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MILITARY STANDARD

QUALITY CONTROL OF GASEOUS AND LIQUID AVIATOR'S BREATHING OXYGEN AT AIRCRAFT CONTRACTOR FACILITIES

AMSC N/A

FSC 6830

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FOREWORD

Quality Control of Gaseous and Liquid Aviator's Breathing Oxygen
At Aircraft Contractor Facilities

1. This Military Standard is approved for use by the Directorate of Aerospace Fuels, Department of the Air Force, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: San Antonio ALC/SFRM, Kelly AFB TX 78241-5000, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

CONTENTS

1. SCOPE

1.1 Purpose. The purpose of this standard is to provide minimum guidance, information, instructions, and procedures for quality control of Aviator's Breathing Oxygen.

1.2 Scope. This standard applies to aircraft contractor facilities that maintain a supply of Aviator's Breathing Oxygen for servicing aircraft.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 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 listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

MILITARY

MIL-O-27210 - Oxygen, Aviator's Breathing, Liquid and Gas.
MIL-S-27626 - Sampler, Cryogenic Liquid.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia PA 19120-5099.)

2.2 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document shall take precedence.

3. DEFINITIONS

3.1 Contractor. The company that is performing the aircraft maintenance or production for the government.

3.2 Gaseous oxygen. Gaseous oxygen is colorless, odorless, and slightly heavier than air. It is nonflammable, but it supports rapid combustion.

3.3 Incident samples. These are samples drawn when an incident and/or accident has occurred and the quality of the oxygen used by the air crew is suspect.

3.4 Liquid oxygen. Liquid oxygen is a pale blue, nontoxic fluid with a temperature of 297 degrees F below zero. It is nonflammable, but it supports rapid combustion of most materials.

3.5 Particulate matter. For purposes of this standard, a piece of matter which remains solid at room temperature is defined as a particle or as a special class of particles, a fiber. A fiber is a filament-like particle whose maximum cross-sectional dimension is less than 40 micrometers.

3.6 Procurement limits. The procurement limits defined in MIL-O-27210 are minimum quality levels to which oxygen provided by a supplier must conform. The limits for liquid oxygen establish quality levels which permit some deterioration to occur before the oxygen becomes unusable.

3.7 Quality Assurance Representative (QAR). The individual directly charged with performance of the Government procurement quality assurance function at a contractor facility.

3.8 Supplier. The company that is providing aviator's breathing oxygen to the contractor.

3.9 Use limits. Use limits are a second level of quality. They normally represent the minimum quality levels required for aviator's breathing purposes.

4. GENERAL REQUIREMENTS

4.1 Introduction. Quality control of Liquid and Gaseous Aviator's Breathing Oxygen requires frequent and continuous surveillance to prevent contamination. Surveillance begins with procurement and continues throughout storage, handling, transfer, and servicing of the aircraft. Adequate and reliable quality control of oxygen demands that each operation be carried out in strict compliance with procedures established by this standard to assure flight safety and mission completion.

4.2 Scope. This standard provides information, guidance, instructions, and procedures for contractor quality control of liquid and gaseous oxygen used for aviator's breathing purposes.

4.3 Quality control personnel. Personnel selected to perform operations in the supply system for aviator's breathing oxygen shall be trained in order to develop a thorough knowledge of the characteristics of oxygen, its contaminants and the systems in which it is used. Reliable and knowledgeable personnel are the key to an effective quality control program.

4.4 Control of contamination. A knowledge and understanding of how contaminants are concentrated in liquid oxygen are essential for effective quality control. (See Appendix A.)

4.4.1 Vaporization. The concentration of contaminants due to liquid oxygen vaporization cannot, of course, be prevented. The rate of increasing contamination due to this cause, however, shall be controlled by minimizing heat additions in handling and transfer through proficient and careful performance of operations.

4.4.2 Equipment. Addition of contaminants from equipment shall be reduced or prevented by operating and maintaining generators, storage tanks, servicing carts, and aircraft liquid oxygen systems in accordance with applicable technical manuals.

4.4.3 Handling and transfer. The addition of contaminants from the environment shall be prevented by careful and proficient handling and transfer operations. Liquid oxygen strongly attracts and absorbs atmospheric gases, some of which are odorous and may be present due to an environmental source.

meet the acquisition requirements (see p. 2) and the following:

5. DETAILED REQUIREMENTS

5.1 Quality control requirements of Liquid Aviator's Breathing Oxygen.

5.1.1 Procurement limits. The procurement limits for purity and contamination, which include the absence of odor, for Aviator's Liquid Breathing Oxygen are contained in specification MIL-O-27210.

5.1.2 Use limits. The use limits of Liquid Aviator's Breathing Oxygen are as follows:

Odor	None	
Purity (percent by volume)	99.5	(min)
Carbon dioxide (ppm by volume)	10	(max)
Methane (ppm by volume)	50	(max)
Acetylene (ppm by volume)	0.1	(max)
Ethylene (ppm by volume)	0.4	(max)
Ethane and higher hydrocarbons (ppm by volume)	6	(max)
Nitrous oxide (ppm by volume)	4	(max)
Halogenated compounds:		
Refrigerants (freons, etc) (ppm by volume)	2	(max)
Solvents (trichloroethylene, carbon tetrachloride, etc) (ppm by volume)	0.2	(max)
Other (ppm by volume)	0.2	(max)

5.1.3 Supply sources of Liquid Aviator's Breathing Oxygen (Type II).

5.1.3.1 Oxygen purchases from a commercial supplier must conform to specification MIL-O-27210, Type II, and the basic contract. To meet the requirements of MIL-O-27210, the following shall be included in the purchase order or contract:

5.1.3.1.1 Preproduction and periodic production samples of the liquid oxygen shall be sent to a laboratory listed in Table I and selected according to paragraph 5.1.5.1.

5.1.3.1.2 The Liquid Oxygen Sampler TTU-131/E or the Cryogenic Liquid Sampler FCS 2001 shall be used for sampling. The sampler shall be furnished by the commercial supplier or the contractor.

5.1.3.1.3 The samples shall be identified by AFTO Form 176 or DD Form 1222. Include a sample number and point of contact (individual's name and phone number) on the form.

5.1.3.1.4 A test report of quality conformance signed by a representative of the commercial supplier shall accompany each shipment. The report shall contain purity, odor, moisture, and date of last periodic sample submission.

5.1.3.2 Liquid oxygen supplied as government-furnished material either from an Air Force operated generating plant or a US government contractor shall

comply with MIL-O-27210, Type II.

5.1.4 Test methods applicable to contractor's facilties. Testing shall be performed by the contractor as required by this standard. The contractor shall maintain a record of all tests performed.

5.1.4.1 Odor test. A liquid sample shall be tested for odor by pouring approximately 200 ml of the sample into a clean 400-ml beaker or similar container after covering the bottom of the beaker with a clean, dry filter paper equivalent to Whatman No. 1, unwashed, medium diameter 5.5 cm, or other absorbent paper. A watchglass cover or some other means of partially covering the top of the beaker shall be provided as the 200 ml of liquid evaporates to dryness. This will prevent atmospheric constituents from being absorbed by the exposed liquid. The liquid shall be permitted to evaporate to dryness and warm up to approximately room temperature in an area free from air currents or extraneous odors. When the liquid has completely evaporated, the watchglass shall be removed and the beaker contents smelled at frequent intervals until the accumulated frost on the outside of the beaker has completely melted. Odors will be most prevalent when the beaker has warmed to nearly room temperature.

5.1.4.2 Particulate test. Pour 200 ml of the sample into a clean 400-ml beaker or similar container without a filter paper in the bottom. A watchglass cover or some other means of partially covering the top of the beaker shall be used as the 200 ml of liquid evaporates to dryness. When the frost on the outside of the beaker has melted, the outside of the beaker shall be wiped with a clean, dry cloth and the beaker placed on a clean white paper. The interior of the beaker shall be visually examined, without the aid of magnification, for the presence of particles.

5.1.5 Periodic or requested tests for purity and amounts of contaminants.

5.1.5.1 Samples, except in two instances, shall be sent to a laboratory listed in Table I which is selected in this manner. Find the location of the sample submitter in Table II and note the number to the right of it. Find this number in Table I and the designated laboratory for the submitter will be listed to the right along with addresses and telephone numbers. If the location of a submitter is not listed a request should be sent to San Antonio ALC/SFTI, Kelly AFB TX 78241-5000, for a laboratory designation. Exceptions follow:

5.1.5.1.1 Incident samples (see 3.3) may be sent to any laboratory listed in this standard.

5.1.5.1.2 Other laboratories may be authorized by San Antonio ALC/SFTT.

5.1.5.2 The laboratories will return the samplers and test reports to the contractor.

5.1.5.3 The contractor shall provide a Liquid Oxygen Sampler TTU-131/E or a Cryogenic Liquid Sampler FCS 2001 for 90-day periodic and other requested

TABLE I. Air Force Testing Laboratories.

#	Shipping Address	Mail Address	Telephone Numbers
1	Aerospace Fuels Laboratory Det 13, San Antonio ALC/SFTLA Area B, Bldg 70 Wright-Patterson AFB OH 45433-6503	Aerospace Fuels Laboratory Det 13, San Antonio ALC/SFTLA Wright-Patterson AFB OH 45433-6503	(513)255-5687/2106
2	Aerospace Fuels Laboratory Det 20, San Antonio ALC/SFTLB - Bldg 14 Trundy Rd Searsport ME 04974-0408	Aerospace Fuels Laboratory Det 20, San Antonio ALC/SFTLB PO Box 408 Searsport ME 04974-0408	(207)548-2451
3	Aerospace Fuels Laboratory Det 21, San Antonio ALC/SFTLC - Bldg 1121 MacDill AFB FL 33608-0051	Aerospace Fuels Laboratory Det 21, San Antonio ALC/SFTLC PO Box 6051 MacDill AFB FL 33608-0051	(813)830-3645/4948
4	Aerospace Fuels Laboratory Det 35, San Antonio ALC/SFTLD 100 Front St, DFSC Terminal Mukilteo WA 98275-0046	Aerospace Fuels Laboratory Det 35, San Antonio ALC/SFTLD PO Box 46 Mukilteo WA 98275-0046	Everett, Washington (206)355-4122
5	Aerospace Fuels Laboratory Operating Location San Antonio ALC/SFTLF - Bldg 725 RAF Mildenhall Suffolk, England	Aerospace Fuels Laboratory Operating Location San Antonio ALC/SFTLF - Bldg 725 APO New York 09127-5000	Mildenhall 71-3879
6	Aerospace Fuels Laboratory Det 44, San Antonio ALC/SFTLG - Bldg 854 Kadena AB JA	Aerospace Fuels Laboratory Det 44, San Antonio ALC/SFTLG APO San Francisco 96239-5000	Kadena AB Ext. 4-3394

TABLE I. Air Force Testing Laboratories - Continued.

#	Shipping Address	Mail Address	Telephone Numbers
7	Aerospace Fuels Laboratory Operating Location San Antonio ALC/SFTLI - Bldg 837 Holloman AFB NM 88330-5000	Aerospace Fuels Laboratory Operating Location San Antonio ALC/SFTLI Holloman AFB NM 88330-5000	(505)479-5053/5953
8	Sacramento ALC/MAQCB - Bldg 368 ATTN: Physical Sciences Laboratory McClellan AFB CA 95652-5990	Sacramento ALC/MAQCB - Bldg 368 ATTN: Physical Sciences Laboratory McClellan AFB CA 95652-5990	(916)643-6987

TABLE II. Laboratory Designations.

Location	#	Location	#	Location	#	Location	#
Alabama	3	Illinois	1	Nebraska	1	Pennsylvania	1
Alaska	4	Indiana	1	Nevada	4 or 8	Rhode Island	2
Arizona	7 or 8	Iowa	1	New Hampshire	2	South Carolina	3
Arkansas	3	Kansas	1	New Jersey	2	South Dakota	1
California	4 or 8	Kentucky	1	New Mexico	7 or 8	Tennessee	3
Colorado	7 or 8	Louisianna	3	New York	2	Texas	7 or 8
Connecticut	2	Maine	2	North Carolina	3	Utah	4 or 8
Delaware	1	Maryland	1	North Dakota	4	Vermont	2
Europe	5	Massachusetts	2	Ohio	1	Virginia	1
Florida	3	Michigan	1	Oklahoma	7	Washington	4
Georgia	3	Minnesota	1	Oregon	4	West Virginia	1
Greenland	2	Mississippi	3	Pacific	6	Wisconsin	1
Iceland	2	Missouri	1	Panama	3	Wyoming	4 or 8
Idaho	4	Montana	4				

samples.

5.1.5.4 Samples shall be identified by AFTO Form 176 or DD Form 1222. Include a sample number and point of contact (individual's name and phone number) on the form.

5.1.6 Receipt of Liquid Aviator's Breathing Oxygen at contractor's facilities. Testing of the supplier's shipping container is not required upon receipt except when contamination is suspected.

5.1.6.1 Sampling location. Outlet port of the shipping container.

5.1.6.2 Tests. Test for odor according to paragraph 5.1.4.1. Test for particles according to paragraph 5.1.4.2.

5.1.6.3 Rejected shipping containers. When testing reveals the presence of odor or particles in the contents of the shipping container, do not unload the contents into storage. Permit unloading for disposal purposes only if the shipment cannot be returned. Immediately notify the QAR.

TABLE III. Sampling and testing requirements 1/

Source	Test	When sampled	See paragraph
Supplier's shipping container	Odor and particulate	When contamination is suspected	5.1.6
Storage tanks	Odor	When odor is detected in servicing trailer	5.1.7.2
	Purity, odor, and minor constituents	Every 90 days	5.1.7.2
Servicing trailers	Odor	After first filling each day	5.1.8.2
Aircraft converters	As directed	After incidents affecting flying personnel	5.1.5 5.1.10

1/ This table is provided for reference only. See text for actual requirements.

5.1.7 Contractor's Storage Tanks. Sample and test the storage tank as follows:

5.1.7.1 Sampling Location. At the drain valve.

5.1.7.2 Tests and frequencies. Test for odor if any servicing trailer filled from the storage tank contains an odor. Once every 90 days and whenever contamination is suspected, a sample of the contents of storage tanks shall be sent to a laboratory listed in Table I and selected according to paragraph 5.1.5.1. Identify sample by completing AFTO Form 176 or equivalent (DD Form 1222) and attaching it to the sampler (omit procurement data). Be sure to include a sample number and point of contact (individual's name and phone number) on the form. The following statement shall be included as a note or remark: "Testing is required to determine if oxygen is within use limits defined by MIL-STD-1551." Samples will be tested for conformance to the use limits specified in 5.1.2. Records shall be maintained for all 90-day samples.

5.1.7.3 Quality control requirements.

5.1.7.3.1 Odor - None.

5.1.7.3.2 The contents of the storage tanks shall not exceed the use limits specified in paragraph 5.1.2.

5.1.7.4 Purging requirements.

5.1.7.4.1 Tanks which contain product that has an odor or has exceeded the use limits shall be drained and purged according to the applicable technical manual.

5.1.7.4.2 Storage tanks shall be purged in accordance with applicable technical manuals when both of the following conditions occur:

a. The storage tank has become empty due to evaporation of contents.

b. The storage tank has warmed to ambient temperature.

5.1.8 Servicing trailers. Sample and test each servicing trailer as follows:

5.1.8.1 Sampling location. At the drain valve.

5.1.8.2 Test and frequency. Test for odor in accordance with paragraph 5.1.4.1 immediately after first filling each day.

5.1.8.3 Quality control requirements. Odor - None.

5.1.8.4 Purging requirements.

5.1.8.4.1 Servicing trailers which contain product that has an odor shall be drained and purged according the applicable operation and service technical manual. See 5.1.7.2 for sampling storage tanks from which trailer was filled.

5.1.8.4.2 Liquid oxygen servicing trailers shall be purged in accordance with the applicable operation and service technical manual when both of the following conditions occur:

a. The trailer has become empty due to evaporation of contents.

b. The trailer has warmed to ambient temperature.

5.1.8.5 Records. AFTO Form 134 shall be maintained on all liquid oxygen servicing trailers. These forms may be destroyed two weeks after the date of the last recorded aircraft servicing.

5.1.8.6 Transfers. The contents of trailers shall not be returned to storage.

5.1.8.7 Low use trailers. It is advisable to keep trailers containing liquid oxygen to a minimum. Those trailers not required for current levels of operation should be maintained in standby status. See the subsection on preservation for storage and/or shipment in the applicable operation and service technical manual. There are two reasons for this. First, the low use which results when too many trailers contain liquid oxygen may allow contaminants to increase to unacceptable levels due to selective evaporation of oxygen. See paragraph 90.2. Second, servicing trailers have higher evaporation rates than storage tanks and, as a result, are less efficient storage containers. The above, therefore, affects both quality control and cryogenics conservation. The following criteria are provided for those organizations who must employ low use trailers.

5.1.8.7.1 Definition. A low use trailer is one which was used to service aircraft on less than 5 of the past 12 calendar days.

5.1.8.7.2 When to fill a low use trailer. A low use trailer shall be filled before servicing aircraft if it was not filled during the past two calendar days.

5.1.8.7.3 When to drain and fill a low use trailer. A low use trailer shall be drained and filled before servicing aircraft if it was not drained during the past 12 calendar days.

5.1.8.7.4 Data on trailer draining and use for servicing may be obtained from the AFTO Form 134. Drainings shall be recorded in the remarks column of the form.

5.1.9 Aircraft converter system. Sample, test, and purge the aircraft liquid oxygen converter system as follows:

5.1.9.1 Sampling location. At the drain valve.

5.1.9.2 Tests and frequencies. Test for odor in accordance with paragraph 5.1.4.1 as follows:

5.1.9.2.1 As soon as possible after the report of in-flight odors by aircrews.

5.1.9.2.2 In accordance with applicable aircraft manuals.

5.1.9.3 Purging methods and frequencies. In accordance with applicable technical manuals.

5.1.10 Additional Air Force testing laboratories for Aviator's Breathing Oxygen/air crew exposure incidents.

5.1.10.1 Send samples to the address listed below only if an incident/ accident has occurred and the oxygen is suspected. The USAF OEHL can be contacted through the Base Command Post after duty hours.

USAF OEHL/SAO
Brooks AFB TX 78235-5000

5.1.10.2 If an incident/ accident has occurred in the USAFE area and the oxygen is suspected a sample may be sent to the address listed below.

WR4S09 FB5600
ITO US Military Community
Wiesbaden AS, APO New York 09457
ATTN: Environmental Health Laboratory
Bldg 10007, Lindsey AS

5.2 Quality control requirements of Gaseous Aviator's Breathing Oxygen (Type I).

5.2.1 Procurement limits. The procurement limits for purity and contamination, which include the absence of odor, for aviator's gaseous breathing oxygen are contained in specification MIL-O-27210.

5.2.2 Use limits. See Table IV.

5.2.3 Supply sources of Gaseous Aviator's Breathing Oxygen (Type I).

5.2.3.1 Oxygen purchases from a commercial supplier must conform to specification MIL-O-27210, Type I, and the basic contract. To meet the requirements of MIL-O-27210, the following shall be included in the purchase order or contract:

5.2.3.1.1 Preproduction and periodic production samples of the liquid oxygen will be sent to a laboratory listed in Table I and selected according to paragraph 5.1.5.1.

5.2.3.1.2 Samples shall be identified by AFTO Form 176 or DD Form 1222. Include a sample number and point of contact (individual's name and phone number) on the form.

5.2.3.1.3 A test report of quality conformance signed by a representative of the commercial supplier shall accompany each shipment. The report shall contain purity, odor, moisture, and date of last periodic sample submission.

Table IV. Use Limits (Type I).

Odor	None	
Purity (percent by volume)	99.5	(min)
Carbon dioxide (ppm by volume	10	(max)
Methane (ppm by volume)	50	(max)
Acetylene (ppm by volume)	0.1	(max)
Ethylene (ppm by volume)	0.4	(max)
Ethane and higher hydrocarbons (ppm by volume)	6	(max)
Nitrous oxide (ppm by volume)	4	(max)
Halogenated compounds:		
Refrigerants (freons, etc.) (ppm by volume)	2	(max)
Solvents (trichloroethylene, carbon tetrachloride, etc) (ppm by volume)	0.2	(max)
Other (ppm by volume)	0.2	(max)
Moisture (mg/liter at 70 degrees F and 760 mm Hg)	0.005	(max)
(ppm by volume)	6.7	(max)
(dewpoint, degrees F)	-82	(max)

5.2.4 Requested tests for purity and amounts of contaminants.

5.2.4.1 Samples, except incident samples (see 3.3), shall be sent to a laboratory listed in Table I and selected according to paragraph 5.1.5.1. Incident samples may be sent from any location to any laboratory listed in this standard.

5.2.4.2 The laboratories will return the samplers and test reports to the contractor.

5.2.5 Receipt of Aviator's Gaseous Breathing Oxygen at contractor's facilities. Upon receipt of product from a commercial supplier, sampling and testing of the contents of the cylinders are not required; however, each cylinder shall be inspected for the following:

5.2.5.1 Proper painting and marking (see specification MIL-O-27210).

5.2.5.2 Valves are tightly closed.

5.2.5.3 Safety caps or safety plugs are leak-tight and secure.

5.2.5.4 Evidence of grease or oil on the valves or cylinders. Cylinders with evidence of oil, grease, or dirt on the valve outlet threads or opening shall be rejected and returned to the supplier for cleaning. Other external cylinder surfaces may be cleaned locally using approved procedures.

5.2.6 Servicing trailers.

5.2.6.1 AFTO Form 134 shall be maintained on gaseous oxygen servicing trailers. These forms may be destroyed two weeks after the date of the last recorded aircraft servicing.

5.2.6.2 Before charging any aircraft oxygen system, be sure that the purifier cartridge has been changed within the prescribed interval. No more than 16 gaseous oxygen cylinders shall be discharged through a single purifier cartridge.

5.2.7 Processing of "empty" cylinders to be returned for refilling. Prior to shipping "empty" cylinders for refilling, each cylinder shall be inspected and processed as follows:

5.2.7.1 Ensure that cylinders are emptied to less than 25 psig pressure but not less than 5 psig. If the cylinder pressure is already below 5 psig do not repressurize. Close the valve if it is open and ship the cylinder for refilling.

5.2.7.2 Screw valve protection cap securely on cylinders.

6. NOTES

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

6.1 Subject term (key word) listing.

Aviators
Contamination
Cryogenic liquid
Laboratories
Oxygen
Procurement limits
Properties
Quality assurance representative
Quality control
Sampling
Servicing trailers
Storage tanks
Tests
Use limits

6.2 Issue of DODISS. When this standard is used in acquisition, the issue of the DODISS to be applicable to this solicitation must be cited in this solicitation (see 2.1.1).

APPENDIX A

Description, Properties, and Contamination of Oxygen

10 Scope. This appendix provides general information on the description and properties of oxygen. It also provides information on sources and types of contaminants in oxygen. This appendix is not mandatory.

20 Description and Properties of Oxygen. Oxygen can exist as a solid, liquid, or gas depending upon the temperature and pressure to which it is subjected. At atmospheric pressure, oxygen exists as a solid at temperatures below its melting point, -361 degrees F (-218 degrees C). Solid oxygen turns into a liquid at its melting point and remains in this state until the temperature rises to its boiling point, -297 degrees F (-183 degrees C). At the latter temperature, liquid oxygen vaporizes into the gaseous state. Conversely, gaseous oxygen will turn into liquid, at atmospheric pressure, by cooling to a temperature below -297 degrees F. By increasing the pressure, gaseous oxygen can be liquefied at higher temperatures, up to its critical temperature, -182 degrees F (-119 degrees C). Oxygen will not condense to a liquid at temperatures above its critical temperature regardless of the pressure applied. The pressure required to liquefy oxygen at its critical temperature is known as its critical pressure, 736.5 psia. The application of high pressure and ultra low temperatures to convert gases into their liquid state is known as the science and technology of cryogenics. Liquid oxygen is a cryogenic fluid.

30 Source of Oxygen. Air, which contains about 21 percent oxygen by volume, is the source of liquid and gaseous oxygen. Air is compressed and cooled to liquefaction, whereupon the liquid oxygen is separated by distillation and taken off as liquid product or gasified for gaseous product.

40 Physical Properties of Oxygen. Gaseous oxygen is colorless, odorless, tasteless, and about 1.1 times as heavy as air. Liquid oxygen is an extremely cold (approximately 395 degrees below body temperature) pale blue fluid, which flows like water. One gallon of liquid weighs 9.519 pounds which is approximately 1.14 times the weight of one gallon of water. (See Table IV.) Liquid oxygen is stored and handled at atmospheric pressure in well insulated containers which maintain the liquid at its boiling point. Therefore, liquid oxygen is always boiling as it slowly turns into gaseous oxygen. As the expanding gas from the boiling liquid increases in amount, it builds up pressure within the container. Therefore, the expanding gas must be vented to the atmosphere, because confinement is both dangerous and impractical. When the cold and colorless gas is vented to the atmosphere, it produces a fog as it immediately condenses moisture and carbon dioxide in the air.

50 Chemical Properties of Oxygen. Oxygen is a very reactive material and combines with most of the chemical elements. The union of oxygen with another substance is known as oxidation. Extremely rapid or spontaneous oxidation is known as combustion. While oxygen in non-combustible in itself, it strongly and rapidly accelerates the combustion of all flammable materials; some to an explosive degree. Oxygen, as supplied, contains a minimum of 99.5 percent by

volume of pure oxygen. The remaining 0.5 percent consists principally of argon, plus various organic and inorganic compounds in amounts measured in the parts per million range.

Table V. Oxygen weight-volume equivalents.

MASS		LIQUID VOLUME AT BOILING POINT			GAS VOLUME AT ONE ATMOSPHERE AND 70 F	
Grams	Pounds	Liters	Gallons	Cubic Feet	Liters	Cubic Feet
1.000	0.002205	0.0008766	0.0002316	0.00003096	0.7540	0.02663
453.6	1.000	0.3976	0.1050	0.01404	342.0	12.08
1141.0	2.515	1.000	0.2642	0.03523	860.11	30.38
4318.0	9.519	3.785	1.000	0.1337	3256.0	115.0
32300.0	71.21	28.32	7.481	1.000	24355.0	860.1
1.326	0.002924	0.001163	0.0003072	0.00004106	1.000	0.03532
37.55	0.08280	0.03292	0.008697	0.001163	28.32	1.000

60 Contaminants and Contamination. Liquid oxygen as produced by generating plants contains contaminants which are not completely removed by the generating process. Atmospheric air from which liquid oxygen is generated is the primary source of contamination. An additional source of contamination is the compressors and other equipment of the generating plants. Airborne contaminants and those added by the generating plants are partially removed by a system of filters, absorbers, driers, and heat exchangers before the air is finally liquefied. When the liquid oxygen separates from the liquefied air, it carries with it those contaminants which are not completely removed. The variety and quantity of contaminants which separate with the product depend on how effective the removal has been during the generating process. Generating plants are designed to remove contamination to the lowest limits possible for safety of operation and for quality of product. The contamination limits of oxygen produced by any generating plant for breathing oxygen are specified as procurement limits. Procurement limits (MIL-O-27210) and the ultimate use limits (paragraph 5.1.2) of contamination are based on the types and significance of contaminants, and the sources of increasing contamination in liquid oxygen during storage, handling, and transfer. Procurement and use limits of contamination for gaseous aviator's breathing oxygen are the same.

70 Types of Contaminants.

70.1 Hydrocarbons. These contaminants are present in atmospheric air, and are also added by the compressors and other equipment of the generating plant. They are only partially removed by the low temperature hydrocarbon absorption purifiers of the generating plants. Those which separate with the liquid oxygen are called light hydrocarbons because they contain four carbon atoms or less, such as methane, acetylene, ethane, propane, and butane. Heavier hydrocarbons are removed to insignificant concentrations in properly operating plants. However, through mistakes, carelessness, or breakdown of equipment during storage, handling and transfer of liquid oxygen, heavy hydrocarbons can cause contamination in the form of solvents, oils, greases, or fumes. The

presence of hydrocarbons in liquid oxygen constitutes a potential fire and explosion hazard. The hazard increases during storage and handling because all of the common hydrocarbon contaminants are less volatile than liquid oxygen and, therefore, increase in concentration. If either the solubility limit or the lower flammability limit of a hydrocarbon is exceeded, the condition is especially hazardous. A source of ignition can initiate a fire or explosion if the hydrocarbon is present in sufficient concentration to sustain combustion. Ignition sources can be static electricity, mechanical and fluid friction, and shock waves introduced by impact. Whenever a hydrocarbon is present in quantities greater than its solubility in liquid oxygen, it separates out of the liquid as a solid. Even the smallest grain of hydrocarbon solid in liquid oxygen has the potential of continued burning upon suitable ignition. Although one tiny particle may not be dangerous in itself, a collection of such particles could be serious, since ignition may propagate from particle to particle. Acetylene is especially hazardous in this respect.

70.1.1 Acetylene. Acetylene is the most hazardous hydrocarbon contaminant because it is very insoluble; it can readily be triggered into ignition; and, since it is chemically unstable, it can decompose under certain conditions and become its own source of ignition.

70.1.2 Significance in Aviator's Liquid Breathing Oxygen. Hydrocarbon contaminants in liquid oxygen create, in addition to their potential fire and explosion hazards, potential psychological and physiological hazards to aircrews when liquid oxygen is used for breathing purposes. Depending upon the type and concentrations of hydrocarbons, psychologically, the effects may be uneasiness, apprehension or possible panic, resulting from detecting their presence by odor; physiologically, the effects may be nausea, illness, intoxication or possible asphyxia.

70.2 Inert Solids. These contaminants are classified as inert solids because in the concentrations normally encountered they do not create a fire and explosion hazard when they react with oxygen, and to distinguish them from hydrocarbons, which become solids when their solubility limits are exceeded. Inert solids consist of three distinct forms:

70.2.1 Particulate Matter. These solids consist of rust, metal fragments, dust and fibers derived from the equipment or the environment of the liquid oxygen supply system. These contaminants are solids at normal temperatures as well as liquid oxygen temperature.

70.2.2 Moisture. In its liquid or vaporous form, moisture condenses to ice on contact with liquid oxygen or with the cold surfaces of equipment. Atmospheric moisture is an ever present source of contamination.

70.2.3 Carbon Dioxide. This contaminant is slightly soluble in liquid oxygen but separates out of liquid oxygen as a solid when its solubility limit is exceeded. Inert solid contaminants in liquid oxygen are hazardous for a number of reasons. First, they may cause mechanical malfunctions or failures. Second, they may cause plugging of filters, lines, injectors, valves, etc. Third, they may accumulate charges of static electricity.

80 Toxic and Odorous Contaminants. The odorous and toxic characteristics of hydrocarbons have already been discussed. In addition to the hydrocarbons, there are other contaminants which, if present in aviator's liquid breathing oxygen, may also affect the mental and physical well-being of aircrews. In particular, these contaminants are nitrous oxide and chlorinated hydrocarbons.

90 Sources of Contamination.

90.1 Initial Contamination. The initial contamination of liquid oxygen in the generating plant increases continuously after generation, as nonvolatile contaminants are concentrated by the evaporation of liquid oxygen. The gradual process of increasing contamination is accelerated if contaminants are introduced during storage, handling, and transfer operations, all of which are portential sources of increasing contamination. The added contamination of liquid oxygen is therefore compounded each time contaminants are introduced. This means that the problem of controlling contaminants becomes more severe as the liquid oxygen passes through the aviator's breathing oxygen supply system. The problem is increased by the potential toxicity and lower maximum limits of contaminants in liquid oxygen. Thus, an acceptable concentration of contaminants in liquid oxygen as generated or procured can increase to a point which may threaten the safety or reliability of the mission. Therefore, procurement limits establish higher quality of aviator's breathing oxygen to allow for increase of contamination to established use limits. This margin of safety does not provide a margin for error or for unexpected contamination, and personnel should not relax their vigilance in quality control against the ever present source of increasing contamination of liquid oxygen.

90.2 Increasing Concentration Due to Evaporation of Liquid Oxygen. Contaminants in liquid oxygen are always increasing in concentration as the amount of liquid decreases. This ever present process of increasing contamination is intensified by "cool down" vaporization losses associated with liquid transfer operations. Concentration of contaminants will increase in approximate proportions to the amount by liquid oxygen loss by vaporization.

90.3 Handling and Transfer Operations. These operations are a continuing source of increasing contamination by contaminant addition. The types of contaminants range from dust and dirt to moisture and carbon dioxide and other atmospheric constituents. Whenever transfer operations require the connection or disconnection of a transfer line, the opportunity for introducing additional contamination arises. At the time of connection, atmospheric contaminants or dust and dirt may be trapped in a section of the transfer line, to be carried into the supply system by the flowing liquid. At the time of disconnection, atmospheric contamination may become deposited inside the cold transfer equipment, ready to enter the rest of the system during the next transfer operation. Field and laboratory experiments have shown that strong convective currents are formed by the density difference between cold oxygen vapors and warm ambient air. As the cold, denser oxygen vapors flow out of the low points of cold transfer equipment, the warm, less dense air flows in at the high points, depositing moisture and other condensables in the form of frost. Both mechanisms of contamination can be controlled by strict adherence to

procedures. The trapped portion of the atmosphere may be removed by adequate purging before transferring, and condensables may be prevented from entering cold transfer connections by allowing the connections to warm up before disconnecting. The making and breaking of transfer connections should be accomplished as quickly as careful handling will permit.

90.4 Equipment. The sources of increasing contamination of liquid oxygen from equipment are variable both as to time and origin. Long-term deterioration of mechanical equipment must be expected. The moving parts of valves and pumps will wear and contribute to particulate contamination. Other sources of potential contamination are the solvents and solids which may remain from repair or cleaning operations. Strict adherence to maintenance cycles and procedures for the servicing equipment must be followed.

100 Contaminants and Contamination of Gaseous Aviator's Breathing Oxygen. Prior to acceptance by the contractor, gaseous aviator's breathing oxygen and cylinders are inspected to determine compliance with contractual requirements. Tests which are required prior to shipment are performed at the supplier's facility by supplier personnel. Trace contaminants are analyzed at government laboratories at 45-day intervals. Once the quality of oxygen within a cylinder has been established, that quality will continue so long as a positive pressure is maintained within the cylinder under normal storage conditions. Consequently, retesting of the oxygen at periodic intervals during storage is not necessary.

110 Periodic Sample. The purpose of the periodic sample is not to determine the exact composition of each shipment of aviator's breathing oxygen. Its purpose is to provide data that each generating facility is capable of supplying good product and that subsequent operations have not changed the product radically. Small variations from the procurement or use limit are not physiologically critical but are indicators that demand a return to the originally good product. The liquid oxygen periodic sample from the base storage tanks provides information that the tanks are clean and capable of maintaining the ABO at an acceptable level of quality.

120 Sampling. Sampling is required in order to obtain a small portion of a large quantity, and it is the most important operation in preparing for the analysis of oxygen. Great care should be exercised in selecting the portion of the whole so that it will represent the composition of the sampled storage container. The best analysis can be completely invalidated by poor sampling.

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3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
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6. REMARKS

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