_{100}	2
T_{cr} [°C]	171.3
P_{cr} [MPa]	2.90
T_b [°C]	33.4

HFO-1336mzz(Z)

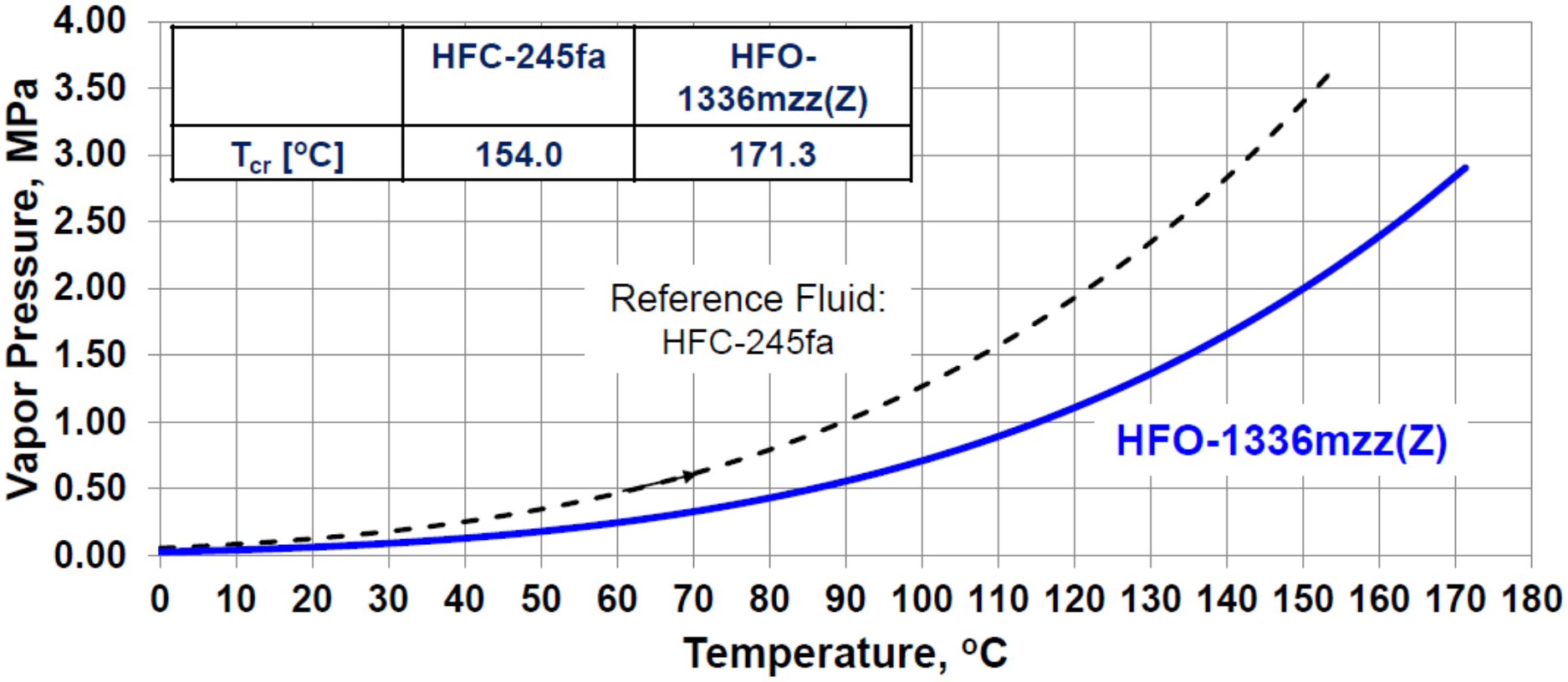
Opteon™ MZ



HFO-1336mzz-Z

- R-1336mzz(Z) **classified as A1** (low toxicity, No flammability)
- Very low GWP

HFO-1336mzz(Z) Vapor Pressure compared with HFC-245fa



Set of properties now set in latest version of NIST Database (REFPROP)

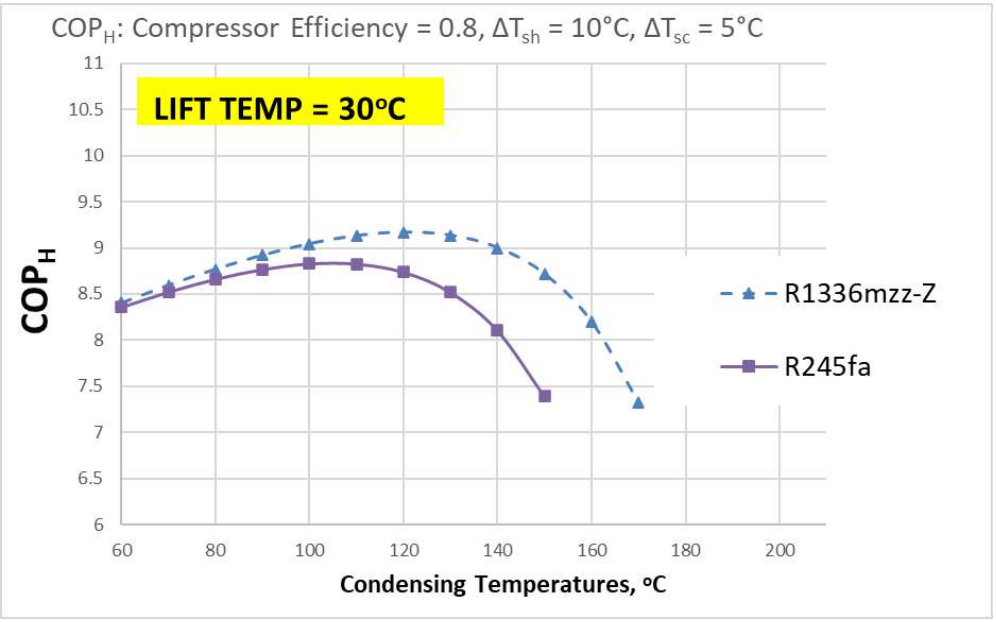
HFO-1336mzz(Z) High Temperature stability

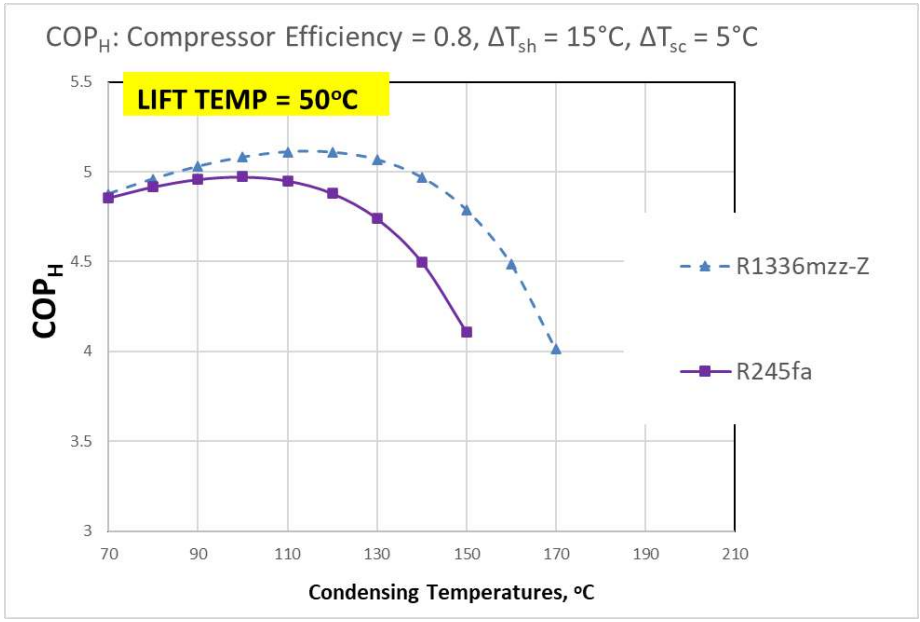
High Chemical Stability up to at 250 C in the presence of air, moisture, carbon steel, copper and aluminum.
Visual inspections of the tubes and coupons after aging showed no liquid or metal discoloration, insoluble residues or other signs of degradation

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

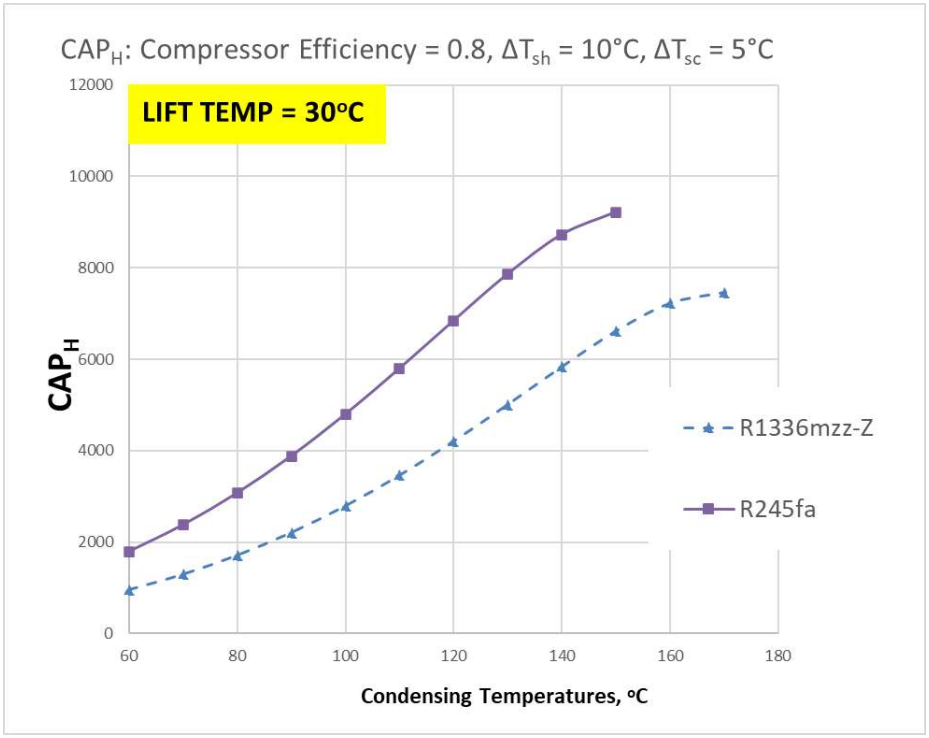
Theoretical Coefficient of Performance (COP)

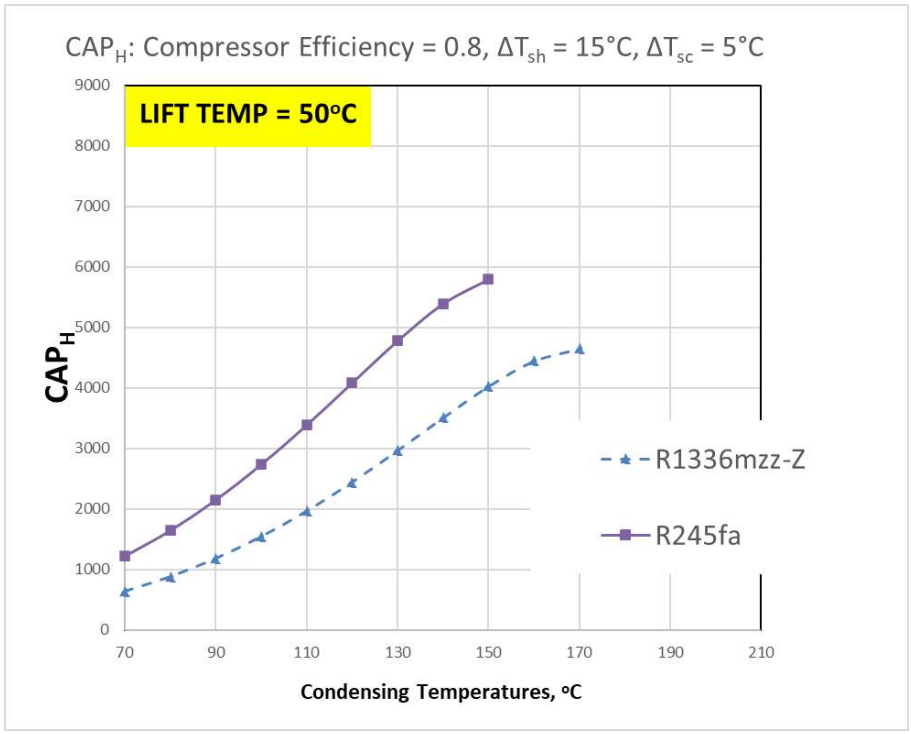




- COP of the heat pump for an application envelope of 90 °C evaporation temperature and 160 °C condensation temperature could result in a good COP >3.5 but with some operating limits (Temp. lift)
- R1336mzz-Z exceeds other material alternative in application temperatures above 140oC

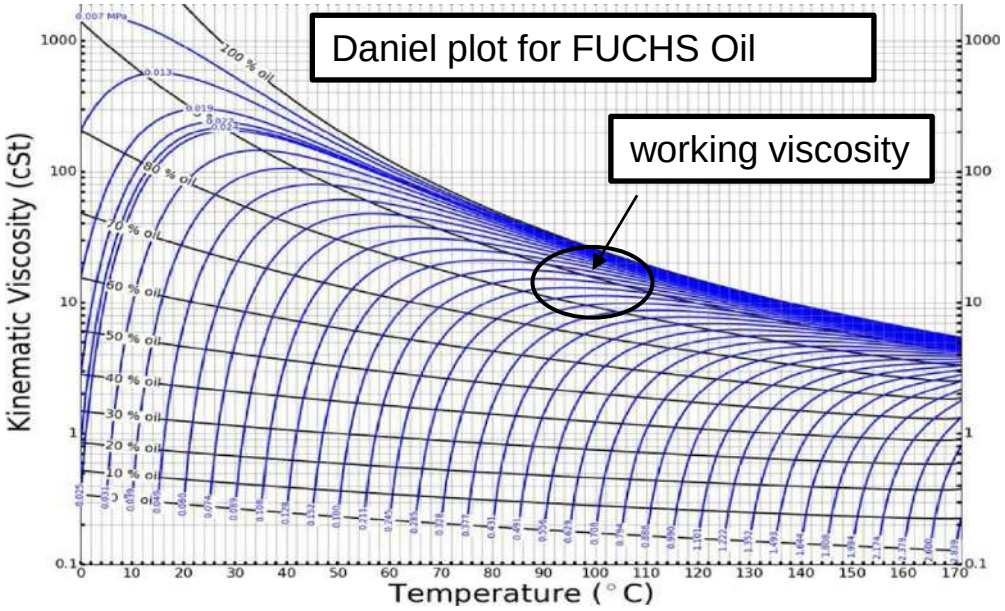
Theoretical Heating Capacity (CAP_H)





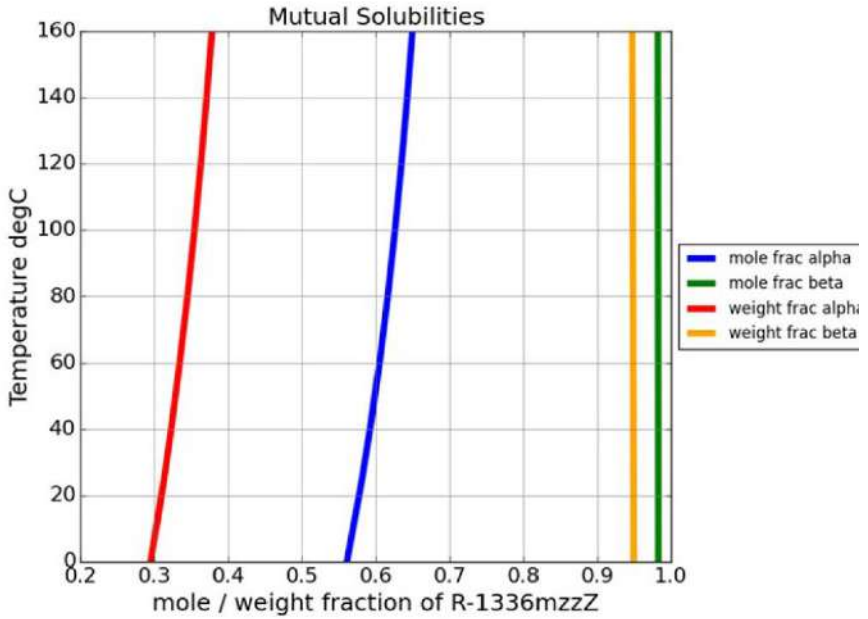
- R1336mzz-Z also has a very good CAPH which is approximately the same as R245fa, and still exceeds incumbent alternatives in application temperatures above 140oC

Lubricant Selection: Lubricity



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

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



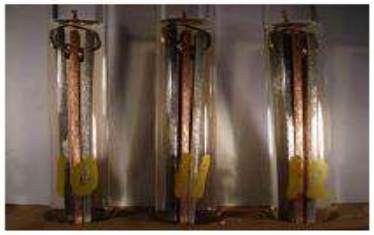
Miscibility of various lubricants (POE and PAG) evaluated thru vapour-liquid-equilibrium (VLE) and liquid-liquid-equilibrium (LLE) predictions and mutual solubility curves were calculated

Figure 9: Mutual solubility curve for refrigerant and POE VG 520

Stability tests with refrigerant and lubricants

HFO-1336mzz-Z /
POE oil, dry air (after)

HFO-1336mzz-Z /
PAG oil, dry air (after)



HFO-1336mzz-Z /
POE oil, wet air (after)

HFO-1336mzz-Z /
PAG oil, wet air (after)

- 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

EPDM E7131 + Elastomers after 0 hrs	0 hr Rating	0 hr % Weight Change	0 hr % Linear Swell	0 hr Hardness Change, Delta
POE 211 + DR2	1	11	3	-7
POE 211 + DR2	1	11	3	-6
POE 212 + DR2	1	12	4	-6
POE 212 + DR2	1	13	4	-7
EPDM E7131 + Elastomers after 24 hrs	**24 hr Rating**	**24 hr % Weight Change**	**24 hr % Linear Swell**	**24 hr Hardness Change, Delta**
POE 211 + DR2	0	8	2	-5
POE 211 + DR2	0	8	2	-5
POE 212 + DR2	0	10	3	-5
POE 212 + DR2	0	10	2	-7

Before/ After EPDM

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

*Conducted in Sealed Tube Tests - ASHRAE Standard 97-2007

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

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THANK YOU
Questions?

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