DMT GmbH & Co. KG
Building Safety

Expert Body for Fire Protection

Tremoniastraße 13
44137 Dortmund
GERMANY

Phone +49 231-5333-0
Fax +49 231-5333-299

Emaill: gs@dmt.de
http://www.dmt.de

Survey of the Burning Behaviour of the Refrigerant HFO-1234yf

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Brief Report

Document number:	20640227-GS3&5-Re/Hi/Hoi
Order number:	206 40227
Customer:	Deutsche Umwelthilfe e.V. Hackescher Markt 4 10178 Berlin
Order from:	31 October 2013
Order contents:	Survey of the burning behaviour of the refrigerant HFO-1234yf
Part:	Execution of the "fire loss" fire tests in the burning gallery for the study of inflammation of the refrigerant HFO-1234yf as well as for the formation of hydrogen fluoride
Test date:	13 & 14 January 2014
Valid until:	unlimited

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Deutsche Umwelthilfe e.V.
Hackescher Markt 4
10178 Berlin

2 Background to the Assignment

The reason for the survey is to determine respectively to estimate the hazard potential of the refrigerant 2,3,3,3-tetrafluoroprop-1-en (R1234yf). The refrigerant is currently preferred by many car manufacturers as a replacement for the previously used R134a. According to the Honeywell safety data sheet, the ignition temperature of the refrigerant R1234yf is 405°C and reference is made to the possibility of the formation of hydrogen fluoride (HF) in the case of fire.

It is assumed that for humans an exposure level of 42 mg/m³ (50 ppm HF) over 30 to 60 minutes can be lethal. The IDLH value ("immediately dangerous to life or health") has been set at 25 mg/m³ (30 ppm) [*NIOSH IDLHs "Documentation for Immediately Dangerous to Life or Health Concentrations (IDLHs)" U.S. Department of Health and Human Service, Cincinnati May 1994*].

The Expert Body for Fire Protection at the Centre for Fire and Explosion Protection at the company DMT GmbH & Co. KG has been commissioned by the Deutsche Umwelthilfe e.V. (German Environmental Aid Association) with carrying out targeted fire tests in order to clarify the following question:

During the (partial) combustion of a current car model, does the refrigerant HFO-1234yf ignite and is any hydrogen fluoride (HF) formed?

3 Description of the Performance of the Fire Test and Measurement Procedure

The targeted combustion of the vehicle in the burning gallery for the simulation of a tunnel fire was performed on the fire test site at DMT in Dortmund. The combustion gases were passed via an exhaust pipe to the flue gas cleaning system, where they were cleaned. Within the context of this brief report, only the important results obtained with respect to this accident scenario are reproduced. A final report includes all test results.

Combustion of the Vehicle in the Burning Gallery

The test vehicle equipped with thermocouples with the refrigerant R1234yf in the air conditioning system was set up in the burning gallery at DMT Dortmund. The vehicle was placed with the engine compartment facing the direction of flow. It was fitted with thermocouples in various positions in order to record the temperature profiles, with the thermocouples being connected by cables to a data collector.

The flow velocity in the fire gallery was adjusted to 1.5 m/s for adaptation to the conditions in a road tunnel. With an open cross-section of 10 m² this corresponds to a flow rate of 54,000 m³/h.

The simulation of an ignition process, which often comes into play in cases of vandalism and results in the fire being transferred from the ignited tyre to the rest of the body, was carried out as follows. A tray filled with approximately 1 litre of diesel was placed near to the tyre (front tyre on the left when seen from the driver's perspective). Ignition of the diesel, and subsequently the tyre and then the vehicle itself, was performed by means of a grill lighter which was immersed in the tray of diesel.

The gas measurement technology (FT-IR) and temperature data acquisition system were located in the side corridor of the burning gallery. By means of a steel capillary (6 mm OD, 4 mm ID), combustion gas was extracted by suction out of the gallery 20 m downstream of the back of the vehicle via a heated sampling line (180°C) through the measuring cell of the Fourier transform infra-red spectrometer (FT-IR). Infra-red spectra of the gases were recorded at regular intervals. The quantitative amounts of the resulting combustion gases were determined using the substance-specific bands. Main focus was the determination of HF.

After approximately 45 minutes the vehicle, which was still burning, was extinguished.

4 Results of the Fire Test

Before the middle-class car was burnt [redacted] the air conditioning system contained 372 g of refrigerant R1234yf. The curves for the combustion gases shown in Figure 1, i.e. carbon monoxide (CO), carbon dioxide (CO_2) and hydrogen fluoride (HF), show that in comparison to the rise in carbon monoxide as an indicator of the development of the fire, the increase in hydrogen fluoride in the combustion gases occurs after a delay of 4 minutes.

Figure 2 shows the temperature profiles at various measurement positions on the vehicle (engine section) in the burning gallery, as well as the temperature of the air in front of and behind the vehicle.

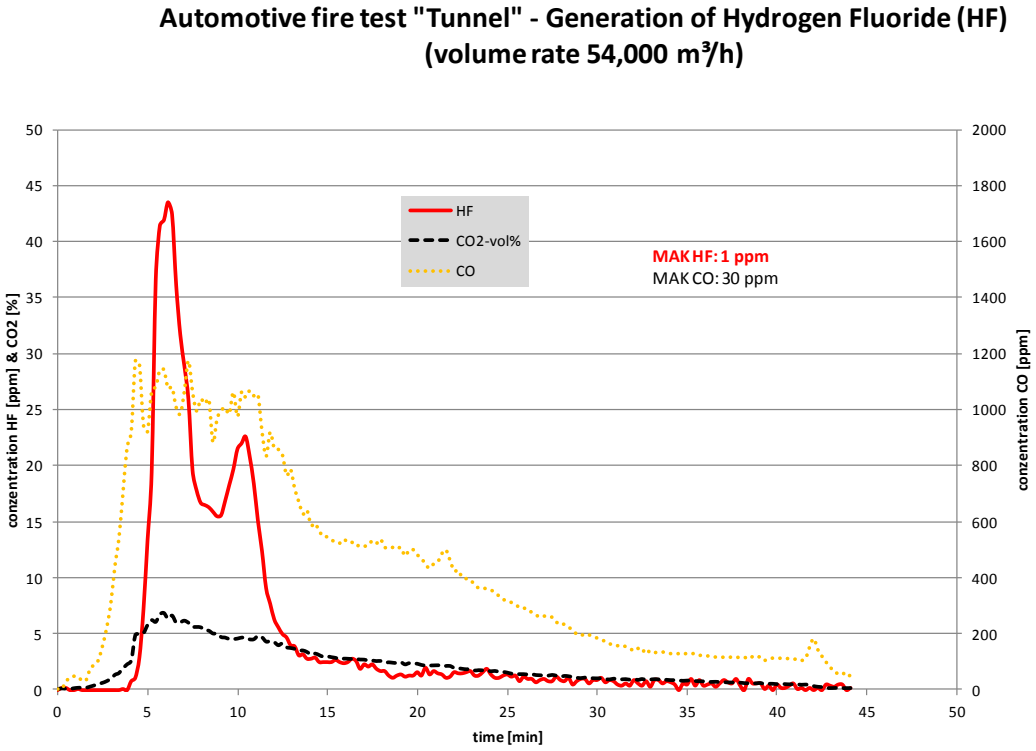

Fig. 1) *Change over time of the combustion gases carbon monoxide (CO), carbon dioxide (CO_2) and hydrogen fluoride (HF)*

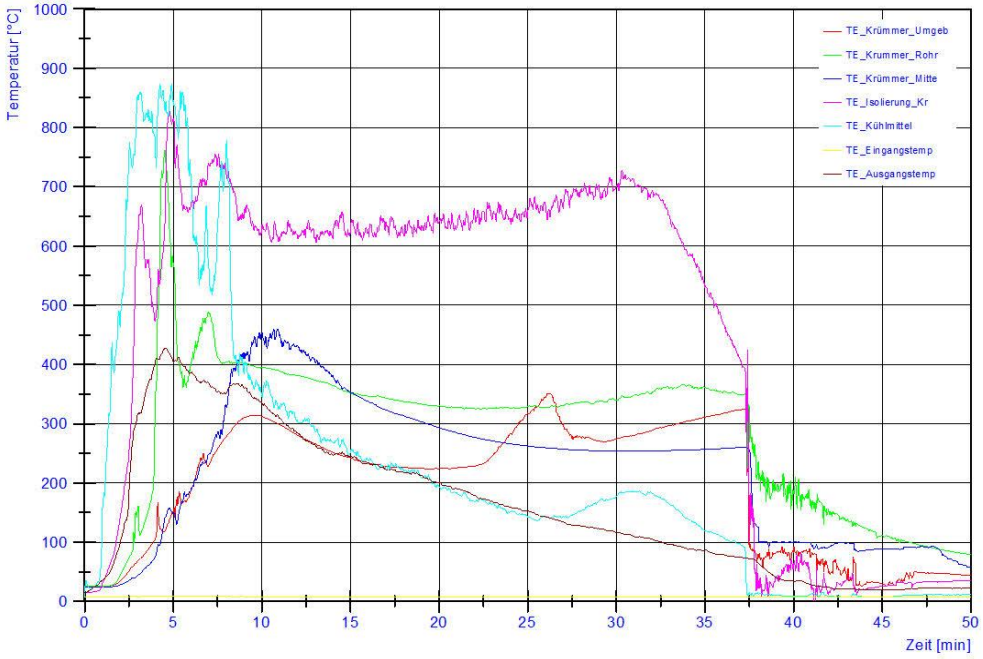

Fig. 2) *Change over time of the temperatures at the various measurement points in the engine section, as well as in front of (input) and behind (output) the vehicle*

Figure 1 shows that under the combustion conditions in the fire gallery, up to almost 43 ppm v hydrogen fluoride was present in the exhaust air behind the vehicle. Within the period of 5 to 15 minutes after the start of the vehicle fire, an average of 17 ppm v HF was recorded in the exhaust air behind the burning vehicle.

The integration of the HF mass flow in the burning gallery during the fire results in a quantity of 126 g of pure hydrogen fluoride that was formed.

5 Summary

The Deutsche Umwelthilfe e.V. (German Environmental Aid Association) has commissioned the Expert Body for Fire Protection at the firm DMT GmbH & Co. KG to carry out a fire safety test involving a vehicle fire in the burning gallery in order to simulate a tunnel fire. The aim of the test was the determination or assessment of the hazard potential caused by the formation of hydrogen fluoride in case of fire. The selected medium class vehicle [redacted] has an air conditioning system which is filled with the new refrigerant R1234yf.

The result of the fire test is as follows:

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. Under the selected fire test conditions the limit value for workplaces (AGW) and the "maximum workplace concentration" (MAK) of 1 ppm v were significantly exceeded by a HF concentration of up to 43 ppm v which was registered in the exhaust air.

Dortmund, January 24th 2014

(Dr. Renschen) (Hoischen)

Note:
This official opinion on fire test only applies to the aforementioned fire test of a medium-class car equipped with R1234yf [redacted] under the described test conditions. It is not possible to transfer the above results to other test scenarios or tunnel geometries, etc.