AEROSPACE INFORMATION REPORT

AIR825™/3 REV. A

Issued 2010-08
Reaffirmed 2021-08
Revised 2022-05

Superseding AIR825/3

Gaseous Oxygen and Oxygen Equipment, Introductory

RATIONALE

The content of the SAE Aerospace Information Report is updated to reflect the latest oxygen system design practice realized on current aircraft.

References to actual standards (e.g., SAE, ISO) are added. Extensive revision of the chapters fire risks, design precautions and the use of check valves are included. Editorial changes are made in addition.

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1. SCOPE

This SAE Aerospace Information Report provides a general discussion on gaseous breathing oxygen and oxygen equipment for use on commercial aircraft. Other types of oxygen systems are mentioned to assist in this discussion. For detailed information on systems other than gaseous, refer to the appropriate section of AIR825.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of the other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR825/4 Chemical Oxygen Systems

AIR825/5 Liquid Oxygen Systems

AIR825/6 On-Board Oxygen Generating Systems (Molecular Sieve)

AIR825/8 Continuous Flow Oxygen Systems

AIR825/9 Demand Oxygen Systems

AIR825/12 Oxygen System Integration and Performance Precautions

AIR825/13 Guide for Evaluating Combustion Hazards in Aircraft Oxygen Systems

AIR825/14 Basic Aircraft Oxygen Systems Design

AIR1059 Oxygen Cylinder Quality, Serviceability, Maintenance Transfilling, and Marking

AIR5742 Packaging and Transportation of Oxygen Equipment

ARP1176 Oxygen System and Component Cleaning

ARP1532 Aircraft Oxygen System Lines, Fabrication, Test, and Installation

ARP4287 Supplemental Oxygen Devices with Automatic or Manual Presentation

ARP6390 Location of Crew and Passenger Oxygen Masks, Portable Oxygen System, and Protective Breathing Equipment

AS1046 Minimum Standard for Portable Gaseous, Oxygen Equipment

AS1066 Minimum Standards for Valve, High Pressure Oxygen, Cylinder Shut Off, Manually Operated

AS1225 Oxygen System Fill/Check Valve

AS8010 Aviator's Breathing Oxygen Purity Standard

AS8025 Passenger Oxygen Mask

2.1.2 Airworthiness Requirements

CS 25	Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes (EASA)
CS 25.1445 (a)	Equipment standards for the oxygen distributing system
CS 25.1453	Protection of oxygen equipment from rupture
14 CFR Part 25	Airworthiness Standards, Transport Category Airplanes, Federal Aviation Administration (FAA)
14 CFR 25.1445 (a)	Equipment standards for the oxygen distributing system
14 CFR 25.1453	Protection of oxygen equipment from rupture

2.1.3 Other Publications

ISO 9809-1	Gas Cylinders – Design, construction and testing of refillable seamless steel gas cylinders and tubes – Part 1: Quenched and tempered steel cylinders and tubes with tensile strength less than 1100 MPa
CGA V-1	Standard for Compressed Gas Cylinder Outlet and Inlet Connections
CGA S1-1	Pressure Relief Device Standards Part 1 – Cylinders for compressed gases

2.2 Definitions

CGA: Compressed Gas Cylinder Association – North American Standardization Organization of safety standards in the industrial, medical, and food gases industry; founded in 1913.

CYLINDER VALVES: A device installed on the end of the pressure vessel to control or shutoff the flow of the gas.

DOT: Department of Transportation. The DOT was established in 1966 and incorporated many of the functions of the ICC, including regulating the manufacture and transportation of pressurized vessels in the U.S.

EIGA: European Industrial Gases Association. EIGA was founded in 1991. It provides Authorities and Standardization bodies with expert advice on production, transport, storage and applications of industrial, medical and food gases.

ICC: Interstate Commerce Commission. The ICC was an independent agency of the U.S. government that was established in 1887; one of the function of the agency was to regulate the manufacture and transportation of pressurized vessels. The ICC's safety functions were transferred to the Dept. of Transportation in 1966.

ISO/TC58: Technical Committee for Gas Cylinders founded in 1947. Standardization of gas cylinders and other pressure receptacles, their fittings and requirements relating to their manufacture and use.

OHFRA: Oxygen Hazard and Fire Risk Analysis – an oxygen equipment and systems combustion risk assessment.

OXYGEN CYLINDER: Pressure vessel to store breathing gas (oxygen) under pressure. Such equipment is available in various sizes and designed according to EIGA, UN, ICC, or DOT specifications.

PRESSURE RECEPTACLES: The UN refers Gas cylinders and tubes collectively as “pressure receptacles.”

UN NUMBERS: UN numbers specify a certain type of pressure vessel usable for specific gas(es).

3. OXYGEN

Aircraft oxygen systems may utilize either a gaseous, chemical, liquid, or on-board generated oxygen supply. These systems indicate the method of storage/supply, from which the system delivers the oxygen to the user in a gaseous state.

3.1 Gaseous Oxygen

Gaseous oxygen systems store oxygen in its gaseous state in a variety of oxygen cylinders types. Currently, the oxygen storage cylinders may be high pressure 12.75 to 20.68 MPa (1850 to 3000 psig) or low pressure 2.76 to 3.45 MPa (400 to 500 psig). A regulator or shutoff device is installed on the cylinder as a means to start and stop the flow of oxygen. Additionally, a regulator will regulate the oxygen pressure from the cylinder down to about 0.68 MPa (100 psi) or less as a means to minimize the use of high-pressure oxygen lines.

3.2 Chemical Oxygen

A chemical oxygen generator produces gaseous oxygen by means of a chemical reaction involving the decomposition of a chemical. For information on chemical oxygen generators, refer to AIR825/4.

3.3 Liquid Oxygen

Liquid oxygen systems are designed to store oxygen in its liquid state and convert it to its gaseous state when required for use. This type of oxygen system is primarily used for military and medical applications and not for commercial transportation use due to logistical reasons. For information on liquid oxygen, refer to AIR825/5.

3.4 On-Board Oxygen Generating Systems (Molecular Sieve)

On-board oxygen generator systems utilize the ability of molecular sieve materials by using a rapid pressure swing adsorption process to separate and concentrate oxygen in the product gas from the surrounding air, respectively air provided from a compressor or bleed air provided by the aircraft engine. This oxygen enriched air is provided as supplemental oxygen for the crew and in some cases the passengers. For information on OBOGS, refer to AIR825/6.

3.5 Other On-Board Oxygen Generating Technologies

Other on-board oxygen generator systems are electrolysis or ceramic membrane technology. Electrolysis utilizes the ability of electric power to split water molecules into oxygen and hydrogen gases while a ceramic membrane acts as gas filtration to separate oxygen from air. Both technologies provide the breathing oxygen for the crew and in some cases the passengers. As of now these technologies have not been certified on an aircraft application.

4. OXYGEN SUPPLY SYSTEMS

Oxygen equipment to fulfill human's physiological needs in aircraft fall into two general categories: fixed and portable. Fixed equipment is generally provided in aircraft in which oxygen is frequently required or many passengers are involved. The installation of a quantity of portable oxygen units on aircraft, which has fixed oxygen, depends on the regulatory agency such as FAA or EASA requirements for the crew and passengers and whether there is a requirement to move around the aircraft cabin. Portable oxygen equipment, which may also be required for first aid and/or therapeutic purposes, can be provided in aircraft where the use of oxygen is infrequent. For information on minimum standards for portable gaseous oxygen equipment, refer to AS1046.

4.1 Fixed Oxygen Systems

A fixed gaseous oxygen system typically will consist of an oxygen cylinder(s) to store the supply, a means to regulate the pressure of that stored oxygen, and a means to dispense the oxygen supply.

4.1.1 Oxygen Storage

The supply of oxygen (i.e., how it is stored on the aircraft) will depend on the type of oxygen being used. In a gaseous oxygen system, the oxygen is stored in a pressure vessel/cylinder, where typical maximum cylinder pressure is 12.75 to 20.68 MPa (1850 to 3000 psig). The cylinders in common usage are made from steel and composite materials (e.g., Kevlar or carbon fiber). The cylinder assembly must have a means to start and stop the flow of oxygen. Additionally, if applicable, the cylinder assembly should have a means to regulate the flow of oxygen from the cylinder. It is recommended that this be accomplished with a cylinder mounted slow opening valve or cylinder mounted regulator assembly to avoid adiabatic compression of the downstream components.

4.1.1.1 High Pressure Cylinders

The cylinders store gas at 12.75 to 20.68 MPa (1850 to 3000 psig) and are available in a variety of shapes and sizes.

Steel cylinders: Steel cylinders of regular shape with hemispherical ends are commonly in use. Refer to AIR825/14 for illustrations of the weights and dimensions of the cylinders used by commercial carriers.

DOT Specification 3AA covers the design and manufacture of regulator non-shatterable cylinders. DOT Specification 3HT covers "lightweight" cylinders of the same basic sizes, which show a saving in weight of 15 to 30% of the weight of the equivalent 3AA type.

The requirements for UN pressure receptacles are based on standards published by the International Organization for Standardization (ISO). The relevant International Standards are produced by ISO technical committee ISO/TC58 "Gas Cylinders:"

- Steel: ISO 9809-1, ISO 9809-2, ISO 9809-3
- Aluminum alloy: ISO 7866

Composite cylinders: Composite oxygen cylinders consists of a metal (mostly aluminum alloy) seamless inner liner that is wrapped with Kevlar or carbon fiber and sealed in epoxy matrix. These cylinders provide approximately 50 to 60% weight saving over the conventional steel cylinders; however, they have a shorter useful life.

Composite cylinders holding an approval under a DOT Special Permit, which includes clauses permitting their usage for oxygen on aircraft, are also acceptable (e.g., covered by DOT–FRP-1 for Kelvar-wrapped cylinders and DOT-CFFC for carbon fiber-wrapped cylinders).

DOT authorizes the use of UN pressure receptacles, including composite cylinders designed and manufactured under the following specifications: ISO 11119-1, ISO 11119-2, and ISO 11119-3, albeit with certain restrictions.

4.1.1.2 Low Pressure Cylinders

These cylinders are intended to store gas at 2.76 to 3.45 MPa (400 to 500 psig). They are used mainly in military applications where the smaller energy release on bursting is considered a useful characteristic. For commercial application and use, DOT approved cylinders are available.

4.1.1.3 Cylinder Filling

Typically, the cylinders are filled or "charged" from other oxygen cylinders with higher storage pressures. The common practice is to perform the filling process while the cylinder remains installed onboard the aircraft or the cylinder can be removed from the aircraft and filled at a remote location. Suitable procedures must be followed to ensure safety during the filling process. For aircraft filling or topping off, filler valves are often used that meet AS1225. For information on filler valves, refer to AS1225. For information on transfilling and maintenance of oxygen cylinders, refer to AIR1059.

4.1.1.3.1 On Board Oxygen Generation

Oxygen generated on board the aircraft can be used to supply oxygen directly to dispensing equipment, to fill or to top off the oxygen storage cylinders. Several methods of generating the oxygen on board are chemical generation, molecular sieve, electrolysis, or ceramic membrane. Systems utilizing these sources of oxygen may have different controls, sensors, or components than discussed herein. In addition, consideration of any differences in oxygen quality and oxygen percentage in the breathing gas shall be taken into account in the system's design. For information on chemical generation, molecular sieve, electrolysis, or ceramic membrane, refer to AIR825/4 or AIR825/6, respectively.

4.1.2 Supply System Accessories and Components

Various items and components are required to provide a complete and workable system. The components referred to herein may be optional in some designs, not applicable in some designs, or mandatory in others. Added components not mentioned may be needed depending on particular system requirements.

4.1.2.1 Cylinder Valves

Varieties of cylinder valves are available with threads on the body for screwing into the cylinder neck.

Typically, the outlet thread on the side of the cylinder valve is a 0.903-14 Compressed Gas Association No. 540 (3000 psi) and an adapter is needed to convert to a standard tube fitting.

Other typical oxygen cylinders outlet connections are conforming to CGA No. 577 (4000 psi) or No. 701 (4000 to 5500 psi) depending on maximum servicing pressure (refer to CGA Pamphlet V-1).

State of the art cylinder valves are available with “slow-opening” feature. This feature decreased the heat build-up due to adiabatic compression and thus protects downstream components from reaching their ignition temperatures.

Some cylinders hand valves have an integrated position indication switch. This allows the flight deck crew to determine if the oxygen cylinders are open or closed prior to flight.

For more information on minimum standards applicable to manually operated high-pressure oxygen cylinder shutoff valves, refer to AS1066.

4.1.2.2 Safety Devices

DOT regulations require that all high-pressure cylinders be provided with a safety device to guard against bursting due to excessive pressure (e.g., caused by too high temperatures). This generally takes the form of a rupture disc incorporated in the cylinder valve.

DOT-3HT/-FRP-1/-CFFC cylinders (12.75 MPa [1850 psig] or below) must be equipped with a frangible disc safety relief device, without fusible backing as specified in CGA S1-1. The rated bursting pressure of the disc shall not exceed 90% of the minimum required test pressure of the cylinders with which the device is used.

For the sizing of the safety device, the regulatory agency such as FAA or EASA regulations for pressure strength have to be considered in addition (in particular, refer to 14 CFR/CS 25.1453).

A threaded outlet is provided on some designs of cylinder valves so that oxygen discharge may be piped overboard to avoid an unsafe local oxygen enrichment in case of cylinder discharge. Stainless steel lines are typically utilized for this overboard piping.

A commonly used method to indicate a discharge from the cylinder is by utilizing a overboard discharge port. The overboard discharge port is made of a housing with hole through the middle and a frangible disc installed over the hole. When a cylinder discharge occurs, the frangible disc is discharged from the housing and indicates to the flight crew during preflight checks or maintenance personnel during inspections that a discharge has occurred. The discharge port is commonly installed on the aircraft skin in locations easily accessible to the flight crew or maintenance personnel.

4.1.2.3 Cylinder Pressure Gauges

These are desirable when cylinders are to be recharged away from the aircraft and are incorporated as part of the cylinder valve in most designs. They are also used in some cases when the cylinder is accessible to indicate the available volume. Pressure gauges are usually not equipped on cylinders which are not supposed to be recharged during their design life.

4.1.2.4 Remote Pressure Gauges

Remote pressure gauges or monitors are sometimes required to indicate the quantity of the oxygen supply. They may indicate directly or they may transmit a signal to a remote monitor by using a pressure transducer. This type of gauge is used to monitor the cylinder filling process when cylinders are filled onboard and for a cockpit indication of available pressure of the cylinders. In some cases, a temperature sensor can be used to allow a more precise indication of available oxygen pressure.

4.1.2.5 Warning Devices

On some systems various devices are used to give warning of low system contents and warning when shutoff valves are closed.

Pressure gauges may have the lower end of the scale colored red. Audible or visual warning devices are also used to show loss of pressure, flow in gas lines, or shutoff valves not fully in the open position. Among the devices used are mechanical blinkers or pressure switches connected to a warning light or indication in the cockpit.

4.1.2.6 In-Line Fuse

Shut-off type valves are sometimes installed in the system to enable the distribution lines to be isolated. These are sometimes referred to as “pneumatic fuses” because they are designed to permit a normal rate of flow to pass, while shutting off the flow when the flow becomes excessive following a downstream ruptured line (e.g., following a damage caused by an engine fragment). The fuse or fuses are located as close to the supply as accessibility requirements will allow, so that in the event of a ruptured line, as much of the system as possible may be isolated. The fuse or fuses are commonly used for rotor burst protection of the oxygen lines (see 4.1.6). Particular attention should be paid that those valves will be open prior to beginning of aircraft operation. The fuse design and sizing need to consider the need to permit an initial flow surge when the system is pressurized initially. The fuse shall not close in this case, they need to close when a line is ruptured during system operation only.

The same function is sometimes accomplished using a network of sensors and solenoid valves.

4.1.2.7 Oxygen System Valves

4.1.2.7.1 Crew Shutoff Valves

In crew oxygen systems, there is always a shutoff valve at the supply source to isolate each high-pressure oxygen cylinder from the aircraft distribution system. In addition, some designs include an additional shutoff valve accessible to the flight crew. These valves separate the flight crew masks from the distribution system and are utilized primarily for maintenance such as when the aircraft is parked, or during ground operations.

4.1.2.7.2 Passenger Shutoff Valves

In passenger oxygen systems, there is always a shutoff valve to isolate each high-pressure oxygen cylinder from the aircraft distribution system. In addition, valves are installed to separate the oxygen source from the distribution system. These valves may be integrated into regulators or components commonly referred to as flow control units. Passenger shutoff/isolation valves are normally closed during flight for safety reasons and to limit potential system leakage. They open automatically in case of a cabin decompression or manually by the flight crew, anytime oxygen through the passenger system may be required, such as for therapeutic reasons.

4.1.2.7.3 Valves to Reserve the Supply to the Flight Crew

In systems where both crew and passengers draw oxygen from the same supply source, it is mandatory to have a means to reserve the minimum oxygen supply required by the flight crew on duty in FAA/EASA certified aircraft (refer to 14 CFR/CS 25.1445). In multi-cylinder installations, check valves may be used to prevent the cylinder(s) carrying the flight crew supply from feeding into the passenger system while allowing the flight crew to draw off the passenger supply when necessary.

This can also be accomplished by providing a manually operated shutoff valve which the flight crew can use to close the oxygen flow to the passenger oxygen system while maintaining continued use by the flight crew. This shut off function can also be accomplished automatically by the passenger regulator or control panel. A form of pressure limiting valve may be used which automatically cuts off the passenger supply when the cylinder pressure has reduced to a predetermined value.

These shutoff/isolation valves only allow the flight crew on duty access to the oxygen source. This can be found in single and multi-cylinder installations. Since this design only prevents oxygen flow to the passenger system, the flight crew always has access to the oxygen supply.

4.1.2.7.4 Check Valves in Multi-Cylinder Installations

Check valves installed in a multi-cylinder installation usually provide a means of preventing total oxygen system loss should one or more cylinder(s) become damaged or leaking (e.g., by a failure of connecting flexible hoses installed).

4.1.2.8 High-Pressure Lines

The diameter of lines is dictated by the mass flow to be carried and the acceptable pressure drop. In multi-cylinder installations, the inter-cylinder lines are of small diameter, 4.76 to 7.94 mm (3/16 to 5/16 inch) OD with suitable wall thickness. At least one coil or loop is formed in the lines between each cylinder to avoid damage occurring during cylinder removal and to prevent load being applied due to relative movement between cylinders or lines. Steel braided flexible hoses intended for high pressure may also be used in such applications. The use of high-pressure lines shall be kept at a minimum.

The materials normally used are copper, copper alloys, or stainless steel. With such small diameters, bursting is usually not a problem and the proximity of adjacent cylinders makes it acceptable to rely on the tube end fittings for support of the line.

In the case of multi-cylinder installation, the higher flow through a single distribution line fed by the multiple cylinders may necessitate a larger diameter. These lines should be properly supported at sufficient frequencies. In addition, such lines are bound to pass through zones where other equipment is installed. Areas of combustibles or possible damage during aircraft servicing shall be avoided for installation. Refer to AIR825/12 for oxygen system integration and performance precautions.

Refer to ARP1532 for further details on tubing practices.

4.1.2.9 High-Pressure Fittings

Typical inter-cylinder connections are made with brazed-on nipples and loose coupling nuts (copper and copper alloys), regular flared or flareless tube stainless steel fittings.

For the distribution system, flared or flareless fittings are used.

Usually, fittings are of the same material as the supply lines. Normally, stainless steel fittings are used with stainless steel supply lines and aluminum fittings with aluminum supply lines. The use of aluminum and stainless steel together is not recommended. The aluminum alloy has a wide divergence in electrolytic potential with stainless steel.

Non-stainless steel, cadmium-plated material, and titanium should not be used in an oxygen system due to the following reasons:

1. Non-stainless steel prone to rapid oxidation.

2. Cadmium plating oxidizes rapidly in contact with the oxygen, forming a toxic compound.

3. Titanium undergoes a chemical reaction, potentially resulting in a fire.

4.1.2.10 Low-Pressure Lines

Pressure in the distribution lines from the regulators is dependent upon the flow required and the mask or outlet orifice characteristics.

The range of pressures is of the order of up to 0.55 MPa (80 psig). Mass flow in large transport aircraft can reach more than 700 L/min, so pressure drop in the lines can be critical. To accommodate the pressures and flows of this order, the aircraft capable of carrying 150 passengers requires lines of at least 9.52 mm (3/8 inch) OD if outlets at the end of the system are to deliver comparable flows with those close to the supply regulator.

Thus, metallic lines in large low-pressure distribution systems are commonly of 9.52 to 12.7 mm (3/8 to 1/2 inch) OD x 0.71 mm (0.028 inch) aluminum alloy. In systems for small aircraft of up to 20 passengers, 7.94 mm (5/16 inch) OD lines are generally sufficient.

4.1.2.11 Low-Pressure Fittings

Fittings for metallic low-pressure lines are flared or flareless, similar to high-pressure lines, and should be made of the same material as the lines.

4.1.2.12 Flexible Hoses

Flexible hoses are used in the oxygen system (high and low pressure) to compensate for elongation of oxygen lines (temperature effect), the routing is complicated or relative movement between equipment and lines installed in the aircraft. The design is depending on the pressure rating of the flexible hoses. The minimum hose bending radius has to be obeyed in the design. Flexible hoses are more fragile and of higher weight than metallic lines. Due to potential movement, flexible hoses should be installed with access for inspection as far as practicable. Oxygen ignition factors shall be considered when installing flexible hoses with non-metallic materials exposed to oxygen.

4.1.2.13 System Vent and Bleed Valve

Passenger oxygen system distribution circuits are usually unpressurized in stand-by and are pressurized when the system is activated only. An activation may be done for testing purpose also. In order to prevent a slow pressurization of the system in stand-by because of leakages at the shutoff valves, system bleed valves are integrated. The bleed valves will ensure that low pressures building up in the system are released to the cabin. The bleed valve are closing when the pressure/flow is raising above a pre-defined value. Other designs are utilizing open port(s) which stay open with a small leakage flow also during system operation.

In addition a feature should be incorporated into the distribution system to allow pressure release from the distribution system to the ambient air after system pressurization for testing purposes.

4.1.3 System Pressure Regulator

Typical operating pressure range of a gaseous oxygen cylinder is up to 20.68 MPa (3000 psig). This pressure must be reduced and regulated. This can be accomplished by using a cylinder-mounted regulator or an in-line regulator. The performance of this regulator is dependent upon design and will vary based on manufacturer's specifications. Regulators are available that will provide a constant outlet pressure or regulate outlet pressure based on ambient pressure. The later design is called an altitude-compensating regulator and is typically used to supply the passenger oxygen system. A pressure reducer is sometimes installed before the altitude compensating regulator to step down the cylinder pressure to a suitable input pressure for the regulator.

For information on continuous flow oxygen, refer to AIR825/8.

4.1.4 Dispensing Oxygen

Oxygen is typically dispensed to the user through a mask assembly. The type of mask will depend on the regulations of the regulatory agency such as FAA or EASA the aircraft is certified to and if the user is a flight deck crewmember or a cabin occupant. Masks should meet the minimum performance requirements as referenced in the applicable equipment standards, such as ETSO/ TSO as well as any additional requirements deemed necessary by the approving authority.

4.1.4.1 Flight Deck Crew Oxygen Dispensing Systems

Crew oxygen dispensing systems are typically demand flow equipment. This type of system requires an additional regulator, which can be panel or mask mounted. Demand flow equipment can be straight demand (a system which delivers pure oxygen) or can be obtained with an air mixing feature (diluter-demand) to conserve oxygen. The distinguishing feature of the demand system is the outlet control valve in the regulator, which responds to changes in ambient pressure. The slight negative pressure (referenced to ambient) created within the mask at the onset of inhalation opens the valve and permits flow to pass into the mask until the end of inspiration. At this point, the mask pressure has become slightly positive and the valve shuts off the flow. In this manner the demand system operates as the name implies, on demand, supplying flow at the rate required by the user and conserving the oxygen supply during the entire exhalation phase of each breathing cycle.

For information on demand and pressure demand oxygen equipment, refer to AIR825/9.