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Examination Standard for Oxygen Reduction Systems

Class Number 5800

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Foreword

This standard is intended to verify that the products and services described will meet stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of this standard is to present the criteria for examination of various types of products and services.

Examination in accordance with this standard shall demonstrate compliance and verify that quality control in manufacturing shall ensure a consistent and reliable product.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states testing and certification requirements for oxygen reduction systems for use as fire prevention systems.

1.1.2 Testing and certification criteria may include, but are not limited to, component, system performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a surveillance program.

1.2 Scope

1.2.1 This standard encompasses the design and performance requirements for oxygen reduction systems. This standard does not include requirements for the installation, application and maintenance of oxygen reduction systems.

1.2.2 Oxygen reduction systems may use membranes or pressure swing adsorption, including vacuum pressure swing adsorption, as the nitrogen separation mechanism. Other technologies may be evaluated on a case-by-case basis.

1.2.3 This standard is intended to verify that the product described will meet stated conditions of performance, safety and quality useful to the ends of property conservation.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists has also been considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of oxygen reduction systems for the purpose of obtaining certification. Oxygen reduction systems having characteristics not anticipated by this standard may be certified if performance equal, or superior, to that required by this standard is demonstrated.

1.4 Basis for Certification

Certification is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate:

- The suitability of the product;
- The performance of the product as specified by the manufacturer and required for certification; and, as far as practical,
- The durability and reliability of the product.

1.4.2 An examination of the manufacturing facilities and audit of quality control procedures may be made to evaluate the manufacturer's ability to consistently produce the product, which is examined and tested, and the marking procedures used to identify the product. Subsequent surveillance may be required by the certification agency in accordance with the certification scheme to ensure ongoing compliance.

1.4.3 A review of the proposed oxygen reduction system “Design, Installation, Operation and Maintenance” manual.

1.5 Basis for Continued Certification

The basis for continual certification may include, but is not limited to, the following based upon the certification scheme and requirements of the certification agency:

- production or availability of the product as currently certified;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated by the certification;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory surveillance audits conducted as part of the certification agencies product surveillance program.

1.6 Effective Date

The effective date of this certification standard mandates that all products tested for certification after the effective date shall satisfy the requirements of this standard.

The effective date of this Standard is eighteen (18) months after the publication date of the standard for compliance with all requirements.

1.7 System of Units

Units of measurement used in this Standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Conversion of U.S. customary units is in accordance with ANSI/IEEE/ASTM SI 10. Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection and are used in this Standard.

1.8 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies:

ASME Publications
American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016

ASME *Boiler and Pressure Vessel Code*

ASTM Publications
American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

ASTM B117-16, *Standard Practice for Operating Salt Spray (Fog) Apparatus*
ASTM D395 *Standard Test Methods for Rubber Property – Compression Set*, 2003
ASTM D412*Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension*, 2006
ASTM D573, *Standard Test Method for Rubber – Deterioration in an Air Oven*, 2004
ASTM SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System*

FM Approvals
1151 Boston-Providence Turnpike, P.O. Box 9102, Norwood, MA 02062 USA
http://www.fmapprovals.com

FM 1321/1323, *Examination Standard for Controllers for Electric Motor and Diesel Engine Driven Fire Pumps*
FM 3010, *Examination Standard for Fire Alarm Signaling Systems*

FM 6340, *Examination Standard for Toxic Gas and Oxygen Depletion Detectors*

ISO Publications

International Organization for Standardization, Chemin de Blandonnet 8, CP 401 - 1214 Vernier, Geneva, Switzerland

ISO 9001, *Quality Management Systems*

ISO 10380:2003, *Pipework — Corrugated metal hoses and hose assemblies*

NFPA Publications

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101

NFPA 72, *National Fire Alarm Code*, 2019

1.9 Terms and Definitions

For purposes of this standard, the following terms apply:

Accepted

This term refers to installations acceptable to the authority having jurisdiction and enforcing the applicable installation rules. Acceptance is based upon an overall evaluation of the installation. Factors other than the use of certified equipment impact upon the decision to accept the equipment. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere.

Amplitude

The maximum displacement of sinusoidal motion from position of rest to one-half of the total displacement.

Authority Having Jurisdiction

The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

Conditioning Equipment

For the purposes of this standard, conditioning equipment refers to all filters and other devices used to condition the compressed air before it enters the nitrogen separating mechanism.

Control Panel

Electrical component for monitoring, controlling, and operating the function and alarms of the oxygen reduction system. Minimum requirements for the control panel are found in Section 4.2.

Maximum System Pressure

The highest pressure available from the pressure source. Typically, this would be the pressure setting of the pressure relief device.

Membrane nitrogen generator

A method of generating nitrogen using the process of passing compressed air through a membrane. Different gases have different rates of permeation and this can be used to separate nitrogen from the other atmospheric gases. The resulting product is mostly nitrogen.

Minimum Bend Radius

The smallest radius (expressed in inches [mm]) that a flexible hose is safely allowed to bend, as specified by the manufacturer.

Nozzle

A device with one or more orifices that is connect to a termination of a pipe network for the purpose of uniformly distributing nitrogen into an enclosure.

Operating Pressure

The pressure at which a component functions under normal conditions.

Pressure Swing Adsorption (PSA)

A method of generating nitrogen using the process of adsorption by which a thin layer of molecules temporarily adheres to the surface of another material. A PSA nitrogen generator consists of two or more towers filled with adsorbent material. Air is drawn into one tower and oxygen adheres to the adsorbent material. The remaining atmospheric gas, which is mostly nitrogen, passes through. The towers are cycled so that waste oxygen is being "cleaned" from one tower while the other is used to produce nitrogen, and the two are switched periodically.

Protected Volume

The space to be protected by the oxygen reduction system.

Rated Working Pressure

The maximum pressure at, or below, which all components shall operate trouble free.

Relief Valve

A device that allows the diversion of liquid or gas in order to limit excess pressure in a system.

Working Pressure

The maximum anticipated static (non-flowing) pressure applied to the system components exclusive of momentary spike or surge pressures.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 An oxygen reduction system is a system which is used to displace the oxygen in an enclosed environment using one or more nitrogen generators to create an oxygen concentration in the enclosed environment that will not support ignition for various hazards.

2.1.2 In order to meet the intent of this standard, oxygen reduction systems shall be examined on a model-by-model, type-by-type and manufacturer-by-manufacturer, and plant-by-plant basis. This is predicated on the basis that identical designs, fabricated in identical materials by different manufacturers or, even by different plants of the same manufacturer, have been seen to perform differently in testing. Sample oxygen reduction systems, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

2.2 Certification Application Requirements

The manufacturer shall provide the following preliminary information with any request for certification consideration. All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level.

2.2.1 Any marketing literature showing the general specifications and functions of the system.

2.2.2 A complete list of all models, types, sizes, and system variations and options to be examined. This may be submitted in the form of a specification or drawing.

2.2.3 An instruction manual–listing all design, installation, operation, and maintenance instructions.

2.2.4 Quality control procedures detailing routine testing and final inspection procedures. These may include receiving inspection, in-process inspection, final inspection, and calibration of measuring and testing equipment procedures.

2.2.5 Procedures detailing the system acceptance testing once the oxygen reduction system is installed.

2.2.6 The following drawings should be provided:

- Electrical schematic(s)
- Final assembly drawings and parts lists sufficient to detail primary components (all), operator controls, and their locations;
- Complete set of mechanical drawings for all machined parts;
- Complete part specifications (including manufacturer’s model numbers, size, ratings, etc.) for all purchased parts;
- Specification sheets for all parts/components;
- Drawings showing all construction details, sheet metal gauge and paint finish;
- Product label drawing(s) showing all required marking information. The label drawing shall show the proposed label location on the equipment and artwork showing the manufacturer’s name, address, model and serial numbers, equipment ratings, and warning markings

2.2.7 The number and location of manufacturing facilities.

Test programs will be scheduled only on receipt of all material listed above. All foreign language documents shall be provided with English translation.

2.3 Requirements for Samples for Examination

Following generation and authorization of a certification examination, the manufacturer shall prepare components for examination and testing. Sample requirements are to be determined by the certification agency following review of the preliminary information. Sample requirements may vary depending on design features, results of prior testing, and results of the foregoing tests. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototype components or systems is at the sole discretion of the certification agency.

3. GENERAL REQUIREMENTS

3.1 Design, Installation, and Maintenance

The design, installation, and maintenance of oxygen reduction systems shall be in accordance with a standard/code that is acceptable to the Authority Having Jurisdiction. This includes, but is not limited to, the following:

- Oxygen design concentration for the protected volume based on the hazards present.
- Oxygen reduced air required flow rate including required safety factors based on size, geometry, leakage rate and temperature of the protected volume as well as maximum wind conditions.
- Oxygen reduction system oxygen percentage alarm thresholds and fault signals.
- Amount and location of oxygen sensors to ensure homogeneous distribution of oxygen reduced air.
- Amount and location of oxygen reduced air discharge nozzles or outlets to ensure homogeneous distribution of oxygen reduced air.
- Location of, and requirements for, the operating room of the oxygen reduction system.
- Electrical power supply and associated wiring requirements.
- Inspection, testing and maintenance requirements.

3.2 Review of Documentation

During the initial investigation and prior to physical testing, the manufacturer's specifications, technical data sheets, and design details shall be reviewed to assess the ease and practicality of installation and use. The system and its components shall be capable of being used within the limits of the certification investigation.

3.3 Physical or Structural Construction Features

3.3.1 An oxygen reduction system shall at a minimum consist of a supply of oxygen reduced air, a fixed piping system with fittings, valves, and nozzles, oxygen sensors and control panel, and alarms. The manufacturer shall provide a diagram or schematic drawing of the system which indicates the minimum and maximum system operating pressures of each section, or sub-system, of the oxygen reduction system.

3.3.2 The test program requirements shall be based on assembly and manufacturing drawings supplied by the manufacturer prior to the start of testing. Following the results of testing, if additional hardware is required, the test program will be revised.

3.3.3 For all components downstream of the nitrogen generation system the test pressures will be calculated using a base working pressure equal to the maximum system operating pressure of the pressurized system.

3.3.4 Hydrostatic strength of components should be based on 2 times the maximum system operating pressure but not less than 350 psi (24 bar). Leakage pressure testing should be based 120 percent of the maximum system pressure.

3.3.5 Pressure Vessels (Storage Tanks and Adsorption Towers)

3.3.5.1 Pressure vessels utilized in nitrogen generators shall conform to the appropriate regulations and design standards for the installation location. They shall be new vessels, cleaned and dried, and have safety relief valves as required by the design standards for the installation location. In the U.S.A., pressure vessels must typically conform to the following regulations:

- ASME Boiler & Pressure Vessel Code, Section VIII, Division 1 – "*Rules for Construction of Pressure Vessels*"

3.3.5.2 Samples of the following documents shall be submitted for each size pressure vessel design, to demonstrate compliance with the relevant design standard:

- Calculation of wall thicknesses in accordance with the method specified in the design standard, with appropriate supporting references, as necessary
- Certificate of chemical analysis of materials
- Certificate of physical properties of materials

3.3.6 Generally, no plastic or elastomeric components are to be used (these parts may be used at the sole discretion of the certification agency, contingent on additional testing). Suitability of materials along with certification of materials compatibility shall be submitted for review. Suitability of materials with the expected environmental atmospheres (such as wet benches) along with certification of material and environment compatibility shall be submitted for review.

3.3.7 The use of certified oxygen detection devices and associated controls is required for oxygen reduction systems.

3.3.8 Non-certified electrical components, including control panels, sequence boxes, and other applicable devices, will be included within the scope of the certification project examination.

3.3.9 Documented use of certified components, if evaluated for the same system characteristics, may be sufficient reason to waive the tests described below for those components, based on the sole discretion of the certification agency.

3.3.10 Placement of all system components, with the exception of the nozzles, piping and associated detection and alarm components, shall be in a location outside the protected area.

3.4 Materials

All materials used in oxygen reduction systems shall be suitable for the intended application. Parts exposed to moist compressed air shall be constructed of corrosion resistant materials. When unusual materials are used, special tests may be necessary to verify their suitability. All components shall withstand the normal abuse of shipping, handling, and installation.

3.5 Conditioning of Compressed Air

The oxygen reduction systems shall contain sufficient equipment to condition the air produced by the compressor(s) in order to protect the nitrogen separating mechanism. The air shall be conditioned to the membrane or adsorption media manufacturer's specifications. This typically includes a prefilter, a coalescing filter, and a particle filter with water removal. Coalescing filters and filters with water removal shall have provisions for piping the water to a drain fitting on the system.

The conditioning should be designed to accommodate air intake conditions typically found in installation conditions which may include high humidity, minor levels of dust, etc.

3.6 Components

A component of an oxygen reduction system covered by this standard shall comply with the requirements for that component and shall be used in accordance with its rated values and other limitations. For a component that contains features or characteristics that are not necessary in the application of the component in the oxygen reduction system, the component is not required to comply with the corresponding performance requirement(s) specified by this standard.

3.7 Markings

3.7.1 Oxygen Reduction System Marking

3.7.1.1 A permanently-marked, legible, corrosion-resistant nameplate shall be securely attached to the system in an easily visible location. The nameplate shall include the minimum following information:

- Manufacturer's name or trademark;
- Model identification;

- System ratings;
- Equipment operating ratings;
- Serial number or other traceable code markings;
- Certification Marks and,
- Manufacturing location source code where necessary.

3.7.1.2 Any other pertinent marking information required by the referenced standards or other national or international standards to which the system is manufactured shall be permanently marked on a suitable data plate.

3.7.1.3 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the certification agency's mark of conformity.

3.7.1.4 The certification agency's mark of conformity shall be displayed visibly and permanently on the product and/or packaging as appropriate and in accordance with the requirements of the certification agency. The manufacturer shall exercise control of this mark as specified by the certification agency and the certification scheme.

3.8 Manufacturer's Design, Installation, Operation and Maintenance Manual

Design, installation, operation and maintenance instructions shall be furnished by the manufacturer in the form of a manual with every oxygen reduction system. This manual shall be submitted to the certification agency as a part of the examination of a system. Reference Section 4.20 for manual requirements.

Additionally, maintenance should be possible with basic training and using only commercially available tools or tools supplied with the unit. Maintenance such as checking safety valves, replacing membrane/adsorbent material, replacing filters, and servicing other parts of the nitrogen generator, using the manufacturer's design installation, operation and maintenance manual, should be possible.

3.9 Calibration

3.9.1 Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment is required. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard and certified by an ISO/IEC 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service provider's accreditation certificate as an ISO/IEC 17025 accredited calibration laboratory should be available.

3.9.2 When the inspection equipment and/or environment is not suitable for labels or stickers, other methods such as etching of control numbers on the measuring device are allowed, provided documentation is maintained on the calibration status of thus equipment.

3.10 Test Facilities

The component and system tests to be conducted shall be specified by the certification agency. The manufacturer shall provide facilities and all properly calibrated instrumentation required to perform the tests deemed necessary by the certification agency as necessary. If other standards are contemplated, they should be forwarded to the certification agency for review and acceptance prior to the generation of the test program. The manufacturer shall also provide personnel to install and operate the oxygen reduction system as necessary. A representative of the certification agency shall witness all the tests and shall receive copies of the data and equipment calibration certificates.

3.11 Tolerances

Tolerances on measurements shall be as described in Appendix B, unless otherwise specified.

4. PERFORMANCE REQUIREMENTS

Since the design of oxygen reduction systems vary a comprehensive absolute standard for the testing of oxygen reduction systems is not possible. The testing of oxygen reduction systems is determined on a case-by-case basis. The performance requirements section is intended to be used as a guideline for the manufacturer as to what type of test program can be expected. Performance requirement testing may be conducted for an individual component, component assembly or as an entire system, as deemed necessary at the sole opinion of the certification agency. Use of certified equipment is strongly encouraged where possible. Documented use of certified components, if evaluated for the same system characteristics, may be sufficient reason to waive the tests described below for those components or sub-assemblies, based on the sole discretion of the certification agency. Upon request for a program, and appropriate system documentation, the certification agency will prepare a customized evaluation program for the specific oxygen reduction system. The manufacturer's design calculations, stated performance requirements, and component functionality and reliability will be verified.

4.1 General Examination and Performance Requirement Test Procedures

Tests described in Section 4.1 are cited throughout the component performance requirements. They are described here in detail, and only referenced in other sections. All testing is conducted at a normal ambient temperature of 70°F ± 5°F (21.1°C ± 2.8°C) unless otherwise specified.

4.1.1 Examination

4.1.1.1 Requirements

The oxygen reduction system shall conform to the manufacturer's drawings and specifications and to certification requirements.

4.1.1.2 Test/Verification

An oxygen reduction system, and all individual system components, representative of the manufacturer's final production equipment to be certified shall be examined and compared to drawings and engineering specifications. It shall be verified that the sample system conforms to the physical and structural requirements described in Section 3, General Requirements.

4.1.2 Valve Seat Leakage

4.1.2.1 Requirements

All valves shall be leak tight when subjected to an upstream hydrostatic test pressure of 120 percent of the maximum system operating pressure.

4.1.2.2 Test/Verification

With the outlet side open to atmosphere, the upstream side of each size valve shall be subjected to hydrostatic pressure of 120 percent of the maximum system operating pressure, to prove the sealing ability. The test pressures shall be maintained for five minutes, with no leakage allowed.

4.1.3 Hydrostatic Strength

4.1.3.1 Requirements

Component bodies shall withstand 2 times the maximum system operating pressure, but not less than 350 psi (24 bar), without rupture, cracking or permanent distortion.

4.1.3.2 Test/Verification

Component bodies of each size shall be subjected to a hydrostatic test pressure of 2 times the maximum system operating pressure, or 350 psi (24 bar), whichever is greater, for five minutes. No rupture, cracking or permanent distortion of the component body is allowed. After this test the component shall be fully operable. Reinforcement of gaskets is permitted, if necessary, during testing.

4.1.4 Operating Pressure

4.1.4.1 Requirements

Operational components of each size shall be tested in an as received condition to determine their pressure operating characteristics and minimum operating pressure.

4.1.4.2 Test/Verification

Components of each size shall be tested in an as received condition five times to determine the pressure operating characteristics and the recommended minimum operating pressure. It shall be determined that each component is capable of operating between 85 and 110 percent of the recommended operating pressure for the component. If there is an adjustment, the component will be tested at the minimum and maximum settings, as recommended by the manufacturer, to determine the operating characteristics. Results shall be included in the installation and operating instructions of the oxygen reduction system.

4.1.5 Durability - Cycling

4.1.5.1 Requirements

At the conclusion of a cycle operational test, excessive component wear or damage shall not occur. The number of cycle operations shall be 500 for instantaneous, single or limited component operations and 100,000 for continuous component operations.

4.1.5.2 Tests/Verification

Prior to the start of the durability test, a sample component shall be hydrostatically pressurized to the maximum system operating pressure. The sample shall then be cycled 500 times if of the instantaneous or single operation type device or 100,000 times if of the continuous operation type device, depending on its normal expected operation, through its full open to close and close to open positions, or its full range of travel.

The pressure upstream of the test component in the closed position shall be equal to the maximum system operating pressure for the duration of this test. The pressure downstream of the test component shall alternate between atmospheric (0 psi, 0 bar) and maximum system operating pressure. During the test, the pressurization rate shall be five to ten cycles per minute. After this test, the component shall be fully operable. The component shall then be disassembled and moving parts shall be visibly examined for signs of excessive wear or damage. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

4.1.6 Extreme Temperatures Operation

4.1.6.1 Requirements

Following the completion of the minimum and maximum operational temperature exposure periods, a sample component shall be evaluated for proper operation with the inlet pressurized, if applicable, to the maximum system operating pressure. The component shall then be visually examined and, if deemed necessary, shall be subjected to any of the appropriate tests as detailed in this standard.

4.1.6.2 Test/Verification

The component shall be conditioned in an environmental chamber set at 40°F (4.4°C), or the manufacturer's published minimum temperature if lower, for a period of 24 hours. Immediately upon removal from the conditioning chamber the component shall be tested for proper function, with the inlet pressurized, if applicable, to the maximum system operating pressure. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

The same component that completed the low temperature exposure test shall be conditioned in an environmental chamber set at 130°F (54.4°C), or the manufacturer's published maximum temperature if higher, for a period of 24 hours. Immediately upon removal from the conditioning chamber, the component shall be tested for proper function, with the inlet pressurized, if applicable, to the maximum system operating pressure. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

4.1.7 Salt Spray Corrosion

4.1.7.1 Requirements

In order to evaluate the resistance to corrosion of the component or component assembly, such as might be experienced by dissimilar materials in contact over long periods of time, the component shall withstand a timed exposure to a salt spray atmosphere. When tested as detailed in Section 4.1.7.2 (Salt Spray - Corrosion), visual evidence of severe deterioration or impending failure of any component shall constitute failure. Corrosion resistant material specifications shall be submitted for review.

4.1.7.2 Test/Verification

One previously untested component, component assembly, or system shall be operated to confirm proper operation prior to exposure.

If necessary, the component shall be filled with deionized water and sealed with a non-reactive material (e.g., plastic cap) so as to prevent the introduction of salt fog into the waterway of the component. The component shall be supported in its intended installation position.

The sample component shall be exposed to salt spray (fog) as specified by ASTM B117, *Standard for Salt Spray (Fog) Testing*, with the exception of the salt solution. The salt solution shall consist of 20 percent (by weight) of common salt (sodium chloride) dissolved in deionized water with a pH between 6.5 and 7.2 and specific gravity from 1.126 and to 1.157.

The sample shall be exposed for a period of 10 days.

Following the exposure to the salt fog, the sample shall be removed from the test chamber and permitted to air dry for a two- to four-day drying period. Following this drying period, the component shall be fully operable under rated operating pressure conditions. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

4.1.8 Vibration Resistance

4.1.8.1 Requirements

The component, or component assemblies, shall withstand vibration without leakage, joint separation, or excessive wear to the sealing components as a result of vibration resistance testing.

4.1.8.2 Tests/Verification

Compliance shall be verified by testing one sample of each component type or size. The component shall be pressurized to the maximum system operating pressure during the entire test and shall be subjected to the vibration sequence of Table 4.1.8. The plane of vibration shall be vertical, both along its longitudinal and latitudinal axis. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

The component, or component assemblies, shall be attached to a mounting plate. The mounting plate shall be attached, by the method of the manufacturer's suggested installation procedure, to the table of a vibration machine so that the component or component assemblies are vibrated vertically. This test shall be conducted with the component, or component assemblies, pressurized. The component, or component assemblies, shall be subjected to the above vibration conditions and continuously monitored for 15 minutes for each condition (75 minutes total). If one or more resonant point(s) are detected, the component, or component assemblies shall be vibrated for the remainder of the test at such frequency or frequencies for a period of time proportionate to the number of resonant frequencies. If resonant point(s) are not detected, the component, or component assemblies, shall be subjected to each vibration condition for a period of 5 hours (25 hours total).

Table 4.1.8 Vibration Conditions

Total Displacement/Stroke		***Frequency***	***Time***
inch	***(mm)***	***Hz***	***Hours***
0.020	(0.51)	28	5
0.040	(1.04)	28	5
0.150	(3.81)	28	5
0.040	(1.04)	18 to 37 (variable)	5
0.070	(1.78)	18 to 37 (variable)	5

4.1.9 Valve Locking/Supervision Ability

4.1.9.1 Requirements

All manual hand operated valves, and mechanisms, shall be provided with a device such that it can be secured and/or locked and/or supervised in the intended installation position.

4.1.9.2 Tests/Verification

Submitted sample valves shall be examined for the provision of a secured and/or locking and/or supervision device, which will be tested during other applicable valve testing requirements for suitability.

4.1.10 Friction Loss Determination

4.1.10.1 Requirements

The construction of any valve shall be such that any obstruction to the passage of nitrogen through the valve body is minimal. With the ball or disc in the full open position, the loss in pressure through the valve shall not exceed 5 percent of the manufacturer's published values at the required maximum system pressure and flow requirements.

4.1.10.2 Tests/Verification

Tests shall be conducted to verify that the friction loss through any valve does not exceed 5 percent of the manufacturer's published values at the maximum system pressure and flow requirements. A sample valve shall be installed between two test pipes of the same nominal diameter as the valve and equipped with piezometer rings. The pressure loss between the piezometer shall be measured for sufficient flow rates to determine the friction loss characteristics of the valve. This test may be waived at the sole discretion of the certification agency if drawing and calculation reviews of the manufacturer's flow data are satisfactory.

4.1.11 Seals and O-rings

4.1.11.1 Requirements

A. Parts shall have a tensile set of the material in the as-received condition of not more than 19 percent. Parts constructed with silicone rubber (rubber having poly-organosiloxane as its characteristic constituent) shall have a tensile strength of not less than 500 psi (34.5 bar) and at least 100 percent ultimate elongation. Parts constructed with material other than silicone rubber shall have a tensile strength of not less than 1500 psi (103.4 bar) and at least 200 percent ultimate elongation. Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with ASTM D 412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension,* Method A, with exceptions as stated in Section 4.1.11.2A.

B. A compression set of the material in the as-received condition shall be not more than 15 percent, as determined in Section 4.1.11.2B.

C. Seals formed using a rubber material or synthetic elastomer shall be subjected to an accelerated aging test, as described in Section 4.1.11.2C. Following the test the material shall have not less than 80 percent of the as-received tensile strength and 50 percent of the as-received ultimate elongation.

4.1.11.2 Tests/Verification

For standard elastomers, the material manufacturer's certificates of compliance verifying the conformance to the performance requirements listed in Section 4.1.11.1 shall be considered acceptable. The test certificates shall demonstrate that the tests were conducted by an ISO *9001, Quality Management Systems*, certified facility, and that the test equipment was calibrated by an ISO 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*, certified agency. Where such certifications are not available, tests of the elostomer shall be conducted, as follows:

A. Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with ASTM D 412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension,* Method A, with the exception that, for tensile set determinations, the elongation shall be maintained for 3 minutes, and the tensile set shall be measured 3 minutes after release of the specimen. The elongation of a specimen for a tensile set determination shall be such that the 1 in. (25 mm) spacing of the benchmarks increases to 3 in. (76 mm). If a specimen breaks outside the benchmarks, or if either the measured tensile strength or ultimate elongation of the specimen is less than the required value, an additional specimen shall be tested, and those results shall be considered final. Results of tests for specimens that break in the curved portion just outside the benchmarks shall be permitted to be accepted if the measured strength and elongation values are within the minimum requirements.

B. Testing shall be conducted in accordance with ASTM D 395, *Standard Test Methods for Rubber Property - Compression Set*, Method B. Type I specimens of the material shall be prepared and then exposed for 22 hours at 70°F ± 2°F (21°C ± 1°C).

C. Specimens shall be prepared in the same manner as for tensile strength and ultimate elongation

tests, except that benchmarks spaced 1 in. (25 mm) apart shall be stamped on the specimens after the test exposure. Specimens shall be tested at 212°F (100°C) for 70 hours in accordance with ASTM D 573, *Standard Test Method for Rubber - Deterioration in an Air Oven*.

4.1.12 Pipe Coupling Gaskets

4.1.12.1 Requirements

One sample gasket of each material under examination shall be subjected to high temperature exposure and a different sample to low temperature exposure. Samples subjected to the temperature exposure tests shall be installed in their intended assemblies during exposure. Following the exposure periods, no leakage shall occur when the assembly is exposed to pneumatic pressure equal to 50 psi (3.5 bar). Additionally, the gasket, after removal from the assembly, shall not crack when squeezed from any two opposite points.

4.1.12.2 Tests/Verifications

Certificates of compliance verifying the performance of the sealing compounds for use at the prescribed temperature and pressure ranges, as well as with nitrogen or air, shall be considered acceptable. The test certificates shall demonstrate that any applicable tests were conducted by an ISO 9001, *Quality Management Systems*, certified facility, and that the test equipment was calibrated by an ISO 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*, certified agency. Where such certifications are not available, tests shall be conducted, as follows:

The high temperature exposure shall consist of 300°F (149°C) oven-air exposure for 45 days. After exposure, the assembly will be allowed to cool to ambient air temperature. It shall then be pneumatically pressurized to 50 psi (3.5 bar) and submerged in water. No leakage shall occur. The gasket, after removal from the assembly, shall be squeezed from two opposite points, and observed for evidence of cracking.

The low temperature exposure shall consist of -40°F (-40°C) air exposure for 4 days. After exposure, the assembly shall be submerged in -40°F (-40°C) antifreeze and pneumatically pressurized to 50 psi (3.5 bar).

No leakage shall occur. The assembly will then be allowed to warm to ambient temperature and disassembled. The gasket, after removal from the assembly, shall be squeezed from two opposite points, and observed for evidence of cracking.

4.1.13 Vacuum Test

4.1.13.1 Requirements

Components subject to vacuum shall withstand a vacuum of 26 in. Hg (654 mm Hg) without collapse, leakage or deterioration of performance characteristics. Following the vacuum test detailed in Section 4.1.13.2, there shall be no deterioration of the performance characteristics, and the samples shall not leak or fail when tested in accordance with Section 4.1.3 (Hydrostatic Strength).

4.1.13.2 Tests/Verification

Samples shall be subjected to a vacuum of 26 in. Hg (654 mm Hg) for a period of 5 minutes, during which time there shall be no collapse or leakage. After completion of the vacuum test, if deemed necessary by visual inspection, deterioration of the performance characteristics shall be evaluated via applicable tests in this standard at the discretion of the certification agency. The sample shall then be subjected to the hydrostatic post-test as detailed in Section 4.1.3 (Hydrostatic Strength).

4.2 Control Panel/Cabinet

The control panel and/or cabinet shall be evaluated and tested for functionality and compatibility with the electrical specifications of the electrically operated equipment associated with the oxygen reduction system, including the actuating components, fire detection automatic releases, etc. The certification examination shall be based on and in accordance with the *Examination Standard for Controllers for Electric Motor Driven and Diesel Engine Driven Fire Pumps* (Class 1321/1323), the *Examination Standard for Fire Alarm Signaling Systems* (Class 3010), and the local protective signaling systems requirements in NFPA 72, *National Fire Alarm Code*.

4.3 Oxygen Detection Devices/Controls

Oxygen detection devices and associated controls shall be certified in order to be applicable for use in the oxygen reduction system. The certification examination shall be in accordance with the *Examination Standard for Toxic Gas and Oxygen Depletion Detectors* (Class 6340).

4.4 Ball Valve (Manual and Pneumatic Actuation)

4.4.1 Ball or Disc Strength

4.4.1.1 Requirements

The valve ball, disc or other sealing mechanism shall withstand exposure to a hydrostatic pressure of 2 times the maximum system operating pressure or 350 psi (24 bar), whichever is greater. During, and at the conclusion of the test, no fracture, permanent distortion, or functional impairment shall occur. After this test the valve shall be fully operable and shall comply with the leakage requirements in Section 4.1.2 (Seat Leakage).

4.4.1.2 Tests/Verification

A sample valve of each size shall be closed. With one side open to atmosphere, the other side shall be hydrostatically pressurized to 2 times the maximum system operating pressure, or 350 psi (24 bar), whichever is greater. The test pressure shall be held for five minutes. For this strength test, special provisions may be made to prevent leakage past the seat. This test shall be repeated for both directions of flow.

4.4.2 Stem Seal

4.4.2.1 Requirement

Stem seals shall not leak when subjected to a hydrostatic pressure equal to the maximum system operating pressure.

4.4.2.2 Tests/Verification

A sample valve of each size with the ball, disc or other sealing mechanism in a partially open position shall be subjected to its maximum system operating pressure for five minutes with no visible stem leakage. Cycling of the ball, disc or other sealing mechanism a minimum of 12 times during this time span shall not cause leakage past the stem seal.

4.4.3 Operating Force Test

4.4.3.1 Requirements

The force to open the valve shall be measured. An internal hydrostatic pressure of 90 psi (6.2 bar), or 50 percent of the maximum system operating pressure, whichever is greater, shall be applied to the valve for various time periods. The force required to open the valve at the end of each time period shall not exceed 50 lb force (222 N) applied to the outermost end of the valve handle. No damage to

any internal components of the valve shall result.

4.4.3.2 Tests/Verification

Sample valves shall be subjected to 90 psi (6.2 bar), or 50 percent of the maximum system operating pressure, whichever is greater, for consecutive periods of one week, two weeks, and one month. Initially, and at the end of each specified period, the force to open the valve shall be measured.

4.4.4 Additional Performance Tests

The following additional tests as referenced elsewhere in this standard are required. In some cases, a test may not be applicable and may be waived or modified depending on the individual component design.

4.1.1 Examination
4.1.2 Valve Seat Leakage
4.1.3 Hydrostatic Strength
4.1.5 Durability-Cycling
4.1.6 Extreme Temperatures Operation
4.1.7 Salt Fog Corrosion
4.1.9 Valve Locking/Supervision Ability
4.1.10 Friction Loss Determination

4.5 Check and Shuttle Valves

4.5.1 Clapper - Poppet Strength

4.5.1.1 Requirements

The valve clapper - poppet shall withstand exposure to a hydrostatic pressure of two times the maximum system operating pressure. During, and at the conclusion of the test, no fracture, permanent distortion, or functional impairment shall occur. After this test, the valve shall be fully operable and shall comply with the leakage requirements in Section 4.1.2.1 (Valve Seat Leakage).

4.5.1.2 Tests/Verification

A hydrostatic pressure of two times the maximum system operating pressure shall be applied to the outlet side of the valve with the inlet of the valve open to atmosphere. The test pressure shall be held for five minutes. During, and at the conclusion of the test, no fracture, permanent distortion or functional impairment shall occur. Full compliance with Sections 4.1.1.2 (Examination) and 4.1.2.1 (Valve Seat Leakage) is required after the clapper - poppet strength test.

4.5.2 Additional Performance Tests

The following additional tests as referenced elsewhere in this Standard are required. In some cases, a test may not be applicable and may be waived or modified depending on the individual component design.

4.1.1 Examination
4.1.2 Valve Seat Leakage
4.1.3 Hydrostatic Strength
4,1,4 Operating Pressure
4.1.5 Durability-Cycling
4.1.6 Extreme Temperatures Operation
4.1.7 Salt Fog Corrosion
4.1.10 Friction Loss Determination
4.1.11 Seals & O-rings

4.6 Fittings and Piping (Including Couplings and Tubing)

All fittings and couplings, and piping and tubing, shall be in accordance with a standard/code that is acceptable to the Authority Having Jurisdiction. Information regarding the fittings and couplings, and piping and tubing, used in the oxygen reduction system shall be submitted to the certification agency. With consideration given to the pressure ratings of the system, these materials will be examined and evaluated for conformance to the materials, hydrostatic strength, and corrosion resistance required by the data sheets referenced above. Manufacturers are strongly encouraged to use certified equipment.

4.6.1 Joining Methods

4.6.1.1 Requirement

All piping and rigid tubing shall be joined by welding, compression or threaded fittings, grooved end couplings, or plain end fittings. All allowable joining methods shall be listed by the manufacturer.

4.6.1.2 Test/Verification

Documentation detailing all allowable joining methods, tools, and equipment shall be submitted by the manufacturer and reviewed to determine necessary examination and testing.

4.6.2 Additional Performance Tests

The following additional tests as referenced elsewhere in this Standard are required. In some cases, a test may not be applicable and may be waived or modified depending on the individual component design.

4.1.3 Hydrostatic Strength
4.1.5 Durability-Cycling
4.1.6 Extreme Temperatures Operation
4.1.7 Salt Fog Corrosion
4.1.8 Vibration Resistance
4.1.11 Seals & O-rings

4.7 Flexible Hose

4.7.1 Fatigue Test

4.7.1.1 Requirements

Flexible hose with threaded end fittings shall be subject to 3,000 cycles of repeated flexing at a rate of 5 to 30 cycles/min, in a direction parallel with the axis of the end fittings. There shall be no deterioration of the flexible hose or its performance characteristics. Following the cycling test, the flexible hose with threaded end fittings shall comply with the hydrostatic test requirements in Section 4.1.3 (Hydrostatic Strength).

4.7.1.2 Test/Verification

The fatigue test shall be conducted in accordance with Section 8.3 of ISO Standard 10380:2003, *Pipework - Corrugated metal hoses and hose assemblies*. A minimum of two samples of flexible hose with fittings, of the longest size submitted for Approval, shall be subjected to the required number of cycles (in Section 4.16.1.1) of repeated flexing at a rate of 5 to 30 cycles/min in a direction parallel with the axis of the end fittings while pressurized to their rated working pressure, as shown in Figure C-1. The sample hose shall be mounted in a U shape, with the end fittings at a horizontal distance from each other of twice the minimum dynamic bend radius of the hose, r, as defined by the manufacturer's literature. One end of the sample shall be held in a fixed position and the other end shall be flexed in the vertical plane a distance of four times the nominal diameter of the nozzle fittings above and below the position of the fixed end, for a total vertical movement of eight times the nominal

diameter. After completion of the required cycles, if deemed necessary by visual inspection, deterioration of the performance characteristics shall be evaluated via the test detailed in Section 4.1.10 (Friction Loss Determination). The samples shall then be subjected to the hydrostatic post-test, as detailed in Section 4.1.3 (Hydrostatic Strength).

4.7.2 Additional Performance Tests

The following additional tests as referenced elsewhere in this Standard are required. In some cases, a test may not be applicable and may be waived or modified depending on the individual component design.

4.1.3 Hydrostatic Strength
4.1.7 Salt Spray - Corrosion
4.1.8 Vibration Resistance
4.1.10 Friction Loss Determination

4. 8 Manual Releases

4.8.1 Manual Release Specifications

4.8.1.1 Requirement

Manual release devices shall operate properly with applied forces no greater than 40 lb (178 N), linear movement no more than 14 in. (36 cm), torque no greater than 40 lbf•ft (54 N•m), nor rotational movement of over 270 degrees when configured with the most adverse arrangement allowed by the manufacturer's installation instructions. Components shall exhibit strength equal to or greater than 1.5 times the required operating force.

4.8.1.2 Test/Verification

A minimum of one sample of each device shall be tested. Properly calibrated force gauges, torque meters, and measuring tapes shall be used to measure operational requirements. Tests shall be conducted under the most adverse condition with respect to normal system pressure, if applicable. Devices using flexible mechanical cable actuation shall be tested with the most adverse cable routing (maximum length of cables, number of changes of direction, etc.). No impairment of operation shall be allowed.

After measurement of the required actuating force or torque, 1.5 times that value shall be applied to the device. No failure or impairment of subsequent operation shall result.

4.9 Pneumatic Actuator

4.9.1 Pressure Requirement Activation Test

4.9.1.1 Requirement

One sample actuator of each type and size shall be subjected to a pressure requirement activation test. The time and pressure to operate the valve with the pneumatic actuator will be recorded and the pressure requirement verified to the specifications of the actuator.

4.9.1.2 Test/Verification

The actuator shall be tested for the pressure required to fully operate the actuator while the device to which the actuator is attached is pressurized to 100 percent of the maximum system operating pressure.

4.9.2 Additional Performance Tests

The following additional tests as referenced elsewhere in this Standard are required. In some cases, a test may not be applicable and may be waived or modified depending on the individual component design.

4.1.3 Hydrostatic Strength
4.1.5 Durability-Cycling
4.1.6 Extreme Temperatures Operation
4.1.7 Salt Spray - Corrosion
4.1.8 Vibration Resistance
4.1.11 Seals & O-rings

4.10 Pressure Gauges

4.10.1 General

Properly calibrated and appropriately selected instrumentation, such as a dead weight tester or a gauge comparator, shall be used for testing, and shall be operated in conformity with their manufacturer's instructions. Generally, a minimum of one unused gauge should be used for each test described herein. Exact sample size and allocation will be determined at the sole discretion of the certification agency.

4.10.2 Accuracy

4.10.2.1 Requirements

Gauge accuracy shall be checked against a properly calibrated dead weight tester, or a gauge comparator, at a minimum of five points spanning the full range of the scale.

4.10.2.2 Test/Verification

Readings shall be within plus or minus two percent of the full-scale of the actual pressure over the center third of the scale and within plus or minus three percent over the remaining two-thirds, after gentle tapping of the gauge to eliminate frictional effects.

4.10.3 Hysteresis

4.10.3.1 Requirements

The required accuracy level per Section 4.10.2 shall be verified in both increasing and decreasing pressure readings.

4.10.3.2 Test/Verification

The five points checked during the accuracy test shall be checked in both ascending and descending order in succession, to evaluate hysteresis error.

4.10.4 Overpressure

4.10.4.1 Requirements

The gauge accuracy shall remain within the limits specified in Section 4.10.2 (Accuracy) after it has been overpressurized.

4.10.4.2 Test/Verification

A pressure equal to 150 percent of the full-scale range of the gauge shall be applied to the gauge by hydrostatic means for a period of five seconds. The accuracy test shall then be rerun. If the

manufacturer specifies that the gauge is suitable for a higher level of overpressure, this test shall be conducted using that level.

4.10.5 Hydrostatic Strength

4.10.5.1 Requirements

The gauge shall be subjected to a hydrostatic pressure equal to 150 percent of the full-scale range, or 350 psi (24 bar), whichever is greater, for a period of five minutes without rupture. The gauge shall then be pressurized to failure. No broken or ruptured part shall be thrown with such violence as to constitute a hazard to personnel. Generally, no debris shall be thrown outside of a 6 ft (1.8 m) cylindrical volume centered on the vertical centerline of the gauge.

4.10.5.2 Test/Verification

The gauge shall be subjected to a hydrostatic pressure equal to 150 percent of the full-scale range, or 350 psi (24 bar), whichever is greater, for a period of five minutes. The pressure shall then be increased until failure occurs. Failure shall be defined as inability to contain pressure.

4.10.6 Vibration

4.10.6.1 Requirements

The gauge accuracy shall remain within the limits specified in Section 4.10.2 (Accuracy) after completion of the vibration sequence.

4.10.6.2 Test/Verification

The gauge shall be connected to a manifold and pressurized to approximately 50 percent of its full-scale range with air as the pressurizing medium. The gauge and manifold assembly shall be mounted on a vibration test machine and subjected to vibration along the vertical centerline of the gauge. The vibration sequence shall be as described in Section 4.1.8 (Vibration Resistance).

4.10.7 Wear

4.10.7.1 Requirements

The gauge accuracy shall remain within the limits specified in Section 4.10.2 (Accuracy) after completion of 100,000 pressure cycles.

4.10.7.2 Test/Verification

The gauge shall be operated 100,000 times between zero and approximately half its maximum scale range by hydrostatic means, at a frequency of approximately 1 hertz.

4.10.8 Salt Spray Corrosion

4.10.8.1 Requirements

After the Salt Spray Corrosion exposure per Section 4.1.7.1, the gauge shall operate freely and reliably. Exposures to other atmospheres may be required to further evaluate the corrosion resistance of certain materials.

4.10.8.2 Test/Verification

The gauge shall have its inlet sealed and be subjected to the test outlined in 4.1.7.2 (Salt Spray Corrosion). Following the exposure period, the gauge shall be permitted to dry in room atmosphere

for two to four days in an upright position. The gauge shall then be disassembled and examined for evidence of stress corrosion cracking of its parts. If no stress corrosion cracking is evident, the gauge should be cleaned as necessary, reassembled, and operated.

4.11 Pressure Relief Devices

4.11.1 Diaphragm Strength

4.11.1.1 Requirements

Any diaphragm supplied shall withstand a strength test without tear, rupture, or other failure.

4.11.1.2 Test/Verification

Diaphragms in either the pressure relief valve or the associated devices shall be subjected to a hydrostatic pressure of two times the maximum system operating pressure for five minutes. During, and at the conclusion of, this test, there shall be no evidence of leakage or functional impairment.

4.11.2 Disc Assembly, or Equivalent Component/Disc Strength

4.11.2.1 Requirements

The valve disc/plug assembly or equivalent component shall withstand strength testing without fracture, permanent distortion, or functional impairment.

4.11.2.2 Tests/Verification

With the inlet open to atmosphere, a hydrostatic pressure of two times the maximum system operating shall be applied to the outlet of the pressure relief valve. This pressure shall be maintained for five minutes. During and at the conclusion of this test, no leakage, fracture, permanent distortion, or functional impairment shall occur.

4.11.3 Operating Pressure

4.11.3.1 Requirements

Operational components of each size shall be tested in an as received condition to determine their pressure operating characteristics and minimum operating pressure. After the valve has been pressurized to the rated set pressure, and the opening pressure has been verified, it shall reseat itself leak tight at no less than 90 percent of the operating pressure. The pressure at which the plug/disc opens shall be within ± 5 percent of the valve set pressure.

4.11.3.2 Test/Verification

The pressure at which the seat/disc opens shall be measured and recorded. The inlet pressure shall then be increased to at least 102 percent of the recorded operating pressure to ensure a clear opening. The pressure shall be reduced slowly until the valve reseats and seals. The reseating pressure shall be measured and recorded. This test shall be repeated three times, with all three readings being satisfactory.

4.11.4 Durability - Cycling

4.11.4.1 Requirements

At the conclusion of the cycle operational test, the spring of a pressure control device shall show no signs of fatigue failure, and the test valve shall meet the requirements of Sections 4.1.1.1 (Examination) and 4.1.2.1 (Valve Seat Leakage).

4.11.4.2 Tests/Verification

The sample shall be subjected to fluctuating pressure, from zero to the maximum system operating pressure, in the direction to exercise the spring, at a rate of no more than 10 cycles per minute for a total of 20,000 cycles. Following this test, the component shall be visually examined for signs of excessive wear or damage. Post testing shall include Sections 4.1.1 (Examination) and 4.1.2.2 (Valve Seat Leakage).

4.11.5 Additional Performance Tests

The following additional tests as referenced elsewhere in this Standard are required. In some cases, a test may not be applicable and may be waived or modified depending on the individual component design.

4.1.1 Examination
4.1.2 Valve Seat Leakage
4.1.3 Hydrostatic Strength
4.1.6 Extreme Temperatures Operation
4.1.7 Salt Spray - Corrosion
4.1.8 Vibration Resistance
4.1.9 Valve Locking/Supervision Ability
4.1.10 Friction Loss Determination
4.1.11 Seals & O-rings

4.12 Pressure Switches

4.12.1 Dielectric Strength

4.12.1.1 Requirement

Electrical components shall be capable of withstanding an applied voltage between all terminals provided for external connections and ground. There shall be no arcing or breakdown, and components shall continue to function properly subsequent to this test.

4.12.1.2 Test/Verification

A test voltage of 1000 V, AC, plus twice the rated operating voltage, shall be applied between electrical terminals and ground for a period of one minute.

Exception: For operating voltages of 54 V or less the test voltage shall be 500 V, AC.

4.12.2 Additional Performance Requirements

The following additional tests as referenced elsewhere in this Standard are required. In some cases, a test may not be applicable and may be waived or modified depending on the individual component design.

4.1.3 Hydrostatic Strength
4.1.4 Operating Pressure
4.1.5 Durability-Cycling
4.1.6 Extreme Temperatures Operation
4.1.7 Salt Spray - Corrosion
4.1.8 Vibration Resistance

4.13 Solenoid Valves

4.13.1 Equipment Assembly Ratings (Voltage Variation)

4.13.1.1 Requirement

A sample solenoid valve of each voltage rating shall operate properly over a primary source voltage range of 85 to 110 percent of the rated voltage while at the maximum and minimum specified installation temperatures. There shall be no change in operating characteristics, or failure to respond to limit alarms and trip points.

4.13.1.2 Test/Verification

A sample solenoid valve shall be conditioned to the minimum specified installation temperature for 16 hours. While still at that temperature, the sample shall be mounted in the position of normal use, and shall be subjected to a source voltage range from 85 to 110 percent of the rated voltage with the associated pressure for the minimum temperature applied to the valve seat. Activation voltage and current shall be documented.

The sample shall then be conditioned to the maximum specified installation temperature for 16 hours. While still at that temperature, the sample shall be mounted in the position of normal use and shall be subjected to a source voltage range from 85 to 110 percent of the rated voltage with the associated pressure for the maximum temperature applied to the valve seat. Activation voltage and current shall be documented.

4.13.2 Dielectric Strength

4.13.2.1 Requirement

Electrical components shall be capable of withstanding an applied voltage between all terminals provided for external connections and ground. There shall be no arcing or breakdown, and components shall continue to function properly subsequent to this test.

4.13.2.2 Test/Verification

A test voltage of 1000 V, AC, plus twice the rated operating voltage, shall be applied between electrical terminals and ground.

Exception: For operating voltages of 54 V or less the test voltage shall be 500 V, AC.

4.13.3 Additional Performance Tests

The following additional tests as referenced elsewhere in this Standard are required. In some cases, a test may not be applicable and may be waived or modified depending on the individual component design.

4.1.1 Examination
4.1.2 Valve Seat Leakage
4.1.3 Hydrostatic Strength
4.1.4 Operating Pressure
4.1.5 Durability-Cycling
4.1.6 Extreme Temperatures Operation
4.1.7 Salt Spray - Corrosion
4.1.8 Vibration Resistance
4.1.9 Valve Locking/Supervision Ability
4.1.10 Friction Loss Determination
4.1.11 Seals & O-rings

4.14 Filters/Strainers

4.14.1 Hydrostatic Pressure Test

4.14.1.1 Requirement

A filter/strainer body shall be able to withstand a hydrostatic pressure equivalent to 2 times the maximum system operating pressure, but not less than 350 psi (24 bar), without rupture, cracking or permanent distortion.

4.14.1.2 Test/Verification

A sample filter/strainer body shall be subjected to a hydrostatic test pressure of 2 times the maximum system operating pressure, but not less than 350 psi (24 bar), for a duration of five minutes. Subsequently, the strainer perforations shall be plugged and the strainer inlet side shall be subjected to a hydrostatic test pressure equal to 120 percent of the maximum system operating pressure, but not less than 250 psi (17.2 bar), for a duration of five minutes.

4.14.3 Additional Performance Tests (As Applicable)

The following additional tests as referenced elsewhere in this Standard are required. In some cases, a test may not be applicable and may be waived or modified depending on the individual component design.

4.1.1 Examination
4.1.7 Salt Spray - Corrosion

4.15 Nitrogen Generator Assemblies

4.15.1 Nitrogen Generation Capacity

4.15.1.1 Requirements

Nitrogen generator assemblies shall be capable of producing nitrogen at a concentration of at least 90%. The flow rate of nitrogen generated shall be -0/+5 percent of the manufacturer's published capacity.

4.15.1.2 Test/Verification

The nitrogen generator shall be placed in a temperature controlled environment maintained at 68 ± 10°F (20 ± 5°C). The unit shall draw supply air from this environment. The output of the nitrogen generator shall be independently vented to the exterior of the test environment.

Start and run the nitrogen generator and pipe the output through an air flow meter to atmosphere. Allow the system to stabilize by running for a minimum of 5 minutes. After the stabilization period, measure the output flow, concentration of nitrogen in the output stream, and pressure. Record the flow for a minimum of 10 minutes. The nitrogen concentration shall be a minimum of 90% for the duration of the test. Calculation of the nitrogen concentration over the duration of the test period shall consider the operation type of the nitrogen generator (e.g., constant or cyclical).

4.15.2 System Endurance

4.15.2.1 Requirement

The nitrogen generator assembly, including all components and assemblies necessary in the operation of the nitrogen generator, shall operate at an acceleration factor of 4 in excess of normal operating conditions for a period of 336 hours without mechanical failure nor any appreciable change in operating characteristics (generation and capacity).

4.15.2.2 Test/Verification

Sample nitrogen generator assemblies, including all components and assemblies necessary in the operation of the nitrogen generator, shall be installed and operated according to the manufacturer's instructions. The assembly shall be operated at an acceleration factor of 4 in excess of normal operating conditions for a period of 336 hours at maximum capacity with all electrically powered components connected to their appropriate power supply requirements. Normal operating conditions, on/off or cycling between towers for pressure swing absorption type systems, of the assembly shall be based on the systems typical timing sequence per the manufacturer's documentation. If an acceleration factor of 4 is not practical for the assembly a lower acceleration factor can be used and the duration of the test extended proportionally. Assemblies shall run continuously over the entire duration of the test period. The outlet of the nitrogen generator shall be piped through and air flow meter to atmosphere. The output flow, concentration of nitrogen in the output stream, and pressure shall be measured for the duration of the test at minimum every ten minutes.

4.16 Air Compressors

4.16.1 Documentation Requirements

Documentation shall be provided by the manufacturer on the safety and design standard(s) the air compressors used in the oxygen reduction systems have been designed and manufactured according to. The safety and design standards shall be relevant to the local requirements were the oxygen reduction systems will be installed.

4.16.2 Air Compressor Performance

4.16.2.1 Requirements

The compressor shall develop its rated capacity and pressure as specified by the manufacturer within -0/+5 percent.

4.16.2.2 Test/Verification

A minimum of one sample compressor of each type and rated capacity shall be tested. The compressor shall be operated under normal conditions and the flow shall be measured with an airflow meter.

4.16.3 Hydrostatic Strength

4.16.3.1 Requirements

No rupture, cracking, or permanent distortion of any part of the compressor shall be observed when the pump is hydrostatically tested at the required pressure for five minutes.

4.16.3.2 Tests/Verification

A sample of each model shall be hydrostatically tested to a pressure greater than or equal to 1.5 times the maximum operating pressure. The test pressure shall be maintained for five minutes.

4.17 Vacuum Pumps

4.17.1 Performance Test

4.17.1.1 Requirements

The time required for the vacuum pump to reach the maximum set pressure, as stated by the oxygen reduction system manufacturer, shall not exceed the manufacturer's published data and shall be suitable for the design requirements for pressure vessels the vacuum pumps are utilized with in the oxygen reduction system.

4.17.1.2 Test/Verification

A minimum of one sample vacuum pump of each type and rated capacity shall be tested. The vacuum pump shall be connected to the maximum size pressure vessel as stated by the oxygen reduction system manufacturer. The initial pressure of the pressure vessel shall be at normal operating conditions. The vacuum pump shall be turned on and the time needed to reach the maximum set vacuum pressure shall be recorded. Vacuum pumps used during nitrogen generator assembly testing in 4.15.1 Nitrogen Generation Capacity do not need to undergo an additional performance test as specified in this section as their performance can be verified during Test 4.15.1 under normal operation of the nitrogen generator assembly.

4.18 Pressure Vessels

4.18.1 Documentation Review

4.18.1.1 Requirements

Documentation shall be submitted to verify that the manufacturer of the pressure vessels is authorized to fabricate a pressure vessel meeting the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, or equivalent.

4.18.1.2 Test/Verification

Documentation shall be reviewed to verify that the manufacturer of the pressure vessel is performing the inspection and tests that apply to the pressure vessel, as described ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1, or equivalent.

If the system is to be installed outside the United States, the pressure vessel shall comply with the regulations of the country in which it is to be installed.

4.19 System Design Calculation Method

4.19.1 Calculation Method

The calculation method used to determine the required nitrogen flow rate from the oxygen reduction system shall be submitted to the certification agency for review and acceptance.

4.19.2 Computer Program

If a computer program calculation tool is used to design systems, the computer calculation program and design manual shall be submitted to conduct sample calculations to verify its accuracy. The program and hand calculations will be reviewed for verification of the design criteria as submitted by the manufacturer.

4.20 Design, Installation, Operation and Maintenance Manual

Design, installation, operation, and maintenance instruction manual(s) shall be submitted for review. An English version of this manual should be submitted to the certification agency.

The review by the certification agency shall verify compliance to the requirements of the applicable standard/code being utilized for the design, installation and maintenance of the oxygen reduction systems. The manual(s) should also reflect those requirements that are applicable to oxygen reduction systems, as outlined in the following sections.

- The manual(s) shall provide a description and operating details of all equipment associated with the oxygen reduction system by part and/or model number.
- The manual(s) shall specify the system design criteria used to provide the required oxygen reduced air flow rate to the protected space including all design variables and calculations. Example design calculations shall be provided. The manual(s) shall specify the size, schedule, supporting method, and material for all piping, tubing, and fittings.

- The manual(s) shall specify all critical system valves and identify the proper positioning of the valves.
- The installation instructions shall be clear and concise and specify all limitations and restrictions. Diagrams of typical system installations shall be included for typical hazards.
- Any variations of the system shall be discussed in detail, including the limitations and restrictions of each system. The manual(s) shall clearly identify which configurations are certified.
- The manual(s) shall specify all discharge nozzle(s) criteria including, but not limited to, maximum ceiling heights, spacing and arrangement.
- The manual(s) shall clearly identify all requirements for detection and actuation.
- The manual(s) shall state the ambient operating temperature range of the oxygen reduction system. If the nozzles and delivery system have different temperature ranges, these shall be specifically noted.
- The minimum and maximum operating pressures of the system and its sub-systems shall be clearly specified at ambient 70°F (21°C) conditions.
- The manual(s) shall specify the required acceptance and commissioning procedures, as described in Section 4.21, this includes a sample test form for Acceptance Testing.
- The manual(s) shall specify the required inspection and maintenance for the system. In addition, the manual(s) shall specify the frequency and method of the inspections and maintenance.
- The manual(s) shall identify either a date or revision to the manual, as well as a designation number, and shall be provided with a means by which the user can readily identify if the manual(s) are of the current revision. These items are to be identified on each page of the manual.
- The manual(s) shall identify the manufacturer or private labeler, address, contact and service information.
- If there are references to other manuals, these publications should be included or summarized so that information needed for proper installation is available.

4.21 System Acceptance and Commissioning Documentation

4.21.1 All oxygen reduction systems shall successfully meet all system acceptance and commissioning procedures and should be documented with copies to the system owner and manufacturer (at a minimum).

4.21.2 All acceptance and commissioning procedures shall be reviewed by the certification agency. Changes requested by the certification agency may be mandatory prior to the granting of certification.

4.21.3 Acceptance and commissioning testing should include the following, at a minimum, and shall be documented in the manufacturer's design, installation, operation, and maintenance manual(s):

4.21.3.1 Acceptance procedures shall be in accordance with a standard/code that is acceptable to the Authority Having Jurisdiction, and the equivalent national code of the country of use.

4.21.3.2 An appropriate Authority Having Jurisdiction representative should be given advance notice of such testing and be present for commissioning of the system.

4.21.3.3 A trained manufacturer's representative should be present to properly test and reset the system following the acceptance test.

4.21.3.4 Test all operating parts of the system to verify their proper function. In addition to direct system operating components, this shall include the operation of dampers, ventilation shutoffs, fuel shutoffs, door closures, and other electrical supplies to the protected area.

4.21.3.5 Inspect, clean, and replace filters and strainers if necessary.

4.21.3.6 The use of personal protective equipment (PPE), including eye and hearing protection, protective clothing, respirators, and other PPE, should be required, as applicable. In the event that personnel cannot witness the discharge as a result of safety concerns, consideration should be given to the use of video cameras to verify the discharge.

4.22 Additional Tests

Additional tests, including performance tests of any accessories, may be required depending on design features, results of any tests, or material application, at the sole discretion of the certification agency.

Unexplainable failures shall not be permitted. A re-test shall only be acceptable at the sole discretion of the certification agency with adequate technical justification of the conditions and reasons for failure.

5. OPERATIONS REQUIREMENTS

5.1 Demonstrated Quality Control Program

5.1.1 A quality assurance program is required to assure that subsequent products produced by the manufacturer shall present the same quality and reliability as the specific products examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests and may be documented in the certification report.
- Continued conformance to this standard is verified by the certifier's surveillance program.
- Quality of performance is determined by field performance and by periodic re-examination and testing.

5.1.2 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- existence of corporate quality assurance guidelines;
- incoming quality assurance, including testing;
- in-process quality assurance, including testing;
- final inspection and tests;
- equipment calibration;
- drawing and change control;
- packaging and shipping; and
- handling and disposition of non-conforming materials.

5.1.3 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

5.1.4 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, for a minimum period of two years from the date of manufacture.

5.1.5 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the certification report, may be required to be reported to, and authorized by the certification agency prior to implementation for production.
- Records of all revisions to all certified products shall be maintained.

5.2 Surveillance Audit Program

5.2.1 An audit of the manufacturing facility may be part of the certification agencies surveillance requirements to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to ensure a uniform product consistent with that which was tested and certified.

5.2.2 Certified products or services shall be produced or provided at, or provided from, location(s) disclosed as part of the certification examination. Manufacture of products bearing a certification mark is not permitted at any other location prior to disclosure to the certification agency.

5.3 Installation Inspections

Field installation inspections may be conducted to review an installation. The inspections are conducted to assess ease of application, and conformance to written specifications. When more than one application technique is used, one or all may be inspected at the sole discretion of the certification agency.

5.4 Manufacturer's Responsibilities

5.4.1 The manufacturer shall notify the certification agency of changes in product construction, design, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation of such changes.

5.4.2 Where all or part of the quality control has been subcontracted, the manufacturer shall, at a minimum, conduct sufficient oversight audits to verify the continued application of the required controls.

5.4.3 The manufacturer shall provide complete instructions for the recharge and usage of systems. The instructions shall provide specific quality assurance procedures on the use of calibrated equipment, such as scales, pressure gauges, and other necessary critical equipment, in the recharging a system.

5.4.4 The manufacturer, or assigned representative, shall perform a documented system acceptance check and operational test in accordance with a standard/code that is acceptable to the Authority Having Jurisdiction. A copy of the results should be left on site and with the owner of the oxygen reduction system, at a minimum.

5.5 Manufacturing and Production Tests

5.5.1 Test Requirement No. 1 - System Operation

The manufacturer shall performance test 100 percent of production oxygen reduction systems, recording both flow capacity and quality (percent Nitrogen), as well as satisfying the appropriate national or international standard(s) used during manufacturing. Due to the size of these systems this test may be done onsite following installation if completed by the manufacturer of the Oxygen Reduction System.

5.5.2 Test Requirement No. 2 - Equipment Seat Leakage

The manufacturer shall test 100 percent of production system equipment, as applicable, for seat leakage at the maximum system operating pressure for a minimum of 15 seconds with no leakage allowed.

5.5.3 Test Requirement No. 3 - Equipment Hydrostatic Strength

The manufacturer shall test 100 percent of production system equipment, as applicable, to 2 times the maximum system operating pressure, but not less than a pressure of 350 psi (24 bar). The pressure shall be held for a minimum of 30 seconds with no evidence of body leakage or distortion. Following the body leakage test, all applicable equipment shall be operated with no evidence of sticking or binding.

6. Bibliography

ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*
ISO 9000, *Quality Management Principles*

APPENDIX A:

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APPENDIX B: TOLERANCES

Unless otherwise stated, the following tolerances shall apply:

Angle:	± 2°
Frequency (Hz):	± 5 percent of value
Length:	± 5 percent of value
Volume:	± 5 percent of value
Rotation:	± 1 RPM
Pressure:	± 5 percent of value
Temperature:	± 5 percent of value
Time:	+ 5/- 0 seconds + 0.1/- 0 minutes + 0.1/- 0 hours + 0.25/- 0 days

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of 68°F ± 18°F (20°C ± 10°C).

APPENDIX C: FIGURE C-1

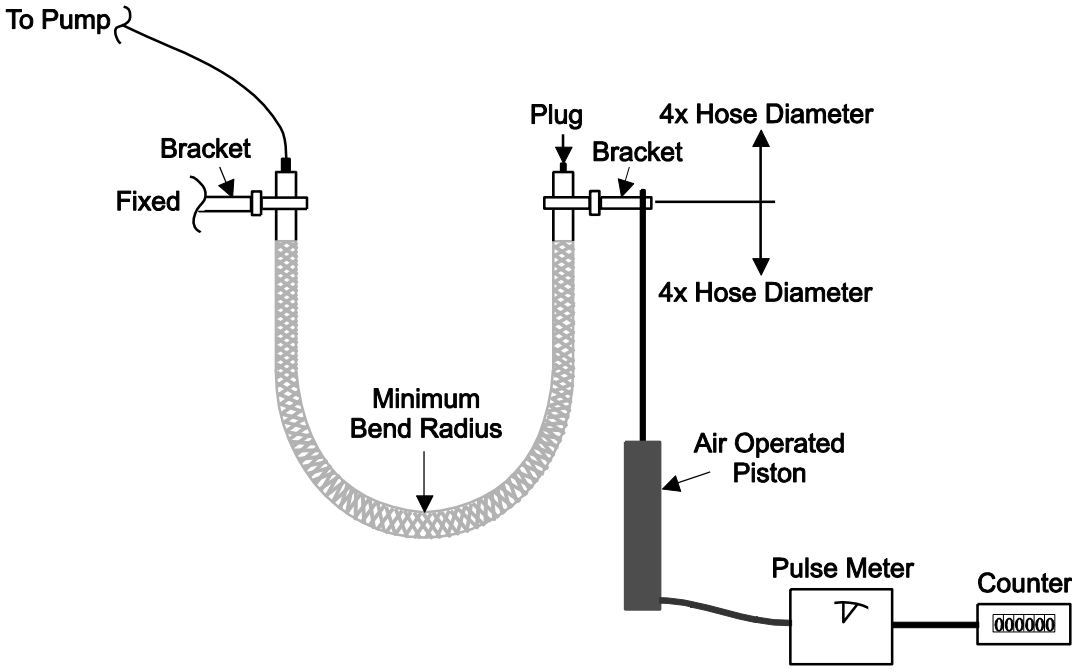

Figure C-1. Test Apparatus for Fatigue Test

APPENDIX D: SAMPLE CERTIFICATION LISTINGS

Certification listings for oxygen reduction systems shall include:

- Manufacturer's designation for system.
- System model identifications and associated capacities including maximum flow rate and operating pressure.
- Minimum and maximum installation temperatures.
- Design, installation, operation, and maintenance manual identification by title, part number, issue date, and revision level.
- Design software title, part number, and version level (if applicable).
- Any limitations to the certification or exceptions to the listed manuals, software, or other documents.
- Installation provisions.