

Technical Memorandum 104821



Guide for Oxygen Component Qualification Tests

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1.0 Scope

Although oxygen is a chemically stable element, it is not shock sensitive, will not decompose, and is not flammable. Oxygen use carries a risk that should never be overlooked, because oxygen is a strong oxidizer that vigorously supports combustion. Oxygen is reactive at ambient conditions, and its reactivity increases with increasing pressure, temperature, and concentration. Most metallic and many nonmetallic materials are flammable in high-pressure oxygen; therefore, systems must be designed to reduce or eliminate ignition hazards.

To promote safety in an oxygen system, the flammability of the materials used should be analyzed. If a material is not flammable it may be used safely, even if ignition sources exist. If the material is flammable but no ignition source exists, the material may still be used safely. However, if an ignition source exists, tests should be performed on the component in the actual use configuration to determine the safety margins to the ignition thresholds of the material.

At the NASA White Sands Test Facility (WSTF), configurational tests of components that are specifically engineered for oxygen service are performed. Such tests are only performed following a detailed WSTF oxygen hazards analysis (Poe 1992). This document outlines recommended test systems, cleaning, handling, and test procedures. These recommendations apply to manual valves, remotely operated valves, check valves, relief valves, filters, regulators, flexible hoses, and intensifiers. Component systems are not covered.

2.0 Objective

The objective of this document is to describe the capabilities and procedures of WSTF configurational tests on components. The objective of all tests outlined in this document is to provide performance test data for use as part of a customer's qualification plan for a particular component in a particular configuration, and under worst-case conditions.

3.0 Test Article

The test article may be provided by the customer, purchased from customer-approved vendors through WSTF's procurement system, or fabricated from customer-approved materials at WSTF.

4.0 Approach

First, a detailed oxygen hazards analysis is performed on the test article. After identifying the test article's type, construction materials, limitations, etc., and its intended use (configuration, operating conditions, etc.), potential oxygen hazards are analyzed (Poe 1992). When the oxygen hazards analysis is completed, WSTF recommends an appropriate test system configuration and test sequence(s).

5.0 Flow and Pressurization Test Systems

WSTF oxygen component test systems are fabricated from materials suitable for oxygen use. All hardware is cleaned for oxygen use to level 50A, per JSCM 5322 (Johnson Space Center (JSC), 1982).

5.1 Data Acquisition and Control

All WSTF test systems use digital data acquisition equipment to record test article and test system parameters, such as thermocouple and pressure transducer data. Standard video coverage is available, with the options of infrared video, high-resolution film, or high-speed video being employed. Computer-enhanced motion analysis can be used to study test footage in the event of a catastrophic test article failure.

5.2 Pneumatic Impact Test Systems

The pneumatic impact test system simulates sudden pressurizations such as might be caused by a rapidly opening valve. Rapid pressurization generates heat that can ignite some materials in the system. WSTF pneumatic impact test systems are capable of test pressures up to 94.80 MPa (13,750 psi). Pressurization from ambient to test pressure can be achieved in under 100 ms, with the exact time depending on the test configuration. Pressurization times can be varied to simulate the actual use conditions of the test article. A typical pneumatic impact component test system is shown in Figure 1.

These systems can heat or cool the test article, the test gas, or both. A heat pump is used for moderately cool or warm temperatures. Cryogenics, heat lamps, and heat tapes are used for more extreme temperatures.

5.3 Particle Impact Test System

Particle impact, caused by contaminants impacting components at high velocities, can cause ignition in oxygen systems. The WSTF particle impact test system is a high-flow system in which particulate simulating contaminants can be injected into the gas just upstream of the test article. At maximum operating conditions, mass flow rates of 4.1 kg/s (9 lb/s) at 37.92 MPa (5,500 psi) for 30 sec can be achieved. Gas temperatures can be varied between 366.5 K (200°F) and 810.9 K (1000°F), and the test article can be either heated or cooled to simulate actual use conditions. Cryogenic liquids can also be flowed through the test article, either alone or simultaneously with a hot gas. The WSTF particle impact test system is shown in Figure 2.

5.4 Flow Test System

A flow test system is designed to simulate the test article's actual use conditions by connecting it to the test article port of a WSTF pneumatic impact test system. The test system is capable of test pressures up to 94.80 MPa (13,750 psi). Pressurization and flow rates can be varied to simulate the actual use conditions of the test article. A typical flow component test system is shown in Figure 3.

5.5 Specialized Test Systems

Several specialized WSTF test systems are used to simulate a range of special test conditions or configurations. For example, the frictional heating test system simulates failures caused by unintentional rubbing or parts, such as occurs in hydrostatic bearings or turbine blade tips. The promoted combustion test system causes ignition of material samples or components to determine burn characteristics. Because these specialized tests must be tailored to each test article configuration, details cannot be included in this document.

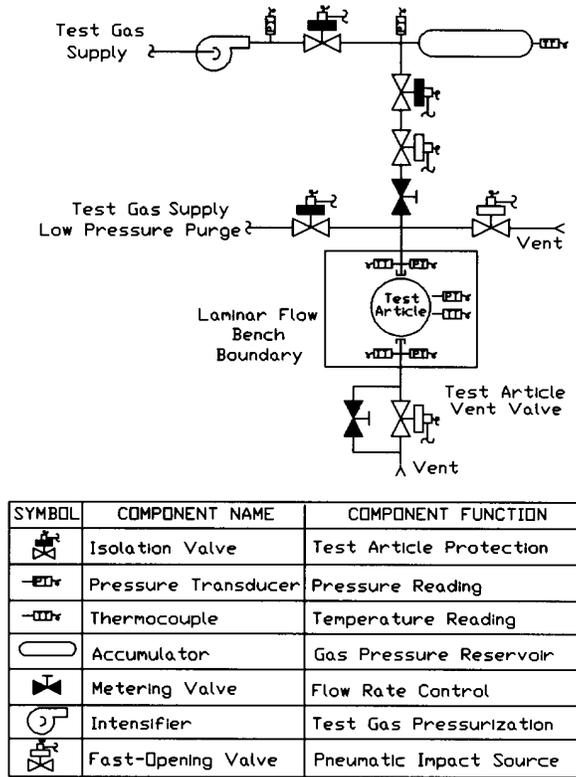


Figure 1 Pneumatic impact component test system

6.0 Test Gases

WSTF test systems can supply high-pressure gaseous oxygen (GO_2) and gaseous nitrogen (GN_2) to the test article. WSTF uses aviator's breathing oxygen that conforms to MIL-0-27210E (GPO 1984). However, customer-specified particulate or hydrocarbon contaminants can be introduced to simulate worst-case test conditions. Special test gases, such as helium or mixtures of inert gases with GO_2 , can also be used. Some test systems are designed to operate with cryogenic fluids, such as liquid oxygen (LOX) or liquid nitrogen (LN_2).

7.0 Pretest Procedures

7.1 Pretest Photographs

Pretest photographs of the test article are taken upon receipt at WSTF.

7.2 Initial Inspection

After the test articles are photographed, each test article is submitted to the WSTF Fluid Components Laboratory. If the test article is received at WSTF cleaned to a level 50A or 100A (JSC 1982), inspection

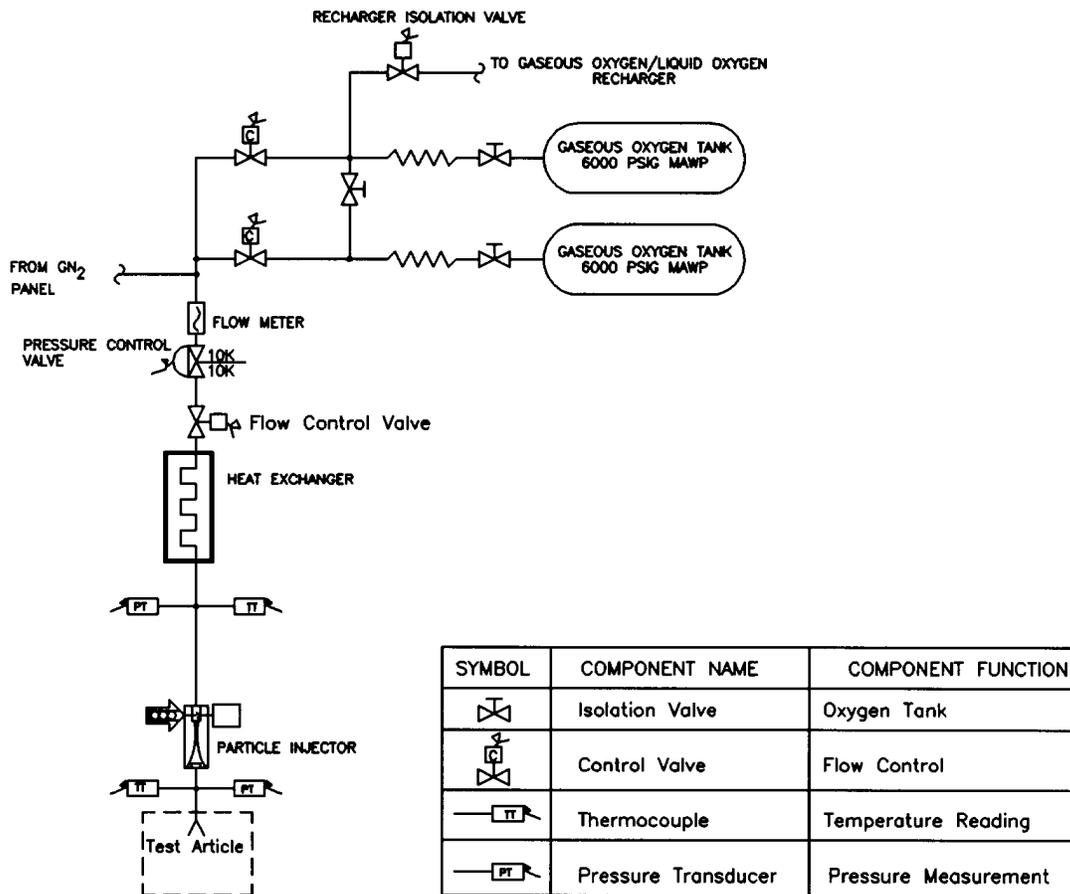


Figure 2 Particle impact test system

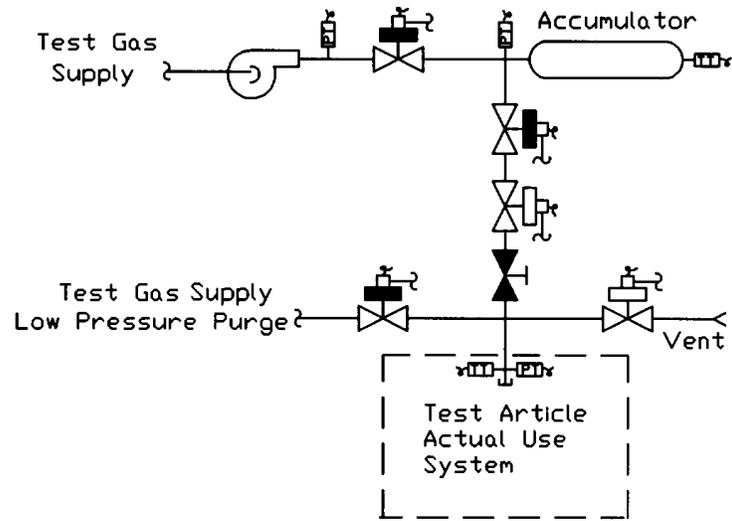
is performed in a Class 100 flow bench. The test article is inspected for damage or contamination; unusual findings are noted and reported.

7.3 Refurbishment

If repair or refurbishment of an article is requested by the customer, WSTF repairs or refurbishes the test article. Replacement parts may be provided by the customer or purchased through WSTF's procurement system. All soft goods and lubricants installed in the test article by WSTF are approved by the cognizant materials control organization, as specified by the customer.

7.4 Cleaning

Test articles can be tested in an as-received condition, or they can be cleaned at WSTF to a level suitable for oxygen use. If no customer direction is given, the test article is disassembled and cleaned for oxygen



SYMBOL	COMPONENT NAME	COMPONENT FUNCTION
	Isolation Valve	Test Article Protection
	Pressure Transducer	Pressure Reading
	Thermocouple	Temperature Reading
	Accumulator	Gas Pressure Reservoir
	Metering Valve	Flow Rate Control
	Intensifier	Test Gas Pressurization
	Fast-Opening Valve	Pneumatic Impact Source

Figure 3 Typical oxygen component test system

use to level 50A per JSCM 5322 (JSC 1982). If the test article is received in a certified clean condition, no further WSTF cleaning is performed.

To maintain cleanliness, test articles are double-bagged and sealed before transportation or storage. All testing or handling of a clean test article is performed in a Class 100 flow bench.

7.5 Nitrogen Functional Check

After cleaning (or after initial inspection if no cleaning is to be performed), the test article is reassembled and functionally checked with GN₂. Internal leakage or functional problems are reported to the customer.

7.6 Installation Leak Check

Before functional testing with the test gas, the test article is installed in the test system and an external GN₂ leak check is performed. This leak check is intended to identify external leak paths at the interface between the test article and the test system.

8.0 Flow and Impact Test Procedures

8.1 General Procedures

WSTF component tests are performed at worst-case pressure, or at 1.25 times the maximum desired working pressure (as specified by the customer), whichever is higher. Each test article is subjected to a number of pressure/vent or flow cycles. This number, which is determined by WSTF, is based on information such as the WSTF hazard analysis results, the number of independent operating test parameters, and the required lifetime. After each test series, the test article is leak-tested at the maximum desired working pressure. Other test conditions (temperature, contamination, etc.) simulate worst-case conditions, as specified by the customer or the hazard analysis team.

8.2 Manual Valve Test Method

The test system simulates the manual valve's actual use configuration. The manual valve is tested in Configurations 1 and 2 described below, and is subjected to the required number of cycles in each configuration.

8.2.1 Manual Valve Test Configuration 1

The manual valve and the test article vent valve are closed initially. Test pressure is applied to the manual valve inlet, and the test article pressure transducers are observed to detect evidence of leakage across the valve seat. If no leakage is noted, the valve's vent valve is opened, and the valve is cycled from fully open to fully closed. The flow test system is vented, and the test is repeated until the required number of pressure/vent cycles have been performed.

8.2.2 Manual Valve Test Configuration 2

The manual valve is adjusted to provide a GN₂ flow rate of approximately 200 standard cm³ (12.1 in³) per minute at an inlet pressure of 20.78 MPa (3,000 psia) across its seat. The valve is tested at the maximum test pressure specified by the customer if the manual valve's maximum allowed working pressure is below 20.68 MPa (3,000 psia). Manual valve adjustment is maintained during installation in the flow test system. Test system vent valves located downstream of the manual valve are opened. Test gas is permitted to flow at the required pressure through the manual valve for 5 sec. The flow test system is repressurized, and the test is repeated until the required number of flow cycles have been performed.

8.3 Remotely Operated Valve (ROV) Test Method

The test system is configured to simulate the ROV's actual use configuration. All ROVs are tested in Configurations 1 and 2 described below, and are subjected to the required number of cycles in each configuration.

8.3.1 ROV Test Configuration 1

The ROV is closed initially. The test system metering valve, located upstream of the ROV, is adjusted to permit the ROV to be rapidly cycled without reducing the flow test system pressure below approximately 95% of the initial pressure, while allowing test gas to flow cross the test article seat.

After the test system metering valve is adjusted, the ROV inlet is pressurized. The ROV is then rapidly cycled until flow system pressure decreases below the required valve. The flow test system is repressurized, and the test continues until the required number of cycles have been performed.

8.3.2 ROV Test Configuration 2

The ROV and the test article vent valve are closed initially. Test pressure is applied to the ROV inlet, and the test article pressure monitoring devices are observed to detect evidence of leakage across the test article seat. If no leakage is noted, the test article vent valve and the ROV are cycled open, then closed. The flow test system is vented, and the test is repeated until the required number of cycles have been performed.

8.4 Check Valve Test Method

The test system is configured to simulate the check valve's actual use configuration. Check valves are evaluated in the following two configurations.

8.4.1 Check Valve Test Configuration 1

The check valve is installed in the test system in the direction that permits flow through it. The test system vent valves are closed, and test pressure is applied. After pressure stabilization, the flow test system is vented, and the test is repeated until the required number of cycles have been performed.

8.4.2 Check Valve Test Configuration 2

The check valve is installed in the direction that prohibits flow through it. The test system vent valves are closed, and pressure is applied to the check valve. When the pressure has stabilized, the pressure monitoring system is used to detect evidence of leakage past the check valve seat. The test system is vented, and the test is repeated until the required number of cycles have been performed.

8.5 Relief Valve Test Method

The test system simulates the relief valve's actual use configuration. The relief valve is installed in the flow test system with the relief valve outlet port connected to the test system, if possible. The relief valve is evaluated in two configurations.

8.5.1 Relief Valve Test Configuration 1

In Configuration 1, the relief valve is pressurized to 1.25 times its set pressure, or to a pressure specified by the customer. The relief valve is allowed to vent to its reseal pressure. Pressure upstream of the relief valve is monitored for evidence of leakage across the relief valve seat after venting ceases. The flow test system upstream of the relief valve is vented, and the test is repeated until the required number of cycles have been performed.

8.5.2 Relief Valve Test Configuration 2

The relief valve is rapidly pressurized to 95% of its crack pressure to maximize the effect of adiabatic heating on the relief valve seat. Pressure monitoring devices are observed to detect evidence of leakage across the relief valve seat. The flow test system upstream of the relief valve is vented, and the test is repeated until the required number of cycles have been performed.

8.6 Filter Test Method

The test system is configured to simulate the filter's actual use configuration. With test system vent valves closed, test pressure is applied at 1.25 times the desired use pressure in the direction of flow marked on the filter, or as otherwise specified on the test request. After pressure stabilization, the flow test system downstream of the filter is vented at a rate that does not exceed the differential pressure limits of the filter. The test is repeated until the required number of cycles have been performed. Normally, a bubble point test and an internal visual inspection of the filter are performed before and after the test.

8.7 Regulator Test Method

8.7.1 Regulator Pressurization Rate Simulation

Because of high gas-flow rates through regulators, they are vulnerable to functional damage. To adequately evaluate an oxygen regulator, WSTF recommends that testing be conducted at pressurization rates simulating actual use conditions. Determining the required test pressurization rate requires detailed knowledge of the upstream end use configuration (for example, valves and filters). WSTF's flow test system is adjusted to provide the appropriate pressurization rate for each test.

8.7.2 Regulator Test Configuration

The test system is configured to simulate the regulator's actual use configuration. With the test system vent valves closed, the regulator is adjusted to the fully reduced position (closed). Test pressure is introduced into the regulator inlet port at the predetermined rate. The pressure monitoring system is used to detect evidence of leakage past the regulator seat. For regulators with self-venting features, the flow test system is vented after pressure stabilizes. Venting of regulators without self-venting features is accomplished after pressure stabilizes by opening a flow test system vent valve downstream of a regulator while the regulator is in the fully increased (open) position. After venting ceases, the regulator is adjusted to the fully reduced position. The test is repeated until the required number of cycles have been performed.

8.8 Flexible Hose Test Method

The test system simulates the flexible hose's actual use configuration. In addition to the flexible hose, WSTF also simulates the upstream and downstream components, as specified by the customer.

The flexible hose is pressurized with the test gas at a rate simulating the actual use pressurization rate. When the temperature of the flexible hose returns to ambient, the pressure is vented. The test is repeated until the required number of cycles have been performed. In addition to the standard instrumentation, an infrared camera is used to monitor the flexible hose temperature.

8.9 Diaphragm-Type Gas Intensifier (Compressor) Test Method

The test system simulates the intensifier's actual use configuration. The test system intensifier is removed and the intensifier is installed in its place. Test system valves are opened between the intensifier and the

test system accumulator (minimum volume of 2.8 liters [0.10 ft³]). The intensifier is operated for 1 hour using the manufacturer's suggested suction pressure.

9.0 Posttest Procedures

After testing, the test article is inspected, double-bagged, and sealed. The test article is transported to the Fluid Components Lab, where it is disassembled, inspected, and photographed. If the test article is in operable condition, it is cleaned, refurbished with new soft goods, functionally checked with an inert gas, double-bagged, and sealed.

The test article is returned to the address specified by the customer, in its original shipping container. If requested, pre-shipment photographs are taken.

10.0 Reporting

A formal test report is transmitted to the customer following completion of the testing. The report includes test article part number and serial number, soft goods identification, handling and processing details, appropriate references to the oxygen hazards analysis, descriptions of the test system used and all the procedures followed, and the test results.

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