



# Safety risks of R1234yf: New test results of DUH

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On the behalf of DUH

Ispra, 24th of January 2014



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## Overview

- Effects of Hydrofluoric acid
- First tests of DUH
- Evaluation: Results of KBA
- Alternative ignition scenarios
- Testing Conditions
- Results of latest DUH-testing
- Recommendations of DUH

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## Effects of Hydrofluoric acid

- An exposition of 30-60 minutes with  $42 \text{ mg/m}^3$  (50 ppm HF) is lethal. IDLH-value („immediately dangerous to life or health“) is set to  $25 \text{ mg/m}^3$  (30 ppm).<sup>1</sup>
- **Characteristics**<sup>2</sup>
  - Highly corrosive liquid / contact poison
  - Penetrates tissue more rapidly than typical mineral acids
  - Poisoning can occur through exposure of skin or eyes, or when inhaled or swallowed
  - Inhalation can cause serious corrosive injuries of the lungs
  - Symptoms of exposure to hydrofluoric acid may not be immediately evident

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## First tests of DUH

- Tests in 2008 and 2009 (together with Federal Institute for Materials Research and Testing, BAM)
- Simulation of frontal collision: potential combustion of emissive refrigerant R1234yf on hot engine parts and a possible formation of HF
- Results:
  - Engine compartment: temperature of 600° Celsius was sufficient to ignite R1234yf
  - More than 90 ppm HF in the passenger compartment
  - In comparison: No ignition of R134a under comparable conditions



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## Evaluation: Results of KBA

- Scenarios 1/2: Crash-Tests with 40 km/h based on the GIDAS-Database
  - Test speed much too slow!
  - ECE R94 requires a speed of 56 km/h and Euro NCAP is conducted at 64 km/h
- Scenario 3: Simulation of larger damages of the AC system
  - More realistic: shows what happens at higher speeds, higher temperatures or in case of ageing material of the AC
  - under more severe conditions R1234yf is dangerous
- DUH (and KBA) stated that further testing is urgently needed
- No testing of alternative ignition scenarios yet!

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## Alternative ignition scenarios

- Previous tests of DUH, BAM, Daimler and KBA with R1234yf: ignition/HF-formation due to emissive refrigerant (-> front collision)
- In Germany approx. **15.500 to 40.000 vehicle fires<sup>3</sup>** each year (not only caused by collisions)
  - Vandalism
  - Overheated tires and brakes
  - Spreading fire of other vehicles
  - Technical defects
- Relevant scenarios which have to be taken into account
  - Fires in tunnels and parking garages
  - Burning car transporters
  - Fires in car repair shops

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## Testing Conditions (1)

- **Used car:** Mid-size van (2013 model, among the top ten sellers of vehicles using R1234yf in Germany)
- **Testing facilities:** DMT GmbH (TÜV Nord Group) in Dortmund (Germany)
- **Date:** 13<sup>th</sup> and 14<sup>th</sup> of January 2014
- **Scenario:** Simulation of car fire in a tunnel



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## Testing Conditions (2)

- Preparation of the vehicle
  - Engine compartment facing the direction of flow
  - Thermal sensors in the engine compartment
  - MAC systems contained 372g of R1234yf
- Measurement of HF through exhaust air
  - Flow velocity: 1,5 m/s (with an open cross-section of 10 m<sup>2</sup>: flow rate of 45.000 m<sup>3</sup>/h)
  - Combustion gas was extracted by suction out of the gallery 20 m downstream of the back of the vehicle
  - Measurement technology: Fourier transform infra-red spectrometer (FT-IR)



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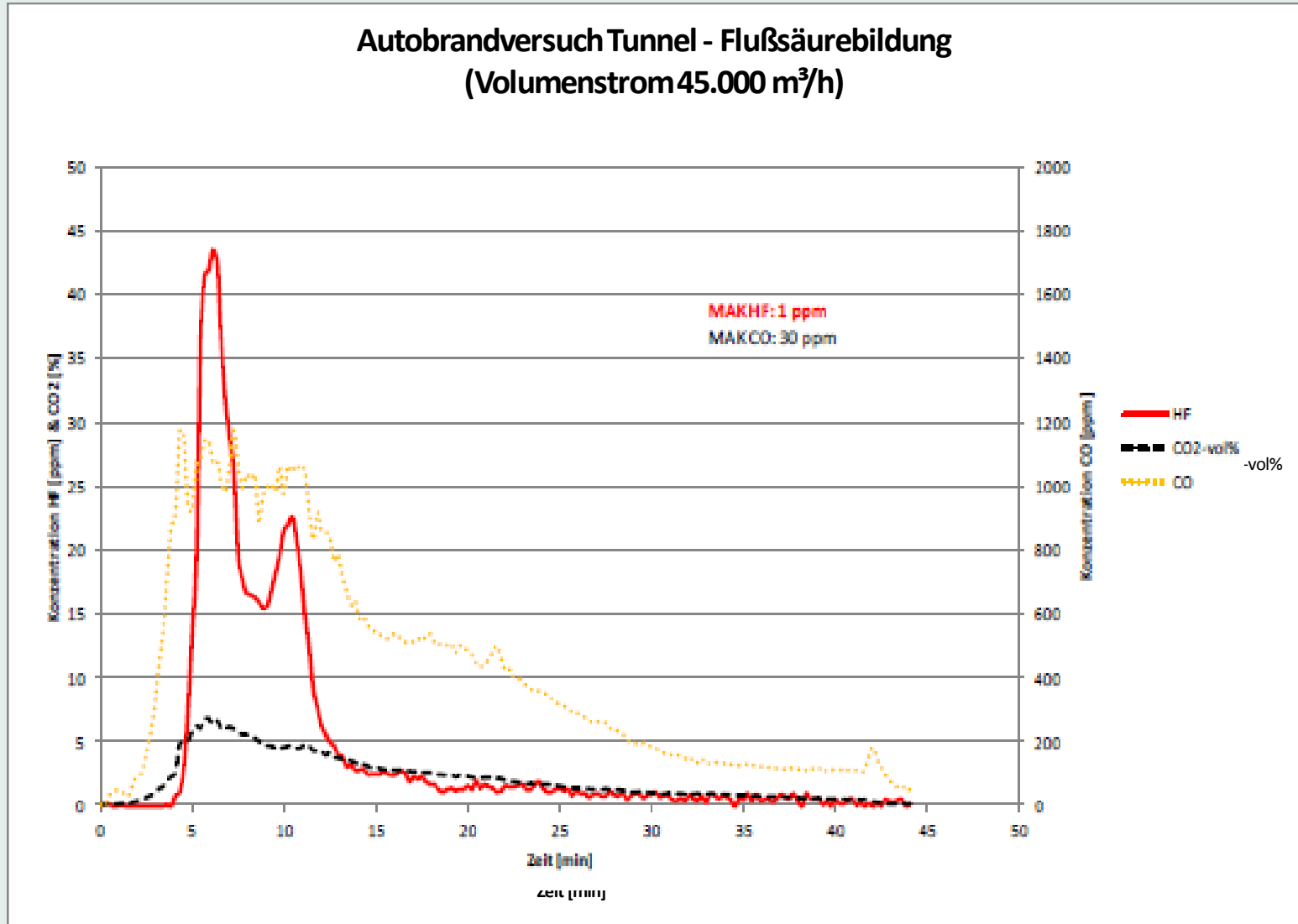
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# Results of latest DUH-testing (1)

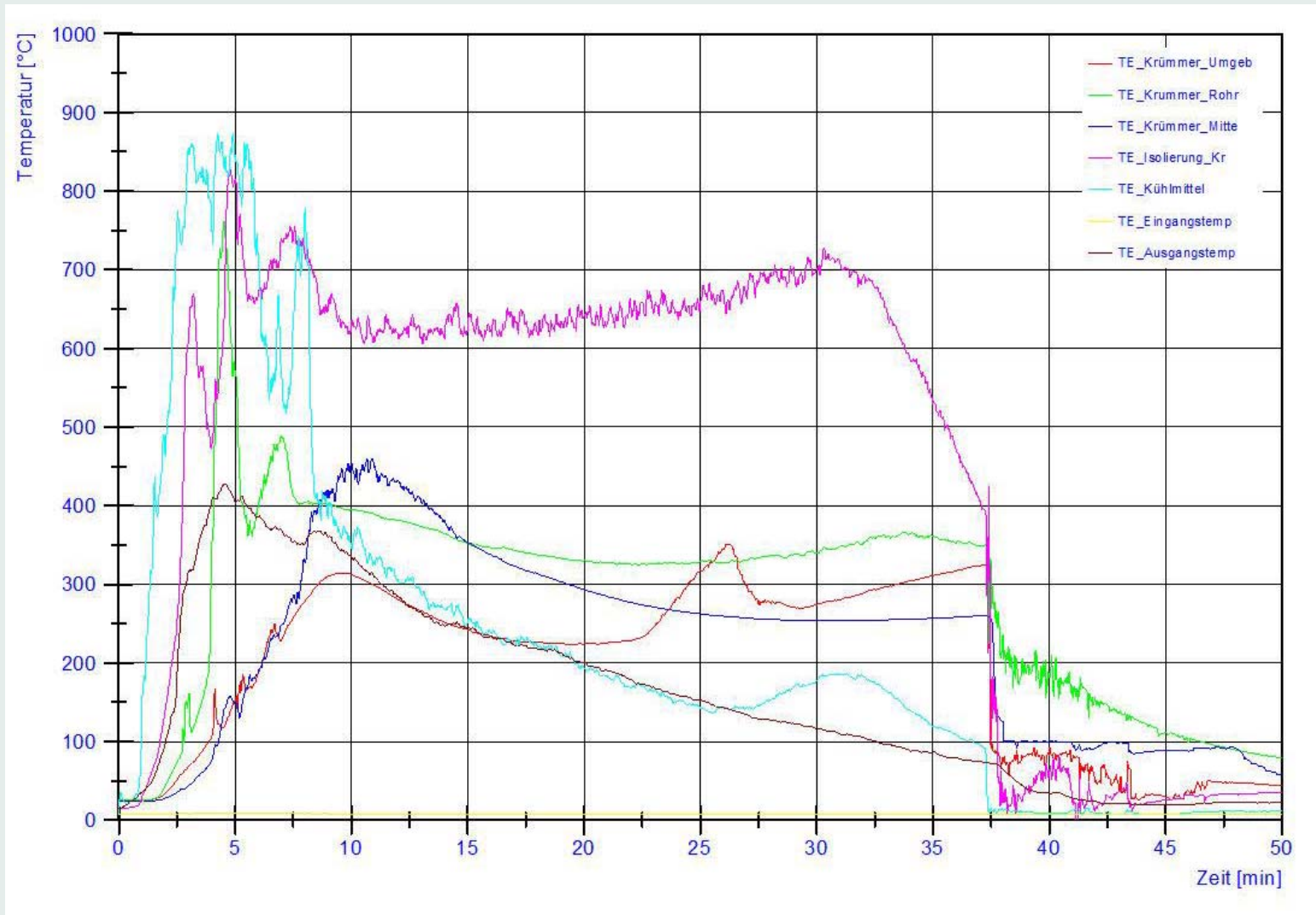


Autobrandversuch Tunnel - Flußsäurebildung  
(Volumenstrom 45.000 m<sup>3</sup>/h)



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## Results of latest DUH-testing (2)



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## Results of latest DUH-testing (3)

- **HF concentrations**
  - Up to almost 45 ppm HF in exhaust air
  - Total amount of HF during the test: 126g
- **Temperatures did not exceed 900° Celsius**
  - Current refrigerant R134a would have not ignited (ignition temperature of R1234yf in comparison: 405° Celsius)
  - In general: hazards of HF-formation of R134a are evaluated to be lower than for R1234yf<sup>4</sup>

- **Summary of DMT:**

*“As a result of a vehicle fire with an air conditioning system filled with the new refrigerant R1234yf, considerable quantities of hydrogen fluoride can be formed in a tunnel and expelled into the tunnel air as combustion gas.”*

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# Recommendations of DUH

- Further testing of R1234yf urgently needed
- Safety concerns of certain car manufacturers in regard to R1234yf have to be acknowledged by the COM
- Automotive industry should switch to the environmentally-friendly and non-flammable refrigerant CO<sub>2</sub>



## Sources

<sup>1</sup>NIOSH IDLHs "Documentation for Immediately Dangerous to Life or Health Concentrations (IDLHs)" U.S. Department of Health and Human Service, Cincinnati Mai 1994.

<sup>2</sup>University medical center Jena ([http://www.zna.uniklinikum-jena.de/zna\\_media/SOPs/Flusss%C3%A4ure.pdf](http://www.zna.uniklinikum-jena.de/zna_media/SOPs/Flusss%C3%A4ure.pdf)).

<sup>3</sup>German Insurance Association (GDV); ADAC.

<sup>4</sup>BAM (2010), Final test report: Ignition behavior of HFO1234yf.



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## CO<sub>2</sub> (R744) as alternative (1)

- Environmentally-friendly: GWP of 1
- No Drop-in (refilling of R134a not possible)
- Cheap and globally available
- In combination with a heat pump: can be used for efficient heating
- Non-flammable
  
- Already used in many domains:
  - Stationary refrigeration
  - More than 30 busses run with CO<sub>2</sub>-MAC systems
  - Deutsche Bahn AG uses CO<sub>2</sub> in its new hybrid-train

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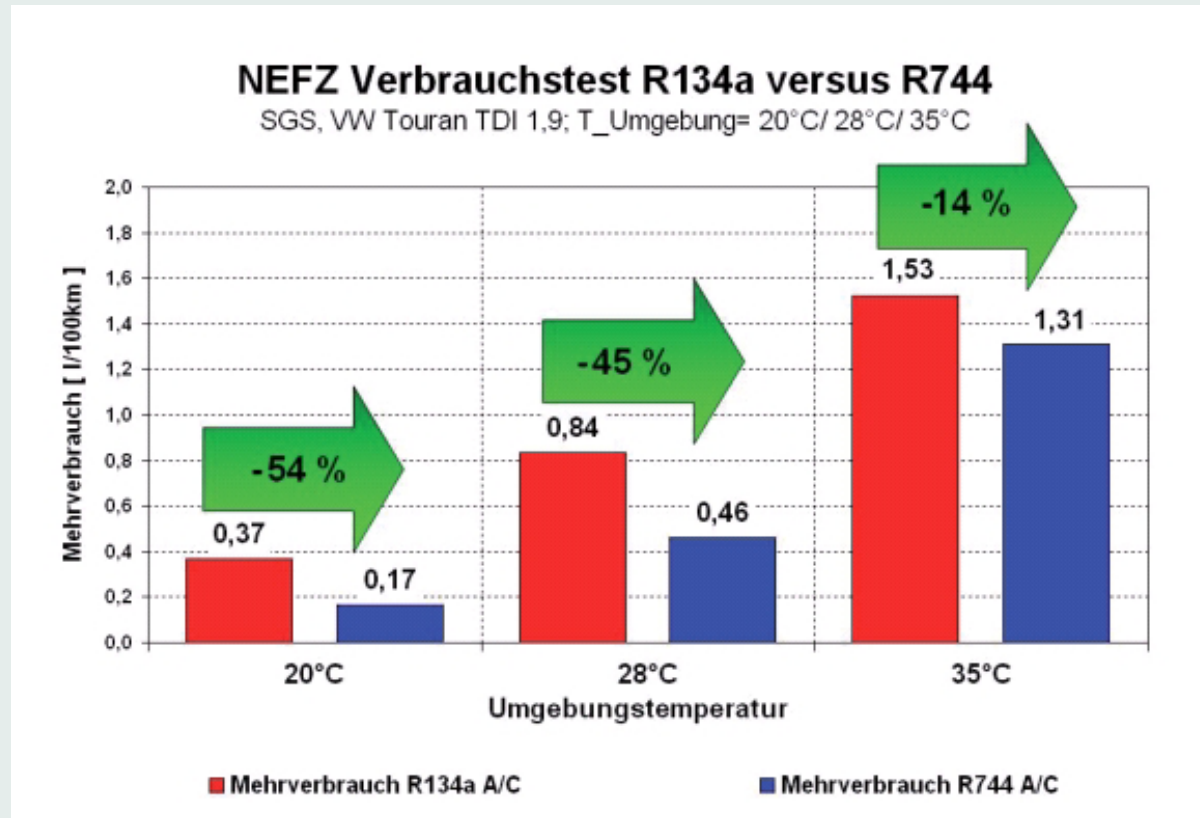


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## CO<sub>2</sub> (R744) as alternative (2)

- Slightly higher costs for CO<sub>2</sub> systems (+ 50 € per car)
- Refrigerant recharge is much cheaper
- More efficient than R1234yf/R134a (at very high temperatures on a par)



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