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AEROSPACE INFORMATION REPORT

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INSTALLATION OF LIQUID OXYGEN SYSTEMS IN CIVIL AIRCRAFT

1. INTRODUCTION

Liquid oxygen supply systems for breathing oxygen for the crew and/or passengers of transport aircraft require design and installation considerations, which are detailed herein.

AIR 825, Oxygen Equipment for Aircraft, contains general information on determination of breathing oxygen requirements and equipment for the crew and passengers of transport category aircraft. This document covers the more specific requirements for either a 70 or 300 psig liquid oxygen system. The standard 70 psig nominal pressure is recommended for use except in cases of excessive pressure drop, flow requirements, and some continuous flow regulators which may require the 300 psig nominal pressure system.

AS 861, Minimum General Standards for Oxygen Systems and AIR 822, Oxygen Systems for General Aviation Aircraft, also contain general applicable information.

Note: When Military Specification components are referenced in this document, it is intended that this be interpreted as a guide and that components functionally equivalent to these units may be used.

2. DESIGN AND INSTALLATION

2.1 General: An aircraft liquid oxygen system should comprise as required, liquid oxygen converters, tubing, fittings, quantity gages, heat exchangers and appropriate pressure and flow control components. The installation may provide for replenishing the liquid oxygen supply by use of quick-removable converters, or, in the case of fixed installation of converters, by providing external access for connection to a portable service trailer.

Components of the oxygen system should not be installed where they will be subjected to temperatures in excess of that specified in the individual components specifications, and no part of the system should be installed in an area which will be subject to a temperature of 265 F or greater. In order to minimize loss due to heat, liquid oxygen converters should not be located near equipment that dissipates a high quantity of heat. The oxygen equipment, tubing, and fittings should be located as remote as practicable from fuel, oil, hydraulic, storage batteries, exhaust stacks, manifolds, and electrical components. Where necessary, deflector plates shall be used to keep flammable fluids away from oxygen lines, fittings, and equipment. Converters shall not be in line with the plane of rotation of the turbine and/or propeller.

2.2 Size and Number of Converters: Civil Transport Category aircraft are required to have either a separate oxygen system or a separately reserved supply for the crewmen. The oxygen system should be designed to provide supplemental oxygen for all crewmen and passengers with flow rates and durations meeting the requirements specified in Federal Aviation Regulations Parts 23, 25, 91, 121, and 135 as appropriate.

If more than one converter is required for passenger oxygen in an aircraft, they should all be of the same size. The number of converters is determined by dividing the oxygen requirement determined from AIR 825 by "Q" from Table I.

TABLE I

Liquid Oxygen Converter Characteristics

Converter Size (Liters)	Operating Pressure (PSI)	Free Gas Available (Liters) NPTD	Design Flow Rate (LPM)	Q (Liters) NPTD
5	70	4300	72	3030
10	70 & 300	8600	82-100	6740
25	300	21500	150	19000
75	300	64500	400	60900

NOTE: Q differs from Free Gas Available to allow for 24 hour evaporation loss plus a safety factor.

It should be noted the above flow ratings are conservative and may be varied through proper heat exchanger design. For detailed information the individual converter and heat exchanger manufacturers should be contacted.

2.2.1 Flow Requirements: The maximum flow required from the converter shall be calculated as indicated in AIR 825, using an appropriate safety factor. This flow shall be required from the converter without pressure degradation. In multiple converter installations, each converter must be capable of supplying the calculated flow requirement. The flow rate will vary with system design features and with other related factors such as temperature, location, etc.

2.3 Quantity Indicators: A quantity indicator shall be installed at the pilot's, co-pilot's or flight engineer station to permit monitoring of the total aircraft oxygen supply. Where more than one converter is installed, a single totalizing indicator could be utilized to show total quantity. Liquid oxygen quantity indicators should be in accordance with MIL-G-19053 or MIL-I-25645, as applicable.

2.4 Press-To-Test: A press-to-test switch in accordance with MIL-S-8805/3 should be located near the liquid oxygen quantity indicator. This switch shall allow the indicator to be functionally checked.

2.5 Gauging System: The gauging system when installed in the airplane shall indicate the amount of liquid oxygen in the converter(s) within an accuracy tolerance of ± 4% of full scale indication plus ± 2% of actual scale indication at any of the major dial divisions on the oxygen quantity indicator. The length of the cables shall not affect the accuracy of the systems. Adequate clearance shall be provided the indicator connectors so that they can be readily disconnected by servicing personnel. Provisions shall be made for the storage of the aircraft connectors to the liquid oxygen converter when they are disconnected.

2.5.1 Dummy Converter: A dummy converter should be installed adjacent to any converter which may be omitted from the aircraft during a flight mission. The dummy converter provides an electrical equivalent of the removed converter for proper gauging system operation. See MIL-D-26393 for dummy converter for 25 liter converter indicator system.

2.6 Fill-Buildup-Vent Valve: Each permanently installed liquid oxygen converter shall be filled from a separate combination fill-buildup-vent valve. Combination fill-buildup-vent valves should be in accordance with MIL-V-25961. Where possible, the filler box should be located approximately 5 feet above the ground in order to be readily accessible from the ground. Clearance shall be left around the fill-mating section of the combination fill-buildup-vent valve to allow the insertion and easy connection of the 2 inch diameter female section of the ground servicing valve (MIL-V-38201).

2.6.1 Fill Line: The length of the fill line between the combination fill-buildup-vent valve to the liquid oxygen converter shall be kept as short as possible to minimize lox loss while filling. Fill line should not be longer than 10 feet. The fill lines shall be insulated to prevent frosting and sweating where they pass over equipment which could be harmed by water dripping from the lines, or suitable drip pans shall be installed under the lines.

2.6.2 Vent Line: The vent line from the combination fill-buildup-vent valve shall be so located as to drain overboard at the bottom of the aircraft within sight of the filler box and not closer than 24 inches to it. Flow from the overboard vent shall be directed away from the filling valve so as to not create a hazard for servicing personnel and not to allow vented gaseous or liquid oxygen to impinge on the aircraft. The vent lines shall be insulated to prevent frosting and sweating where they pass over equipment which could be harmed by water dripping from the lines, or suitable drip pans shall be installed under the lines.

2.6.3 Drain Valve (permanently installed converters): A liquid oxygen drain valve in accordance with MIL-F-25962 should be connected in the fill line between the combination valve and the converter in order to drain the converter. Overboard drain from the liquid oxygen valve should terminate in an end fitting conforming to MS33656 and located in the filler box. It should have a cap in accordance with AN929-5 with a suitable tether permanently attached to the rear of the cap.

2.7 Pressure Relief Valve: The pressure relief valves shall be vented overboard, using 5/16 inch O.D. by 035 inch wall thickness tubing or larger equivalent passage. The relief valve overboard vent may be the same as that used for the combination fill-buildup-vent valve.

2.8 Check Valves: When more than one converter is installed in an aircraft, a spring loaded check valve in accordance with MIL-V-25513 (300 psi) or MIL-V-25514 (70 psi) should be installed to prevent the possibility of supply flowing back into the supply port of another converter. See Figures 1 and 2 for typical circuits for a two converter, one and two manifold designs.

2.9 Removable Converters: When removable converters are to be installed in an oxygen system the installation should provide for simple and rapid replacement, being capable of removal and replacement within approximately three minutes. One example of a removable converter is shown in MIL-C-19803.

2.9.1 Converter Mounting Bracket: The bracket necessary to mount this (MIL-C-19803) converter in the aircraft is in accordance with MS90341 or equivalent design.

2.9.2 Coupling: The quick disconnect couplings for the removable converter supply and vent lines should be in accordance with MS22068 or equivalent design. To insure adequate glove clearance around valves and disconnects the following clearances shall be provided: The minimum clearance shall be a 3 inch diameter circle around the vent and supply disconnects and a 5 inch diameter circle around the filler valve. The centers of the circular clearance areas coincide with the longitudinal axis of the valves.

2.10 Metal Hose (Removable Converters): All metal hose assemblies should be in accordance with MIL-H-22343 or equivalent. Flexible supply lines shall be 5/16 inch minimum ID and flexible vent lines shall be 1/2 inch minimum ID. The bend radius shall not be less than that specified in the flexibility test of MIL-H-22343. Where there is relative motion between two connections, metal hose shall be used and shall be so installed that torsion (twisting) will not occur under any condition of operation. There shall be no tendency for connecting fittings to loosen and clamp type flexible tubing installation shall not be used. Supply and vent lines shall contain metal hose of sufficient length to provide for satisfactory connection or disconnection of the disconnect couplings at the converter. The supply and vent disconnect valves attached to the metal hose shall mate with the corresponding disconnect halves on the converter. All metal hoses shall be suitably protected against chafing, where necessary.

2.11 Tetrafluoroethylene Hose (Permanently Installed Converter): Tetrafluoroethylene flexible hose may be used in place of the above metal hose assemblies and shall be in accordance with MIL-H-26626 and the applicable P/N of MS24548. Only where externally shock-mounted converters are used is flexible hose required.

2.12 Tubing: All plumbing shall have markings indicating Breathing Oxygen, Flow direction, and function such as "VENT", "FILL", "DRAIN", "SUPPLY", etc., with black letters on a green background. Spacing of markings shall be such that at least one identification is visible and recognizable from any observation point along the line. All tubing shall be bonded in accordance with MIL-B-5087. The tubing shall be of aluminum alloy, conforming to WW-T-700/4, or corrosion resistant annealed tubing conforming to MIL-T-8506.

2.12.1 Dimension Data: Where other equipment might be affected by condensation, the supply tubing shall be provided with drip shields, or other suitable means of protection. Tubing for all lines other than fill lines and vent lines connecting to the fill-buildup-vent valves shall have a passage canal of sufficient size to accommodate the required flow rate but shall not be smaller than the equivalent of -5/16 in. O.D. by .035 inch wall thickness tubing. Tubing for the fill line shall have a passage equal to or larger than 3/8 inch O.D. by .035 inch wall thickness tubing. Tubing for the vent line connecting to the fill-buildup-vent valve shall have a passage equal to or larger than 1/2 inch O.D. by .035 inch wall thickness tubing.

2.12.2 Tubing Routing and Mounting: There should be at least 2 inches of clearance between the oxygen system and flexible moving parts of the aircraft. There should be at least 1/2 inch clearance between the oxygen system and rigid parts of the aircraft. The oxygen system tubing, fittings, and equipment should be separated at least 6 inches from all electrical wiring, heat conduits and heat emitting equipment in the aircraft. Insulation should be provided on adjacent hot ducts, conduits, or equipment to prevent heating of the oxygen system. In routing the tubing, the general policy shall be to keep total length to a minimum consistent with Table II. Allow for expansion, contraction, vibration, and component replacement.

All tubing shall be mounted to prevent vibration and chafing. This shall be accomplished by the proper use of rubberized or cushion clips installed at no greater than 20 inch intervals and as close to the bends as possible. The tubing, where passing through or supported by the aircraft structure, shall have adequate protection against chafing by the use of flexible grommets or clips. The tubing shall not strike against the aircraft structure during vibration and shock encountered during normal use of the aircraft.

2.12.3 Heat Exchanger and Frost Line Data: Where the converter does not include warming coils or a heat exchanger, Table II indicates the minimum length of tubing which may be required between converter and first occupant's dispensing equipment for the indicated flow rate. Table III indicates the approximate length of supply tubing along which frost and condensation can be expected for the indicated flow rate. Where other equipment might be affected by condensation, the supply tubing shall be provided with drip shields or other suitable means of protection. The temperature of the oxygen delivered to the occupants should be within 20 F of cabin ambient.

TABLE II

Flow (Liters per minute)	Length (of 5/16 inch tubing, plain, foot)	Length (of 1/2 inch tubing, plain, foot)
20	25	15
30	30	17
40	40	19
50	50	22
60	60	25
70	75	40
80	90	45
100	100	60
120	110	75

TABLE III

Flow (Liters per minute)	Length (of 5/16 inch tubing, plain, foot)	Length (of 1/2 inch tubing, plain, foot)
20	18	3
30	18	7
40	18	10
50	25	12
60	30	14
70	40	20
80	50	23
100	63	32
120	76	35

For passenger oxygen requirements, a heat exchanger is required that is capable of a heat exchange of 475 BTU/1000 liters/minute of NPTD gas required. For these high flow requirements hot gas exchange, electrical flash boiler, or other heat exchange means may be used, such as additional length of tubing in coils or parallel connecting runs.

2.12.3.1 Additional frost line data and heat exchanger data may be found in WADC TR 57-73 (ASTIA, Document AD 118031).

2.13 Fittings: All fittings should be in accordance with applicable standards. Unless suitably protected against electrolytic corrosion, dissimilar metals shall not be used in intimate contact with each other. Dissimilar metals are defined in MS33586.

2.14 Torqueing of Joints: Tightening of flared tube and pipe connections shall be accomplished in accordance with the best commercial practice. Torque wrenches shall be used, and the torque applied shall be within the limits specified in Tables IV and V.

TABLE IV

Torque Requirements for Flared Tube Connections*

Tubing O.D. (inches)	Minimum Torque (inch-pounds)	Maximum Torque (inch-pounds)
5/16	100	125
3/8	200	250
1/2	300	400

TABLE V

Torque Requirements for Pipe Connections *

Nominal Pipe Size (inches)	Minimum Torque (inch-pound)	Maximum Torque (inch-pounds)
1/8	40	150
1/4	60	200
3/8	100	400

*Torque to specified minimum value and check for leakage. If additional torque is required to stop leakage, torque may be applied up to specified maximum value.

2.15 Thread Compound: Anti-seize tape per MIL-T-27730 or thread compound per MIL-T-5542 should be used on all male pipe thread fittings. Anti-seize tape or compound shall not be used on flared tube fitting straight threads, coupling sleeves, or on the outer side of tube flares. None of the tape or compound shall be allowed to enter the inside of a fitting.

2.16 System Cleanliness: The completed installation shall be free of oil, grease, fuels, water, dust, dirt, objectionable odors, or any other foreign matter, both internally and externally prior to introducing oxygen in the system.

2.16.1 Closures: Lines which are required to be disconnected, due to the location of the converter within the aircraft, during aircraft maintenance checks or overhaul shall be capped to prevent materials which are incompatible with oxygen from entering the system when the system integrity is broken. Caps which introduce moisture and tapes that leave adhesive deposits shall not be used for these purposes. All openings of lines and fittings, shall be kept securely capped until closed within the installation.

2.16.2 Degreasing: All components of the oxygen system shall be procured for oxygen service use in an "oxygen clean" condition. Parts of the oxygen system such as tubing, not specifically covered by cleaning procedures, shall be degreased using a vapor phase degreaser in accordance with O-T-634. Ultrasonics may be used in conjunction with vapor phase degreasing for the cleaning of components. After completion of the cleaning and when assembled, General Electric Type H Leak Detector, or equivalent Halide testing apparatus shall be used to determine the absence of the cleaning compound. The maximum hydrocarbon content shall not exceed 10 mg/sq. ft. of surface area within the converter and its associated tubing, and 2 mg/sq. ft. of surface area within other components.

2.16.3 Purging: After initial assembly of oxygen system and after system closure whenever the oxygen system pressure has been depleted to zero or has been left open to atmospheric conditions for a period of time or is opened for repairs, the system shall be purged with hot, dry oxygen, conforming to MIL-O-27210, Type I. The purge flow should be 65 ± 5 LPM and the temperature at the inlet to the system shall be 235 F ± 15 F. The purging procedure should meet the following requirements:

2.16.3.1 Converter Only: The purging of the converter should be per Table VI.

TABLE VI

Converters Capacity (Liters)	Container At Ambient Temperature- Purging Period (Minutes)	Within 6 Hours After Draining- Purging Period (Minutes)
5 and 10	70	120
25 and 75	90	120

2.16.3.2 Converter Supply Line: The time required for purging should be 35 minutes.

2.16.3.3 Hot, dry nitrogen conforming to BB-N-411, Type I, Class I, Grade B may be used for purging components; however, nitrogen shall not be used for purging the completed installed liquid oxygen system.

2.17 Lubricants: Lubricant shall not be used anywhere in the oxygen system.

2.18 Maintenance and Replacement: All parts of the oxygen system should be installed to permit ready removal and replacement without the use of special tools. All tubing connections and fittings shall be readily accessible for leak testing with leak test compound per MIL-L-25567 and for tightening of fittings without removal of surrounding parts.

2.19 Aircraft Marking Requirements: The aircraft shall be permanently and legibly marked in the locations specified below, using a minimum letter height of 1/4 inch:

a. Adjacent to the overboard vent opening: CAUTION LIQUID OXYGEN VENT

b. On outside surface of filler box cover plate: LIQUID OXYGEN (BREATHING) FILL ACCESS

c. On underside surface of filler box cover plate: CAUTION - KEEP CLEAN, DRY, AND FREE FROM OILS

d. In prominent place when filler box is open, preferably near liquid oxygen drain valve: DO NOT OPEN DRAIN VALVE UNTIL DRAIN HOSE AND DRAIN TANK ARE CONNECTED

3. INSTALLATION TESTS

3.1 Leakage: The complete system shall be charged with gaseous oxygen to 70 psig pressure. The oxygen pressure and time shall be recorded. The oxygen pressure shall again be recorded after one-half hour and shall pass the requirements specified in Table VII. Proper allowance for pressure change due to temperature change should be made.

TABLE VII

Converters Capacity (Liters)	Maximum Allowable Pressure Decay (Pounds per Square Inch)
5	12
10	6
25	3
75	2.5

3.2 Evaporation Loss Test (Permanently Installed Converters): The completed aircraft system shall be filled with liquid oxygen, and the mating fill assembly shall be disconnected from the combination fill-buildup-vent valve. One hour after filling the system a wax pencil shall be used to mark positions of pointers on glass faces of liquid oxygen quantity indicators. Twenty-four hours after marking indicators, readings shall be taken on indicators and the evaporation loss shall be within the range specified in Table VIII.

TABLE VIII

Converters Capacity (Liters)	Maximum Acceptable Loss of Liquid Oxygen After 24 Hours (Liters)
5	1.0
10	1.25
25	1.75
75	3.00

3.3 Electrical Continuity Test: The liquid oxygen quantity indicator leads shall be disconnected from the converter. A capacitance tester, capable of providing stable and precise electrical capacitance equivalents to empty and full liquid oxygen converters, shall be connected to the leads disconnected from the converter. The capacitor shall first be set at a value equal to that of an empty converter and then the quantity indicator shall be read. The above shall then be repeated with the capacitor set at a value equal to that of a full converter. Where two or more converters are installed in an aircraft, the above test shall be conducted at each converter with the capacitor connected to the leads disconnected from one converter, as described above, and all other oxygen quantity indicator leads in the system shall be disconnected from the converters and connected to dummy converters. The liquid oxygen indicator shall pass the requirements specified in Table IX.

TABLE IX

Converter Capacitance*

Converter Capacity (Liters)	Converter Capacitance (UUF)	
	Empty	Full
5	63.5 ± 0.5	92.5 ± 1.0
10	123.5 ± 1.2	181.5 ± 2.2
25	303.5 ± 2.5	448.4 ± 5.0
75	910.5 ± 7.5	1345.5 ± 15.0

* When two or more converters, of the same capacity, are installed in the aircraft, the empty and full capacitance and tolerance of one converter shall be multiplied by the number of converters in the aircraft to obtain the total capacitance and tolerance. This applies only to a single totalizing indicator.

3.4 Press-To-Test: The test of the press-to-test button shall be conducted by using the capacitance tester. This tester shall be set so that the indicator pointer indicates a quantity between 1/2 full and full. The pointer of the capacitance gage shall rotate counter-clockwise when the press-to-test button is pressed. The pointer shall return to its original position when the button is released.

4. LIQUID OXYGEN SERVICING INFORMATION

4.1 Aircraft Servicing Information: Because of the fill time element with overboard venting of oxygen, and other services (such as the jet aircraft fuel) it is best to replenish the liquid oxygen supply at a remote area. This is best accomplished through the use of a quick-turn-around converter. These quick removable, self-contained units are filled at some remote area several hours before required as a replacement unit on the flight line. When an aircraft system is to be serviced, the existing equipment is removed from the aircraft through a supply, and vent quick disconnect coupling, two electrical connectors, and one wing nut and tee clamp bolt. Upon its removal, a full pressurized liquid oxygen converter is installed and the above connection points reconnected. In this manner the oxygen breathing system may be serviced within approximately three minute's time.

However, if required to fill a permanently installed converter, or if a spare, filled converter is not available, the existing unit may be topped off with liquid oxygen while remaining in the airframe. Under these conditions, a liquid oxygen service cart is wheeled to the aircraft, and a standard liquid oxygen filler hose and nozzle (MIL-V-38201) is connected to the converter fill valve which in turn "vents" the system to the atmosphere. Topping off a 10 liter converter results in a vented loss of as much as 5 liters of LOX. Therefore, with other stores and supplies in the area this could represent a potential danger spot during ground services and for this reason it usually requires a special service area and crew and a discontinuance of other services or maintenance activities likely to create ignition or combustible sources such as electrical component actuation, refueling, etc. Refer to SAE AIR 822 for more complete servicing instructions.

PREPARED BY
SAE COMMITTEE A-10, AIRCRAFT OXYGEN EQUIPMENT

APPENDIX

Specific cautions applicable to Liquid Breathing Oxygen taken from the National Fire Protection Association Pamphlet, NFPA No. 410B.

NOTE: Liquid breathing oxygen charging operations are not regarded as more hazardous than gaseous breathing oxygen charging operations; however, a spill of liquid oxygen introduces a new hazard which must be specifically safeguarded.

1. Do not permit liquid oxygen to contact any part of the body or clothes. It can cause severe skin injury and make clothing highly combustible. Do not handle liquid oxygen lines with bare hands.

2. Personnel should wear protective clothing while handling liquid oxygen equipment including:

   a. Safety goggles or a clear plastic face shield.

   b. Clean, dry, leather, rubber-coated cotton or asbestos canvas-lined gloves. It is recommended that these gloves be loose fitting without wrist gauntlets.

   c. Clean coveralls with long cuffless sleeves or rubber or asbestos aprons. In cold weather, a clean rubber raincoat, preferably without pockets, may be worn over jackets or coats.

   d. Shoes should preferably be of the high-top type with cuffless trousers worn outside the shoes.

   NOTE: If liquid oxygen is spilled on clothing, the clothing shall be removed immediately and thoroughly aired before reuse.

3. Personnel who have handled liquid oxygen should refrain from smoking for at least 15 minutes after leaving the charging area.

4. Exercise care that no moisture is introduced into a liquid oxygen system and that there is no moisture in fill fittings or nozzles where it may be entrained into the system during transfer operations. Dry, oil-free air, oxygen, or nitrogen may be used to eliminate moisture before introduction of liquid oxygen.

5. Because of its low temperature, liquid oxygen must be handled in equipment constructed of materials suitable for the service. Ordinary rubber or plastic hoses, gaskets, seals, etc., for example, are unsuitable.

6. If it is necessary to transfer liquid oxygen from one container to another, care is needed to avoid splashing. Cool the receiving container gradually to avoid breakage. Easily fracturable containers (such as glass) should not be used. The container must be clean.

7. When transferring liquid oxygen, do not leave valves open all the way; open them wide and then immediately close them about one-quarter turn; otherwise they may freeze in the open position.

8. Use pressure relief devices on all lines in which liquid oxygen may be trapped between closed valves and on closed containers.