

Update on an Ultra-Low GWP Refrigerant For MAC Applications

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Introduction

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- Due to the European Union directive on MAC refrigerants, there is a need to replace R-134a with a refrigerant that has a Global Warming Potential (GWP) of less than 150.
- CO₂ (Carbon Dioxide, R-744) – is a leading alternative, however system cost and service issues remain.
- HFC-152a - has similar properties to 134a with a low GWP of <150, but flammability is an issue.
- Work began in 2002 to identify a new, low GWP, non-flammable R-134a replacement that is primarily targeted at the European auto industry that is facing the phase-out of R-134a beginning in 2011.

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R-134a Replacement For Auto A/C

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Product Requirements

- Low GWP (<150)
- Zero ODP
- Nonflammable
- Low Toxicity
- Close match to R-134a system performance
- Manufacturability
- Ease of Transition
- Cost Effective
- Serviceability

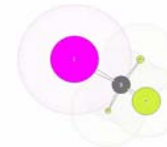
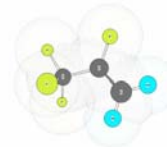
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R-134a Replacement For Auto A/C

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No single component fluid met all the product requirements



Fluid H:

Azeotrope of:

CF₃CF=CH₂ (Major component)

CF₃I (Minor component)

CF₃CF=CH₂:

2,3,3,3 Tetrafluoropro-1-ene

Fluorocarbon Number: 1234yf

New Material

Not Commercially Produced

CF₃I:

Trifluoromethyl iodide

Known Material

Produced In Small Quantities

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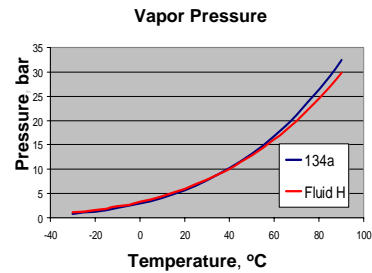
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Fluid H Physical Properties

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	H	134a
• Boiling Point, T_b	-30°C	-26°C
• Critical Point, T_c	97°C	102°C
• P_{vap} , kPa (5°C)	381	350
• P_{vap} , kPa (65°C)	1795	1890
• Flammable	No*	No*
• GWP ₁₀₀	< 10	1300

*ASHRAE Std. 34 & SAE J1657



Close Match To 134a Properties

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Thermodynamic Properties of Fluid H

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Conditions (Assumptions):	Evaporation Temperature	1.5°C
	Condensing Temperature	65°C
	Compressor Suction	10°C
	Compressor Isentropic Eff.	65%

Analysis Results:	R-134a	Fluid H	Comments
Suction Pressure (bar-abs)	3.1	3.4	Higher suction pressure - must change/adjust TXVs or higher superheat will result
Condensing Pressure (bar-abs)	18.9	17.9	Slightly lower system pressure requirements, controls based on pressure must be adjusted
Relative Mass Flow	1	1.43	Higher pressure drop but also better heat exchanger flow distribution. Optimization of hxs
Relative Capacity	1	0.94	Slightly lower cycle capacity & COP but optimized heat exchangers likely will reduce or eliminate this deficit
Relative COP	1	0.95	

Minor property differences between 134a and Fluid H

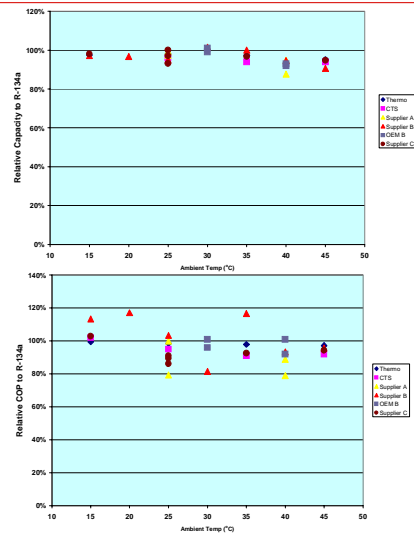
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Performance Evaluation Summary

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- Since the beginning of this year numerous evaluations have been performed.
 - About 8 sets of either vehicle wind tunnel or bench tests at OEMs & Tier 1's (summary of bench test data show here).
- Results show close performance to R-134a considering most do not involve any changes.
- Most recent tests reveal potential to match or exceed R-134a with optimized components.



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Honeywell/Valeo: Demonstration vehicle → first ultra-low GWP F-gas vehicle

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- Converted a 2006 VW Jetta a/c system to Fluid H
- GLI version with 2.0 liter turbocharged engine.
- Modification made:
 - Adapted expansion valve for Fluid H.
- Tests ran at Valeo in France:
 - Vehicle wind tunnel test of similar vehicle (same engine and a/c system).
- Vehicle then took part in the SAE Ride and Drives in Phoenix at the end of June.



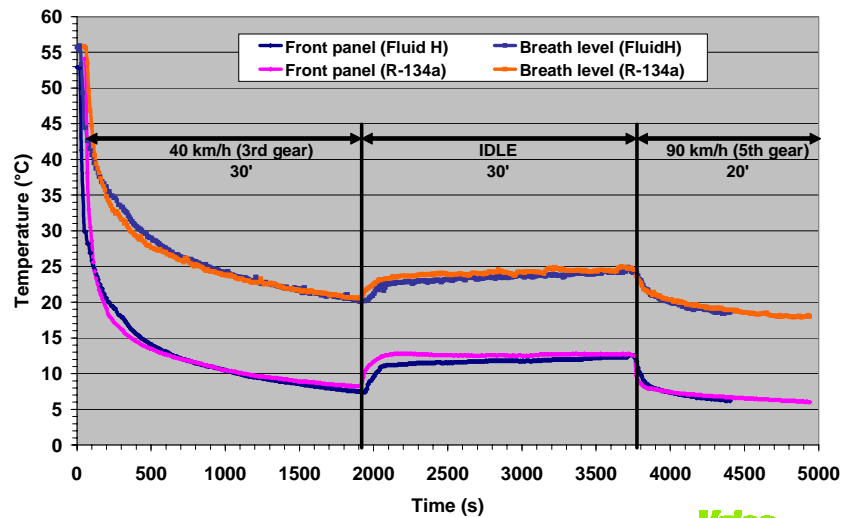
Valeo
Climate Control

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Vehicle Cool Down Test in Valeo's Wind Tunnel

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Climate Control
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Visteon/Hyundai Vehicle Development

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- **Production Vehicle**
 - 2006 Hyundai Accent
- **Production R134a System**
 - VS16 variable swashplate compressor
 - 45mm plate-fin evaporator
 - 16mm condenser with integrated receiver drier
 - TXV
- **Vehicle Configurations Evaluated**
 - Production R134a
 - Fluid H as pure drop-in
 - Modified hardware #1 – “minor modifications”
 - Modified hardware #2
 - ♦ Production compressor, pulley ratio, engine cooling fan
 - ♦ Other refrigerant system components modified to take advantage of H properties (same package & core depth as production)

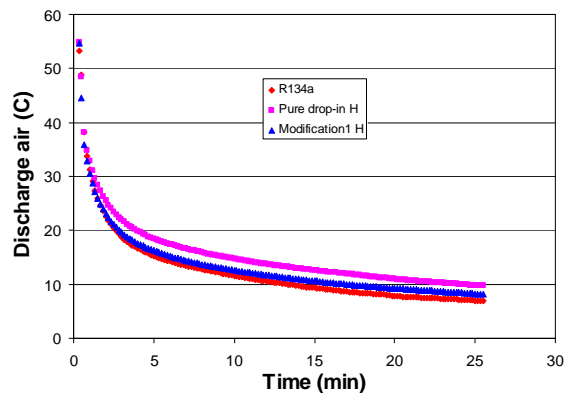


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Visteon/Hyundai Cool Down Tests

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Modification 2
not yet tested in wind tunnel



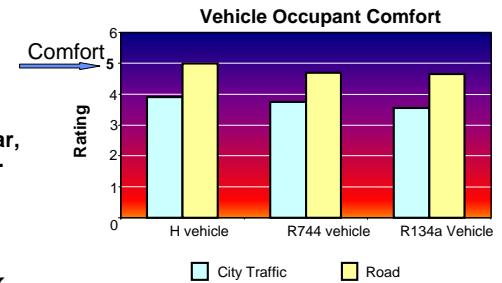
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Phoenix Ride Test Results (cont.)

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- Demonstration cars were driven by conference participants.
- Seven cars were driven through the tests.
 - 2 Fluid H cars, 1 CO2 car, and one R-134a control.
 - 3 cars were used to demonstrate the IMAC results.
- Tests consisted of soak then cool-down.
 - First phase was stop-and-go city.
 - Second phase was extra-urban.



- Comfort ratings were given by all participants in the vehicles.

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COMPATIBILITY: Summary of screening tests

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Molecular Sieves

Testing

- Tested XH-7 and XH-9
- Compatibility was measured by level of fluoride ion found in sieve after exposure

Results

- Data show that sieves are compatible with refrigerant Fluid H.

Elastomers

Testing

- NBR, HNBR, Neoprene (samples provided by customers)
- Standard sealed-tube tests at 150°C for 2 weeks

Results

- Changes observed were within normal limits
- No issues observed in system operations
- Further tests on-going

Metals

Testing

- Tested solid copper, aluminium, steel
- Standard sealed-tube tests at 150°C for 2 weeks

Results

- No corrosion effects observed

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Favourable environmental properties

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1234yf

- Global Warming Potential
 - Infrared absorption measured
 - Measured reaction rate with OH
 - Atmospheric Lifetime = 12 days
 - Direct (well mixed) $GWP_{100} = 6$
- Breakdown products
 - No environmental impact.

CF3I

- Global Warming Potential
 - Infrared absorption measured
 - CF_3I is unstable in UV light
 - Atmospheric Lifetime = 4 days
 - Direct (well mixed) $GWP_{100} \sim 1$
- Breakdown products
 - No environmental impact.

Further tests underway

Encouraging so far

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Vehicle Servicing Issues

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- Operating pressures similar to that of R-134a
- Fluid H can be readily detected with halogen leak detectors and monitors used for R-134a.
- Since Fluid H is an azeotrope, composition will not shift when recovering refrigerant from vehicles
 - It is likely that Fluid H could be re-used after clean-up.
- Requirements for Recovery/Recycling Equipment would be similar to R-134a.

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Conclusions

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- Development work continues on a very low GWP non-flammable refrigerant. Evaluation results are promising.
- System and Vehicle Test Results
 - Initial drop in tests were encouraging but more recent testing of systems that have had modest modifications show very close and even better performance to that of R-134a
 - Any reduction in capacity seen in “drop-in” tests was shown to be overcome by slight modifications to the system:
 - ♦ Change expansion device, modify suction lines, and/or modify heat exchanger flow paths.
- Investigation of Fluid H continues. Results to date have not revealed any major obstacles to the successful development of this refrigerant.
- This refrigerant has the potential to be a more cost-effective replacement than other R-134a alternatives currently in development.

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