Opteon™

Next Generation Refrigerant Solution for Electric Vehicle Heat Pumps

The adoption of heat pumps in battery electric vehicles increases to address deficiencies in thermal management. A new paper "Novel Refrigerant Solution for Electric Vehicle Heat Pumps" examines optimal refrigerant blends for improved performance at a range of temperatures.

Chemours™

REFRIGERANT PERFORMANCE CRITERIA

Presently, no single refrigerant molecule is able to meet all the goals for the evolving EV industry.

CRITERIA	Volumetric capacity	COP	Average Glide	Safety Classification per ASHRAE 34	GWP	NBP
TARGETS	>20% over R-1234yf	> R-1234yf	< 3K	A2L	< 150	< R-1234yf to maintain positive suction pressures at low ambient heating conditions

Average outputs listed above based on thermodynamic system performance using SAE boundary conditions 1-13 for EV.
HP Average outputs listed above based on thermodynamic system performance using SAE boundary conditions 1-13 for EV HP.

THERMO-PHYSICAL PROPERTIES

Using extreme conditions for both AC and HP operations, performance evaluations against R-1234yf were conducted with respect to the noted criteria from the stakeholders.

An optimal blend with mass concentrations of 7.5% R-32, 78.0% R-1234yf, and 14.5% R-152a was selected and given the developmental name of R-457C (HFOG7).

Properties	R-134a	R-1234yf	R-457C
Relative molar mass (g/mole)	102.0	114.0	95.5
Normal Boiling Point (°C)	-26.1	-29.5	-37.3
Dew-point temperature at 101 kPa (°C)	-26.1	-29.5	-32.1
Critical Temperature (°C)	101.1	94.7	94.1
Critical Pressure (kPa)	4059	3382	3956
Specific volume at the critical point (m3/kg)	0.00195	0.00210	0.00224
Latent heat of vaporization @ 60°C (kJ/kg)	139.1	110.4	127.9
Specific heat ratio of the vapor at 60°C	1.45	1.45	1.51
Occupational Exposure Limit (ppm)	1000	500	605
Global Warming Potential (AR5)	1300	<1	72
Safety Class (ASHRAE)	A1	A2L	A2L

This table summarizes key thermo-physical properties of the incumbent fluids (R-134a and R-1234yf) compared to HFOG7.

THERMODYNAMIC CYCLE PERFORMANCE

These evaluations were conducted using Cycle D version 6.0 software from NIST.

R-457C (HFOG7) results at the AC condition exhibited a 22.6% increase in relative cooling capacity and a 1.0% increase in relative COP.

Whereas heating mode showed a 25.1% increase in relative heating capacity and a 3.7% increase in relative COP when compared directly to R-1234yf.

COOLING	Refrigerant	Suction Pressure (kPa)	Discharge Pressure (kPa)	Discharge Temperature (C)	Avg. Glide (K)	Cooling Capacity (kJ/m^3)	COP
	1234yf	316	1018	54.9	0	1974	3.73
	R-457C	372	1223	64.0	3.5	2419	3.77

Evap = 0°C, Cond = 40°C, Evap superheat = 10°C, Subcool = 0°C and Isentropic Eff. = 70%

HEATING	Refrigerant	Suction Pressure (kPa)	Discharge Pressure (kPa)	Discharge Temperature (C)	Avg. Glide (K)	Heating Capacity (kJ/m^3)	COP
	1234yf	99	1302	73.3	0	838	2.19
	R-457C	115	1557	90.3	2.75	1049	2.27

Evap = -30°C, Cond = 50°C, Evap superheat = 10°C, Subcool = 0°C and Isentropic Eff. = 70%

Average outputs listed above based on thermodynamic system performance using SAE boundary conditions 1-13 for EV.
HP Average outputs listed above based on thermodynamic system performance using SAE boundary conditions 1-13 for EV HP.

MATERIAL COMPATIBILITY

R-457C (HFOG7) was evaluated for compatibility with an array of plastics commonly used in refrigeration and air conditioning applications.

Sealed glass tubes were prepared containing HFOG7, POE lubricant (ND-11), and the materials of interest. The tubes were held at 100°C for two weeks and the materials were removed. Measurements for weight, linear swell, and hardness were recorded before and after exposures so differences could be assessed.

Two exposure measurements, immediately after exposure (0 hours) and after 24 hours of exposure, were taken to determine if a time dependent recovery effect occurs with polymers or plastics after separation from refrigerant.

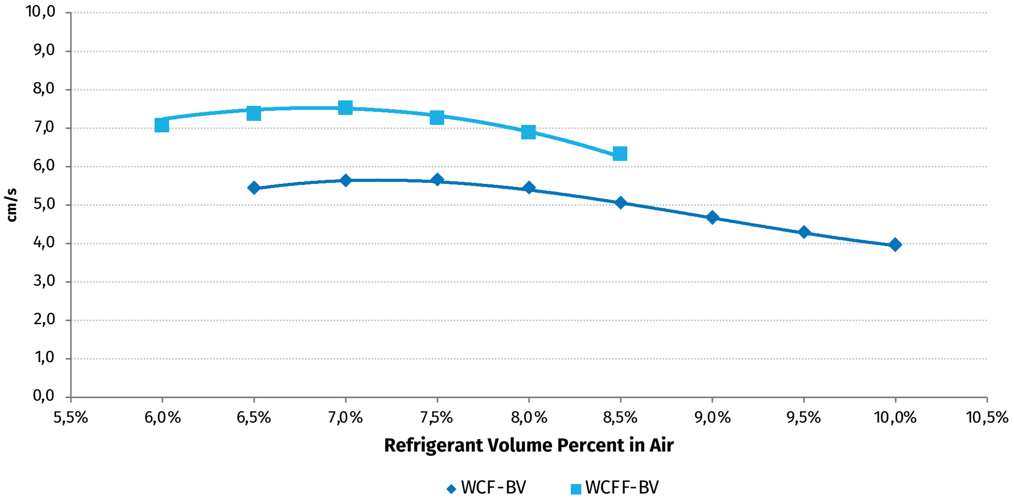
		Rating	% Weight Change	% Linear Swell	Hardness Change, Delta
PLASTICS AFTER 0 HRS	Torlon polymer (polyamide-imide plastic)	0	0	0	-2
	Ryton polymer (polyphenylene sulfide)	0	0	0	0
	PEEK (Ketaspire 820 NT)	0	0	0	0
	nylon 6.6 polymer plastic (Zytel 101)	0	0	0	0
	teflon PTFE	0	2	1	-2
	nylon resin - Zytel 330	0	0	-10	1
PLASTICS AFTER 24 HRS	Torlon polymer (polyamide-imide plastic)	0	-1	0	0
	Ryton polymer (polyphenylene sulfide)	0	0	0	0
	PEEK (Ketaspire 820 NT)	0	0	0	0
	nylon 6.6 polymer plastic (Zytel 101)	0	0	0	1
	teflon PTFE	0	2	1	-2
	nylon resin - Zytel 330	0	0	-10	1

Ratings: 0 = acceptable, 1 = marginal, 2 = unacceptable

FLAMMABILITY

The subclass of 2L refrigerants per ASHRAE Standard 34 requires that all of the criteria of Class 2 be met plus the additional requirement that the maximum burning velocity be a value of less than or equal to 10 cm/s when measured at 23 °C and 101.3kPa in dry air.

The WCF for burning velocity was defined as 8.0% R-32, 77.0% R-1234yf, and 15.0% R-152a while the WCFF for burning velocity was defined as 0.1% R-32, 80.4% R-1234yf, and 19.5% R-152a. HFOG7 burning velocity results for the WCF and WCFF are shown in the table (below).



CONCLUSIONS

Addressing the thermal management deficiencies in BEVs is a key issue for the automotive OEMs where they have identified that both improvements in heating capacity and system efficiency are needed. As the adoption of heat pumps for BEVs becomes mainstream, improvements provided by novel refrigerant HFOG7 will aid in bridging this gap. R-457C (HFOG7) has shown significant improvements in both volumetric heating and cooling capacity, 25.1% and 22.6% respectively, as well as COP over R-1234yf, the incumbent refrigerant.