BAM
Bundesanstalt für
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und -prüfung

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TEST REPORT

on Testing a Nonmetallic Material for Reactivity with Oxygen

Reference Number	16020388 I E
Copy	1. copy of 2 copies
Customer	W.L. GORE® ASSOCIATES GMBH Hermann-Oberth-Straße 26 85640 Putzbrunn Germany
Date of request	April 21 and September 15, 2016 of modified order
Reference	20560362
Receipt of signed contract	August 16 and September 15, 2016 of modified order
Test samples	GORE® GR Sheet Gasketing, batch NC00029545010; BAM Order-No.: 2.1/53 179
Receipt of samples	September 06, 2016
Test date	September 27, 2016 to October 14, 2016
Test location	BAM – Division 2.1 „Gases, Gas Plants"; building no. 41, room 073
Test procedure or requirement according to (in the current version at test time)	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"

All pressures of this report are excess pressures.
This test report consists of page 1 to 6 and annex 1 to 2.

1 Documents and Test Samples

The following documents and samples were submitted to BAM:

1 Test application
„Testing and evaluating the nonmetallic material GORE® GR Sheet Gasketing, batch NC00029545010, for use as a gasket material in flange connections for gaseous oxygen service at temperatures up to 60 °C and 40 bar and for liquid oxygen service.

1 Declaration of safety related information on handling and storing of the material in accordance with the material safety data sheets.
(1 Page, Date of issue: August 6, 2015)

1 Material Data Sheet „GORE® GR SHEET GASKETING";
SEAL-56-DSH-DE-JUN13;
(2 Pages)

1 Safety Information for GORE® Gasketing; SEAL-180-R1-TEC-US-OCT15;
(1 Page)

20 Disks of Gasket Material GORE® GR Sheet Gasketing,
batch NC00029545010
Dimension: Ø 140 mm, Thickness 2,7 mm
Color: White

2 Applied Test Methods for Evaluating the Technical Safety

The product is a nonmetallic material that shall be used as a gasket in flange connections for gaseous oxygen service at temperatures up to 60 °C and 40 bar and for liquid oxygen service.

Tests on ignition sensitivity to gaseous oxygen impacts were not carried out because rapid oxygen pressure changes – so called oxygen pressure surges – can be safely excluded on the material in the intended usage.

A determination of the autogenous ignition temperature (AIT) and an investigation of the aging behavior in high pressure were not necessary as the material is not for use at temperatures greater than 60 °C.

The following test methods were applied:

2.1 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.

2.2 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 Preparation of Samples

To test the nonconductive gasket material the discs were prepared as shown in figure 1 for flange testing.

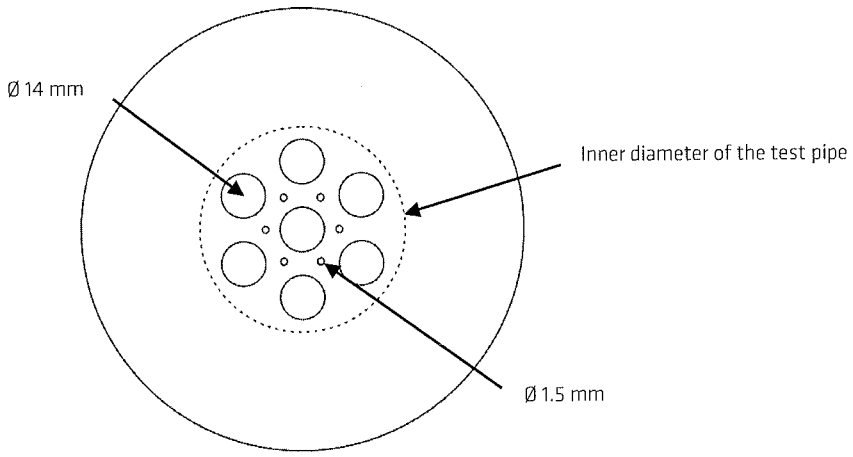

Figure 1: Preparation of the nonconductive gasket material

For the liquid oxygen test, the material was cut into pieces of approximately 1 mm^3 up to 2 mm^3.

4 Tests

4.1 Testing of Gaskets for Flanges in High Pressure Oxygen

The test method is described in annex 1. Based on the specified use conditions by the customer the flange test was performed at a final oxygen pressure of approximately 40 bar and 60 °C.

4.1.1 Assessment Criterion

If 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 between the flanges and the flange connection is still gas tight there are no objections with regard to technical safety to use the gasket under the conditions tested. Such a positive result has to be confirmed in four additional tests.

If the gasket burns with such a hot flame that the fire is transmitted to the steel of the flange (in most case the test apparatus is destroyed), the seal is considered unsuitable right from the beginning.

If, however, the flange connection becomes un-tight during a test, e. g., because of softening or burning of the gasket, the test has to be continued at a lower temperature and oxygen pressure until a positive test result is reached in five tests, as mentioned above.

4.1.2 Results

Test Number	Temperature [°C]	Oxygen Pressure [bar]	Notes
1	60	40	Only those parts of the gasket burn that project into the pipe. The flange connection remains gas-tight.
2	60	40	same behavior as in test no. 1
3	60	40	same behavior as in test no. 1
4	60	40	same behavior as in test no. 1
5	60	40	same behavior as in test no. 1

In five tests at 40 bar oxygen pressure and 60 °C, only those parts of the gasket burn that project into the pipe. The fire is neither transmitted to the steel nor does the gasket burn between the flanges. The flange remains gas-tight.

4.2 Reactivity Testing with Liquid Oxygen on Mechanical Impact

The test method is described in annex 2.

4.2.1 Assessment Criterion

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

4.2.2 Results

Test No.	Drop Height [m]	Impact Energy [Nm]	Reaction
1	1.00	750	severe
2	0.83	625	no reaction
3	0.83	625	severe
4	0.67	500	no reaction
5	0.67	500	no reaction
6	0.67	500	no reaction
7	0.67	500	no reaction
8	0.67	500	no reaction
9	0.67	500	no reaction
10	0.67	500	no reaction

Test No.	Drop Height [m]	Impact Energy [Nm]	Reaction
11	0.67	500	no reaction
12	0.67	500	no reaction
13	0.67	500	severe
14	0.50	375	no reaction
15	0.50	375	no reaction
16	0.50	375	no reaction
17	0.50	375	no reaction
18	0.50	375	no reaction
19	0.50	375	no reaction
20	0.50	375	no reaction
21	0.50	375	no reaction
22	0.50	375	no reaction
23	0.50	375	no reaction

At a drop height of 0.50 m (impact energy 375 Nm), in ten separate tests, no reaction of the sample with liquid oxygen could be detected.

5 Summary and Evaluation

It is intended to use the product GORE® GR Sheet Gasketing as a gasket material in flange connections for gaseous and liquid oxygen service.

Based on the test results and the pre-condition that any oxygen pressure impacts can be safely excluded there are no objections with regard to technical safety to use the gasket material GORE® GR Sheet Gasketing, batch NC00029545010, with a maximum thickness of 2.7 mm in flange connections made of copper, copper alloys or steel at following conditions:

Maximum Temperature [°C]	Maximum Oxygen Pressure [bar]
60	40

This applies to flat face flanges, male/female flanges, and flanges with tongue and groove.

Based on the test results, there are also no objections with regard to technical safety to use the sealing material GORE® GR Sheet Gasketing, batch NC00029545010, for liquid oxygen service. In this case, a limitation to a particular pressure range is not necessary as compression of liquid oxygen causes no significant change in concentration and therefore has no considerable influence on the reactivity of the material.

6 Comments

This safety evaluation considers the fact, that rapid oxygen pressure changes on oxygen components – so called oxygen pressure surges – can be safely excluded in usage.

This evaluation is based exclusively on the results of the tested sample of a particular batch.

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 for gaseous and liquid oxygen service. 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 13, 2016

Division 2.1 "Gases, Gas Plants"

By order

Dipl.-Ing. Peter Hartwig

Distribution list: 1. copy: W.L. GORE® ASSOCIATES GMBH
2. copy: BAM - Division 2.1 "Gases, Gas Plants"

Annex 1

Testing of Gaskets for Flanges in Oxygen Steel Pipings

The test apparatus mainly consists of two DN 65 PN 160 steel pipes, each approximately 2 m in length, with corresponding standard flanges welded to each pipe.

Both pipes are sealed using the gasket to be tested. In case of a gasket disk its inner diameter is chosen in such a way that it projects into the pipe. If a gasket tape is under test, both ends of the tape are allowed to project into the pipe. The test apparatus is then pressurized with oxygen up to the desired test pressure. The flange is heated by heating sleeves to the test temperature, at least 50 K lower than the ignition temperature of the gasket. An electrical filament ignites that part of the gasket projecting into the pipe. If the gasket is electrically conductive, such as spiral seals or graphite foils, a nonconductive primer capsule of organic material (PTFE, rubber) is used which acts on the seal.

The gasket's behavior after ignition is important for its evaluation. If the seal burns with such a hot flame that the fire is transmitted to the steel of the flange (in most case the test apparatus is destroyed), the seal is considered unsuitable from the beginning. If only those parts of the seal burn that project into the pipe and the fire is not transmitted to the flanges and if the seal does not burn between the flanges there are no objections with regard to technical safety to use the seal under the conditions tested. Such a positive result is to confirm in four additional tests. If, however, the flanged connection becomes un-tight during a test, e. g., because of softening or burning of the seal, the test has to be continued at a lower temperature and oxygen pressure until a positive test result is reached in five tests, as mentioned above.

Annex 2

Testing for Reactivity with Liquid Oxygen on Mechanical Impact

Approximately 0.5 g of the liquid or divided sample 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 over the sample which is then exposed to the mechanical impact of a plummet (mass = 76.5 kg). The drop height of the plummet can be varied. A steel anvil with a chrome/nickel steel plate supports the sample cup. The anvil, having a mass eight times of the plummet, is supported by four damping elements mounted on the steel frame of the test apparatus that rests on a concrete base.

A reaction of the sample with liquid oxygen is usually indicated by a flame and a more or less strong noise of an explosion. The impact energy, at which no reaction occurs, is determined in varying the drop height of the plummet. This result shall be confirmed in a series of ten consecutive tests under the same conditions. The tests are finished, if reactions can be observed at impact energies of 125 Nm or less (equivalent to a drop height of the plummet of 0.17 m or less). In this case, with regard to technical safety, the material is not suitable for liquid oxygen service.