



Bundesanstalt für
Materialforschung
und -prüfung

Bundesanstalt für Materialforschung und -prüfung (BAM) · 12200 Berlin, Germany

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**Dr.
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Your reference PO: CA8339632
Your message of 12.06.2020

Our reference 20020356
Our message of 03.07.2020

Date 10.12.2020

Flammability tests on mixtures of iso-butane and HFO 1234ze according to ISO 10156:2017

Dear Mrs. Mandelli,

We finished our flammability tests on gas mixtures of iso-butane and HFO1234ze according to ISO 10156:2017. It was found that mixtures of iso-butane and HFO1234ze are flammable at 35 °C and a relative humidity of 40 %, if the iso-butane fraction is higher than 1 mol%. Tests with lower iso-butane fractions were not possible.

The costs for the services provided are calculated according to the actual Cost Regulation for using BAM services (KostVBAM) and amount to **2,464.00 EUR**. You will receive a separate invoice later by mail.

Yours sincerely

By order

i.v. [Signature]
Dr. Enis Askar

Enclosure

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BMW*i*.





TEST REPORT

FLAMMABILITY TESTS ON MIXTURES OF ISO-BUTANE AND HFO1234ZE

BAM reference	20020356
Copy	1 st copy of 2 copies
Customer	CERN European Organization for Nuclear Research Site de Meyrin 1211 Geneve 23 Switzerland
Order date	June 12 th , 2020
Reference	PO: CA8339632
Receipt of order	June 15 th , 2018
Test samples	R 1234ze SOLSTICE® ZE (purity > 99.5 %), GHC Iso-butane N35 (purity > 99.95 %), Air Liquide Deionized water, BAM-supply Pressurized air, Linde
Test date	October 14 th - 20 th , 2020
Test location	BAM, Unter den Eichen 87, 12205 Berlin
Test procedure in accordance with	ISO 10156:2017 „Gases and gas mixtures - Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets“

This test report consists of page 1 to 4

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2015-06 / 2015-09-17

Sicherheit in Technik und Chemie

TEST REPORT

1 Subject of the tests

BAM was commissioned to examine the maximum amount of iso-butane in HFO 1234ze, at which the mixture is just not flammable at 35 °C and a relative humidity of 40 %.

2 Experimental set-up and test procedure

For examining the flammability of a test gas according to ISO 10156 ignition tests are carried out in a double-walled glass cylinder with a diameter of 60 mm and a length of 300 mm. The test equipment is shown in figure 1. The glass tube can be heated optionally by a temperature-controlled fan heater that blows hot air between the inner and the outer glass tube. Defined mixtures of the test gas with air are injected in the glass cylinder bottom up. The glass cylinder is purged with the mixture previous to all ignition attempts. The purging volume is at least ten times the volume of the glass cylinder. Then an ignition is initiated in the quiescent mixtures with an electric spark (spark gap \approx 5 mm, spark duration = 0.5 s) and it is observed whether a flame propagates through the reaction tube.



figure 1: glass tube for the flammability test according to ISO 10156

The amount of test gas in the mixture is varied in steps of 1 mol% until a flame propagation can be observed. If a clear detachment of the flame from the electrodes and an upwards propagation over a distance of at least 100 mm is observed in one of these tests the test substance is classified as "flammable" (see figure 2).



figure 2: illustration of a flame detachment with flame propagation over a distance of at least 100 mm as criterion for flammability

The defined mixtures of the test gas with air have been prepared in a pressure resistant 14-dm³-vessel of stainless steel according to the partial pressure method. The mixing vessel is equipped with a stirrer. For preparing the mixtures of test gas and air the mixing vessel including the filling pipes is evacuated until the pressure is less than 1 mbar. Afterwards deionized water, water, iso-butane, HFO1234ze and air are filled in the mixing vessel up to their respective partial pressures in the final mixtures. Ideal behavior of all components is assumed, i.e. it was assumed that the partial pressure fractions of the mixture components are equal to the molar fractions. The final pressure of mixture preparation was 2 bar (absolute). The final mixtures were homogenized for at least 3 minutes. The mixtures were not chemically analyzed.

For mixture preparation a piezoresistive pressure transducer with a measuring range of 2 bara (type: Keller, PAA-10) was used. The pressure transducer has been calibrated with a high precision pressure gauge (company: WIKA, type: CPG 2500, measuring range: 10 bara, measuring uncertainty < 0.01 % FS) over the whole measuring range previously. Measuring uncertainty of the pressure transducer was less than 0.2 % FS.

3 Results

The iso-butane fraction in the test gas mixture of iso-butane and HFO1234ze was varied successively in order to find the maximum fraction of iso-butane in HFO1234ze, at which the mixture is just not flammable at 35 °C. In each test 2,25 mol% deionized water was added to the mixture corresponding to a relative humidity of 40 % at 35 °C.

In table 2 the ignition tests with test gas mixtures with different iso-butane fractions are summarized. Flame detachment plus flame propagation over a distance of at least 100 mm was observed even for test gas mixtures with 1.0 mol% iso-butane in HFO1234ze. Thus, it was concluded that mixtures of iso-butane and HFO1234ze are flammable, if the mole fraction of iso-butane is 1.0 mol% or more. Tests with less fractions of iso-butane are not possible with the test-apparatus, because the measuring uncertainty for preparing the mixtures would be too high. In

table 1: ignition tests with test gas mixtures with different iso-butane fractions in HFO1234ze temperature: (35 ± 2) °C, spark duration: 0,5 s

test no.	Iso-butane fraction in test gas mixture in mol%	fraction of test gas mixture of iso-butane and HFO1234ze in mol%	fraction of air including 2.25 mol% water in mol%	reaction
1	10.2	20.0	80.0	-
2	10.4	10.0	90.0	+
3	9.0	30.0	70.0	-
4	8.2	30.0	70.0	-
5	8.1	15.1	84.9	+
6	7.1	29.9	70.1	-
7	6.9	15.1	84.9	+
8	6.0	39.8	60.2	-

test no.	Iso-butane fraction in test gas mixture in mol%	fraction of test gas mixture of iso-butane and HFO1234ze in mol%	fraction of air including 2.25 mol% water in mol%	reaction
9	6.2	15.0	85.0	+
10	6.0	20.0	80.0	-
11	4.2	13.0	87.0	+
12	3.1	10.0	90.0	+
13	2.2	13.0	87.0	+
14	1.1	13.0	87.0	-
15	1.0	10.0	90.0	+
16	0.0	12.0	88.0	-
17	0.0	11.0	89.0	-
18	0.0	10.0	90.0	-
19	0.0	9.0	91.0	-

*++: strong reaction (ignition), +: flame detachment (ignition), A: aureole (no ignition), -: no reaction

Bundesanstalt für Materialforschung und -prüfung (BAM)

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December 10, 2020

Division 2.1 „Explosion Protection Gases and Dusts“

by order

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study director

Distribution list: 1st copy: CERN European Organization for Nuclear Research
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