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TEST REPORT

On Testing a Nonmetallic Material for Reactivity with Gaseous Oxygen

BAM reference	15020715 I E
Copy	1st copy of 2 copies
Customer	FLEXITALLIC LTD Scandinavia Mill, Hunsworth Lane Cleckheaton, West Yorkshire BD19 4LN United Kingdom
Order date	April 1, 2015
Reference	PO316695
Receipt of order	April 13, 2015
Test samples	Novus TI, undisclosed batch; BAM Order-No.: 2.1/52 611
Receipt of samples	April 2, 2015
Test date	July 14 to October 13, 2015
Test location	BAM - Working Group "Safe Handling of Oxygen"; building no. 41, room no. 073
Test procedure according to	ISO 21010:2014 and DIN EN 1797:2002-02 "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, Edition: March 2014; TRGS 407 Technical Rules for Hazardous Substances "Tätigkeiten mit Gasen - Gefährdungsbeurteilung" chapter 3 "Informationsermittlung und Gefährdungsbeurteilung" and chapter 4 "Schutzmaßnahmen bei Tätigkeiten mit Gasen", Edition: June 2013
Safety Related Maximum Operating Conditions	See chapter 4 "Summary and Evaluation"

All pressures of this report are excess pressures.
This test report consists of page 1 to 5 and annexes 1 to 3.

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The German version is legally binding, except an English version is issued exclusively.

TEST REPORT

1 Documents and Test Samples

The following documents and samples were submitted to BAM:

1 Test application
"Testing and evaluating the compatibility of the gasket material Novus TI, undisclosed batch, for use in flanged connections for gaseous oxygen service at temperatures up to 200 °C and at pressures up to 80 bar"

1 Safety Data Sheet
(5 pages, PDS664, issued 09/14)

15 Disks Novus TI, undisclosed batch,
the sealing material is press-fitted on both sides of a perforated metal sheet
Outer-Ø: 140 mm; Thickness: 2 mm
Color: Grey

2 Test Methods

To evaluate the compatibility of Novus TI, undisclosed batch, for use as a gasket material in gaseous oxygen service at temperatures up to 200 °C and at pressures up to 80 bar, a determination of the autogenous ignition temperature (AIT), an investigation of the aging resistance and a flange test were carried out.

Tests on ignition sensitivity to gaseous oxygen impacts were not carried out. According to the customer, oxygen pressure impacts in valves and fittings or in other components can be safely excluded in the intended service.

3 Results

Prior to testing, the nonmetallic material was removed from the perforated metal sheet and was then used to perform the tests.

3.1 Autogenous Ignition Temperature (AIT)

Based on the specified maximum operating conditions, the autogenous ignition temperature test was performed at a final oxygen pressure of approximately 80 bar. The test method is described in annex 1.

Results:

Test No.	Initial Oxygen Pressure p_I [bar]	Final Oxygen Pressure p_F [bar]	AIT [°C]
1	31	83	> 500
2	31	83	> 500
3	31	82	> 500
4	31	82	> 500
5	31	82	> 500

Up to temperatures of 500 °C, no ignition of the sample could be detected in five tests with initial oxygen pressures of p_I = 31 bar. The final oxygen pressure p_F was approximately 82 bar.

3.2 Artificial Aging

In general, the aging test is carried out at the maximum operating pressure and at an elevated temperature, which is 25 °C above the maximum operating temperature. In this case, the aging test was carried out at 225 °C and at 80 bar. The test method is described in annex 2.

Results:

Time [h]	Temperature [°C]	Oxygen Pressure [bar]	Mass Change [%]
100	225	80	± 0.0

After aging of the test sample at 225 °C and at 80 bar oxygen pressure, the test sample was apparently unchanged. The sample mass did not change.

3.2.1 AIT after Artificial Aging

The same test conditions as in chapter 3.1 were used for determining the autogenous ignition temperature after aging. The test method is described in annex 1.

Results:

Test No.	Initial Oxygen Pressure p_I [bar]	Final Oxygen Pressure p_F [bar]	AIT [°C]
1	31	83	> 500
2	31	83	> 500
3	31	82	> 500
4	31	82	> 500
5	31	82	> 500

Up to temperatures of 500 °C, no ignition of the aged sample could be detected in five tests with initial oxygen pressures of p_I = 31 bar. The final oxygen pressure p_F was approximately 82 bar. This shows that, as the non-aged sample, also the aged sample did not ignite at temperatures up to 500 °C.

3.3 Flange Test

Based on the specified maximum operating conditions, flange testing was performed at 80 bar oxygen pressure and at a temperature of 200 °C. The test method is described in annex 3.

Results:

Test Number	Oxygen Pressure [bar]	Temperature [°C]	Notes
1	80	200	Only those parts of the gasket burn that project into the pipe, the flange connection remains gas-tight
2	80	200	same behavior as in test no. 1
3	80	200	same behavior as in test no. 1
4	80	200	same behavior as in test no. 1
5	80	200	same behavior as in test no. 1

In five tests at 80 bar oxygen pressure and 200 °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 Summary and Evaluation

Up to temperatures of 500 °C, no ignition of the test sample could be detected in five tests with initial oxygen pressures of p_I = 31 bar. The final oxygen pressure p_F is 82 bar.

At a temperature of 225 °C and an oxygen pressure of 80 bar, the gasket material Novus TI, undisclosed batch, proved to be aging resistant. The sample mass did not change.

Up to temperatures of 500 °C, no ignition of the aged test sample could be detected in five tests with initial oxygen pressures of p_I = 31 bar. The final oxygen pressure p_F is 82 bar. This shows that, as the non-aged sample, also the aged sample did not ignite at temperatures up to 500 °C.

Generally, in evaluating nonmetallic materials for oxygen service, a safety margin of 100 °C between AIT and maximum operating temperature is being considered for safety reasons. As the maximum operating temperature is 200 °C, the gasket material Novus TI, undisclosed batch, fulfills this criterion.

On basis of the test results, there are no objections with regard to technical safety, to use the gasket material Novus TI, undisclosed batch, with a maximum thickness of 2 mm in gaseous oxygen service in flange connections made of copper, copper alloys or steel at following conditions if oxygen pressure impacts can be safely excluded in the intended service:

Maximum Temperature [°C]	Maximum Oxygen Pressure [bar]
200	80

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

This evaluation does not cover the use of the gasket material Novus TI, undisclosed batch, for liquid oxygen service. For this application, a particular test for reactivity with liquid oxygen needs to be carried out.

5 Comments

This evaluation is based exclusively on the results of the tested batch of Novus TI.

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.

It shall be clear that the product may only be used for gaseous 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

October 29, 2015

Division 2.1
"Gases, Gas Plants"

By order

Dr. Thomas Kasch

Distribution list:
1st copy: FLEXITALLIC LTD
2nd copy: BAM - Division 2.1 "Gases, Gas Plants"

Annex 1

Determination of the Autogenous Ignition Temperature in High Pressure Oxygen

A mass of approximately 0.1 g to 0.5 g of the pasty or of the divided solid sample is placed into an autoclave (34 cm^3 in volume) with a chrome/nickel lining. Liquid samples are applied onto ceramic fiber.

The autoclave is pressurized to the desired initial pressure p_I at the beginning of the test A low-frequency heater inductively heats the autoclave in an almost linear way at a rate of 110 K/min. The temperature is monitored by means of a thermocouple at the position of the sample.

The pressure in the autoclave is measured by means of a pressure transducer. Pressure and temperature are recorded. During the test, as the temperature increases, the oxygen pressure increases within the autoclave. The ignition of the sample can be recognized by a sudden rise in temperature and the final pressure p_F.

It is important to know the oxygen pressure p_F, as the autogenous ignition temperature of a material is a function of pressure. It may decrease as the oxygen pressure increases.

Annex 2

Testing for Aging Resistance in High Pressure Oxygen

A sample with known mass is exposed to high-pressure oxygen at elevated temperature in an autoclave for 100 hours. The temperature, at which the sample is aged, is at least 100 °C lower than the autogenous ignition temperature of the sample.

This test shows whether the sample gradually reacts with oxygen or whether it undergoes other visible changes. If there is no change in appearance, in mass, and in the autogenous ignition temperature of the material, it is considered aging resistant.

Annex 3

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.