HFC152a as the alternative refrigerant

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Note: Organizer questions are shown in RED

Acknowledgement:

- Larry Kettwich Underwriter’s Lab
- James A. Baker Delphi Automotive AC Supplier
- Stella Papasaava General Motors Corporation
HFC152a-background

Chemically Similar – Environmentally Very Different

HFC-134a
ASHRAE A1 [Non-flammable]
GWP = 1300
Used in most production vehicles today

HFC-152a
ASHRAE A2 [flammable]
Similar Materials Compatibility
GWP = 120
Used in many refrigerant blends today
HFC152a-background

Typical HFC152a Direct Expansion System Layout [Initial Concept]
HFC152a-Performance

Vehicle Wind Tunnel Cool-down

- Without system optimization [Drop-in]
- HFC152a shows improved cool-down performance as compared to HFC 134a

Direct Evaporation System reported by Delphi/GM/EPA at SAE Phoenix Alternate Refrigerant Symposium 2002
HFC152a- Direct Emissions

- 95+% Reduction in Direct Refrigerant GHG Emissions as compared to HFC134a
  - GWP of HFC152a is 120 vs 1300 for HFC134a*
  - Smaller Refrigerant charge
    - 35% less than HFC134a as demonstrated in Phoenix in Summer, 2003
  - Leakage is less than HFC134a due to molecular weight and lower system pressures with equivalent system hardware

HFC152a-System mass

- System mass is expected to be similar to HFC134a systems with direct expansion system

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporator</td>
<td>Same</td>
</tr>
<tr>
<td>Compressor</td>
<td>Same</td>
</tr>
<tr>
<td>Condenser</td>
<td>Same</td>
</tr>
<tr>
<td>Charge</td>
<td>-0.2-0.3 kg.</td>
</tr>
<tr>
<td>Plumbing/lines</td>
<td>Same</td>
</tr>
<tr>
<td>Safety system</td>
<td>+ 0.2-0.4 kg.</td>
</tr>
</tbody>
</table>
If secondary loop system is used, additional components would add to system mass/cost.
How much more expensive is a current HFC152a based system compared with HFC-134a?

<table>
<thead>
<tr>
<th>Incremental system cost to manufacture</th>
<th>Direct Expansion</th>
<th>Secondary Loop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 15 € [Est.]</td>
<td>&lt; 40 € [Est.]</td>
</tr>
</tbody>
</table>

If secondary loop system, safety system is not needed, but there are additional system costs.
HFC152a-Cost

- **Manufacturing/Service (investment) equipment**
  - New recovery/recycling equipment and service procedures
  - Additional safety requirements/equipment/training for vehicle assembly plant and service providers
  - Use existing tooling for component suppliers
Risks Associated with HFC-152a

- **Flammability**
  - Under the EPA SNAP program, the use of flammable refrigerants in new systems is acceptable if necessary precautions are taken.
  - Systems will comply with SAE [Society of Automotive Engineers] J639 [Refrigerant Safety Standards] and J1739 [FMEA-Failure Mode Effects Analysis]

- **Combustion production for HFC-152a/HFC-134a**
  - MSDS for both HFC134a and HFC152a have **identical** cautions for decomposition products

- **Flammability and Atmospheric Decomposition products**
  - and their effects will be assessed in the risk assessment
## HFC152a- Risk Assessment

### Comparison of flammability:

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Lower Flammability Limit LFL [%]</th>
<th>Upper Flammability Limit UFL [%]</th>
<th>Heat of Combustion HOC [kJ/g.]</th>
<th>Realistic Combustion energy [kJ/g]#</th>
<th>Index [RF] ##</th>
<th>Molecular Weight [g.]</th>
<th>ASHRAE Class¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC290 propane</td>
<td>2.1*-2.2 #</td>
<td>9.5 #</td>
<td>50.3</td>
<td>44.0</td>
<td>56.6</td>
<td>44*</td>
<td>A3</td>
</tr>
<tr>
<td>HFC152a</td>
<td>3.7*-3.9 #</td>
<td>16.9 #</td>
<td>17.4</td>
<td>6.3</td>
<td>4.6</td>
<td>66*</td>
<td>A2</td>
</tr>
<tr>
<td>HFC134a</td>
<td>-</td>
<td>-</td>
<td>4.2*</td>
<td>-</td>
<td>-</td>
<td>102*</td>
<td>A1</td>
</tr>
</tbody>
</table>

*RF- No.: a New Index for Combustion Hazard of Refrigerants.  
\[RF \text{- No.} = [(\sqrt{UFL \cdot LFL} - LFL) / LFL] \cdot (HOC/M)\]  
UFL: Upper Flammability Limit, LFL: Lower Flammability Limit  
HOC: Heat of Combustion, M: Molecular Weight  
Ref.: S. Kondo, K. Tokuhashi, A. Takahashi, A. Sekiya, 31th Symposium on Safety Engineering (Japan), Sg-1 (2001).

# DuPont Technical Information-presumes less than 100% combustion of refrigerant [3/2002] [NFPA]  
##Based on DuPont numbers  
[Note:Numbers from Journal of Hazardous Materials, A93-2002 fall in between these values.]  
#US EPA 09-MAR-1994, Dean Smith  

1 ASHRAE=American Society of Heating, Refrigeration and Air Conditioning Engineers
Given the liability issues relating to flammability, will the vehicle manufacturers introduce HFC-152a to vehicles?

- Use of HFC152a [with direct or indirect expansion system] will depend on the risk assessment results.

What happens if some refrigerant is mixed with HFC-152a?

- Not likely this will occur in a vehicle system since all refrigerants have unique service fittings per SAE J639
- If other refrigerants are mixed with HFC152a during service, results depend on properties of the refrigerant that is added. [L. Kettwich-UL]
Results of HFC152a tests have shown system to be an average of 10% more efficient than HFC134a at conditions from 27°C to 46°C. Use of secondary loop system will result in efficiency similar to current HFC134a.

**Mechanical COP =**

**System Air Cooling Capacity / Measured Compressor Shaft Power**

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**Direct Evaporation System reported by Delphi/GM/EPA at SAE Phoenix Alternate Refrigerant Symposium 2002**
What are the potential efficiency improvements and what is the limit to these improvements?
- Oil Separator
- Suction line heat exchanger
- Improved Effectiveness of heat exchangers
- Improved efficiency of compressor
- Capacity Controlled compressor, externally controlled
- Controlled Air Re-circulation on the evaporator
- Improved lubricant compatibility

A secondary loop needs to be assessed
- Mass and Cost will increase, efficiency similar to current HFC134a systems

Is it possible to produce a cost vs efficiency improvement pareto?
- Similar to those items under consideration with the enhanced R134a system
HFC152a - LCCP

Direct Evaporation System reported by Delphi/GM/EPA at SAE Phoenix Alternate Refrigerant Symposium 2002

LCCP [kg. of Equivalent CO₂]
Can leaks be identified?

- Use of Infrared technology has been demonstrated to work similar to HFC134a leak detectors.
- Service fittings are identified
What would be such a reasonable transition period?
- 2 additional years of development are necessary to optimize system efficiency, durability, safety, and mass and assure refrigerant manufacturing capacity
- 2-4 additional years is necessary for a global vehicle model introduction

How mature is the technology itself?
- Component technology developed [current HFC134a hardware]
- System controls are still under development

To what extent are the problems relating to the introduction of HFC152a systems related to technology itself, and how much to “simply” cost?
- Problems related to introduction are mainly technical issues around flammability control in operation, servicing and production.
HFC152a-Technological issues

- **Dual evaporator loops?**
  - Secondary loop system would be used for dual evaporator loops

- **Direct expansion vs secondary loop?**
  - No problem to use HFC152a with secondary loop systems
  - Secondary loop will have additional cost and reduced efficiency as compared to direct expansion

- **Heat pump capability?**
  - Per SAE paper 2003-01-0733
    - System demonstrated with coolant as Heat Source
      - Heat capacity at -18°C is over 8 kW
      - Results were similar with both R134a and R152a
HFC152a-Conclusions

- **Environmental Consideration**
  - 95+% reduction in direct refrigerant emissions vs. HFC-134a
  - Up to 10% reduction in indirect emissions vs. HFC-134a [reduced fuel usage]
- **AC system considerations**
  - HFC-152a and HFC-134a have nearly identical pressure / temperature curves-minimal component changes required
  - Cooling performance and overall energy efficiency are better than HFC-134a
  - Current HFC-134a components, lubricants and materials can be used with HFC-152a
    - Flexible component manufacturing possible
- **Relative ease of industry conversion**
- **Risk Assessment**
  - Low flammability
  - R152a is still an HFC and it could fall under any HFC regulations
  - Risk assessment results will be available when complete

Thank you for your kind attention!