Oxygen Pressure Surge Test Report

Test Articles:
Industrial Valves
Drawing #: GSB-G-4F
Report Number:
R-WHA-20085-00-A-EX1

Date:
June 2, 2020

Prepared for:
Admiral Valve LLC dba CPV Manufacturing
503 Schoolhouse Rd.
Kennett Square, PA 19348

IMPORTANT NOTICE:

WHA International, Inc.
5605 Doña Ana Road | Las Cruces, NM 88007 | TEL: (575) 523-5623 | Fax: (575) 541-3621 | www.WHA-International.com

Oxygen Pressure Surge Test Report

Project Details

WHA Project Number	20085-00
Client	CPV
Cost Estimate Number	E-WHA-20085-00-A-EX2
Purchase Order Number	P.O.# 56017
Statement of Work	WHA performed Oxygen Pressure Surge testing to evaluate the ignition sensitivity of the following test articles. The following test was performed, as requested by the client:

Drawing #	WHA TA #	Type of Testing Performed
GSB-G-4F	TA-1.1 to TA-1.6	Oxygen Pressure Surge Testing

Version Summary

Report Number (includes version)	Summary of Changes
R-WHA-20085-00-A-EX1	Original version

Table of Contents

Prepared by:	Reviewed by:	Approved by:
Greg Odom, BSME	Gwenael Chiffoleau, PhD	Barry Newton, PhD, PE

Testing Summary

Test Article Details

Test Article Industrial Valve

Test Article Drawing See **Appendix A**

Test Article Type
☐Medical Regulator
☐Industrial Regulator
☐Cylinder Valve
☒Industrial Valve
☐Other:

Manufacturer/Supplier CPV

Number of Test Articles Supplied[1] 6

Test Article Condition Picture to the right shows a typical test article, as received

Drawing #	Inlet	Testing Performed	WHA Test Article #'s	Max. Rated Pressure	Test Pressure
GSB-G-4F	1/2" FNPT	Oxygen Pressure Surge Testing	TA-1.1 To TA-1.6	6,000 psig	Various (See Test Configurations)

Oxygen Pressure Surge Testing[2]

Test Standard(s) **ISO 10297 (2014)**: Gas cylinders – Cylinder valves – Specification and type testing, **Annex C- *Oxygen Pressure Surge Test***

ISO 7291 (2010): Gas Welding Equipment – Pressure Regulators for Manifold Systems Used in Welding, Cutting and Allied Processes up to 30 MPa (300 bar), **Section 9.4.4 – *Ignition Test for Pressure Regulators for Oxygen***

Test System See **Appendix GFIS**.

Test Article Condition The test articles were tested in their "as received" condition.

[1] Regarding test articles received by WHA, no sampling was performed by WHA nor is WHA responsible for sampling. The sample of test articles received by WHA were selected by the customer
[2] All test conditions, specifications, configurations listed were specified according to the test standard unless otherwise noted.

Oxygen Pressure Surge Testing[2] *(cont.)*

Test Conditions

Condition	Specification
Test Pressure	Various (See Test Configurations)
Test Gas	≥ 99.5% oxygen per MIL-PRF-27210J
Test Gas Temperature	60 °C (+/- 3 °C)
Impact Tube	750 mm long x 14 mm ID
Pressure Surge Application Point	Test Article inlet
Pressure Surge Cycles[3]	20 cycles in two configurations (see below)

Test Configurations Initial testing was only performed in test configuration #2, only. Initial testing was performed (20 cycles per pressure interval) at various test pressures, to help guide the selection of the test pressure for final oxygen pressure surge testing. Initial testing was performed on test articles TA-1.1, 1.2 and 1.3 at test pressures of 6,500, 6,800, and 7,200 psig, respectively. A new test article was used for each test pressure and was disassembled and inspected after initial testing at a particular test pressure.

Final testing (performed on 3 new valves in 2 configurations) was performed at the highest test pressure that did not result in an ignition during the initial testing. Final testing was performed on three test articles (TA-1.4, 1.5 and 1.6).

- **Configuration #1:** The test articles were subjected to 20 oxygen pressure surges with the test article fully closed and the outlet open to the atmosphere. The test articles were pressurized to the test pressure through the test article inlet.
- **Configuration #2:** The test articles were subjected to 20 oxygen pressure surges with the test article fully open and a plug installed on the outlet side of the test article. The test articles were pressurized to the test pressure through the test article inlet.

Test Results[4]

- **Initial Testing**: Oxygen pressure surge cycles were conducted on three (3) test articles (TA-1.1, TA-1.2 and TA-1.3) according to test configuration #2.
  - 20 cycles performed on TA-1.1 at a test pressure of 6,500 psig. Post-test disassembly and inspection did not reveal any signs of ignition within the test article.
  - 20 cycles performed on TA-1.2 at a test pressure of 6,800 psig. Post-test disassembly and inspection did not reveal any signs of ignition within the test article.
  - 20 cycles performed on TA-1.3 at a test pressure of 7,200 psig. Post-test disassembly and inspection did not reveal any signs of ignition within the test article.

[3] Due to high test pressures and limited upstream oxygen volume, the 20 cycles per configuration were performed in multiple groups of ≤10 cycles. Between each group of cycles, the WHA oxygen booster was used to boost the upstream oxygen supply. The surface temperature of the test article was monitored during testing. When necessary, a heat tape positioned on the exterior of the test article between the cycle groups, was used to ensure the test article temperature at the beginning of each new cycle group, was the same as it was at the end of the previous cycle group.
[4] These results represent opinions and interpretations based on qualitative measurements using visual or audible observations.

Oxygen Pressure Surge Testing[2] *(cont.)*

- **Final Testing**: Oxygen pressure surge cycles were conducted on three (3) test articles (TA-1.4, TA-1.5 and TA-1.6) according to test configurations #1 and #2.
    - For each test article (TA-1.4, TA-1.5 and TA-1.6), 20 cycles were performed in each test configuration, at a test pressure of 7,200 psig.
    - No evidence of ignition was observed visually or audibly during testing. Leaking was not observed during the testing. Post-test disassembly and inspection did not reveal any signs of ignition within the test articles.
- Post-test photographs of the test articles are provided in **Appendix B**.
- Based on the results observed during this testing, the test articles (TA-1.4, 1.5, and 1.6) were judged by WHA personnel to have successfully **met** the requirements of **ISO 10297 (2014): Annex C - Oxygen Pressure Surge Tes**t and **ISO 7291 (2010):** ***Section 9.4.4*** **– Ignition Test for Pressure Regulators for Oxygen**

Disclaimer

The results documented in this report only relate to the test articles tested. WHA International, Inc. (WHA) does not endorse or warrant any component or item tested by WHA personnel as being suitable for any design function or service application what-so-ever. WHA has not performed any evaluation or testing beyond that stated herein, and expressly denies any responsibility for having evaluated the test article for function or safety. WHA disavows any responsibility for the function or safety of test articles.

Appendix A – Test Article Drawings

NOTES:

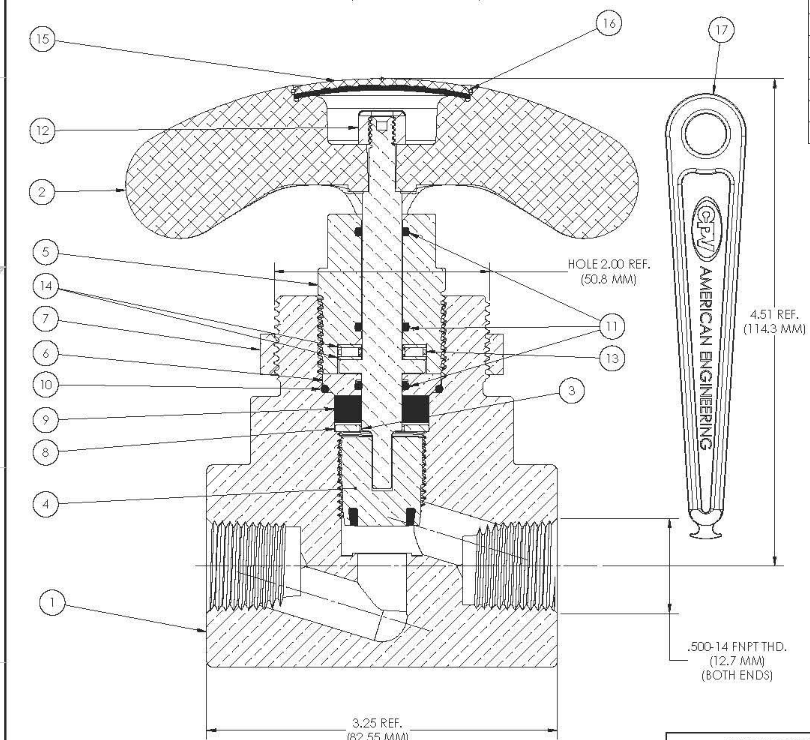
1. ALL VALVE COMPONENTS SHALL BE CLEANED AND PACKAGED PER PROCEDURE CPV OX-1.

2. LUBRICATION:
   A. BONNET PACKING AREA, STEM THREADS & BURNISHED AREA, AND ALL ELASTOMERS SHALL BE LUBRICATED WITH TURMOXYGEN LCO 45 plus.

3. TORQUE REQUIREMENTS:
   A. GLAND NUT TO BONNET: 45-50 ft-lbs

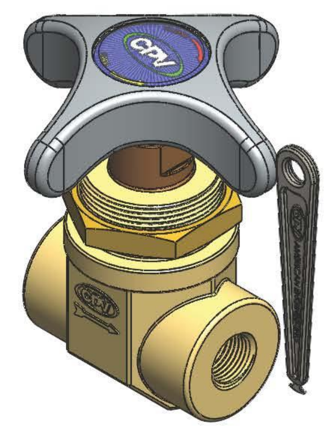
4. PRODUCTION TESTING:
   4.1. SEAT TEST (NITROGEN) (VALVE CLOSED): 6000 PSI (1 Minute)
   4.2. SHELL TEST (NITROGEN) (VALVE OPEN, OUTLET CAPPED): 9000 PSI (1 Minute)

5. MARK BODY WITH THE FOLLOWING: PN, 6000 PSI INERT, 6000 PSI OXYGEN.



BILL OF MATERIALS

ITEM NO.	QTY.	TYPE/ITEM	MATERIAL	MFG. Part Number	REMARKS
1	1	BODY	AS N. BRASS ASTM B283 UNS C46400	143753AS	
2	1	HANDLE	DL ALUM. 6061 ASTM B221 UNS A96061	143700DL	
3	1	STEM	DC MONEL (NiCu) ASTM B164 UNS N04405	143812DC	
4	1	GUIDE ASS'Y	AO CUNI 70/30 UNS C71500	143792AO	
5	1	GLAND NUT	AF NAB ASTM B150 UNS C63200	143772AF	
6	1	RETAINER	AG NBR ASTM B21 UNS C46400	143802AG	
7	1	PANEL NUT	AG NBR ASTM B21 UNS C46400	142243AG	
8	1	PACKING RETAINER	AA COMMERCIAL GRADE BR. OR BRZ.	142222AA	
9	1	PACKING	FA EPDM COMPOUND E4207A90 PEROXIDE CURED	002912FA	
10	1	O-RING	ED EPDM (ETHYLENE PROPYLENE)	000022ED	
11	3	O-RING	ED EPDM (ETHYLENE PROPYLENE)	000012ED	
12	1	LOCKNUT	CA COMMERCIAL GRADE S.S.	007608CA	NYLON INSERT
13	1	BEARING	BA COMMERCIAL STEEL	143840BA	
14	2	BEARING WASHER	BA COMMERCIAL STEEL	143850BA	
15	1	CAP	ALUMINUM WITH CRYSTAL COATING	143713	
16	1	RETAINER RING	CA COMMERCIAL GRADE S.S.	143911CA	
17	1	INSTALLATION TOOL	EH NYLON	144300EH	



PROPRIETARY AND CONFIDENTIAL

This document contains information that is confidential and proprietary to Admiral Valve, LLC dba CPV Manufacturing. This document is furnished on the understanding that the document and information it contains will not be copied or disclosed to others except with written consent of Admiral Valve, LLC dba CPV Manufacturing. It will not be used for any purpose other than conducting business with Admiral Valve, LLC dba CPV Manufacturing, and will be returned and all further use discontinued upon request by Admiral Valve, LLC dba CPV Manufacturing.

REVISIONS

REV	Description	Date	By	Released	Appr
0	ECN 20-047:	03/04/20	JT	6/2/20	JT

TOLERANCES-UNLESS OTHERWISE SPECIFIED				
CAST RADII .125	MACHINED RADII .031	DECIMAL		FRACTION
CAST FINISH 250 RMS	MACH FINISH 125 RMS	2 PL	3 PL	
BREAK SHARP-EDGES .005 RAD.	ANGLES ±1°	±.010"	±.005"	±.016"
UN. SCREW THDS. PER STD-14201	STUB ACME THDS. PER STD-14202			
NPT TAPERED THDS. PER STD-14030				

ADMIRAL VALVE, LLC dba
CPV MANUFACTURING
KENNETT SQUARE, PA

MASTER VALVE, GLOBE, SHUTOFF
Size -3, .456 ORF. X 0.50" FNPT, "D" SOFTGOODS

SCALE: 3:2	SIZE	CAGE	DRAWING NUMBER	REV.
WEIGHT: 5.271 lbs	C	99565	GSB-G-4F	0

ALTERNATE P/N	GSB-G-4F

Appendix B – Pre and Post-Test Photos of Test Articles

Photo 1: Typical test article in its “as received” condition.

Photo 2: Typical test article installed behind the WHA blast shield.

Photo 3: Post-test view of test article TA-1.1 after disassembly.

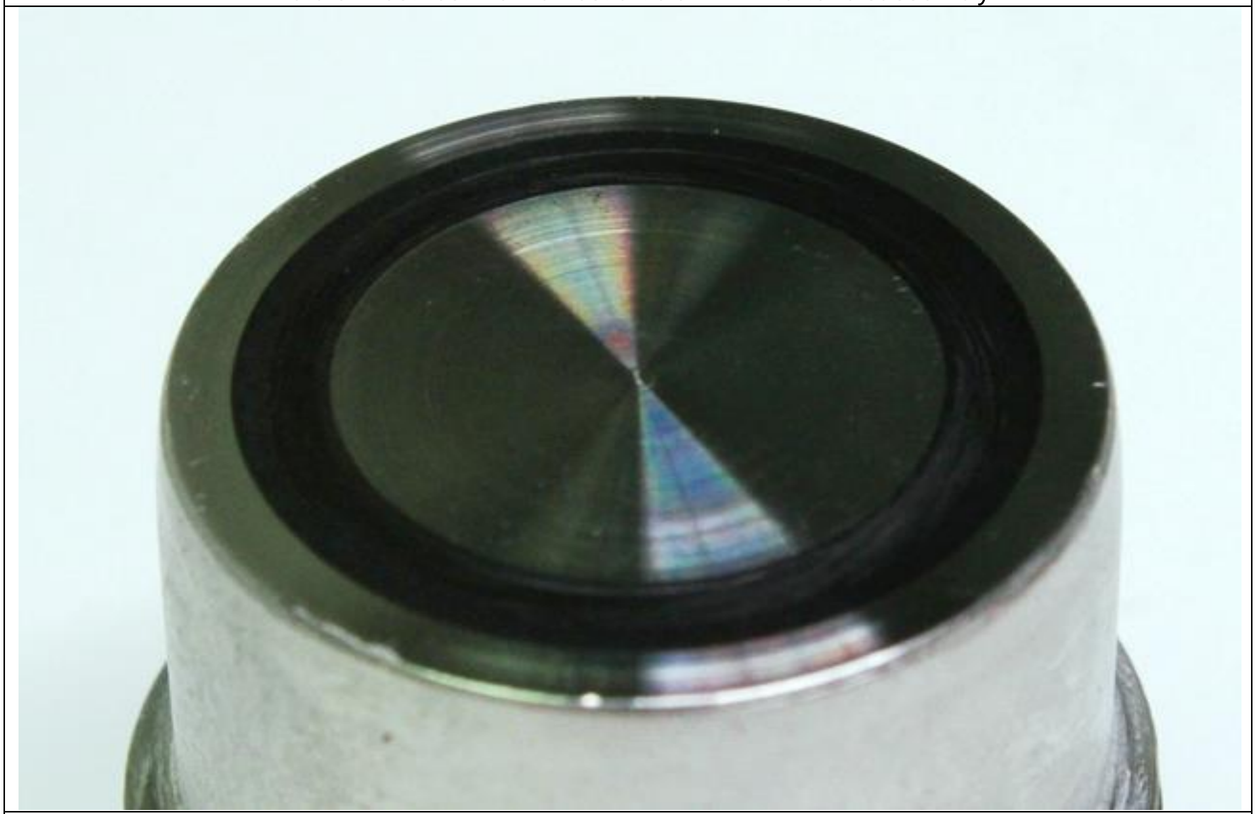


Photo 4: Post-test view of test article TA-1.1 shutoff valve seat.

Photo 5: Post-test view of test article TA-1.2 after disassembly.

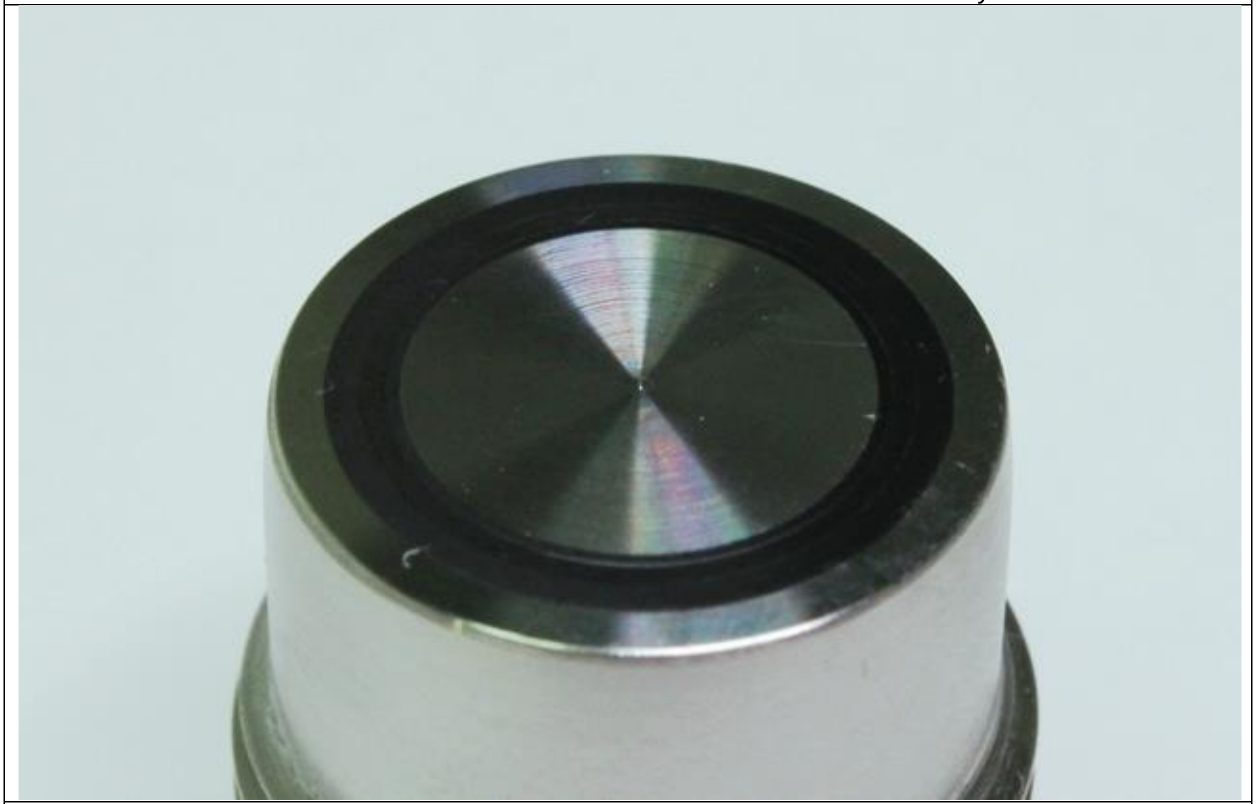


Photo 6: Post-test view of test article TA-1.2 shutoff valve seat.

Photo 7: Post-test view of test article TA-1.3 after disassembly.

Photo 8: Post-test view of test article TA-1.3 shutoff valve seat.

Photo 9: Post-test view of test article TA-1.4 after disassembly.

Photo 10: Post-test view of test article TA-1.4 shutoff valve seat.

Photo 11: Post-test view of test article TA-1.5 after disassembly.

Photo 12: Post-test view of test article TA-1.5 shutoff valve seat.

Photo 13: Post-test view of test article TA-1.6 after disassembly.

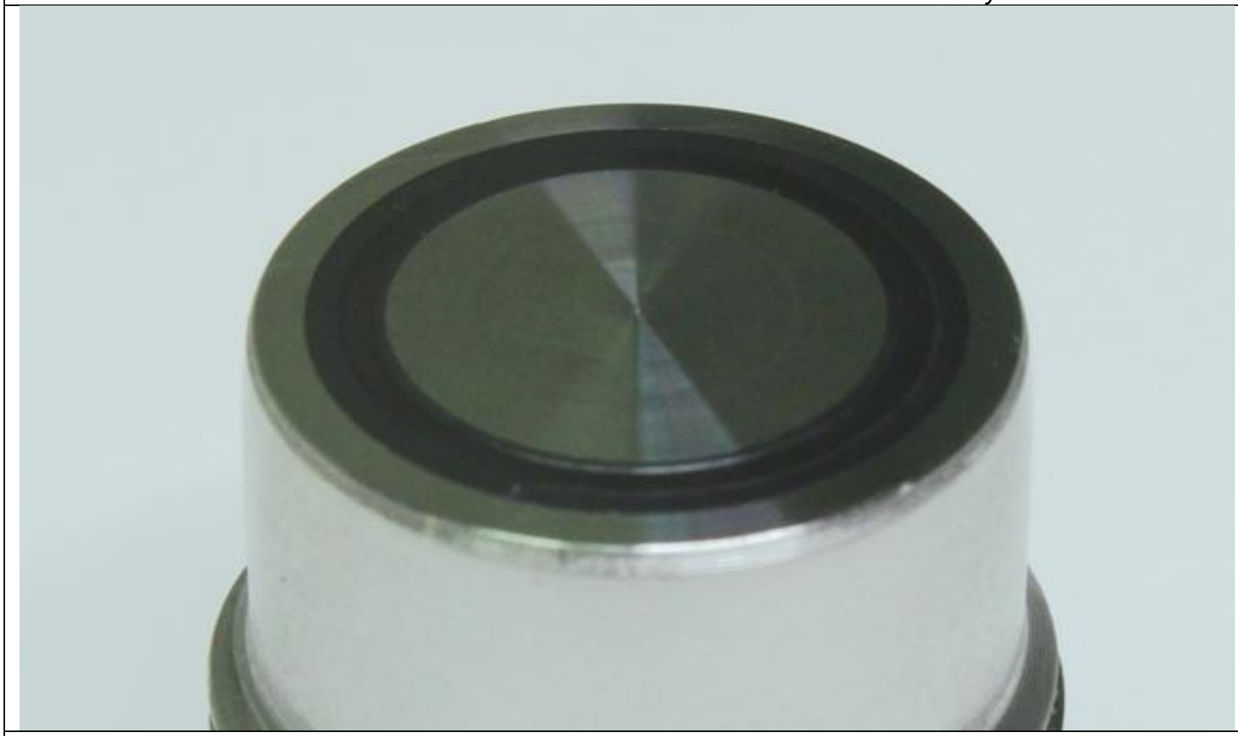


Photo 14: Post-test view of test article TA-1.6 shutoff valve seat.

Appendix GFIS – WHA Test Description: Gaseous Fluid Impact Sensitivity Testing

1 Description

The Gaseous Fluid Impact Sensitivity (GFIS) test represents a method to determine the ignition sensitivity of nonmetallic materials (e.g., plastics, elastomers, coatings, lubricants) or components (e.g. regulators, valves, flexible hoses) to dynamic pressure impacts by gases such as oxygen, air, or blends of gases containing oxygen. This type of testing is also known as oxygen pressure shock, adiabatic compression, rapid pressurization, or pneumatic impact testing and involves subjecting test articles to rapid pressurization and heat of compression. WHA is capable of conducting GFIS testing in accordance with multiple test standards including, but not limited to, those indicated in **Table 1**.

Table 1 – Applicable Test Standards for WHA GFIS Testing

Organization	Standard[1]
ASTM	G74, G175
ISO	21010, 2503, 7291, 10297, 10524-1, 10524-2, 10524-3, 14113
CGA	E-4, E-7, E-18, V-9
EN	13949, 14143

1.1 Test Objective

The objective of the GFIS test is to determine whether the heat from gaseous fluid impact will result in ignition or a precursor to ignition of a test material or component. Unless otherwise noted by a test standard, WHA refers to ASTM G74 which defines ignition or precursor to ignition as "burning, material loss, scorching or melting of a material detected through direct visual means". For material tests, this applies to the test sample. For component tests, this applies to the internal nonmetallic parts of the test article, once disassembled post-test. In order to meet the requirements of the GFIS test, test articles shall not ignite or show precursors to ignition.

2 Test System

The WHA GFIS test system is detailed in **Figure 1**. The test system includes an accumulator to supply heated (typically ~60 °C), high-pressure oxygen to a rapid opening valve (i.e. impact valve). The tube (impact line) between the impact valve and the test article interface is typically either *a)* 1000 mm long, 5 mm inside-diameter, or *b)* 750 mm long, 14 mm inside-diameter. Impact line dimensions are specified within the various test standards.

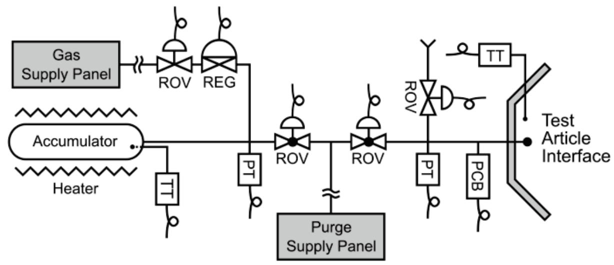


Figure 1 – WHA Gaseous Fluid Impact Sensitivity Test System

A test article is affixed to the WHA test system at the test article interface. A vent valve to relieve pressure in the test system is located between the impact valve and the test article. Between test cycles, the test system accumulator is automatically replenished with oxygen via a gas supply panel. To ensure that the required test article pressurization rate is achieved for each cycle, the test system is instrumented with a high-frequency response pressure transducer. The test system is computer-controlled and instrumentation data is digitally logged for each test.

For material testing, a test sample reaction chamber assembly is used. This reaction chamber is consistent with the design shown in ASTM G74, with the addition of a light detector. The light detector is used to detect ignition from light emission and includes a glass lens feedthrough that provides visual access to the sample via video. Therefore, in addition to detection of a temperature rise or observations from a post-test inspection, ignition can be confirmed via detection of light emissions consistent with combustion.

For component testing, the test article is fitted with a surface thermocouple to help detect an internal ignition that may not propagate externally. Detection of a sudden temperature rise does not confirm an ignition unless post-test inspection identifies evidence of ignition or precursors to ignition.

2.1 System Calibration

Prior to testing, calibration cycles are performed on the WHA test system to ensure that the required pressure rise time (typically 15 to 20 ms) is achieved at the end of the capped impact line. **Figure 2** shows a typical oxygen pressure shock test cycle. Test equipment used to measure critical test variables is calibrated, maintained, and used in testing according the WHA calibration and measurement procedures QPR-018, "Control of Monitoring and Measuring Equipment

[1] See §7 for a detailed list of applicable test standards.

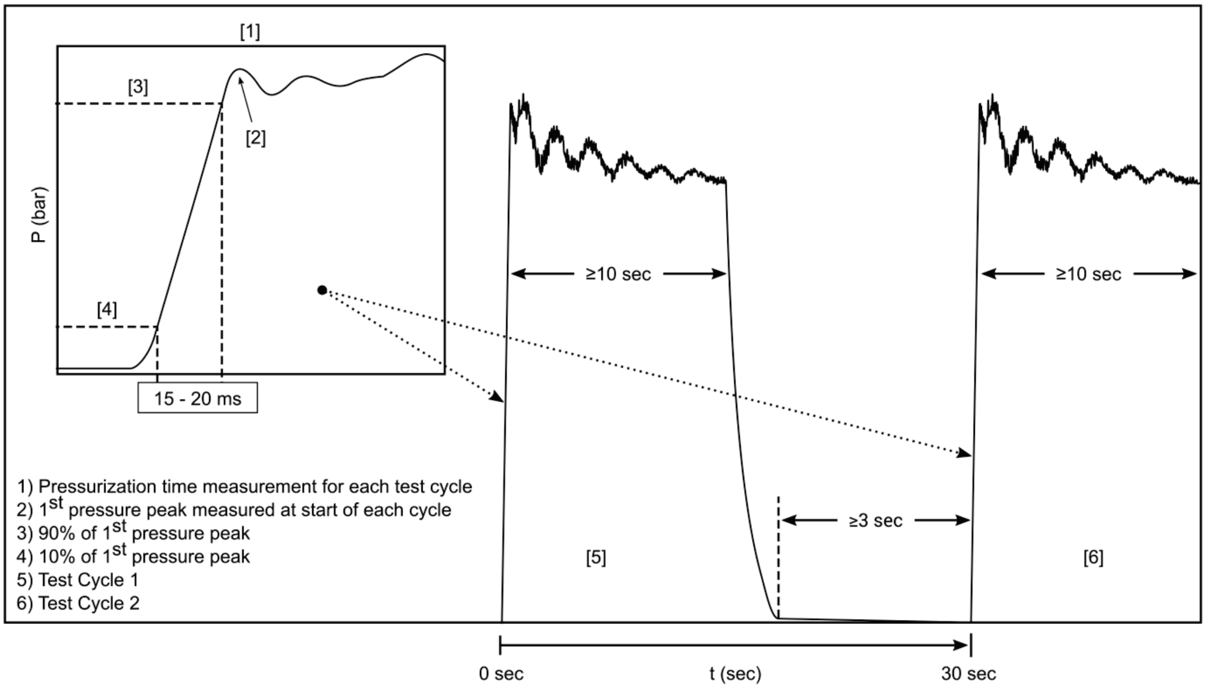


Figure 2 – Typical Oxygen Pressure Shock Cycle

Procedure", and QPR-019, "Estimation of Uncertainty of Measurement Procedure". **Table 1** lists the critical test variables and the corresponding measuring equipment typically used in the GFIS test system.

Table 2 – GFIS Critical Test Variables and Measurement Instrumentation

Test Variable	Measuring Instrument	Instrument Range	Instrument Uncertainty
pressure	pressure transducer	0 to 10,000 psig	± 17 psi
dynamic pressure	pressure transducer	0 to 10,000 psig	± 11 psi
temperature	type K thermocouple	-328 to 2282 °F (-200 to 1250 °C)	± 4 °F (± 2 °C)

3 Test Articles

The WHA GFIS test system can accommodate most component types including: regulators, valves, VIPRs, hoses, check valves, etc. Test specifications and configurations are dependent on the applicable test standard for each component type. When WHA is unaware of a specific test standard for oxygen pressure shock testing for a particular component, testing is based on the most applicable test standard. In this scenario, test configurations may be modified to be more applicable to the specific component being tested with respect to compression heating hazards. Generally, test articles are attached to the WHA test system in their "as received" condition, unless otherwise specified[2]. Material samples are prepared as noted in the test report.

4 Procedure

The test article is attached to the test system at the test article interface. The test article and test system are then configured appropriately to meet the specifications of each test configuration. An oxygen gaseous fluid impact cycle consists of rapidly pressurizing the test article with heated oxygen up to the test pressure, holding at test pressure for 10 s, then venting pressure back to ambient.

Pressurization rates are monitored and recorded during each pressure shock. The test is performed under computer control and data is recorded digitally.

The testing is monitored remotely and video is recorded for each test. Test operators monitor the testing and will pre-maturely stop the testing if signs of ignition are observed (from video monitor or test data) prior to completing the specified number of test cycles. Test parameters, observations, and results are recorded for each test. For components, typically three test articles are tested in the applicable test configurations within the

[2] Unless otherwise specified, WHA does not perform oxygen cleaning on components that are received for GFIS testing. Test articles should be received in an oxygen clean condition.

Table 3 – GFIS Test Conditions for Material Testing

Condition	Material Testing Specifications	Component Test Specifications
Test Pressure	Variable	1.2 x Nominal inlet pressure[3]
Test Gas	Oxygen – 99.5% (minimum)	Oxygen – 99.5% (minimum)
Pressurization Rate	20 ms (+0, -5 ms)	20 ms (+0, -5 ms)
Test Cycle Period	30 s	30 s
Pressure Hold Period	10 s (minimum)	10 s (minimum)
Vent Time Between Cycles	3 s (minimum)	3 s (minimum)
Test Gas Temperature	60 °C (+/- 3 °C)	60 °C (+/- 3 °C)
Impact Tube	(1000 mm long x 5 mm ID) or (750 mm x 14 mm ID)	(1000 mm long x 5 mm ID) or (750 mm x 14 mm ID)
Pressure Surge Location	Inlet of sample reaction chamber	Test Article Inlet
Pressure Surge Cycles	5 cycles per sample	20[4] cycles per configuration

designated test standard. **Table 3** shows the typical GFIS test conditions for both material and component testing.

5 Post-test Inspection

After the testing has been completed, each test article is disassembled and inspected for signs of ignition, scorching, melting or deterioration as outlined in §1.1.

6 Results and Analysis

The criteria for meeting the requirements of GFIS testing are relatively similar between most test standards. Generally, if signs of ignition or heat damage are observed, the test article did not meet the requirements of the oxygen pressure shock testing. WHA refers to the pass/fail specifications as defined by the designated test standard for the given round of testing. However, if interpretation of the test results is unclear, WHA refers to ASTM G74 for clarification.

[3] The majority of test standards specify the test pressure for this testing as 1.2 x nominal inlet pressure; however, this is not the case for all test standards.

[4] Although most test standards only require 20 cycles per test configuration (for oxygen pressure shock testing), WHA recommends that 60 cycles are performed per test configuration for greater statistical confidence in the test results.

7 Test Standards

List of Test Standards

ASTM Standard G74, (2013), "Standard Test Method for Ignition Sensitivity of Nonmetallic Materials and Components by Gaseous Fluid Impact”

ASTM Standard G175, (2013), “Standard Test Method for Evaluating the Ignition Sensitivity and Fault Tolerance of Oxygen Pressure Regulators Used for Medical and Emergency Applications”

ISO 21010, (2014), “Cryogenic Vessels - Gas/Materials Compatibility"

ISO 10524-1, (2006), “Pressure regulators for use with medical gases – Part 1: Pressure regulators and pressure regulators with flow-metering devices”

ISO 10524-2, (2005), “Pressure regulators for use with medical gases – Part 2: Manifold and line pressure regulators”

ISO 10524-3, (2005), “Pressure regulators for use with medical gases – Part 3: Pressure regulators integrated with cylinder valves”

ISO 10297, (2014), “Gas cylinders – Cylinder valves – Specification and type testing”

ISO 7291, (2010), “Gas welding equipment – Pressure regulators for manifold systems used in welding, cutting and allied processes up to 30 MPa (300 bar)”

ISO 14113, (2013), “Gas welding equipment – Rubber and plastics hose and hose assemblies for use with industrial gases up to 450 bar (45 MPa)”

ISO 2503, (2009), “Gas welding equipment – Pressure regulators and pressure regulators with flow-metering devices for gas cylinders used in welding, cutting and allied processes up to 300 bar (30 MPa)”

CGA E-4, (2010), “Standard for Gas Pressure Regulators”

CGA E-7, (2013), “Medical Gas Pressure Regulators, Flowmeters, and Orifice Flow Selectors”

CGA E-18, (2015), “Medical Gas Valve Integrated Pressure Regulators”

CGA V-9, (2012), “Compressed Gas Association Standard for Compressed Gas Cylinder Valves”

EN 13949, (2003), “Respiratory equipment. Open-circuit self-contained diving apparatus for use with compressed Nitrox and oxygen. Requirements, testing, marking”

EN 14143, (2013), “Respiratory equipment. Self-contained re-breathing diving apparatus”