Bundesanstalt für
Materialforschung
und -prüfung

Test report

on testing a nonmetallic material for reactivity with oxygen

BAM reference	23026672-E
Copy	1st copy of 2
Customer	TEADIT International Produktions GmbH Europastraße 12 6322 Kirchbichl Austria
Order date	August 30, 2023
Reference	BAM TF 1590
Receipt of order	September 12, 2023
Test Samples	PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7
Receipt of Samples	September 12, 2023
Test Date	September 12, 2023, to November 30, 2023
Test Location	BAM, Division 2.1 "Safety of Energy Carriers"; building no. 41; Unter den Eichen 87, 12205 Berlin, Germany
Test procedure according to (in the current version)	DIN EN 1797 und ISO 21010 "Cryogenic Vessels - Gas/Material Compatibility" Annex of code of practice M 034-1 (BGI 617-1) "List of nonmetallic materials compatible with oxygen", by German Social Accident Insurance Institution for the raw materials and chemical industry TRGS 407 Technical Rules for Hazardous Substances "Tätigkeiten mit Gasen - Gefährdungsbeurteilung" Chapter 3 "Informationsermittlung und Gefährdungsbeurteilung" and Chapter 4 "Schutzmaßnahmen bei Tätigkeiten mit Gasen"

This test report consists of page 1 to 10 and enclosures 1 to 4.

1 Documents and Test Samples

The following documents and samples were submitted to BAM:

1 Test application
Safety-related investigation on PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7, for use in gaseous oxygen service at temperatures up to 250 °C and at pressures up to 50 bar as well as for use in liquid oxygen.
If the material does not pass the investigation for use in gaseous oxygen service at these conditions, the investigation for use in gaseous oxygen service shall be continued at a temperature of 200 °C and at a pressure of 40 bar.

1 Compliance Statement REACH REGULATION and SVHC
(3 pages, Fa.TEADIT International Produktions GmbH, June 21, 2023)

1 Sicherheitshinweise TF 1590
(4 pages, TEADIT International Produktions GmbH, Rev.: 05/30112020)

1 Costumer Master Data Sheet (CMDS) (July 21, 2023)

20 Disks of PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7
Dimensions: Ø 140 mm, Thickness: 2 mm
Color: Beige

2 Applied Test Methods

The PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7, shall be used in gaseous oxygen service at temperatures up to 250 °C and at pressures up to 50 bar as well as in liquid oxygen service. Testing of ignition sensitivity to impacts of gaseous oxygen was not carried out as, according to the client, oxygen pressure impacts on the material can safely be excluded at intended use.

The following test methods were applied:

2.1 Determination of the Autogenous Ignition Temperature (AIT) in High Pressure Oxygen

Usually, this test method is required if the material is for service temperatures greater than 60 °C.

The AIT is a safety characteristic and indicates the temperature at which the material shows self-ignition in the presence of oxygen without an additional ignition source. Therefore, it is relevant for the maximum use temperature that is generally set 50 °C below this AIT for gasket materials.

2.2 Testing for Aging Resistance in High Pressure Oxygen

This test is necessary whenever a material is intended for service at higher temperatures than 60 °C. It simulates the use of a material in practice and helps analyze whether ignition temperature or properties of the material change due to the aging processes.

2.3 Testing of Gaskets for Flanges in High Pressure Oxygen

This test simulates the faulty installation of a gasket in a flange connection where the sealing material projects into the inner diameter of the pipe. This test investigates the fire behavior of the gasket material in a standard flange after artificial ignition. It shows whether the fire of the disk is transferred to the metal of the flange or if the flange connection becomes leaky.

2.4 Testing for Reactivity with Liquid Oxygen on Mechanical Impact

Generally, this test method is required if direct contact of the material with liquid oxygen and mechanical impacts cannot be safely excluded in usage.

3 Sampling

The material sample used for the investigation was provided by the customer.

3.1 Preparation of Samples

For testing according 2.1 and 2.4 the PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7, was cut into parts of ca. 1 mm to 2 mm in edge length and was used in this form.

For testing according 2.2, the PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7, was cut into parts of ca. 10 mm to 20 mm in edge length and was used in this form.

For testing according 2.3, the disks were prepared as shown in figure 1.

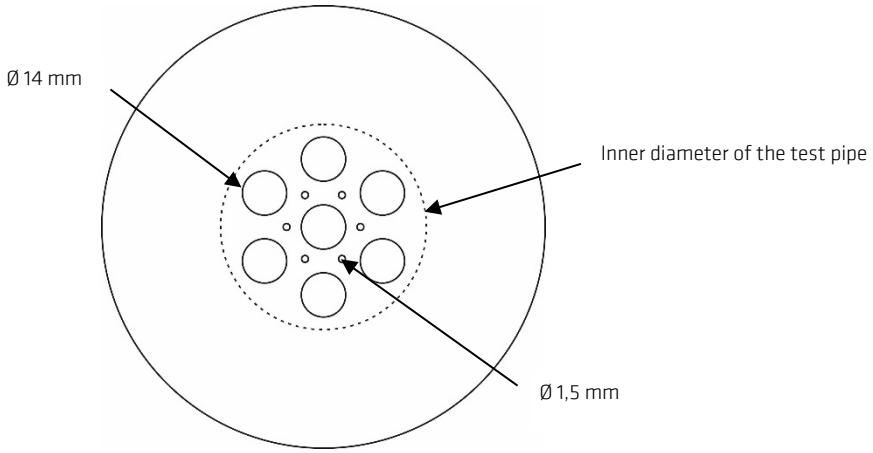

Figure 1: Preparation of the nonconductive flat gasket material

4 Tests

4.1 Determination of the Autogenous Ignition Temperature (AIT) in High Pressure Oxygen

The test method is described in enclosure 1.

Based on the maximum use pressure, mentioned by the customer, this test was performed at a final oxygen pressure of approximately 50 bar.

4.1.1 Assessment Criterion

The criterion for a reaction of the sample with oxygen is a distinct increase in pressure and a more or less steep increase in temperature.

4.1.2 Results

Test No.	Final Oxygen Pressure p_F [bar]	AIT [°C]
1	51	456
2	51	458
3	50	457
4	52	462
5	51	460

In five separate tests, the following mean AIT could be determined.

Mean Final Oxygen Pressure p_F [bar]	Mean AIT [°C]	Standard Deviation [°C]
51	459	± 2

4.2 Testing for Aging Resistance in High Pressure Oxygen

The test method is described in enclosure 2.

In general, artificial aging is carried out at the maximum use pressure and at an elevated temperature, that is 25 °C above the maximum operating temperature. Consequently, the test temperature was 275 °C. Based on the intended maximum use pressure, mentioned by the customer, the test was carried out at a final oxygen pressure of 50 bar.

4.2.1 Assessment Criterions

There are three criteria for evaluating the aging behavior:

If there is a change in mass $\Delta m \leq 1$ %, the sample is aging resistant, in case of $\Delta m > 1$ % and $\Delta m \leq 2$ %, the sample is sufficient aging resistant, and in case of $\Delta m > 2$ %, the sample is insufficient aging resistant.

Changes in color, consistency, shape or surface texture of the sample or gas releases from the sample that can be detected after testing will be also considered by BAM.

The AIT of the aged sample is compared to the AIT of the non-aged sample. If there is a distinct deviation between both AITs, the lower value is considered for safety reasons.

4.2.2 Results

4.2.2.1 Testing for Change in Mass or Physical Appearance

Time [h]	Temperature [°C]	Oxygen Pressure [bar]	Mass Change [%]
100	275	50	± 0.0

After aging, the test sample was apparently unchanged and had no change in mass.

4.2.2.2 Determination of the AIT of the Aged Material in High Pressure Oxygen

The test method is described in enclosure 1. The AIT test of the aged material was performed at same conditions as described in chapter 4.1.

Test No.	Final Oxygen Pressure p_F [bar]	AIT [°C]
1	51	461
2	51	463
3	51	461
4	51	462
5	51	463

In five separate tests, the following mean AIT could be determined.

Mean Final Oxygen Pressure p_F [bar]	Mean AIT [°C]	Standard Deviation [°C]
51	462	± 1

4.3 Testing of Gaskets for Flanges in High Pressure Oxygen

The test method is described in enclosure 3.

Based on the intended maximum use conditions, mentioned by the customer, the flange test was carried out at a final oxygen pressure of 50 bar and at a temperature of 250 °C.

Before starting the test, the flanges were tightened in accordance with the tightening diagram supplied by the customer:

- Tighten crosswise with 30% of the target torque
- Tighten crosswise with 60% of the target torque
- Tighten crosswise with 100% of the target torque
- Tighten clockwise with 100% of the target torque
- Tighten once again clockwise with 100% of the target torque

The target torque is 300 Nm. This torque is necessary to ensure the required minimum surface pressure under load.

4.3.1 Assessment Criterion

If after artificial ignition only those parts of the gasket burn that project into the pipe and the fire is not transmitted to the flanges, and if the gasket does not burn more than 2 mm between the flange faces and the flange connection is still gas tight, there are no objections regarding technical safety to use the gasket under the conditions tested. Such a positive result has to be confirmed in four additional tests.

If, however, the gasket burns between the flange faces or the flange connection becomes un-tight, the gasket material has not passed the test. In this case, the test may be continued at a lower temperature or oxygen pressure after consultation with the customer:

4.3.2 Results

Test Number	Temperature [°C]	Oxygen Pressure [bar]	Notes
1	250	50	All parts of the gasket burned that project into the pipe. The flange faces remained undamaged. The flange connection remained gas tight.
2	250	50	All parts of the gasket burned that project into the pipe. In addition, the gasket burned partly up to 7 mm between the flange faces. The flange connection remained gas tight. The test was failed.

As requested by the customer, the test was repeated at a pressure of 40 bar and at a temperature of 200 °C.

Test Number	Temperature [°C]	Oxygen Pressure [bar]	Notes
1	200	40	All parts of the gasket burn that project into the pipe. The flange faces remain undamaged. The flange connection remains gas tight.
2	200	40	Same behavior as in test no. 1
3	200	40	Same behavior as in test no. 1
4	200	40	Same behavior as in test no. 1
5	200	40	Same behavior as in test no. 1

In five tests at a temperature of 200 °C and at an oxygen pressure of 40 bars, only those parts of the disk burn that project into the pipe. In all tests, the fire is neither transmitted to the steel nor does the sample burn between the flange faces. The flange connection remains gas tight. After the tests, the tested samples had a thickness of 1.9 mm.

4.4 Testing for Reactivity with Liquid Oxygen on Mechanical Impact

The test method is described in enclosure 4.

4.4.1 Assessment Criterion

According to the BAM-Standard "Testing for Reactivity with Liquid Oxygen on Mechanical Impact", a nonmetallic material is not suitable for liquid oxygen service if reactions occur with liquid oxygen at a drop height of 0.17 m (impact energy 125 Nm) or less.

4.4.2 Results

Test Series No.	Drop Height [m]	Impact Energy [Nm]	Behavior on Mechanical Impact
1	0.67	500	reaction in 1st single test
2	0.50	375	reaction in 4th single test
3	0.33	250	reaction in 6th single test
4	0.17	125	reaction in 7th single test

At drop heights of 0.67 m, 0.50 m, 0.33 m and 0.17 m (impact energies of 500 Nm, 375 Nm, 250 Nm and 125 Nm), reactions of the test sample with the liquid oxygen were detected.

5 Summary of the Test Results

At a mean final oxygen pressure p_F of 51 bar, the test sample has a mean autogenous ignition temperature of 459 °C with a standard deviation of ± 2 °C.

The material proved to be aging resistant at 275 °C and at 50 bar oxygen pressure.

The investigation of the burning behavior of disks of the gasket material in a standard flange at a temperature of 250 °C and at an oxygen pressure of 50 bar showed, that not only those parts of the sample burned that project into the pipe. The test samples burned more than 2 mm between the flange sealing surfaces. In all cases, the flange connection remained gas tight.

The investigation of the burning behavior of disks of the gasket material in a standard flange at a temperature of 200 °C and at an oxygen pressure of 40 bar showed, that only those parts of the sample burned that project into the pipe. The sample did not burn more than 2 mm between the flange faces. In all cases the flange connection remained gas tight.

Testing of the sample for reactivity to mechanical impacts in liquid oxygen showed, that a reaction was detected at an impact energy of 125 Nm.

6 Measurement uncertainty

The tests are carried out in accordance with the standards or guidelines indicated on the cover sheet of this report. Thereafter, the temperature measurement should have a maximum deviation of ± 2 K and the pressure measurement should have a maximum deviation of ± 2 bar.

For the test in chapter 4.1, the uncertainty is 0.7 K (according to the calibration protocol from January 23, 2023) for the temperature measuring system, and the uncertainty is 0.3 bar (according to the calibration protocol from January 25, 2023) for the used pressure measuring system.

For the test in chapter 4.2, the uncertainty is 1 K (according to the calibration protocol from March 13, 2023) for the temperature measuring system, and the uncertainty is 0.3 bar (according to the calibration protocol from February 13, 2023) for the used pressure measuring system.

For the test in chapter 4.3, the uncertainty is 2.7 K (according to the calibration protocol from August 12, 2023) for the temperature measuring system, and the uncertainty is 0.6 bar (according to the calibration protocol from August 14, 2023) for the used pressure measuring system.

The measurement uncertainty in determining the height of fall during the test in Chapter 4.4 is estimated to be ± 0.01 m. Experience has shown that this measurement uncertainty has no influence on the test result.

7 Statements of conformity

The tests are carried out in accordance with the standards or guidelines, stated on the cover sheet of this report. Deviating or supplementary test criteria are described in the respective subchapter "Assessment Criterion" in Chapter 4 "Tests".

8 Opinion and Interpretation

It was intended to use the PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7, as a gasket material in gaseous oxygen service at temperatures up to 250 °C and at pressures up to 50 bar as well as in liquid oxygen service.

As the material did not pass the flange test at a temperature of 250 °C and at a pressure of 50 bar, these intended use conditions had to be discarded. As requested by the customer, the test was repeated at a temperature of 200 °C and a pressure of 40 bar.

On basis of the test results, the requirements for gasket materials, described in the code of practice M034, annex 2 of code of practice M034-1, Technical Rules for Hazardous Substances TRGS 407 and based on the assessment criteria described in this test report, there are no objections regarding technical safety, to use the PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7 for gaseous oxygen service at following use conditions only:

Maximum Temperature [°C]	Maximum Oxygen Pressure [bar]
200	40

Based on the test results and according to BAM' s standard "Testing for Reactivity with Liquid Oxygen on Mechanical Impact", the PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7, is not suitable for liquid oxygen service.

9 Comments

This safety-related investigation considers the fact, that on the one hand rapid oxygen pressure changes - so-called oxygen pressure surges – can be safely excluded and that on the other hand direct contact of the material with liquid oxygen and mechanical impacts cannot be safely excluded in usage. In addition, the safety related investigation considers the fact, that the material shall be used in gaseous oxygen service at temperatures greater than 60 °C.

The content of the test report refers exclusively to the test sample of the PTFE-based gasket material TEADIT TEALON TF 1590, batch 202303240046/7.

Our experience shows that the safety characteristics of a product may vary from batch to batch. Therefore, today, we recommend batch testing of products, that are included for oxygen service. In this context, we would like to mention our paper from September 2009: "The Importance of Quality Assurance and Batch Testing on Nonmetallic Materials Used for Oxygen Service", Journal of ASTM International, Vol. 8th; Paper ID JAI102309. This publication can be purchased at www.astm.org.

Products on the market that contain a reference to BAM testing shall be marked accordingly. It shall be evident that only a sample of a batch has been tested and evaluated for oxygen compatibility. The reference shall not produce a presumption of conformity that monitoring of the production on a regular basis is being performed by BAM.

The product may be used as a gasket material for gaseous oxygen service only. The maximum safe oxygen pressure of the product and its maximum use temperature as well as other restrictions in use shall be given.

Bundesanstalt für Materialforschung und -prüfung (BAM)
12200 Berlin

December 7, 2023

Division 2.1 "Safety of Energy Carriers"

by order

Dr. Thomas Kasch
Study Director

Dr. Martin Schmidt
Deputy Head of Division

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Enclosure 1

Determination of the Autogenous Ignition Temperature of Nonmetallic Materials in High Pressure Oxygen (V 2023-01)

0.2 g to 0.5 g of the paste-like, of the divided solid, or with ceramic fibres mixed liquid material is placed into an autoclave with a volume of 34 cm^3. The autoclave is pressurized to the initial pressure p_i and inductive heated. The temperature increases in an almost linear way at a rate of 110 K/min.

Pressure and temperature are recorded by a PC-system. As the temperature increases, the oxygen pressure in the autoclave increases continuously. The ignition of the material is recognized by a sudden rise in temperature and a more or less rise of the pressure.

In this way, the ignition temperature is determined at a specific final oxygen pressure p_f. In principle, the ignition temperature of a material depends on the pressure. The ignition temperature decreases with increasing final oxygen pressure.

For this test, the maximum test pressure is 250 bars, and the maximum test temperature is 500 °C.

Enclosure 2

Testing for Aging Resistance of nonmetallic materials in High Pressure Oxygen (V 2023-01)

A sample of the solid material is exposed to compressed oxygen and elevated temperature in an autoclave for 100 hours. The sample mass is determined before the test.

This test is intended to simulate the use of the material in practice and to show whether the material properties such as color, consistency, surface texture or the ignition temperature of the material change as a result due to aging processes.

For this test, the maximum test pressure is 250 bars, and the maximum test temperature is 325 °C.

Enclosure 3

Testing Nonmetallic Gaskets for Flanges in Oxygen Steel Pipings (V 2023-01)

The test facility mainly consists of two DN 65 PN 160 steel pipes, each 2 m in length, with corresponding standard flanges welded to each pipe. The customer provides the nonmetallic gasket material in form of disks. Using this disk, the standard flanges are flanged gas tight.

The test facility is heated to the intended maximum use temperature and pressurized to the intended maximum use pressure with oxygen. Thereafter, the part of the nonmetallic gasket material is ignited, which projects into the pipe.

The nonmetallic gasket material passes the test, if only that part of the gasket burns that projects in to the pipe, the material does not burn between the flange faces more than 2 mm, and the flange connection is still gas tight. The test is finished, if there is no reaction of the material detected in five single tests.

If a reaction occurs and after consultation the customer, testing the nonmetallic gasket material can be continued for use at lower operating conditions.

For this test, the maximum test pressure is 160 bars, and the maximum test temperature is 300 °C.

Enclosure 4

Testing for Reactivity with Liquid Oxygen on Mechanical Impact (V 2023-01)

Approximately 0.5 g of the paste-like, of the divided solid, or with ceramic fibres mixed liquid material is placed into a sample cup (height = 10 mm; diameter = 30 mm), made of 0.01 mm copper foil. Liquid oxygen is poured into the cup which is then exposed to the mechanical impact of a plummet (mass = 76.5 kg).

A reaction of the material is indicated by a flame and a more or less strong noise of an explosion. The impact energy, at which no reaction occurs, is determined by varying the drop height of the plummet. This result shall be confirmed in a series of ten consecutive tests at same conditions, and then this test is finished.

Test is stopped, if a reaction is observed at an impact energy of 125 Nm, this equals a drop height of the plummet of 0.17 m. In this case, with regard to technical safety, the material is not suitable for use in liquid oxygen.