

R-152a Mobile A/C System

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(LCCP)**



WARNING: HFC-152a is a flammable refrigerant and should not be used in systems unless specifically designed for its use.



EPA Supports Innovation

- **Founding Member, The Mobile Air Conditioning Climate Protection Partnership (MAC-CPP)**
- **Financial Sponsor, SAE Cooperative Research Program (CRP)**
- **Grant to Delphi--R-152a Performance Testing**
- **Grant for Documenting DaimlerChrysler CO₂**
- **Risk Analysis for EPA SNAP Listing of CO₂ and R-152a including occupant/service exposure**
- **Proactive Authority on Transportation Safety and Environment**

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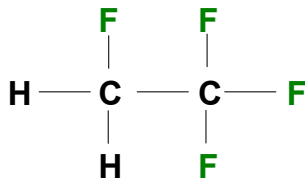
Why Reconsider HFC-134a?

- **Significant Greenhouse Gas contribution**
- **Disappointing HFC recovery at service/disposal**
- **Vehicle AC penetrating global markets**
- **European Agreement of +25% fuel efficiency by '08 (aiming at 140 g/km and further to 120 g/km)**
- **New Vehicle Platforms--DI, fuel cell, hybrid**
- **R-152a and R-744 may be superior refrigerants**

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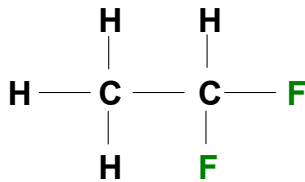
Why R-152a?

Chemically Similar – Environmentally Very Different



R-134a Molecular Weight = 102
1,1,1,2 – Tetrafluoroethane

GWP = 1300



R-152a Molecular Weight = 66
1,1 - Difluoroethane

Similar Materials Compatibility

GWP = 140

**93% Reduction in Climate Impact from Refrigerant Change
(not including energy savings)**

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Both chemicals are classified as HFC's because they contain only carbon, hydrogen and fluorine. They do have similar chemical compatibilities with commonly used A/C system materials - and that's a good thing - but act very differently in the atmosphere. While the atmospheric lifetime of HFC-134a is 14.7 years, the lifetime of HFC-152a is only 1.5 years. This is reflected in the much lower GWP assigned to HFC-152a.

Due to the lower molecular weight of HFC-152a, only 2/3 as much charge would be required to fill the system compared to HFC-134a. Since GWP is based on mass, the relative system GWP would be $140 \times \frac{2}{3} = 91$ versus 1300 for the HFC-134a system. Hence, the overall climate impact would be reduced to only 7% that of HFC-134a $(91)(100\%)/(1300) = 7\%$

Alternatively stated, the change to HFC-152a from HFC-134a would result in a 93% reduction attributable to the refrigerant alone, I.e., not including any energy savings.

Now let's take a look at how the refrigerant performs as a refrigerant.

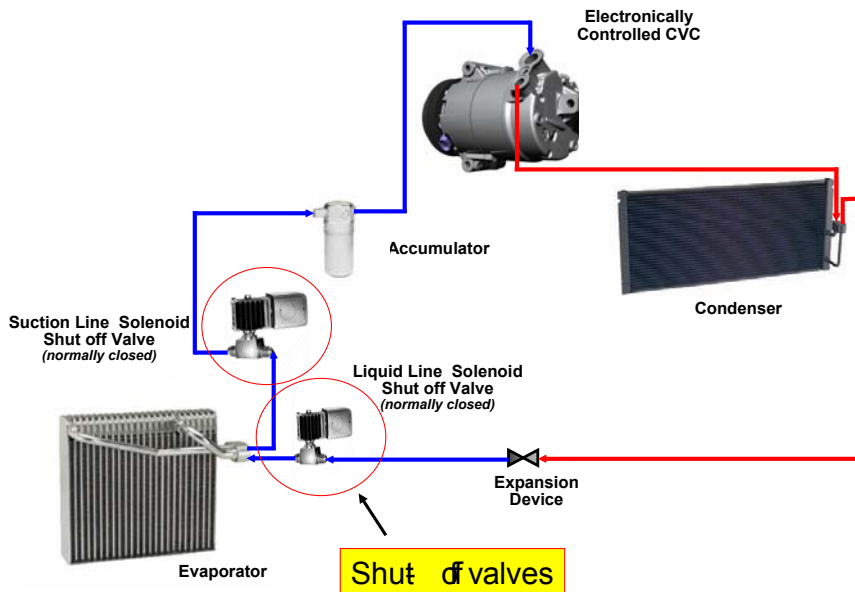
- ◆ **Full size sedan production vehicle**
- ◆ **Same vehicle and same wind tunnel used for testing both R-134a & R-152a systems**
- ◆ **Vehicle first tested with O.E. R-134a system, then equipped & tested with R-152a system**
- ◆ **Same condenser and evaporator air flows for both systems**
- ◆ **Refrigerant charge: 2 lb (908 g) for R-134a baseline system versus 1 lb (454 g) for R-152a**

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R-152a heat exchangers that replaced the OE R-134a heat exchangers were of the same face areas, resulting in maintaining the same condenser and evaporator air flows. Other changes included replacing XH7 with XH9 desiccant and a smaller diameter orifice tube.

Prototype System Description

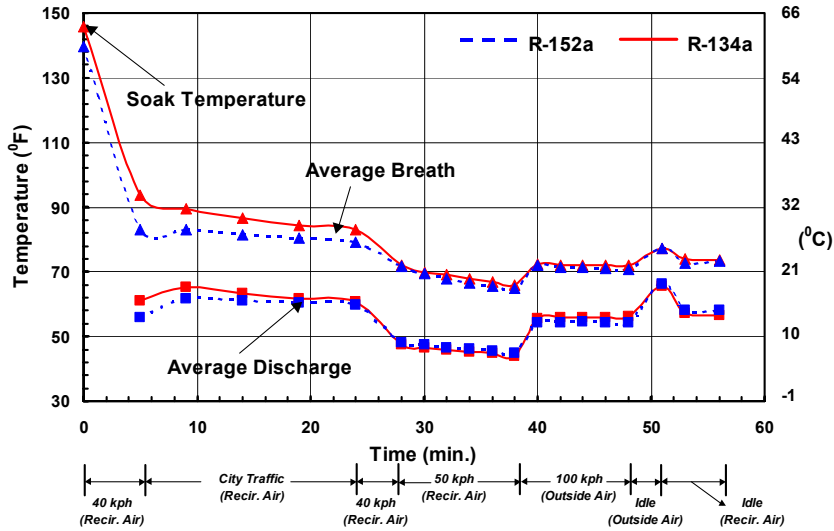
R-152a Mobile A/C System



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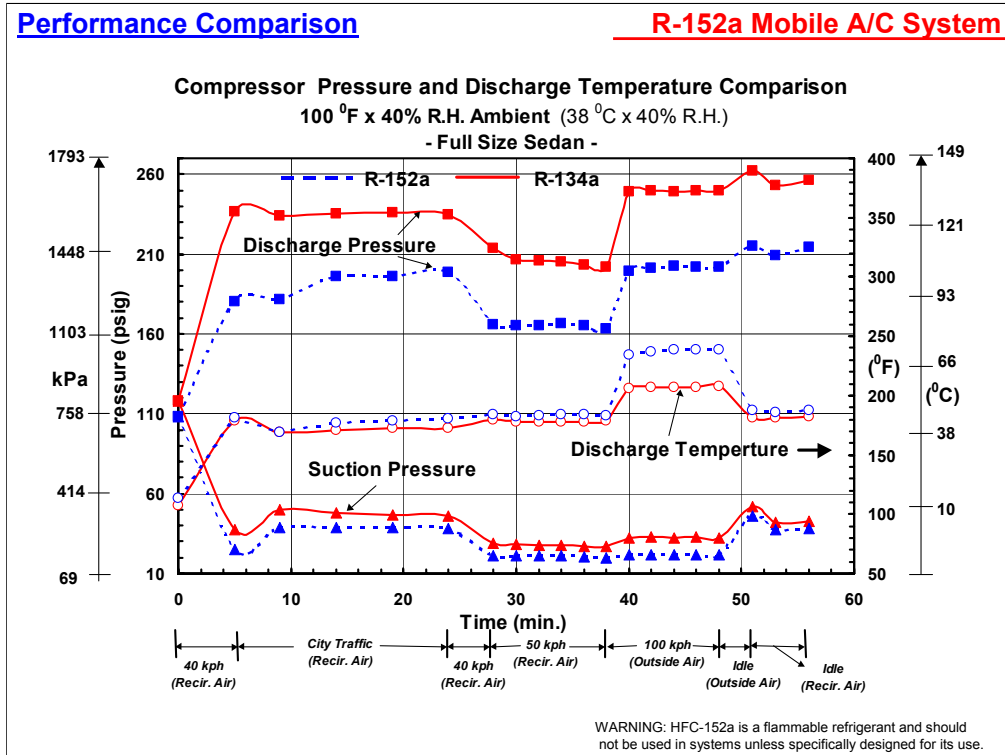
- ◆ The components used in the R-152a system are current production R-134a components
- ◆ Same lubricant and amount for both systems
- ◆ “Solenoid Shut-Off Valves” function is to minimize the refrigerant amount in the evaporator during A/C system operation and vehicle shut off

Discharge A/C Temperature Comparison
100 °F x 40% R.H. Ambient (38 °C x 40% R.H.)
- Full Size Sedan -



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This is a typical wind tunnel test that simulates the cooling down of a previously parked, hot vehicle. The soak temperature is the interior temperature reached after parking the vehicle in the sun. Average breath temperature is the temperature at passenger head level and the average discharge temperature is the temperature of the air coming out of the A/C vents.

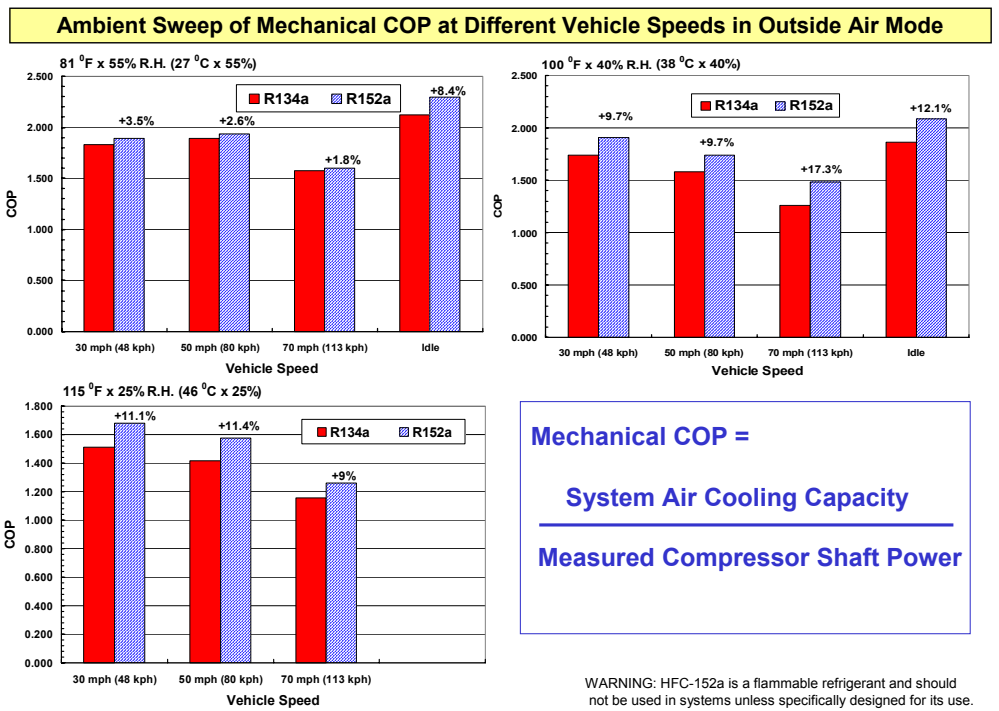


Overall

- ◆ R-152a system showed better or equal discharge temperatures than the R134a baseline system
- ◆ R-152a system exhibited lower discharge and suction pressures than the R134a system
- ◆ The low discharge pressures of R-152a system would allow longer idles without A/C cut off due to high discharge pressures
- ◆ R-152a system displayed higher compressor discharge temperatures

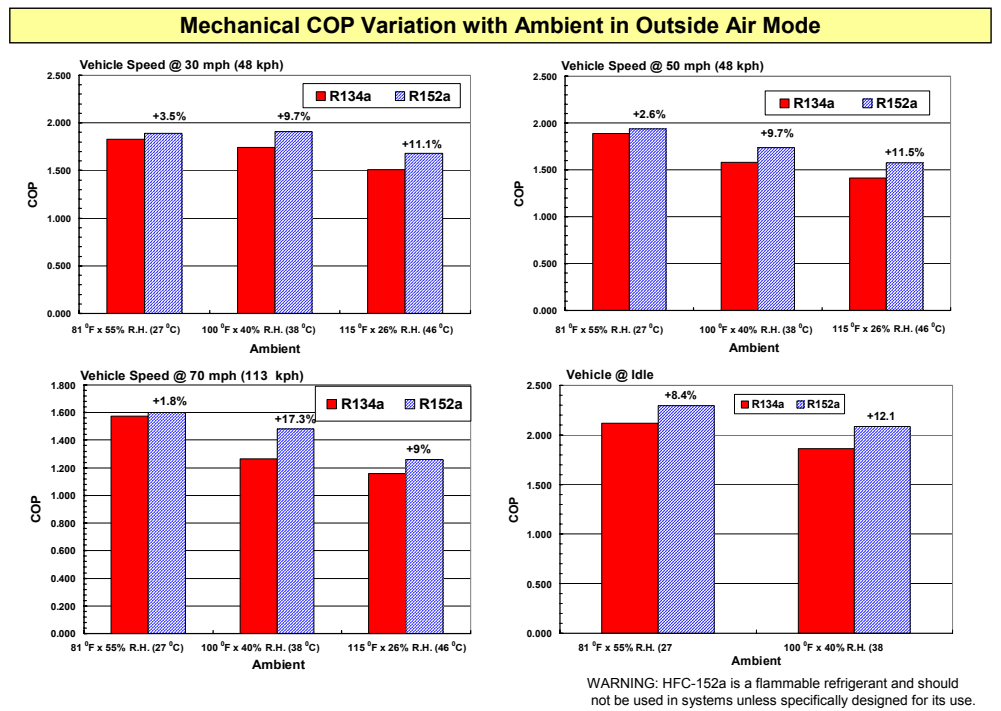
- ◆ Full size sedan production vehicle
- ◆ Vehicle was tested with O.E. R-134a system, then evacuated, recharged & tested with R-152a in the same tunnel (No components changed)
- ◆ Same condenser and evaporator air flows for both systems

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Overall

- ◆ R-152a system showed 1.8 to 17% mechanical COP improvement over R-134a baseline system
- ◆ COP improvement gets better with higher ambients



Overall

- ◆ At low to idle vehicle speed, R-152a system showed 8 to 10% mechanical COP improvement over R-134a baseline system
- ◆ COP improvement is more pronounced at higher ambients

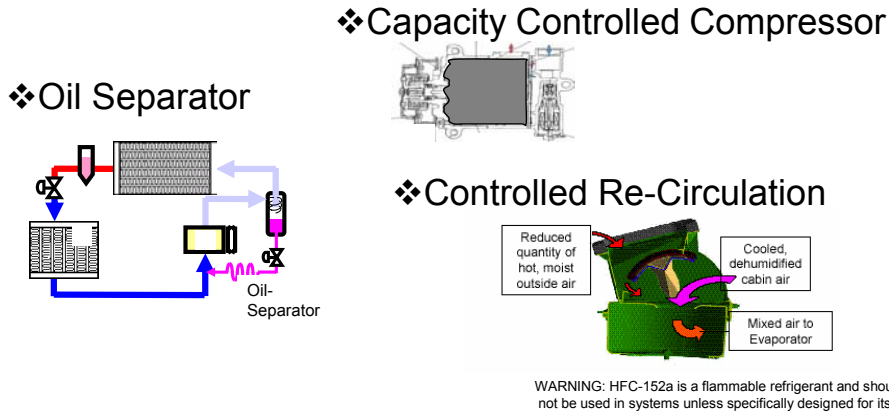
Summary

- **Better cooling performance**
- **Higher mechanical COPs resulting in lower energy usage**
- **Lower compressor discharge pressures allow longer idles without A/C cut off due to high compressor discharge pressures**
- **Lower suction pressures**
- **Higher compressor discharge temperatures**
- **Data show that reducing the pressure drop through the solenoid valves would further increase the performance**

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Potential Efficiency Improvements with Enhanced Systems (R-152a or R-134a)

- Basic development in three months
- Just like R-134a, R-152a system can be enhanced!



The R-152a system that is discussed in this presentation was developed in less than three months with existing component technology.

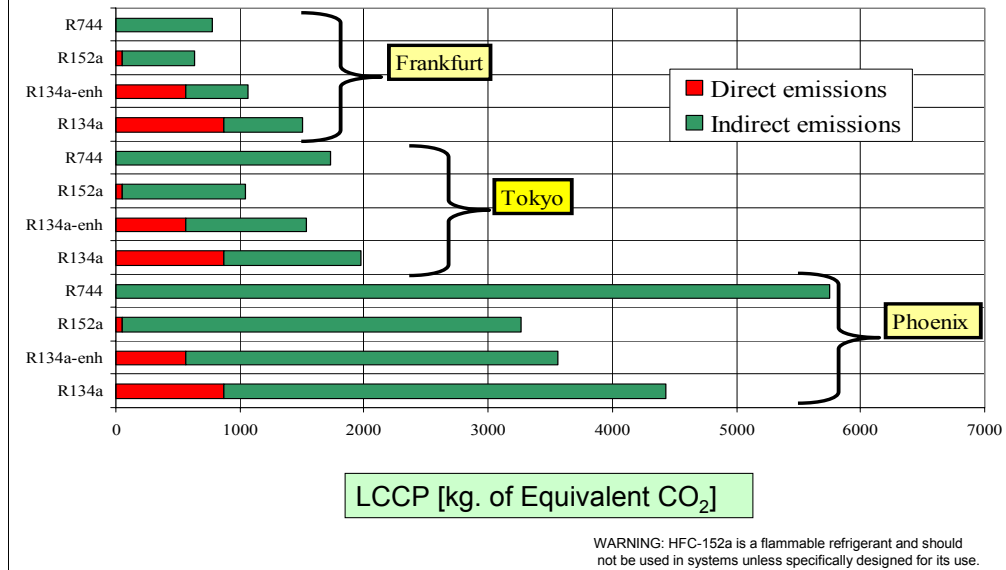
This system as well as many other R-134a systems in production today have the potential for significant “enhancement”.

The three technologies presented here are a few of those that are readily available to enhance the performance and the efficiency of these systems.

Other basic heat exchanger efficiency improvements and compressor efficiency improvements can offer further enhancements!

LCCP Analysis

Comparison of R-134a, R-134a-enh., R-152a, and R-744 Vehicle A/C Systems Versus Climate



This is an update of the presentation made several years ago by General Motors at the Phoenix Forum. LCCP is defined as the Life Cycle Climate Performance of a refrigerant and takes into account the energy and refrigerant emissions from all phases of manufacturing, use, servicing, recycling, and scrap throughout the life cycle of the A/C system.

It compares the baseline R-134a system to an enhanced system and to R-152a and R-744 at various ambient temperature and drive cycle conditions.

Environmental Considerations

- ◆ **Addresses the growing international concern over global warming**
- ◆ **R-152a results in a 93% reduction in direct carbon-equivalent emissions vs. R-134a**
- ◆ **R-152a use reduces energy consumption (fuel) by ~ 10% vs. R-134a**
- ◆ **These combined attributes result in a net emission reduction equivalent to completely offsetting the current impact of R-134a MAC emissions**
(reduced fuel emissions offset R-152a emissions)

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The growing concern over the emissions of greenhouse gases require each industry to look at its own emissions and work toward developing means to reduce those emissions.

For mobile air conditioning, R-152a offers outstanding environmental advantages over R-134a.

The use of R-152a offers both a reduction in carbon-equivalent emissions as well as a significant fuel savings potential. **These attributes combined result in completely offsetting the current impact associated with refrigerant R-134a MAC emissions**

A/C System Considerations

- ◆ **R-152a and R-134a have nearly identical pressure / temperature curves**
- ◆ **R-152a cooling performance and energy efficiency are better than R-134a**
- ◆ **Current R-134a components, lubricants and materials can be used with R-152a**
 - **Flexible manufacturing possible**

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From a system standpoint, R-152a performs better as a refrigerant and uses significantly less energy in the process.

R-152a can be used with the same components currently used with R-134a, which would allow flexible manufacturing and/or ease the transition for those wishing to change from R-134a to R-152a.

R-152a systems are expected to be identical in size and weight to current R-134a systems.

Safety Considerations

◆ **Very low flammability – currently used in many consumer products**

- Hair sprays
- Shaving Creams
- Antiperspirant sprays
- Dusting sprays (100% HFC-152a)
(HFC-152a aerosols considered not-flammable per U.S. CPSC test)

◆ **Low charge minimizes risk – Large cars need less than 1 pound (454 g) !**

- **Safety engineering enhancements can further minimize risk**

Strategically placed solenoid valves create multiple containment areas to protect passenger and engine compartments.

HVAC case sensing system to protect passenger compartment

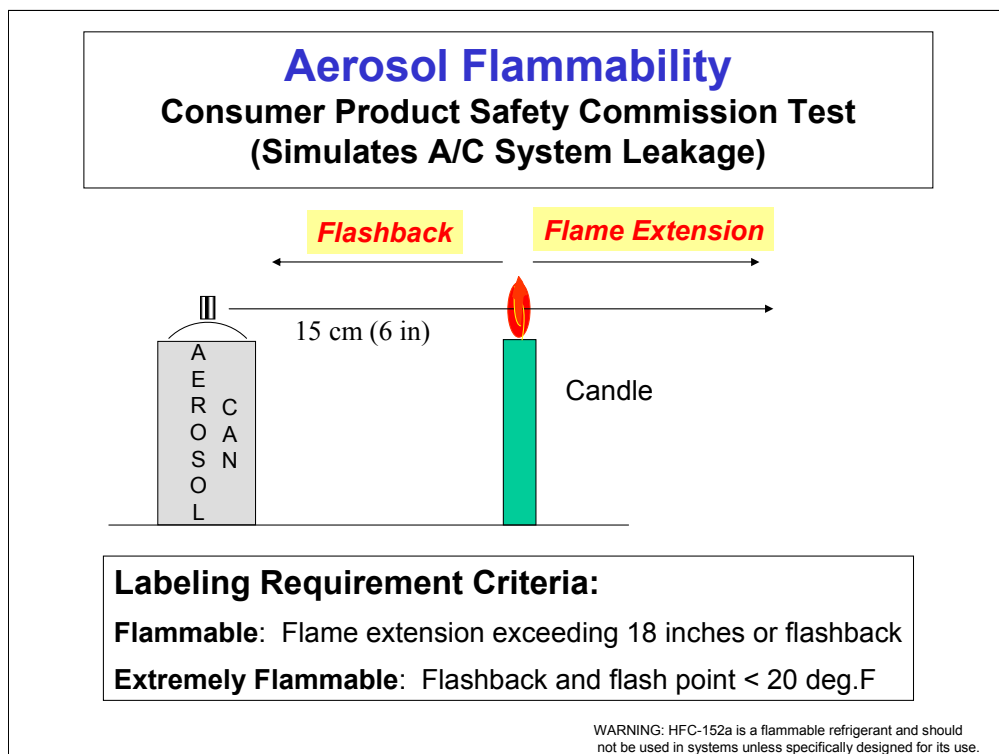
◆ **Service procedures needed to ensure safe use and handling (SAE)**

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Safety is, of course, a concern with any flammable material. An investigation of the flammability of this material suggests that its flammability is very mild as attested to by its use in common consumer products. Of particular interest is its use as a dusting spray to dust off such things as computers, keyboards, etc. It is also used as the propellant in spray paints and spray insulating foams. For these uses, it is deemed non-flammable by the Consumer Product Safety Commission aerosol flame extension test. The next slide provides more detail on the CPSC test.

Should it be needed, refrigerant system isolation valves and in-car sensor systems could provide enhanced safety for the engine and passenger compartments.

Of course, new service procedures to safely handle the refrigerant would be required. Such procedures would be developed by the SAE Interior Climate Control Standards Committee, which is currently revising its safety document SAE J639 to accommodate alternative refrigerants.



There are, of course, no current tests for assessing mobile air conditioning systems with a ‘flammable’ refrigerant. Given that leaks in such a system would behave very similarly to an aerosol spray, the flammability assessment of aerosol sprays provides insight into the expected behavior of refrigerant leaks from a mobile A/C system.

The Consumer Product Safety Commission has reviewed aerosol safety and uses the flame extension test to determine the need to alert the consumer to flammability via labeling based on the outcome of the test.

Per this test, the aerosolized material is sprayed directly into the flame of a candle and any flame extension and/or flashback to the can is observed and noted. Label requirements are as follows:

Extremely Flammable if a flashback occurs

Flammable if the flame extension exceeds 18 inches

HFC-152a gives **no flame extension and no flashback** and, as a result, does not fall under the requirement of being labeled as ‘Flammable’.

HFC-152a Safety According to Industry Experts

- ◆ **Dupont (Dymel 152a Technical Bulletin ATB-29)**
HFC-152a “does not give a flame extension or flashback in the standard test used to measure the flammability of aerosol products”

- ◆ **IEC (International Electrotechnical Commission) 60335-2-40, Ed. 3: Part 2-40 (Draft being balloted)**
“Particular Requirements for electrical heat pumps, air-conditioners and dehumidifiers containing flammable refrigerants”
 - **For HFC-152 charges below 520 grams - “Special precautions to the relationship between the charge amount and the room size are not necessary for installation and storage”**

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Additional information gathered from the experts on the safety of using HFC-152a include publicly available information from Dupont’s Dymel 152a literature and the IEC draft currently under ballot. The IEC standard is being developed to assure the safety of vapor compression systems (including air conditioning) using flammable refrigerants in the home environment, both inside and outside, above and below grade.

Their considered opinion is that there is a refrigerant charge amount for each potential refrigerant that is small enough that should cause no need for great concern. For HFC-152a, this amount is 520 grams.

HFC-152a Safety According to Industry Experts

- ◆ United Nations Sub-Committee of Experts on the Transport of Dangerous Goods
 - Enclosed Space Ignition Test –proposal to designate as Non-Flammable for transport if:
 - “its deflagration density is greater than or equal to 100 g/m³”
 - or
 - “its heat of combustion is less than 20 kJ/g”
 - HFC-152a meets both criteria for non-flammability designation
- ◆ U.S. Consumer Product Safety Commission has allowed consumer products containing HFC-152a for many years. As much as 12 oz. (0.34 kg) of pure HFC-152a can be sold without restriction to the general public

Most future R-152a vehicle air conditioning systems would operate on far less than 520 grams (19 oz.)

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As concerns transporting the material (in the vehicle and otherwise), the criteria noted above suggest that the flammability of HFC-152a is mild enough to warrant being labeled “non-flammable”.

Further the USCPSC allows at least 12 ounces (340 grams) to be sold in an aerosol can to the general public without restriction for dusting off surfaces. Endust™ has been selling such a product for the past 6 years.

It is noteworthy that most future vehicles that would use HFC-152a would require far less than the 520 grams noted by the IEC, and that **a significant percentage of vehicles could be fully charged with the contents of a 12 ounce can.**

Conclusions

◆ R-152a Offers

- Outstanding environmental advantages
- Improved cooling performance vs R-134a
- Improved energy efficiency vs R-134a
- Relative ease of industry conversion

R-152a Merits Consideration by Vehicle Makers for Future A/C Systems

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R-152a has been carefully assessed for its value as a refrigerant in mobile air conditioning and found to offer significant advantages over R-134a, its flammability/combustibility notwithstanding. Its clearly superior environmental, energy, and cooling performance make it a refrigerant that merits consideration for future systems.