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DEPARTMENT OF DEFENSE DESIGN CRITERIA STANDARD

AIRCRAFT CREW BREATHING SYSTEMS USING ON-BOARD OXYGEN GENERATING SYSTEM (OBOGS)



AMSC N/A

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FOREWORD

1. This standard is approved for use by the Department of the Air Force and is available for use by all Departments and Agencies of the Department of Defense.
2. This standard covers the design, integration, certification, and sustainment/maintenance requirements for aircraft crew breathing systems using an On-Board Oxygen Generating System (OBOGS). The intent is to provide a minimum set of criteria to ensure the safety and effectiveness of these flight critical systems. This standard shall be cited in acquisition contracts and shall be directive upon the contractor. Compliance with the standard is mandatory.
3. Comments, suggestions, or questions on this document should be addressed to ENGINEERING.STANDARDS@US.AF.MIL. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at <https://assist.dla.mil>.

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1. SCOPE**1.1 Scope.**

This standard establishes the minimum design criteria for an aircraft crew breathing system using an On-Board Oxygen Generating System (OBOGS). The criteria address an OBOGS which produces aviator's breathing gas by the Pressure Swing Adsorption (PSA) process. The source air for the OBOGS is assumed breathable quality air from engine bleed air or aircraft environmental control system (ECS). Integration, certification, and sustainment/maintenance are also addressed. This standard will be cited in acquisition contracts and will be directive upon the contractor. Appendices A, B, and D will be mandatory. Appendix C identifies Government testing required to verify/validate a breathing system to satisfy the requirements in Section 5. Appendix E is not mandatory.

1.2 Background.

Military aircraft capable of flying at altitudes where the aircrew must be supplied with supplemental oxygen have historically been equipped with either stored gaseous oxygen or liquid oxygen systems. OBOGS can produce enriched oxygen breathing gas during flight by concentrating oxygen from engine bleed air or environmental control system air. The benefits of a breathing system using OBOGS are: elimination of liquid oxygen storage and support equipment; elimination of potential operational vulnerabilities of a base LOX storage facility; purchasing LOX at a deployed location; elimination of potential safety issues associated with aircraft LOX servicing; potential long-term economy achieved by reduction in the use of liquid oxygen; and the elimination of instances where the aircrew oxygen supply has been a limiting factor in aircraft range. Although several methods for concentrating oxygen from ambient air have been investigated, the technology which appears most applicable for military tactical and strategic aircraft is based on concentrating oxygen by pressure swing adsorption using a synthetic molecular sieve. For continuous production of breathing gas the OBOGS employs a process of cyclic pressure swings in two or more molecular sieve canisters. An oxygen rich product gas is delivered by the molecular sieve canisters and routed to the aircrew through distribution lines and breathing regulators. A small portion of the product gas is used to purge the depressurized canisters of nitrogen, water vapor, and contaminants. This vented gas is referred to as OBOGS waste gas. The waste gas (containing about 17% oxygen, 82% nitrogen, and 1% argon) is vented overboard the aircraft. Adsorption and desorption times are on the order of several seconds, and are regulated by electronics and control valves. Both oxygen and argon are concentrated because these molecules are similar in size and are non-polar. Nitrogen molecules have some polarity, and therefore, can be preferentially adsorbed and separated. The maximum oxygen concentration obtainable from an oxygen generator under ideal operating conditions is approximately 95 percent with the balance mostly argon. Product gas oxygen concentration is dependent on various operating parameters, such as, inlet air pressure, cabin altitude, and demand flow. The oxygen concentration typically varies between 40% and 95% depending on the specific operating conditions. Some oxygen generators use control algorithms to vary the product gas oxygen concentration based on cabin altitude. Some systems use dilution regulators that mix cabin air with OBOGS product gas to obtain the desired oxygen concentration in the breathing gas.

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2. APPLICABLE DOCUMENTS**2.1 General.**

The documents listed in this section are specified in sections 3, 4, or 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this standard, whether or not they are listed.

2.2 Government documents.**2.2.1 Specifications, standards, and handbooks.**

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-DTL-7905 Cylinders, Steel, Compressed Gas, Non-Shatterable, Seamless, 1800 PSI and 2100 PSI

MIL-PRF-27210 Oxygen, Aviator's Breathing, Liquid and Gas

(Copies of these documents are available online at <http://quicksearch.dla.mil> or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094.)

3. DEFINITIONS

The following acronyms are applicable to this standard.

ABO	Aviator's Breathing Oxygen
ATPD	Ambient Temperature and Pressure Dry
CDR	Critical Design Review
CSMU	Crash Survivable Memory Unit
ECS	Environmental Control System
G _z	Acceleration in the z-axis
Hz	Hertz
in Wg	Inches of Water Gauge
IPT	Integrated Product Team
L	Liter
Min	Minute
mm Hg	Millimeters of Mercury
OBOGS	On-Board Oxygen Generating System*
PBA	Pressure Breathing for Altitude
PBG	Pressure Breathing for G
PDR	Preliminary Design Review

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PF	Protection Factor
PSA	Pressure Swing Adsorption
psi	Pounds Per Square Inch
psig	Pounds Per Square Inch Gauge
Sec	Second
T	Temperature

* OBOGS refers to the oxygen concentrator or oxygen generator.

4. GENERAL REQUIREMENTS

The criteria established in this military standard are applicable to an aircraft crew breathing system using OBOGS based on pressure swing adsorption (PSA) technology. The air delivered to the OBOGS inlet port shall be breathable quality air (see 5.8) and be from the same air stream as the air delivered to the aircraft cabin. The crew shall be continuously supplied with breathable quality oxygen during all phases of aircraft operation whether on the ground or in-flight, including any periods of ECS and/or engine bleed air anomalies or shutdown. The intent of these criteria is to address normal and emergency operations.

4.1 System criticality.

An aircrew breathing system with OBOGS shall be managed by the aircraft program office as a safety critical system throughout the aircraft's lifecycle. Design criteria are provided in Section 5. Additional requirements are provided in Appendix A for Integration Readiness, Appendix B for Contractor Verification and Validation, Appendix C for Government Verification and Validation, and Appendix D for Sustainment/Maintenance.

5. DETAILED REQUIREMENTS

5.1 Concentration of oxygen and flow rate of the inspired gas.

The minimum concentration of oxygen in the mixed inspired gas:

- a. Should maintain an alveolar oxygen tension of at least 100 mm Hg (i.e., sea level equivalency). Assume the partial pressure of water vapor in the lungs is 47 mm Hg.
- b. Should maintain blood oxygen saturation above 95%.
- c. Should prevent the alveolar oxygen tension from falling below 30 mm Hg on rapid decompression of the cabin when at least 99.5% oxygen conforming to MIL-PRF-27210 is delivered to the mask automatically after the decompression.

Oxygen concentration and pressure breathing for altitude (PBA) for a fighter aircraft with a ceiling of 50,000 feet and a standard 5 psi cabin pressurization schedule shall conform to Figure 1. The minimum oxygen concentration curve maintains the alveolar oxygen tension at 100 mm Hg. The step in the minimum oxygen concentration curve combined with the pressure breathing schedule and the volume of inspired gas prior to 99.5% oxygen being delivered to the mask cavity are key aspects to ensure at least 30 mm Hg alveolar oxygen tension is maintained after a rapid decompression. An oxygen warning threshold shall be placed at or above the minimum oxygen concentration curve.

Adjustments to the oxygen concentration and PBA schedules will occur for aircraft with different pressurization schedules and ceiling altitudes. NOTE: For aircraft not using the standard 5 psi

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cabin pressurization schedule or having a maximum ceiling other than 50,000 feet, the aircraft program office can contact 711 HPW (see 6.3) for assistance.

In order to reduce the incidence of acceleration atelectasis and/or delayed otitic barotrauma, the concentration of oxygen in the inspired gas shall not exceed 60% at cabin altitudes between 0 and 15,000 feet or 75% at a cabin altitude of 20,000 feet, except momentary excursions 10% higher in oxygen concentration percentage shall be permitted. Between 15,000 and 20,000 feet the maximum oxygen concentration shall increase in a linear manner. Above 20,000 feet the oxygen concentration can rise above 75% (see Figure 1).

For fighter and trainer aircraft the oxygen concentration delivered by the breathing system using OBOGS shall be above the oxygen warning threshold at steady-state breathing gas flows from 1) 7 to 60 liters/minute/crew member Ambient Temperature and Pressure Dry (ATPD) from Sea Level to a cabin altitude of 7,999 feet; and 2) 7 to 80 liters/minute/crew member (ATPD) from a cabin altitude of 8,000 feet to the aircraft maximum ceiling. (NOTE: If the breathing system using OBOGS will supply oxygen to a demist system, for example as part of a chemical defense ensemble, the steady-state flow should be increased accordingly.) The system shall be capable of achieving peak inspiratory and expiratory flows of up to 4.3 liters/sec ATPD (258 L/min ATPD) (see Table I).

For bomber and cargo aircraft the oxygen concentration delivered by the breathing system using OBOGS shall be above the oxygen warning threshold at steady-state breathing gas flows from 7 to 50 liters/minute/crew member Ambient Temperature and Pressure Dry (ATPD) from Sea Level to the aircraft maximum ceiling. (NOTE: If the breathing system using OBOGS will supply oxygen to a demist system, for example as part of a chemical defense ensemble, the steady-state flow should be increased accordingly.) The system shall be capable of achieving peak inspiratory and expiratory flows of up to 2.5 liters/sec ATPD (150 L/min ATPD) (see Table I).

5.2 Emergency oxygen.

a. Upon decompression of the cabin and cabin altitude exceeding 25,000 feet, the concentration of oxygen in the gas delivered to the mask cavity shall rise to at least 99.5% when no more than 0.6 liter ATPD of gas (one breath) has been inspired. The gas, conforming to MIL-PRF-27210, shall be supplied automatically from an oxygen breathing regulator, without pilot initiation and for as long as the cabin altitude exceeds 25,000 feet. There shall be no delay in this activation. The pilot shall be provided alerts when: 1) 99.5% oxygen is activated and 2) the quantity required for a safe ejection is remaining. The OBOGS oxygen shall be prevented from flowing to the aircrew when the emergency oxygen is activated. Constant flow emergency oxygen systems shall not be used.

b. If the aircraft is equipped with an ejection seat(s), upon ejection the pilot shall be provided with 99.5% oxygen delivered to the mask cavity when no more than 0.6 liter ATPD of gas (one breath) has been inspired. Sufficient oxygen shall be provided for descent to an altitude where oxygen is no longer required.

c. Oxygen shall be provided to the pilot in case of smoke and fumes in the cockpit. The oxygen shall be manually activated by the pilot and shall be free from smoke and fume contamination.

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5.3 Oxygen mask internal volume.

The volume of expired gas which can be re-inspired from the breathing system shall not exceed 0.2 liter ATPD.

5.4 Mask cavity pressures.

The minimum and maximum pressures and the total change of pressure during the respiratory cycle shall not exceed the limits in Table I. Above 38,000 feet the mask pressure shall be as noted on Figure 1 when peak flows up to 1.5 liters/sec (90 liters/min) are applied to the system. In general, mask pressure is dependent on the performance of the oxygen mask and breathing regulator. The breathing system design shall include a flow indicator or "blinker" easily visible to the crewmember. As a minimum, an on-aircraft Ground Level, press-to-test, oxygen mask fit check shall be accomplished at 16 ± 2.0 in Wg.

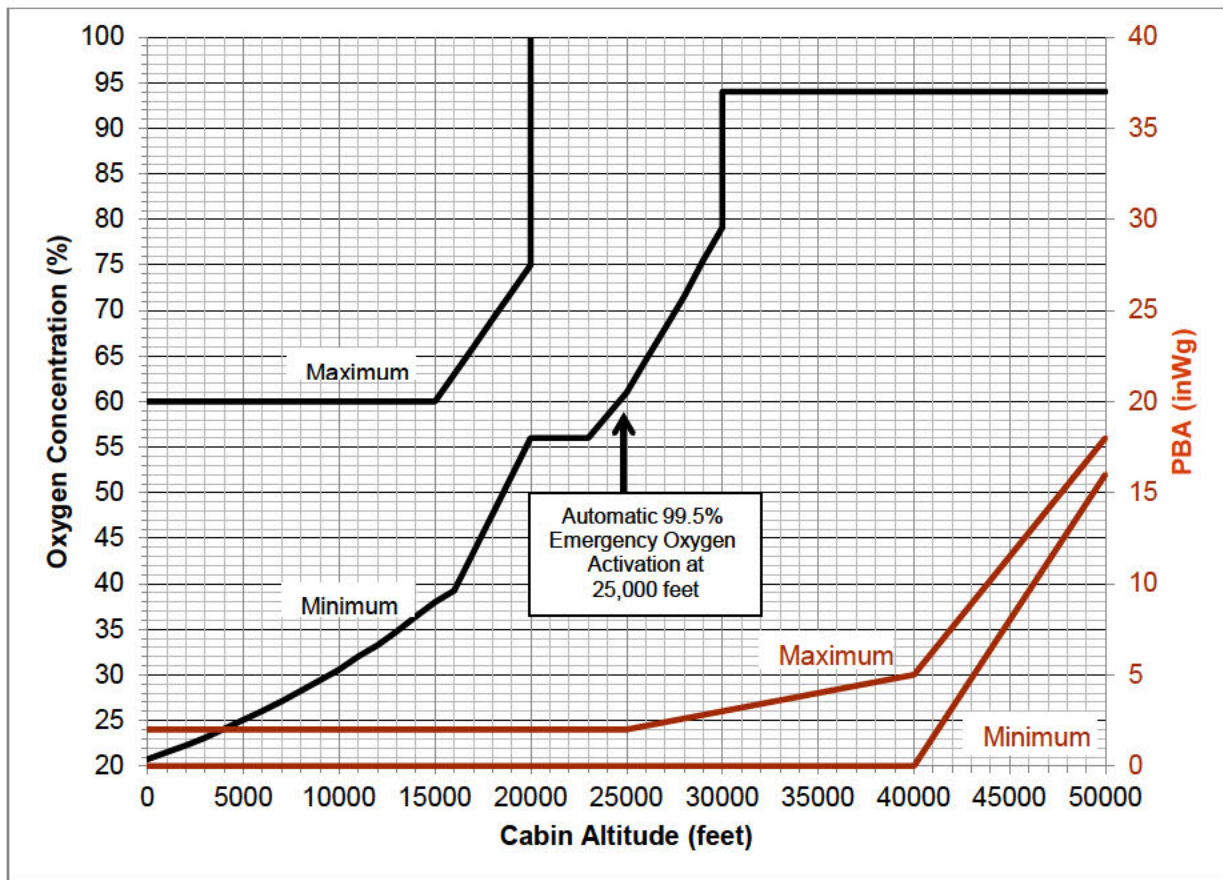


FIGURE 1. Oxygen concentrations and regulator pressure schedule for an aircraft flying to 50,000 feet with a 5 psi differential pressure cabin.

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TABLE I. Inspiratory and expiratory mask pressures.

Peak Inspiratory and Expiratory Flows (liter ATPD/min)	Mask Cavity Pressure (in Wg)		
	Minimum	Limits to Maximum	Maximum Swing
	Without Safety Pressure		
30 [*]	-1.5	+1.5	2.0
90 [*]	-2.2	+2.6	3.4
150 [*]	-4.5	+4.0	7.0
200 [^]	-7.6	+6.0	12.0
258 [#]	-7.6	+6.0	12.0
	With Safety Pressure		
30 [*]	+0.1	+3.0	2.0
90 [*]	-0.8	+3.8	3.4
150 [*]	-3.5	+5.0	7.0
200 [^]	-7.0	+6.6	12.0
258 [#]	-7.0	+6.6	12.0
* Cabin altitude from Sea Level to 38,000 feet.			
^ Cabin altitude from Sea Level to 7,999 feet.			
# Cabin altitude from 8,000 feet to 38,000 feet.			

5.5 Pressure breathing for aircraft capable of up to +9 G_z.

PBG mask pressures shall be defined as shown on Figure 2. The approach shall have a fail-safe design to prevent PBG without G-suit inflation, a failure mode which could cause a physiological incident.

5.6 G suit pressures.

Trouser pressures during G shall be as defined on Figure 3. The air supply for the trousers shall be provided by the aircraft environmental control system or bleed air system.

5.7 Expansion of trapped gas on rapid decompression.

The pressure in the mask cavity during and immediately after a rapid decompression (1 second) shall not exceed the ambient cabin pressure plus 41 mm Hg (22 inches of Water gauge) for longer than 100 milliseconds. The mask pressure shall never exceed 70 mm Hg (37.5 inches of Water gauge) above the ambient pressure. Lessons learned: Unmanned testing generally gives the "worst case" mask pressure spikes. During manned testing the pressure spikes are lower.

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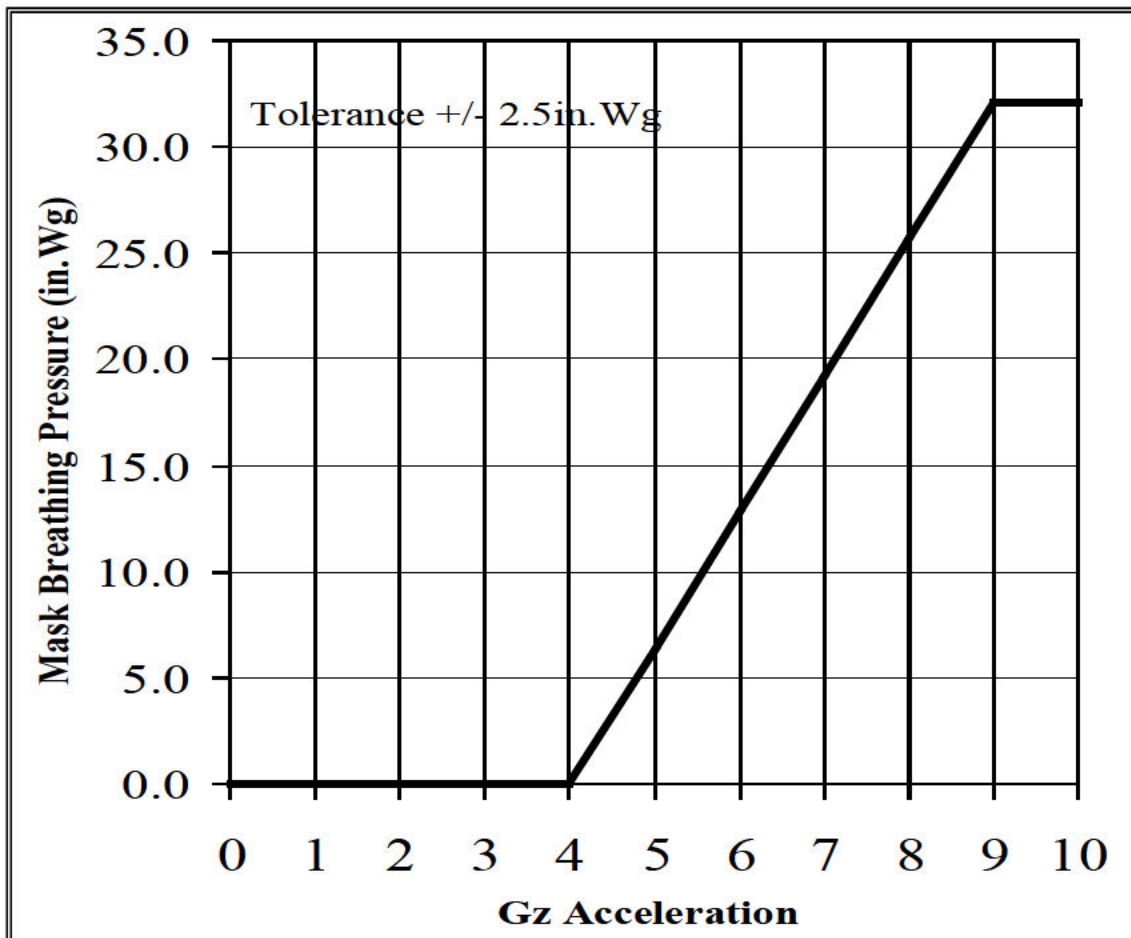


FIGURE 2. Mask breathing pressure schedule with G.

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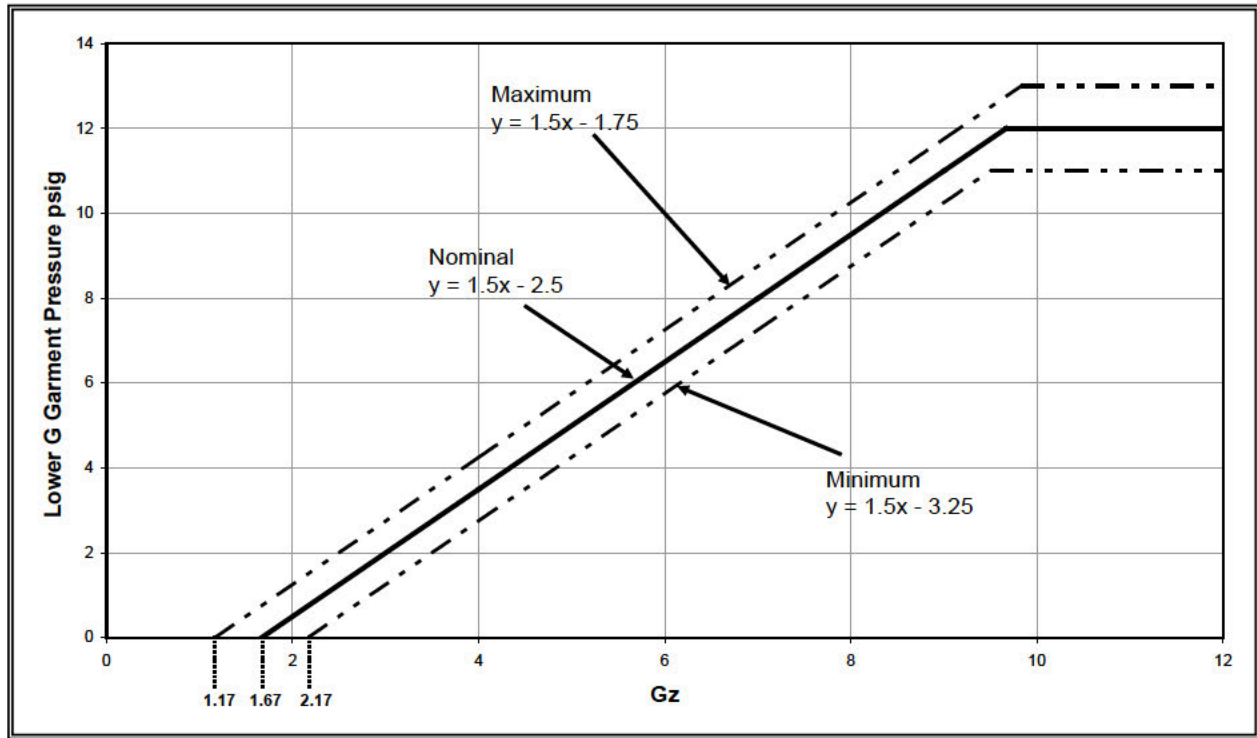


FIGURE 3. G trouser pressure schedule with G.

5.8 OBOGS inlet air contaminant limits.

OBOGS inlet air shall be breathable quality air and the air supplied shall be from the same source used to supply air to the aircraft cabin. OBOGS inlet air contaminant limits are specified in Table II. For new contaminants discovered during sample analysis, the contractor shall identify and report the contaminants to the Government. The aircraft program office can contact 711 HPW (see 6.3) for assistance.

The breathing system and air source/s design shall consider conditions where the aircraft engine/s might ingest jet engine exhaust gas during ground or shipboard operations; or fuel spillage during aerial refueling. Also, the breathing system and air source/s design shall consider failure modes where aircraft fluids (hydraulic fluid, coolant fluid, etc.) might leak into the OBOGS source air. The aircraft program office and aircraft manufacturer shall assess the level of potential contamination.

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TABLE II. OBOGS inlet air maximum allowable contaminant concentrations.

SUBSTANCE	MAXIMUM ALLOWABLE CONCENTRATION (ppmv)
Acrolein	0.1
Aldehydes	1
Carbon Dioxide	5000
Carbon Monoxide	50
Ethanol	1000
Fluorine (as HF)	0.1
Hydrogen Peroxide	1
Methyl Alcohol	200
Methyl Bromide	20
Nitrogen Oxides	5
Ozone	0.1
Oil Breakdown Products	1
Total Remaining Hydrocarbons	250
Vapor Phase Water	+75°F Dew Point Maximum
Nickel	0.5 mg/m ³
Cobalt	0.1 mg/m ³
Submicron Particles	0.5 mg/m ³

5.9 OBOGS product gas contaminant limits.

The gaseous contaminants in the aircrew breathing gas shall not exceed the limits noted in Table III. For new contaminants discovered during sample analysis, the contractor shall identify and report the contaminants to the Government. The aircraft program office can contact 711 HPW (see 6.3) for assistance.

5.10 OBOGS over-board waste gas line

The OBOGS exhaust gas shall be vented. There are two venting options: internal and external. External venting is preferred. Regardless of method used, difference in pressure at the OBOGS exhaust port and the ambient aircraft pressure shall be less than ± 0.03 psi. If vented internally, the OBOGS waste gas shall not be allowed to enter the aircraft cabin. OBOGS waste gas shall be prevented from back flowing into the ECS or bleed air system during low pressure or loss of pressure conditions.

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TABLE III. Breathing gas maximum allowable contaminant concentration.

SUBSTANCE	MAXIMUM ALLOWABLE CONCENTRATION (ppmv)
Acrolein	0.05
Aldehydes	0.2
Aromatics	0.1
Carbon Dioxide	500
Carbon Monoxide	10
Ethanol	500
Fluorine (as HF)	0.05
Halogenated Solvents	0.2
Hydrogen Peroxide	0.5
Methyl Alcohol	100
Methyl Bromide	1
Nitrogen Oxides	0.1
Ozone	0.05
Total Remaining Hydrocarbons	25
Unsaturated Hydrocarbons (alkenes, alkynes)	0.2
Nickel	0.125 mg/m ³
Cobalt	0.025 mg/m ³
Oil and Particulate Matter	0.2 mg/m ³

5.11 OBOGS inlet and outlet pressures and flows.

a. The OBOGS shall have an inlet plenum and/or a secondary air supply line to stabilize air flow and pressure during engine bleed air and ECS pressure transients, pressure fluctuations, rapid pressure drop-offs, and pressure spikes. Only the OBOGS shall be connected to the plenum and/or secondary air supply line. ECS and engine bleed air pressures tend to vary significantly. These wide variations can degrade OBOGS performance. The plenum and/or the secondary air supply will improve the stability of the OBOGS inlet air flow and pressure.

b. The OBOGS shall have an outlet plenum with sufficient volume to meet the aircrew member/s dynamic breathing requirements. The plenum shall be located between the OBOGS and the aircrew breathing regulator(s). The plenum shall ensure an adequate volume of breathing gas is available at high breathing demands (noted in Table I). Also, this volume will allow mixing of the breathing gas and reduce oxygen concentration fluctuations. The volume of the breathing system piping shall not be used in the calculation of plenum volume.

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c. The plenums shall have a void volume. Molecular sieve filled plenums shall not be used.

5.12 OBOGS inlet and outlet check valves.

a. A check valve shall be placed on the primary air supply line. If a secondary air supply line is used, a separate check valve shall be installed on this line. If a plenum is used, the plenum shall be installed downstream of the check valve/s. The inlet side check valve/s shall have a pressure drop of less than 2 psi at the maximum flow condition. The check valve/s will ensure reverse flow does not occur at the OBOGS inlet.

b. A check valve shall be placed at the OBOGS outlet and upstream of the OBOGS outlet plenum to prevent back flow of product oxygen gas. The check valve shall have a pressure drop of less than 1 psi at the maximum flow condition.

5.13 OBOGS pressure sensors.

a. OBOGS inlet air pressure is the most critical parameter for proper OBOGS operation and performance. The OBOGS shall have a pressure sensor to continuously monitor the real time air inlet pressure. The pressure sensor shall be located downstream of the OBOGS inlet filter and upstream of the OBOGS pressure reducing valve or pressure regulating device. The OBOGS inlet filter will ensure the pressure sensor is not subjected to excessive moisture and particulates.

b. The OBOGS shall have a pressure sensor to continuously monitor the OBOGS real time outlet pressure.

5.14 OBOGS monitoring, warning and recording.

a. An oxygen monitor shall monitor the OBOGS outlet gas. An oxygen warning threshold shall be set at or above the minimum oxygen concentration curve.

b. The OBOGS shall have built-in test features to check the oxygen monitor, electronic circuits, and molecular sieve canister valve operation during system start-up. The pilot shall be immediately notified of any faults.

c. Operating parameters (listed below) shall be stored within the OBOGS or on-board the aircraft for the last ten (10) hours of operation, as a minimum. The sample rate shall be at least ten (10) samples/second for OBOGS Inlet Air Pressure, OBOGS Outlet Pressure, and OBOGS Outlet Oxygen Concentration; and at least two (2) samples/second for other parameters. The data shall be capable of convenient download at field locations. The operating parameters (listed below) shall be sent to the aircraft Crash Survivable Memory Unit (CSMU), if the aircraft is equipped with a CSMU. The intent is to have OBOGS operational data available in the event of a physiological incident or aircraft crash.

d. Operating parameters:

- (1) OBOGS Inlet Air Pressure
- (2) OBOGS Outlet Pressure
- (3) OBOGS Outlet Oxygen Concentration

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- (4) OBOGS Electronic Faults
- (5) Discrete Low Oxygen and Low Inlet Pressure Warnings
- (6) Cabin Altitude
- (7) Backup Oxygen Activation
- (8) Emergency Oxygen Activation
- (9) Aircraft Time Clock

5.15 Backup oxygen.

Backup oxygen shall be provided to the pilot when the OBOGS cannot supply breathing oxygen. The backup oxygen shall be at least 90% oxygen (i.e., 90 - 95% OBOGS product gas or 99.5% Aviators' Breathing Oxygen). The backup oxygen shall be connected downstream of the OBOGS outlet check valve and upstream of the aircrew regulator. The intent is to ensure low oxygen content gas does not enter the OBOGS product gas line. The backup oxygen supply may be contained within a separate system or integrated within the OBOGS. The pilot shall be alerted when the backup oxygen is activated. The breathing gas flow transition between OBOGS to backup oxygen shall be seamless to the pilot.

a. The backup oxygen shall automatically activate if the oxygen concentration at the OBOGS outlet drops below the oxygen warning threshold. There shall be no delay in these activations. The backup oxygen shall flow for an additional 30 seconds after the OBOGS outlet oxygen concentration rises above the oxygen warning threshold. The additional 30 seconds is needed for the OBOGS to reestablish steady-state operation.

b. While in-flight the backup oxygen shall automatically activate if at any time the pressure at the OBOGS inlet pressure sensor drops below the OBOGS in-flight minimum inlet air pressure specification. While on the ground the backup oxygen shall automatically activate if at any time the pressure at the OBOGS inlet pressure sensor drops below the OBOGS ground minimum inlet air pressure specification. There shall be no delay in these activations. The backup oxygen shall flow for an additional 30 seconds after OBOGS inlet pressure exceeds the minimum OBOGS inlet air pressure specification.

5.16 Type of molecular sieve.

If a molecular sieve other than 13X with sodium cations is used, the OBOGS supplier shall disclose the specific molecular sieve and provide data verifying system performance equal to or better than 13X molecular sieve with sodium cations. Also, the OBOGS supplier shall provide data verifying no adverse effect on human subjects when breathing from a system using the specific type of molecular sieve. This information shall be submitted to the aircraft program office for review and approval.

5.17 Prevention of molecular sieve breakdown.

Prior to loading the molecular sieve into the canisters residual molecular sieve crystals shall be removed. The molecular sieve pellets shall be secured within the canister to prevent movement and breakdown due to pressurization cycles and vibration.

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5.18 OBOGS particulate and coalescing filter.

- a. OBOGS shall have an inlet and coalescing filter capable of capturing particles with a size of 1 micron or greater, and venting any liquid or aerosolized water.
- b. OBOGS shall have an outlet particulate filter capable of capturing particles with a size of 0.4 micron or greater.

5.19 Breathing gas temperature.

The breathing gas to the aircrew mask during normal ground and flight operations shall be within +10 °F and -20 °F of the ambient aircraft cabin temperature.

5.20 Breathing gas odor.

During normal operations the breathing gas shall have no discernible or objectionable odor.

5.21 Oxygen pressure vessels.

Pressure vessels used to store high pressure oxygen (above 500 psi) shall have a shatter-proof design and conform to MIL-DTL-7905.

5.22 Prevention of liquid water entry into OBOGS.

The OBOGS air inlet shall be protected from entrained liquid water. Liquid water will significantly degrade OBOGS performance.

- a. The air source should have a water separator and/or a water drain valve. The valve should not activate after the OBOGS completes power-up and the valve should not activate in-flight. The design should consider cold weather operations and the possibility of freezing.
- b. The OBOGS inlet air connection should not be located at a low point in the air supply piping.

5.23 Government verification and validation of crew breathing system using OBOGS.

Appendix C identifies testing required to verify/validate a breathing system using OBOGS and satisfying the requirements in this section.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use.

This standard is intended to provide a minimum set of requirements to ensure the safety and effectiveness of aircraft breathing systems using OBOGS. Where applicable, the requirements are mandatory.

6.2 Acquisition requirements.

Acquisition documents should specify the following:

- a. Title, number, and date of this standard.

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6.3 Pressurization schedules and ceiling altitudes assistance.

For aircraft not using the standard 5 psi cabin pressurization schedule or having a maximum ceiling other than 50,000 feet, the aircraft program office can contact 711 HPW/RHCP, DSN 798-3573 or 937-938-3573 for assistance.

6.4 Patent notice.

The Government has a royalty-free license under the following listed patent for the benefit of manufacturers of the item either for the Government or for use in equipment to be delivered to the Government.

US4916630

6.5 Subject term (key word) listing.

- Aerosolized water
- Air contaminants
- Aircraft ceiling altitude
- Breathing system
- Cabin altitude
- Chemical contaminants
- Crash survivable memory unit
- Decompression
- Emergency oxygen system
- Expiratory mask pressure
- Inspiratory mask pressure
- Molecular sieve
- Oxygen System

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APPENDIX A**OBOGS INTEGRATION READINESS****A.1 SCOPE****A.1.1 Scope.**

This appendix details the approach for OBOGS integration readiness. Integration readiness is a critical process for ensuring a safe and effective breathing system using OBOGS is realized. This appendix is a mandatory part of this standard. The information contained herein is intended for compliance.

A.2 Government documents.**A.2.1 Specifications, standards, and handbooks for reference.**

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE STANDARDS

MIL-E-5007 Engine, Aircraft, Turbojet and Turbofan, General Specification For

(Copies of this document are available online at <http://quicksearch.dla.mil> or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094.)

A.3 MEETINGS**A.3.1 Design meetings.**

The contractor shall conduct periodic meetings between the Life Support System, Environmental Control System, and Engine design teams during the aircraft development process to evaluate the OBOGS and its air source (i.e. environmental control system and engine bleed air) interfaces. As a minimum, the meetings shall evaluate the interface characteristics noted below.

a. OBOGS Minimum In-Flight Inlet Air Pressure and Conformance to the OBOGS Specification.

b. OBOGS Minimum Ground Inlet Air Pressure and Conformance to the OBOGS Specification.

c. OBOGS Maximum Inlet Air Temperature and Conformance to the OBOGS Specification.

d. OBOGS Inlet Air Pressure While Other Aircraft Subsystems Are Demanding Air Flow at Their Maximum Rate and Conformance to the OBOGS Specification.

e. Engine Bleed Air Quality and Conformance to MIL-E-5007, 3.1.2.11.3.

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- f. OBOGS Inlet Air Quality and Conformance to 5.8 and Table II.
- g. Predicted Frequency and Potential Causes for In-Flight Loss of OBOGS Inlet Air Pressure.
- h. Predicted Frequency and Potential Causes for In-Flight OBOGS Inlet Air Low Pressure Transients (i.e., Below the OBOGS Minimum Inlet Air Pressure Specification).

A.4 REVIEWS

A.4.1 Engineering technical reviews.

The contractor shall present documentation supporting OBOGS integration readiness at the Life Support System, Environmental Control System, and Engine Preliminary Design Reviews and Critical Design Reviews. As a minimum, the contractor shall evaluate OBOGS integration readiness based on the interface characteristics noted in A.3.1. Any conditions causing an OBOGS out-of-specification condition shall be identified and analyzed. Approaches for mitigating any out-of-specification condition shall be evaluated. The contractor shall provide engine bleed air and ECS modeling results and/or data as evidence the OBOGS inlet pressure and temperature interface conditions will be met throughout ground and flight operations. The contractor shall submit an OBOGS Integration Readiness Document summarizing the integration readiness analysis, results, and conclusions. The document shall be submitted to the Government for review and approval.

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APPENDIX B**CONTRACTOR VERIFICATION AND VALIDATION OF CREW BREATHING SYSTEM USING OBOGS****B.1 SCOPE****B.1.1 Scope.**

This appendix details the methods of compliance and substantiating data of compliance that apply to crew breathing systems using OBOGS. This appendix is a mandatory part of this standard. The information contained herein is intended for compliance. The intent was to identify a minimum set of required and suggested tests but not every possible test. Aircraft program offices and contractors may need to add other tests, as necessary. Government Verification/Validation is addressed in Appendix C.

B.2 APPLICABLE DOCUMENTS**B.2.1 Government documents.****B.2.1.1 Specifications, standards, and handbooks for reference.**

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-810 Environmental Engineering Considerations and Laboratory Tests

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-516 Airworthiness Certification Criteria

(Copies of this document are available online at <http://quicksearch.dla.mil> or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094.)

B.3 METHODS OF COMPLIANCE**B.3.1 System hazard and failure analysis.**

The contractor shall conduct an oxygen system safety analysis of the compatibility of the life support system components, including OBOGS, to ensure the components are compatible with oxygen at the pressures and temperatures of use. The system safety analysis shall include a fire hazard analysis and failure mode effects criticality analysis.

B.3.2 Qualification testing.

The contractor shall conduct qualification testing of the breathing system components, including OBOGS, to include environmental testing, acceleration, vibration, and electromagnetic interference testing. The testing shall comply with MIL-STD-810 but may be tailored to the specific operating conditions. The system components shall pass qualification testing prior to initiation of safe-to-fly testing.

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B.3.3 Airworthiness certification.

The contractor shall provide documentation that demonstrates compliance with oxygen system airworthiness criteria in MIL-HDBK-516.

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APPENDIX C**GOVERNMENT VERIFICATION AND VALIDATION OF CREW BREATHING SYSTEM USING OBOGS****C.1 SCOPE****C.1.1 Scope.**

This appendix details the methods of compliance and substantiating data of compliance that apply to crew breathing systems using OBOGS. This appendix is a mandatory part of this standard. The information contained herein is intended for compliance. The intent was to identify a minimum set of required and suggested tests but not every possible test. Aircraft program offices and contractors may need to add other tests, as necessary. Contractor Verification/Validation is addressed in Appendix B.

C.2 METHODS OF COMPLIANCE**C.2.1 OBOGS chemical contaminant testing.**

As a minimum, the OBOGS shall be tested with carbon dioxide and carbon monoxide at the level noted in Table II. Testing shall be accomplished at nominal and minimum specification inlet air pressures; minimum and maximum OBOGS product gas flow rates; room temperature; and ground level. The OBOGS product gas shall not exceed the levels in Table III. Protection factors (PF) shall be calculated, where $PF = \text{Contaminant Inlet Concentration (ppmv)} / \text{Contaminant Outlet Concentration (ppmv)}$. The goal is to establish baseline protection factor data.

C.2.2 Safe-to-fly testing.

a. The breathing system using OBOGS shall undergo safe-to-fly testing prior to aircraft flight testing. Safe-to-fly testing shall be conducted by a Government agency. The test agency shall prepare the test plan, including success criteria. Prior to testing the test agency shall coordinate the test plan with the contractor and the aircraft program office. Testing shall be conducted at OBOGS nominal inlet air pressure and minimum inlet air pressure specification at altitudes from ground level to the maximum ceiling of the aircraft.

b. Unmanned testing phases shall, as a minimum, include steady-state flow testing at minimum and maximum flows, dynamic flow testing at peak flows (as noted in Table C-1), rapid ascent and descent, full range of G_z levels, rapid decompression, and the various OBOGS operating modes. Unmanned testing shall be accomplished at various altitudes while the OBOGS inlet pressure is transitioned from 1) nominal inlet pressure to loss of inlet pressure; 2) highest expected inlet air pressure to the minimum specification inlet air pressure and back; and 3) nominal inlet pressure to loss of inlet pressure and back using durations of 5, 10, 15, 20, 25, and 30 seconds.

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TABLE C-I. Breathing simulator profiles.

Profile	Peak Flow (liters/min)	Breathing Rate (breaths/min)	Breath Volume (liters)
1	17	8	0.5
2	90	50	0.6
3	125	40	1.0
4	150	25	2.0
5	188	24	2.5
6	258	50	1.5

c. Human system testing shall be accomplished when any of the criteria below are met:

(1) The aircraft operating conditions during normal or failure mode operation place the crew in an extreme environment (aircraft altitude, Gz exposure, etc.) where physiological protection requirements are not well understood. These conditions shall include (but are not limited to):

- (a) The aircraft operating ceiling is above 50,000 feet.
- (b) The aircraft operating conditions during normal operations exceed +7.5 Gz.

(2) During unmanned testing pressures at the mask deviate from Table 1 when simulating normal or emergency operating conditions.

(3) New or novel technology is being introduced into the breathing system.

(4) If directed by the aircraft program office.

d. Human testing of the breathing system, if required, shall address the full range of normal cabin altitudes, rapid decompression altitudes, G_z levels, and emergency operating conditions.

e. Where a modification of a previously certified breathing system is proposed that may impact system safety and effectiveness, the system shall be re-tested. A tailored testing approach may be applied.

C.2.3 Safe-to-fly letter.

The test agency shall prepare a safe-to-fly letter and final report (if required) discussing the test data/results, pass/fail criteria results, and significant findings. The letter shall state the recommendation for system maximum ceiling altitude and maximum G level; and document any anomalies found.

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C.2.4 Flight testing.

A minimum of 100 flight hours of dedicated or piggy-back flight testing shall be conducted. A qualified Government agency shall conduct the flight testing. Twenty-five (25) flight hours shall be conducted after an aircraft cold soak. Cold soaking shall be defined as aircraft exposure to below 32 °F for 12 hours prior to flight. The breathing system and air source/s (i.e., ECS and secondary air source, if used) shall be instrumented. Samples of the OBOGS inlet air and breathing gas shall be collected during ground engine runs. As a minimum, ten (10) samples shall be collected and analyzed from each location. The results shall be compared with Table II and Table III. After the 100 hours of dedicated or piggy-back flight testing a surveillance program shall be initiated to review OBOGS stored flight data on randomly selected flights to assess system performance. If anomalies are found, they shall be reported. The goal is to ensure the breathing system and the air source/s maintains acceptable performance under flight conditions.

C.2.5 Flight test letter.

The flight testing agency shall prepare a flight test letter and final report (if required). The flight test letter shall summarize the results of the flight testing program, assess breathing system performance and suitability, and document any anomalies. If anomalies are noted, the flight test agency shall assess the impact on system safety and effectiveness when the aircraft is used in its planned mission role.

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APPENDIX D**PROCEDURES FOR SUSTAINMENT/MAINTENANCE FOR BREATHING SYSTEM
USING OBOGS****D.1 SCOPE****D.1.1 Scope.**

This appendix details the sustainment/maintenance procedures for a breathing system using OBOGS. The intent is to include this information in the applicable aircraft technical orders. This appendix is a mandatory part of this standard. The information contained herein is intended for compliance.

D.2 APPLICABLE DOCUMENTS**D.2.1 Other Government documents, drawings, and publications.**

The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

U.S. PATENT & TRADEMARK OFFICE (USPTO)

US4916630

Bed Tester for Molecular Sieve Oxygen Concentrator

(Copies of this document are available online at <http://www.uspto.gov/> or from Mail Stop Document Services, Director of the U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria VA 22313-1450.)

D.3 PROCEDURES

Where applicable, the contractor shall incorporate the information below in the aircraft technical orders.

D.3.1 Periodic breathing system performance checks.

The performance check shall be based on 1) a built-in design feature which periodically and automatically assesses oxygen performance and trending in-flight during defined operating conditions; or 2) a ground test performed periodically to assess the oxygen concentration delivered at the aircrew oxygen mask connector. When using the ground test the flow at the aircrew oxygen mask connector shall be adjusted to the minimum specification steady-state outlet flow and the OBOGS shall be run using the engine/s, auxiliary power unit (APU), or ground air source. If the aircraft engine/s, APU, or ground air source can't be run, then the OBOGS shall be removed and performance checked using a bench test. The performance check shall be conducted while the OBOGS is operated in a mode that optimizes oxygen performance. This mode is sometimes referred to as "MAX" mode. As a minimum, a single oxygen concentration performance point shall be used as a pass/fail criterion. If the breathing system is unable to perform at or above this single performance point, a breathing system leak check shall be performed. If the system is found leak-tight, then the OBOGS shall be replaced. If the system fails the leak check, the system shall be made leak-tight and the performance check re-accomplished. The oxygen concentration performance result shall be recorded.

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Engineering analysis and/or maintenance data shall be used to determine the interval for conducting the periodic breathing system performance check. If an analysis or data are unavailable, the breathing system shall be tested every 100 flight hours. The intent is to identify low performing OBOGS.

D.3.2 Periodic breathing system leak checks.

Engineering analysis and/or maintenance data shall be used to determine the interval for conducting the periodic breathing system leak checks. If an analysis or data are unavailable, the leak checks shall be conducted every 100 flight hours.

D.3.3 Periodic filter checks.

Engineering analysis and/or maintenance data should be used to determine the interval for conducting the periodic filter checks. If an analysis or data are unavailable, the filter checks should be conducted every 100 flight hours.

D.3.4 OBOGS overhaul.

The OBOGS shall be overhauled based on an interval determined by engineering analysis and/or maintenance data. If an analysis or data are unavailable, the overhaul interval shall be every 1,000 flight hours. Molecular sieve canisters shall be replaced during overhaul. The used canisters should be tested using a method defined in D.3.6 below and/or the OBOGS can be performance checked using a bench test. If a bench check is used, the OBOGS should be operated at a specified inlet pressure and demand flow. The outlet oxygen concentration can then be compared to standardized performance curves to assess relative performance. The results shall be recorded.

D.3.5 Incident where a chemical contaminant is suspected.

After an aircraft incident where breathing gas contamination is suspected gas samples should be collected. Gas samples of the breathing gas should be collected and analyzed for compliance with Table III. During the sampling the aircraft engine should be run. If the samples show the breathing gas is out-of-compliance based on Table III, the OBOGS should enter the maintenance process. The used canisters should be tested based on a method defined in D.3.6 below or the OBOGS can be performance checked using a bench test. The results should be recorded.

D.3.6 Molecular sieve canister assessment methods.

OBOGS molecular sieve canisters should be assessed 1) prior to OBOGS production; 2) during the OBOGS maintenance process; and 3) prior to OBOGS overhaul. Manufacturers should identify one of the following methods for testing their molecular sieve canisters. The intent is to identify and analyze molecular sieve canister degradation rates; and use this information for trend analysis. Molecular sieve activity level is a critical parameter for OBOGS performance and contaminant protection.

a. Method No. 1 - Molecular Sieve Canister Washout Time Assessment: A method of testing for contaminant permeation is based on measurement of OBOGS canister washout time. The test is performed by flowing 100% dry oxygen (30 liter/min at a pressure of 75 Lb/in² gauge) until the outlet gas shows 100% oxygen for a length of time sufficient to confirm the canister is saturated with oxygen - nominally 10 minutes. At time zero, the inlet gas is switched from 100% oxygen to 100% nitrogen at the same flow, and the time required for the product gas concentration to drop from 100% to 37% oxygen is recorded. The time on the canister under

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test is compared to the baseline time on an identical canister containing fresh molecular sieve packed in accordance with the manufacturer's specifications, and tested at the same temperature and flow rate. The molecular sieve in the test canister can be considered an adequate barrier to contaminant permeation, if the time required to reach 37% oxygen concentration remains greater than one-half the baseline time. When the time required for the product gas concentration to drop from 100% to 37% oxygen is less than one-half the baseline, then the canister must be considered marginally effective for contaminant removal, and the molecular sieve should be replaced.

b. Method No. 2 - Molecular Sieve Canister Activity Assessment: This method for assessing the activity of molecular sieve is based on nitrogen adsorption capacity. The amount of nitrogen adsorbed for the test canister is compared to the amount of nitrogen adsorbed on an identical canister filled with fully activated molecular sieve. Any loss in adsorption capacity is due to molecular sieve degradation or loss of available adsorption sites. The method is summarized below. More details may be found in Patent No. US4916630 (see 6.4).

- (1) The void volume in the canister is determined by evacuating the canister and injecting a known amount of helium. The void volume is determined by the change in helium pressure.
- (2) The canister is evacuated and the initial weight is measured. Pure nitrogen is injected into the canister at a pressure of 60 psig. The canister final weight is measured.
- (3) Measured values of pressure, temperature, and weight are used to calculate the weight gain due to nitrogen adsorption.
- (4)

Molecular sieve activity % =	$\frac{\text{Weight of nitrogen in test canister (grams)}}{\text{Weight of nitrogen in fully activated canister (grams)}} \times 100$
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- (5) The OBOGS manufacturer will be required to define the following:
 - (a) Minimum acceptable activity percentage for a canister loaded with fresh molecular sieve.
 - (b) Minimum acceptable activity percentage for a used but serviceable canister.
 - (c) The manufacturer minimum activity percentages should be used to determine if the canister passes or fails the molecular sieve activity test.

D.3.7 Oxygen mask press-to-test check.

Prior to flight a press-to-test oxygen mask fit check shall be accomplished in the life support shop at 16 ±2.0 inches of Water gauge (as a minimum). Pressures up to 32 ±2.5 inches of Water may be used. This press-to-test check verifies the mask exhalation valve will hold pressure under G.

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APPENDIX E**SUPPLEMENTAL INFORMATION USED TO ESTABLISH BREATHING SYSTEM
USING OBOGS REQUIREMENTS****E.1 SCOPE****E.1.1 Scope.**

This appendix contains additional guidance documents which may be required for guidance during the design, acquisition, certification or sustainment/maintenance for aircraft breathing systems using an On-Board Oxygen Generating System (OBOGS). This Appendix is not a mandatory part of the standard. The information contained herein is intended for guidance only.

E.2 DOCUMENTS USED FOR GUIDANCE.

AIR FORCE INSTRUCTION

AFI 11-202V3 General Flight Rules

(Copies of this document are available online at www.e-publishing.af.mil/.)

INTERNATIONAL STANDARDIZATION AGREEMENTS

ASCC AIR STD 18/4	Contamination Limits for Engine Bleed Air
ASCC AIR STD 61/101/2	Development Test and Evaluation of Aircraft Oxygen Delivery Systems
ASCC AIR STD 61/101/6	Minimum Physiological Requirements for Aircrew Demand Breathing Systems
ASCC ADV PUB 61/101/10	The Minimum Quality Criteria for On-Board Generated Oxygen
ASIC ADV PUB ACS (ASMG) 4060	The Minimum Quality Criteria for On-Board Generated Oxygen

DEPARTMENT OF DEFENSE SPECIFICATIONS

JSSG 2010-10 Crew Systems Oxygen Systems Handbook

(Copies of these documents are available online at <https://quicksearch.dla.mil/> or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094.)

TECHNICAL ORDERS (TO)

T.O. 15X-1-1 Maintenance Instructions, Oxygen Equipment

(Copies of this document are available by accessing the Enhanced Technical Information Management System (ETIMS) through the AF Portal at <https://www.my.af.mil/>. Open the Applications A-Z Index and go to ETIMS.)

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CONCLUDING MATERIAL

Custodian:
Navy - AS
Air Force – 11

Preparing activity:
Air Force - 11

Review activities:
Air Force – 10

(Project No. 15GP-2013-003)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at <https://assist.dla.mil>.