



AEROSPACE RECOMMENDED PRACTICE

ARP1398™**REV. A**

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Superseding ARP1398

Testing of Oxygen Equipment

RATIONALE

ARP1398A has been reaffirmed to comply with the SAE five-year review policy.

FOREWORD

Changes in this revision are format/editorial only.

1. SCOPE:

This ARP delineates requirements for system cleanliness, test gas supply system, test stand design, environmental chamber definition, instrumentation, dynamic test equipment and testing procedures.

1.1 Purpose:

The purpose of this SAE Aerospace Recommended Practice (ARP) is to establish or outline, or both, methods and procedures for use in testing oxygen equipment.

2. REFERENCE DOCUMENTS:

(Use current issue)

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096

AIR822	Oxygen Systems for General Aviation
AIR825	Oxygen Equipment for Aircraft
ARP1109	Dynamic Testing System for Oxygen Breathing Equipment
AIR1176	Oxygen System and Component Cleaning and Packaging
AS8010	Aviators Breathing Oxygen Purity Standard

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Documents

Document Sharing Hub

2.2 Other Publications:

MIL-STD-17B-2	Mechanical Symbols for Aeronautical, Aerospacecraft and Spacecraft Use
MIL-STD-167	Mechanical Vibrations of Shipboard Equipment
MIL-STD-810	Environmental Test Methods for Aerospace & Ground Equipment
MIL-E-4970	Environmental Testing, Ground Support Equipment, General Specification for
MIL-E-8189	Electronic Equipment, Guided Missiles, General Specification for
MIL-O-27210	Oxygen, Aviator's Breathing, Liquid and Gas
MIL-P-27401	Nitrogen Gas
BB-N-411	Nitrogen Gas
AFSC P 80-6	Laboratory Capabilities Pamphlet

AMERICAN NATIONAL STANDARDS INSTITUTE, INC.

S1.1 (1960 Issue)	Acoustical Terminology (including Mechanical Shock and Vibration)
NFPA 99	Health Care Facilities 1987, Standards for

3. GENERAL REQUIREMENTS:

3.1 System Cleanliness:

System and component cleaning and packaging should be accomplished as specified in AIR1176.

3.2 Lubrication:

3.2.1 Tape Type, Antiseize: Polytetrafluoroethylene tape conforming to MIL-T-27730A may be used as the antiseize lubricant only on pipe thread fittings and straight thread fittings for permanent type joints. It shall not be used on sleeve or flares of tubing connections.

3.2.1.1 Tape Application: The tape should be applied to the male threads, beginning with the second thread, by wrapping in the direction of the thread spiral and overlapping the end of the tape. When a joint is disassembled, the previously applied tape shall be removed and replaced with new tape on subsequent reassembly.

- 3.2.2 Compound Type, Antiseize: Only antiseize lubricant conforming to MIL-G-27617C (KRYTOX) shall be used on all joints that the tape type antiseize is not permitted, and may be used on joints that tape type antiseize is approved. Do not apply compound to the first two threads of tapered pipe threads. Do not apply compound to the nose section of AN fittings or flared section of matching tube.

CAUTION:

1. Lubricants such as Krytox must not be used with aluminum and light alloys under high shear. A serious explosion could result even with the absence of oxygen.
2. Due to the critical nature of cleanliness, lubricants should be used carefully and sparingly when working with oxygen systems and components.
3. Be certain that lubricants coming in direct contact with oxygen are compatible for oxygen service.

3.3 Test Gas:

The gas used in testing the unit shall be oxygen conforming to specification MIL-O-27210, AS8010, or water pumped nitrogen conforming to specification MIL-P-27401 (Type I), or nitrogen per BB-N-411, or air having the following purity levels:

Moisture: Dew point of -70 °F (-57 °C) or lower
Hydrocarbons: 3 ppm maximum
Particles: No greater than 25 µm in size

The concentration of particles in the 0.5-10 µm range shall not exceed 1000 particles per cubic foot and the concentration of particles in the 10-25 µm range shall not exceed 25 particles per cubic foot.

If nitrogen or air is used, calibration curves shall be determined for correcting flow data. These calibration curves shall be determined on the test setup by using oxygen and either nitrogen or air. The gases used during calibration shall conform to the above specifications. The correction factors determined by using the calibration curves shall then be applied to the subsequent test data.

3.4 Test Stand Design for Sea Level Ambient Temperature Testing:

3.4.1 General Layouts:

- 3.4.1.1 Test Stand Drawing Layouts: A pictorial drawing of the test stand face, and another of the backside (plumbing side) shall be provided. The backside pictorial drawing will depict the plumbing detail (that is, tubing-runs) as simple straight lines with right angle bends. This will prevent a format that is too cluttered or confusing.

Each valve and instrument shall have connection numbers inscribed near the fitting(s). An additional drawing titled "plumbing chart" shall be provided showing a dimensional layout of tubing or pipe runs, specifying the tubing to be used, their sizes and bend radii, and the plumbing chart shall show in tabular form, which connections are joined together.

Example:

Plumbing Chart

The connector numbers listed together below are to be connected with indicated tubing:

#2 to #4 – 1/4 in (6 mm O.D.) x 0.035 (0.89 mm) Wall Copper Tubing
#12 to VAC Source – 1/2 in (12 mm O.D.) PVC Tubing of suitable wall thickness
#36 to 02 Pressure Source – 3/4 in (18 mm O.D.) SS Tubing of suitable wall thickness

A schematic drawing of the plumbing layout shall be provided. If required, an electrical schematic shall also be included.

Schematic drawings shall utilize oxygen and electrical symbols from AIR822, AIR825B and MIL-STD-17B-2.

- 3.4.1.2 Manuals: A manual shall be provided containing a description of the test stand, operating instructions, maintenance, calibration and troubleshooting information.
- 3.4.1.2.1 Document Storage: Test stand storage provisions shall be made to accommodate the test stand manuals, calibration charts, procedures and schematic diagrams. A copy shall be stored with the test stand.
- 3.4.1.3 Instrument Layout: Test stand instrumentation shall be positioned at eye level. Consideration shall be given as to whether the operator is normally standing or seated. Instrumentation shall be as closely grouped together as space and plumbing allows. Parallax resulting from placement of instrument scales at excessive angle(s) to the operator's eyes, shall be avoided.
- 3.4.1.4 Instrument Test Conditions: Each instrument shall be clearly and permanently labeled as to percentage of accuracy, the calibration date, the calibration medium and standard conditions. Example: Accuracy = 0.5% full scale, oxygen at 760 mm Hg (101.3 kPa) and 70 °F (21 °C). Each instrument shall bear a limited use marking to ensure accuracy and require proper recalibration. This marking should include the certification/calibration date and the expiration date. The instrument must not be used beyond the expiration date until recalibration is accomplished.

- 3.4.1.4.1 A mercury barometer and thermometer should be on or near the test stand to determine actual test conditions.
- 3.4.1.5 Instrument Mounting: Instruments such as manometers, draft gages, flowmeters, etc., shall be mounted level and square on the test stand so as to minimize instrument error. A test stand leveling instrument shall be permanently mounted. Means of adjusting the test stand to level position shall also be provided. The test stand shall have adequate support and sufficiently rigid construction so it will not be damaged during transport and cannot inadvertently move out of plumb by forces exerted by the operator or by attached hoses or equipment.
- 3.4.1.6 Protective Devices: All instruments, chambers and rig plumbing must be adequately protected against overload by means of check valves, relief valves, or quick-acting shut-off valves, or quick-acting manometer bypass valves, or both. All manometers shall also be equipped with traps and zeroing devices. Instruments requiring protection from “adiabatic compression” shall be protected.

If the test stand uses oxygen, it may be desirable to use blowers or other ventilation means to prevent oxygen concentrations from accumulating inside of cabinets.

- 3.4.1.7 Controls: Test stand controls shall be centrally located to the operator and shall be clearly and permanently marked as to their function or control number, or both. Control numbers shall be preceded by a letter (or letters) and numbers as follows:

V4- = Valve 4-Way
V2- = Valve 2-Way
V3- = Valve 3-Way
R- = Regulator
RV- = Regulator Vacuum
SW- = Switch
CV- = Check Valve
SV- = Solenoid Valve
CN- = Connector
SWP- = Switch, Pump
VR- = Valve, Relief
VB- = Valve, Bleed
VN- = Valve, Needle
VF- = Valve Filler Recharge
VV- = Valve Vent
PR- = Pressure Reducer
BD- = Burst Disk

Example: 4-Way Control Valve #6 will be marked “V4-6”.

3.4.1.7 (Continued):

Marking: Test stand regulators or bleed valves shall be permanently and clearly marked and identified. Test stand valves shall be clearly and permanently marked with positions such as “on-off”, etc. Test stand components shall be clearly and permanently marked “Oxygen Pressure”, “Vacuum Supply”, etc.

High pressure valves or controls shall be so marked.

The test stand operating manual shall identify each control. As an option to the above, and if the actuation of a single valve or switch accomplishes complete test, that valve or switch may be marked on the face of the test stand with the name of that test. Example – “Suction Leakage”.

- 3.4.1.8 External Inputs: External inputs to the test stand such as electric power, oxygen, nitrogen or air, etc., shall be permanently and clearly labeled or tagged at the point of inlet to the test stand with both the name and grade of the gas or input, plus the minimum and maximum allowable pressure (lbf/in² (gage) or kPa), voltage, and special or unconventional connections such as left-hand thread, etc.

Gaseous input connectors and fittings should be standard CGA (Compressed Gas Association) type for each particular gas.

3.4.2 Hardware:

- 3.4.2.1 Test Chambers: Test fixtures, connectors and chambers are identified as the chamber or fixture into or onto which the unit to be tested is housed, positioned or attached to during the test procedures.
- 3.4.2.1.1 Care shall be taken in the design of test chambers to assure that sufficient pressure is applied to adequately seal the chamber and not distort the item to be tested (especially pneumatically closed chambers). Connectors and ports shall be of sufficient size so as not to affect the test results, and not so large as to greatly increase dead air space.
- 3.4.2.1.2 Design consideration is required to prevent gas flows from becoming nonlinear because of excessively acute turns resulting in induced resistance to flow and erroneous test results.
- 3.4.2.1.3 Pressure taps (or piezometers) shall be located as close to the test item as possible. Upon completion of the chamber, fixture or test connectors, trial tests shall be conducted using a dummy test item to determine that final test results are not unduly affected by too small test connectors, acutely angular flows, and pressure taps or piezometer location in relation to the test item.
- 3.4.2.1.4 The test chamber surfaces shall be suitably protected from corrosion by plating or by use of corrosion resistant finishes.

- 3.4.2.1.5 Plumbing: Stainless steel, copper or copper alloys (suitably protected or plated against corrosion) are preferable; seamless aluminum is acceptable for gas pressures below 500 lbf/in² (gage) (3450 kPa); PVC tubing is acceptable for pressures below 200 lbf/in² (gage) (1380 kPa) for air, nitrogen or oxygen.

Stainless steel or copper alloy fittings may be brazed-on nipples or regular flared or flareless fittings. Aluminum tubing shall utilize regular flared fittings with coupling sleeve.

- 3.4.2.1.6 Fittings: Forged, cast and machined fittings such as elbows and tees for stainless steel, copper or aluminum tubing shall be welded or brazed. For low pressures below 200 lbf/in² (gage) (1380 kPa) soldering is acceptable if all traces of flux are removed. Matching or interfacing dissimilar metals together shall be avoided.
- 3.4.2.1.7 Tubing bends (radii) shall be as large and sweeping as practicable (see 3.4.2.1.2).
- 3.4.2.1.8 Routing: In the interest of minimizing dead air space, the tubing need not be square or parallel to the test stand sides. Rather, it may go directly from point to point (that is, direct from valve to manometer to test chamber) regardless of the resultant tubing angle(s) to the test stand. However, neatness of appearance and minimum stress in misaligned tubing should be considered. Ease of servicing shall be considered in the plumbing layout.

- 3.4.2.2 Valves: Valves of all major types may be used. A partial list includes:

- a. Poppet
- b. Rotor
- c. Ball
- d. Needle
- e. Plate-Seat
- f. Gate

Each valve shall be of a type suitable for its intended use. (For example, a needle valve for fine adjustment.)

- 3.4.2.3 Regulators: Regulators shall be clearly and permanently marked as to type (demand, vacuum, pressure demand manual, etc.), MIL-Spec number, and functional positions (that is, increase pressure, decrease pressure, etc.), and pressure range.

- 3.4.2.4 Vacuum Systems:

- 3.4.2.4.1 Accumulator or Reservoir: A vacuum accumulator of sufficient volume shall be utilized to prevent excessive fluctuations in vacuum negative pressures. Usually, a preset vacuum regulator shall be positioned between the accumulator and the vacuum source (pump) to maintain a constant negative pressure to the accumulator. Naturally, a vacuum pump of sufficient capacity to maintain constant negative pressure in the accumulator is required. Use of an ejector system is recommended for evacuating oxygen rich atmospheres.

- 3.4.2.5 Filters: The test stand shall include necessary filters insuring that all test supply gases or fluids, or both, are filtered upstream of all valving, metering, measuring or control devices. Vacuum bleed valves shall also utilize filters on the upstream side to prevent contamination from entering the test stand system.
- 3.4.2.6 Breathing Machines: For information and recommended practices on breathing machines, see ARP1109.
- 3.4.2.7 Other Hardware Items:
 - 3.4.2.7.1 Standard Hardware Items: Standard hardware items such as nuts, bolts, screws, washers, clamp terminal connectors, switches, etc., shall be MS or AN wherever they are suitable for the intended purpose. Commercial utility hardware components may be utilized provided they are suitable for the intended purpose. Such commercial utility hardware components may be utilized provided they are suitably protected by plating, etc., and possess all other suitable properties.
 - 3.4.2.7.2 Materials: The materials used in the construction of an oxygen test stand shall be of high quality, compatible with oxygen, entirely suitable for the intended purpose. Whenever plastics are used, they shall be suitable for the intended purpose.
 - 3.4.2.7.3 Metals: All metals used in construction with the test stand shall be corrosion-resistant or shall be suitably protected to resist corrosion during the normal life of the equipment. Dissimilar metals in intimate contact shall be avoided.

3.5 Environmental Test Chambers:

Environmental chambers for the testing of oxygen equipment or systems to simulate the effects of high altitude and related ambient conditions as contemplated for civil aircraft applications are commercially available. Custom designed chambers for specific applications such as the physiological reaction of humans to environmental extremes are also available. The requirements of the National Fire Protection Association document NFPA 99-1984 must be considered during design, construction and operation of hyperbaric or hypobaric facilities which are man rated.

Although not limited to the following, the majority of equipment for civil aircraft use will be subjected to extremes of altitude, temperature and humidity.

3.5.1 Combination Test Chambers:

- 3.5.1.1 Environmental test chambers capable of multiple testing for altitude, temperature and humidity, or any combination thereof, may be utilized.

- 3.5.1.1.1 Chamber Volume: Chamber internal work volume may vary from as small as 1 ft³ to as large as 250 ft³ (0.028 to 7.08 m³) with some custom built chambers even larger.
- 3.5.1.1.2 Chamber Materials: Internal chamber surfaces shall be constructed preferably of welded stainless steel for purposes of high strength, corrosion resistance, minimization of pressure and temperature loss, and for ease of cleanliness. Any use of wood construction is to be avoided.
- 3.5.1.1.3 Chamber Insulation: The chamber shall be fully insulated for low heat transfer and impermeability to moisture.
- 3.5.1.1.4 Chamber Strength: Structural integrity of the chamber utilized shall be verified for the altitude range desired when subjected to vacuum to prevent implosion.
- 3.5.1.1.5 Access Door: A full opening, full width access door provided with a thermal pane fracture-proof viewing window, along with internal illumination, is desirable. The access door shall be provided with a minimum of two peripheral door seals for vacuum and thermal insulation and with rugged, quick release door latches.
- 3.5.1.1.6 Access Ports: Adequate access ports for pressure and instrumentation lines to the test specimen should be located in the chamber side walls. All pressure or electrical line connectors shall be pressure tight.
- 3.5.1.1.7 Circulation Fans: Internal circulation fans with grid protection shall be available for air circulation and reduction of hot or cold spots. The fans shall be provided with externally located motors and on-off controls; a fan on-off door interlock switch is desirable.
- 3.5.1.1.8 Temperature Sensors: Unless otherwise specified, thermocouples or equivalent temperature sensors utilized to determine or control the specified chamber temperature shall be centrally located within the test chamber where possible or in the return air stream, and shall be baffled or otherwise protected against impingement of supply air and against radiation effects.
- 3.5.1.1.9 Altitude Indicator: An easy to view, externally mounted mercury manometer shall be utilized for direct indication of altitude within the chamber. Dual calibration in millimeters of mercury and altitude in feet is preferred.
- 3.5.1.1.10 Temperature Indicator: Various instruments are available for the measurement or recording of chamber internal temperatures. The device utilized shall be selected to provide sufficient accuracy, response, and range for the test being conducted. Devices available include liquid or bi-metal thermometers, thermowells with electronic readouts, analog or digital readouts with thermocouples or thermistors and strip chart recorders. Electronic readouts designed for use with thermocouples offer certain advantages such as: high accuracy, ability to attach sensors directly to item under test and multichannel capability. For additional information refer to 3.6.4.

- 3.5.1.1.11 Humidity Indicator: A Wheatstone bridge type hygrometer located externally on the chamber, with a varying resistance humidity sensor located within the chamber, may be used as a direct readout for relative humidity. Accuracy of $\pm 1\%$ in the range of 1 to 98% relative humidity is required. Correction factors for the variation in chamber temperature are usually necessary with this instrument.

Another method for measuring humidity is by the use of a dew point hygrometer. Since dew point is independent of temperature the control of chamber temperature is less critical, allowing more convenient indication.

A third method of measuring relative humidity within the chamber is the use of the conventional wet and dry bulb thermometers. While relatively accurate (± 1 to $\pm 4\%$), the direct readout types must be placed directly in the circulated airstream within the chamber, thereby, restricting viewing. By using charts prepared for this purpose, the relative humidity (percent of saturation) can be determined at any given temperature by viewing the difference in reading between the wet and dry bulbs. Remote control recorder indicators using wet and dry bulbs are also available.

- 3.5.1.1.12 Electrical Requirements: All electrical components and wiring shall comply with the national electrical code and OSHA requirements. No exposed wiring shall be allowed within the chamber.

- 3.5.1.2 Low Temperature: Two basic methods of cooling environmental test chambers are in current use. One approach is the injection of cold gases (CO_2 or N_2) taken from their liquid state. The more common method is the mechanical refrigeration type with compressor(s) similar in some respects to the household refrigerator.

Lower temperature, lower operating costs, faster cooling and pull-down with improved control accuracy, together with lower frost and ice buildup, are certain advantages normally associated with the mechanical type vs. the gas injection type.

Mechanical systems are available in single stage or cascade types where extreme low temperatures or rapid pull-down is required.

The gas injection type is normally cheaper to procure or construct, and due to less complexity, is usually considered more reliable in operation and startup after long periods of shutdown. These units are usually easier and less expensive to repair.

Liquid CO_2 or LN_2 are often used as boosters or as a backup cooling system for the primary mechanical refrigeration system.

A third method of cooling, the use of frozen CO_2 (dry ice), may be more difficult to control.

- 3.5.1.2.1 Low Temperature Range: The test chamber shall be capable of reducing the temperature of the internal volume to -100 °F (-73.3 °C) from an ambient temperature of 75 °F (23.9 °C).
- 3.5.1.2.2 Low Temperature Control Accuracy: After stabilization of the chamber internal temperature at any set point from ambient to -100 °F (-73.3 °C), the regulation system shall be capable of maintaining that temperature at the control sensor within ± 2.5 °F (± 1.4 °C). The temperature gradient across the cross sectional area occupied by the test item shall not exceed 0.5 °F (0.3 °C) per foot in any direction.
- 3.5.1.2.3 Temperature Pull-Down Rate: The chamber with the test specimen installed shall be capable of reducing the internal temperature from ambient to -100 °F (-73.3 °C) within a time period of 30 to 90 min.

Special thermal shock units are available for immediate temperature reduction.

- 3.5.1.3 High Temperature: Heating of the chamber shall be conducted by open wire staged heating elements for rapid response and close tolerance control. The heating element(s) shall be suitably protected from the working area by a baffle. Blowers shall be employed for proper heat convection and air flow. If the chamber is to be utilized for high oxygen concentrations, open-wire staged heating elements are potentially hazardous and radiant heating is then recommended.
- 3.5.1.3.1 High Temperature Range: The test chamber shall be capable of raising the internal volume to a temperature of 350 °F (177 °C) from an ambient temperature of 75 °F (23.9 °C).
- 3.5.1.3.2 High Temperature Control Accuracy: After stabilization of the chamber internal temperature at any set point from ambient to +350 °F (177 °C), the regulation system shall be capable of maintaining that temperature at the control sensor within ± 2.5 °F (± 1.4 °C). The temperature gradient across the cross sectional area occupied by the test item shall not exceed 0.5 °F (0.3 °C) per foot in any direction.
- 3.5.1.3.3 Temperature Buildup Rate: The chamber, with the test specimen installed, shall be capable of increasing the temperature from ambient to +350 °F (177 °C) within a time period of 30 to 60 min. Special thermal shock chambers shall be employed where immediate temperature increase is required.
- 3.5.1.4 Altitude: Pressure evacuation of the internal volume of the test chamber shall be by means of adequate, oil free vacuum pumps with appropriate controls. The chamber shall be so constructed as to minimize inboard leakage to prevent excessive pump cycling.
- 3.5.1.4.1 Altitude Range: The internal volume of the chamber shall be capable of being reduced to a vacuum of 33.7 mm mercury (70 000 ft altitude).
- 3.5.1.4.2 Altitude Control Accuracy: After stabilization of the chamber internal volume at any set point from ground level to 70 000 ft (21 336 m), the vacuum control system shall be capable of maintaining that altitude within $\pm 0.5\%$.