Technical Report Documentation Page

1. Report No. FAA-AM-78- 9	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle HUMAN RESPIRATORY CONSIDERATIONS FOR CIVIL TRANSPORT AIRCRAFT OXYGEN SYSTEM		5. Report Date
		6. Performing Organization Code
7. Author(s) E. B. McFadden		8. Performing Organization Report No.
9. Performing Organization Name and Address FAA Civil Aeromedical Institute P.O. Box 25082 Oklahoma City, Oklahoma 73125		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Avenue, S.W. Washington, D.C. 20591		13. Type of Report and Period Covered
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report is intended to acquaint personnel involved in the design, inspection, and maintenance of civil transport oxygen systems with the human respiratory requirements and oxygen system design considerations necessary to effect an interface and provide acceptable high-altitude life support. Simplified explanations and language that should be understandable by lay and semiprofessional engineering personnel are used, with references to sources of more detailed information. The oxygen system designer is directed to applicable Federal Aviation Regulations pertaining to oxygen systems and, where regulatory guidance does not exist, directs the reader to applicable oxygen equipment industry practices, standards, and information reports.

17. Key Words Oxygen systems Protection High altitude Design Civil transport aircraft	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	19	

HUMAN RESPIRATORY CONSIDERATIONS FOR CIVIL TRANSPORT AIRCRAFT SYSTEM

INTRODUCTION

Because of the immediate hazard to life at the altitudes that modern turbine-powered transport aircraft are capable of operating, oxygen systems for these aircraft have been developed and are employed as an emergency system in the event the cabin pressurization fails.

Minimum regulatory requirements for aircraft oxygen systems are detailed in Parts 23, 25, 29, 37, 91, 103, 121, 123, and 135 of the Federal Aviation Regulations (FAR) and take precedence over any conflicting statements or documents issued by other groups. Although these regulations set forth minimum equipment, performance, and operational requirements, they leave the system designer considerable leeway as to the technical and design aspects of the system. The designer should be aware that when Part 4b, Airplane Airworthiness: Transport Categories, of the Civil Air Regulations was recodified and included in Part 25 and other parts of the FARs, cer~~tain interpretive and~~ pol~~icy material detailed~~ in Civil Aeronautic~~s Manual 4b~~ were omitted. The mater~~ial applicabl~~e to oxygen equipment may be found in paragraphs 4b.651-1 through 4b.651-12 of this manual.

The aviation industry has established specific standards and requirements for various types of oxygen systems and equipment. The Society of Automotive Engineers (SAE) Committee A-10, Aircraft Oxygen Equipment, composed of engineering, scientific, and aeromedical specialists, has published a number of Aerospace Standards (AS), Aerospace Recommended Practices (ARP), and Aerospace Information Reports (AIR). Two of the most informative and useful documents for aircraft oxygen system designers are SAE AIR-825A, Oxygen Equipment for Aircraft, and SAE ARP-171B, Glossary of Technical and Physiological Terms Related to Aerospace Oxygen Systems. A brief description and potential application of various industry, governmental, and military documents of value to the designer are given in Appendix 1 of this report.

For oxygen systems to provide reliable protection, life support scientists must communicate with the design engineer and provide the engineer with human requirement criteria on which to base oxygen system design criteria.

Conversely, the designer must be acquainted with the basic physiology of human respiration, mechanics of breathing, and behavior of breathing gases at altitude and in the body to effectively use this information. The basic physiology of exposure to high-altitude environment and human tolerance may be found in the tests of aviation physiology, aerospace medicine, SAE AIRs, scientific journals, and the reports referenced in Appendices 1 and 2.

PHYSIOLOGICAL

The designer must also understand the principal laws of thermodynamics describing the behavior of gases. Human oxygen requirements are expressed in terms of oxygen partial pressures and, when so expressed, reflect the physiological adequacy of the oxygen that is provided, independent of the variables of cabin pressure or altitude.

One of the most important and basic considerations in relating human oxygen requirements to system design is the concept of tracheal gas partial pressures. When oxygen or another gas is inhaled, its volume and partial pressure are immediately modified by saturation with water vapor at body temperature, at which point it is referred to as "tracheal." Tracheal oxygen partial pressure may be calculated by subtracting water vapor from the ambient barometric pressure times the percentage of oxygen in the mixture of gases inhaled:

$$P_{TO_2} = (B-47)F$$

where P_{TO_2} = Tracheal oxygen partial pressure, mmHg
B = Ambient barometric pressure, mmHg
47 = Vapor pressure of water in mmHg at body temperature (37°C), a constant independent of pressure and altitude
F = Fraction of oxygen in gas inhaled.

Appropriate corrections must be made for pressure breathing when gas is not inhaled at ambient pressure.

This simple equation is extremely useful not only in defining human oxygen requirements but also in designing oxygen systems and equipment to meet these requirements. For example, at a standard sea-level barometric pressure of 760 mmHg (14.7 psi) tracheal oxygen pressure, breathing air equals 760 mmHg - 47 mmHg x 0.2094 (fraction of oxygen in air) = 149.3 mmHg. Similarly at 14,000 ft and a barometric pressure of 446 mmHg (8.6 psi), tracheal oxygen partial pressure equals 446 mmHg - 47 mmHg x 0.2094 = 83.5 mmHg. If 40-percent oxygen is breathed at 14,000 ft, the calculation becomes 446 mmHg - 47 mmHg x 0.40 = 159.6 mmHg. Above 33,500 ft, even breathing 100-percent oxygen cannot maintain a sea-level air-breathing equivalent oxygen partial pressure of 149.3 mmHg without the breathing of oxygen under pressure; i.e., 192.5 mmHg - 47 mmHg x 1.00 (100-percent oxygen breathing) = 145.5 mmHg.

Concentrations of oxygen required to produce various levels of tracheal oxygen partial pressures at altitude can be readily calculated by the above equation or are available in tabular form in many publications relating to the use of oxygen in aviation, such as SAE AIR-825A and AIR-822.

The oxygen system designer should also be aware of the behavior of respiratory gases on entering the air sacs or alveoli of the lung, since much of the research and knowledge relative to respiratory research and human altitude tolerances is based on measurements and calculations of alveolar gas partial pressures.

Alveolar oxygen partial pressure (which is in near equilibrium with the blood) may be reliably estimated by subtracting the partial pressure of carbon dioxide prevailing in the alveoli from the tracheal oxygen partial pressure. The partial pressure of carbon dioxide in the alveoli, and therefore the blood, is a primary factor in the regulation of breathing and is normally maintained at a value approximating 40 mmHg. In its simplest form the calculation becomes:

$$P_{AO_2} = (B-47) - 40 \text{ or alternately } P_{AO_2} = P_{TO_2} - 40.$$

The carbon dioxide produced and oxygen absorbed are usually not equal (respiratory exchange ratio) following their transition from tracheal to alveolar gas. Therefore, appropriate corrections must be made for precise calculations. If the inhaled gas contains appreciable amounts of carbon dioxide, additional correction is required.

A more detailed explanation of the deviations and exceptions to the calculation of alveolar gas partial pressures and other factors affecting respiratory gas exchange may be found in various textbooks on respiration and aviation physiology, as well as in the scientific and information reports listed in Appendices 1 and 2.

Although an adequate oxygen partial pressure in the air sacs or alveoli of the lung (and ultimately an adequate blood oxygen saturation) is the objective of any oxygen system, these values may be influenced by physiological conditions such as hyperventilation, blood pH, and the oxygen-carrying capacity of the blood. As an equipment item, the oxygen system and mask in itself is only capable of delivering a breathing mixture with an increased oxygen partial pressure. This philosophy is reflected in the passenger oxygen requirements of Part 25 of the FARs (Airworthiness Standards: Transport Category Airplanes) that defines minimum passenger oxygen requirements in terms of inspired oxygen partial pressure.

PASSENGER OXYGEN

Although continuous-flow passenger oxygen systems may be designed to automatically sense and provide increased oxygen flows at altitude, one basic disadvantage is their inability to automatically adjust to unanticipated increases in breathing and metabolic activity of the wearer. Based on experience and experimental data, the anticipated level of breathing or ventilation (minute and tidal volumes) and oxygen consumption of the passenger must be estimated and the system designed to accommodate these requirements. Requirements for minute and tidal volumes are detailed in the FARs.

In simple terms, minute volume is defined as the volume of gas breathed in 1 min and is valuable in determining the required oxygen flow rate as well as the total oxygen supply required for a specific duration. Methods of utilizing continuous oxygen flow to meet human minute volume requirements are frequently misunderstood. If, for example, 100-percent oxygen is to be administered to an individual with a minute volume of 10 L/min, it is occasionally proposed that a continuous oxygen flow of 10 L/min be delivered to a simple mask covering the nose and mouth. It is then assumed that the individual's breathing requirement consisting of 100-percent oxygen would be met. However, breathing is cyclic in nature; a portion of the time is dedicated to exhalation, followed by inhalation during which time peak inspiratory flows approach 3 to 4 times that of the minute volume. Breathing equipment must be designed to accommodate these peak flows; otherwise, the inability to breathe produces a sensation of suffocation causing the wearer to immediately remove the device. Assuming a conservative factor of 3, and therefore a peak inspiratory flow of 30 L/min, it follows that this system would supply only one-third of the individual's inspiratory requirement; the remaining 20 L must therefore consist of ambient air. For this reason, continuous-flow phase-dilution passenger oxygen masks utilized aboard transport category aircraft are equipped with a reservoir bag to store oxygen during the exhalation phase to increase efficiency and provide sufficient volume to accommodate the subsequent inhalation. The maximum volume of the reservoir is designed in consideration of the highest mean tidal volume anticipated. (Tidal volume is defined as the volume of gas for each breath; i.e., mean tidal volume being simply the minute volume divided by the number of breaths per minute.)

Oxygen flow rates and volumes are normally calibrated and referenced to sea-level conditions in terms expressed as NTPD.* Human requirements are expressed in terms of BTPS.**

Upon delivery, the oxygen is expanded by the reduced ambient pressure at altitude. Immediately upon entering the trachea, the inhaled gas is warmed to body temperature and saturated with water vapor, further increasing its volume. For example, a flow of 3.6 L/min NTPD expands by a factor of 8.5 to a flow of 30.6 L/min BTPS at 40,000 ft. It is fortunate that these physical relationships exist; otherwise, the oxygen supply of a large transport aircraft would have to be increased approximately 8½ times to effectively meet the human breathing requirements of 30 L/min at 40,000 ft as specified in the FARs. This would impose increased weight, economic, and fuel penalties on the aircraft.

CREW-DEMAND OXYGEN

Demand and pressure-demand oxygen systems automatically mix oxygen and air (or at higher altitudes exclude air and/or provide oxygen under pressure) by the action of an altitude-sensing device (aneroid) built into the regulator. In the interest of oxygen economy and wearer protection, the oxygen regulator is designed and calibrated such that the proportions of oxygen added to ambient air automatically provide an acceptable inspired-oxygen partial pressure up to a specific altitude. Demand and pressure-demand oxygen regulators are designed to perform and consistently maintain acceptable inspired oxygen partial pressures throughout the range of tidal and minute volumes that man is normally capable of achieving.

Pressure-breathing oxygen masks equipped with pressure-compensating exhalation valves must be used with pressure-breathing regulators to effectively utilize the pressure-breathing function of the regulator. The

*Normal temperature (70°F or 21°C), pressure (760 mmHg) and dry ($P_{H_2O}=0$).
**Body temperature (98.6°F or 37°C), ambient pressure and saturated with water vapor at a body temperature of 37°C (P_{H_2O} at 37°C = 47 mmHg).

nonpressure-compensating exhalation valves of straight-demand oxygen masks permit a continuous oxygen flow through the mask on application of pressure, fail to provide pressure breathing, and rapidly deplete the oxygen supply.

CONTINUOUS-FLOW PASSENGER OXYGEN SYSTEMS (Gaseous)

The basic gaseous passenger oxygen system employed on turbine-powered air carrier aircraft consists of high-pressure oxygen cylinders, a pressure reducer, and a cabin pressure sensing-triggering device and oxygen flow controller, with distribution lines to calibrated orifices at each oxygen mask outlet. As depressurization occurs and cabin pressure is reduced, oxygen masks are automatically deployed and the oxygen distribution lines are pressurized. Actual flow is initiated during the mask-donning sequence by the passenger who, in placing the mask to his(her) face, extracts a pin or other locking device from an on-off valve located at individual oxygen outlets. The altitude-sensing device and flow controller increase line pressure, thereby inducing increased oxygen flow through the calibrated orifices in relation to the increase in cabin altitude. Oxygen flows may be as low as 0.5 L/min NTPD (1.0 L/min BTPS) at 14,000 ft cabin altitude to as high as 4.5 L/min NTPD (38.3 L/min BTPS) at 40,000 ft cabin altitude. In any case, oxygen flow must meet or exceed the minimum necessary to maintain the tracheal inspired oxygen partial pressures as required by Part 25 of the FARs.

Continuous-flow passenger masks utilized in turbine-powered air carrier aircraft are of the "phase-dilution" type as described by Federal Aviation Administration (FAA) Technical Standard Order (TSO) C64. This type of continuous-flow mask provides the most effective protection and oxygen economy available in a continuous-flow mask for high-altitude operation. However, its functional characteristics are frequently misunderstood and confused with medical or rebreathing masks designed for lower altitude usage. The phase-dilution mask consists of a facepiece equipped with an inhalation or check valve between the facepiece and a reservoir bag, a sensitive spring-loaded dilution valve, and an exhalation valve. The reservoir bag serves as a container to store and conserve the oxygen that continues to flow during exhalation. During the initial phase of inhalation the mask wearer receives 100-percent oxygen from the reservoir bag until the bag collapses. This quantity of oxygen is delivered to the physiologically active air sacs (alveoli) of the lung. When the oxygen in the reservoir bag is depleted and the bag has collapsed, the dilution valve in the mask opens and permits the introduction of ambient air. This quantity of ambient air may only penetrate the upper portion of the respiratory system (mouth, trachea, bronchi, etc.) that is physiologically inactive in the absorption of oxygen. In this manner, a controlled amount of ambient air may be utilized to meet the wearer's breathing requirement, without compromising maintenance of a maximum oxygen concentration in the lung. This ambient air occupies space in the upper portion of the respiratory system and is consequently the first air expelled on exhalation, followed by gas from the lungs. Since less than 6 percent of the oxygen is absorbed, the gas from the lungs is high in oxygen concentration, constitutes the residual left in the mask facepiece and therefore is the first to be inspired on the next inhalation. At lower altitudes where less oxygen is required and lower oxygen flows are provided, the dilution valve adds increased quantities of ambient air. However, an adequate tracheal oxygen partial pressure is still maintained.

Unfortunately, the public has been deluged with fictional medical and emergency popular entertainment media programs depicting oxygen masks, resuscitation equipment, etc., in use. These devices normally employ rebreathing bags, have high flow rates, waste oxygen, and are inefficient and impractical for use on aircraft carrying large numbers of passengers. This indoctrination by the media has conditioned the public to expect the gas bag attached to an oxygen mask to expand and contract with each breath. The reservoir of the phase-dilution mask does not respond in this manner and, consequently, passengers and crewmembers complained that these systems did not function properly. This is understandable since, for example, an oxygen flow of 0.5 L/min NTPD (.85 L/min ATPD*) at 14,000 ft would only partially inflate the reservoir once every min and at 25,000 ft 1.6 L/min NTPD (4.3 L/min ATPD) would inflate fewer than four times per min. At 35,000 ft and a flow of 3.2 L/min NTPD (13.6 L/min ATPD), the reservoir is filled about every 5 s, typically expanding because of the increased oxygen flow and contracting with each inhalation. Therefore, flow is quite obvious to the wearer. At 40,000 ft, 4.5 L/min NTPD (24.3 L/min ATPD), the reservoir fills every 2 to 3 s and may tend to remain continuously distended because of an oxygen flow that may be well in excess of the wearer's demand.

Various types of flow indicators have been proposed that may be located in the mask's oxygen delivery hose or may simply consist of a small portion of the reservoir bag heat-sealed into a separate compartment (with a flow restriction to the main reservoir bag). For these modifications to be effective would require additional passenger briefing and/or possibly a vigorous public education program to alert passengers to the meaning and significance of these devices.

FAA TSO-C64, Oxygen Mask Assembly, Continuous Flow, Passenger (For Air Carrier Aircraft), consists of an adoption of National Aerospace Standard (NAS) 1179 Oxygen Mask Assembly, Passenger. Subpart B of TSO-C64 lists exceptions to NAS 1179 and revises paragraph 1.4, Coding of Performance of NAS 1179, for inclusion in TSO-C64. This revision requires the assignment of an eight-digit performance classification number that includes a coding of the minimum oxygen flow rates to the mask at specified cabin pressure altitudes. A typical example for a hypothetical passenger mask conforming to TSO-C64 and NAS 1179, manufactured by John Doe Company, Part No. 117029, the code NAS 1179-05163045-XX may be deciphered as follows (the XX is reserved for any additional coding by the manufacturer):

John Doe Company Part 117029
NAS 1179-05/16/30/45/XX

*Ambient temperature, pressure dry (ATPD) is used in this case since the oxygen has not yet entered the trachea and it is assumed the volume is influenced only by reduced ambient pressure.

In those systems requiring introduction of oxygen flow by the user's actions, the system must be so designed that a seated, safety-belted occupant cannot place the mask on his(her) face without activating the oxygen flow. This requires careful evaluation of human anthropometrics and "reach arcs" with reference to the seated occupant and the ready position of the mask. These factors are discussed in an SAE AIR, "Convenient Location of Oxygen Masks for Both Crew and Passengers of Aircraft," being processed by SAE.

A thorough human factors study of a new oxygen system, using a statistically valid passenger population under simulated conditions, should be conducted to permit detection and correction of system design deficiencies in relation to passenger behavior patterns and capabilities. Similarly, as a final verification of system effectiveness and safety, physiological studies at altitude with human subjects are required to verify the theoretical protective capability of a system and its dispensing device. Factors such as facial configuration and mask leakage, human breathing patterns, etc., and their effects at altitude make meaningful simulation through the use of mannikins or breathing machines impractical, or virtually impossible, for this final evaluation of the man-system interface and protective capability.

APPENDIX 1

SYNOPSIS OF KEY DOCUMENTS RELATIVE TO THE DESIGN OF OXYGEN SYSTEMS FOR CIVIL TRANSPORT AIRCRAFT

SAE AIR-825A Oxygen System for Aircraft

This report, originally issued in 1965, was revised in 1974 to include the latest available information on the design and use of aircraft oxygen systems. The six sections of the report are:

SECTION I - Basic Physiology
SECTION II - Gaseous Oxygen and Oxygen Equipment-Introductory
SECTION III - Continuous Flow Oxygen Systems
SECTION IV - Demand and Pressure Demand Oxygen Systems
SECTION V - Liquid Oxygen Systems
SECTION VI - Charts, Tables, and Systems Schematics.

Section I provides a brief explanation of the physiological criteria for oxygen system design. Additional physiological information, including tables and figures not included in AIR-825A, may be found in SAE AIR-822, Oxygen Systems for General Aviation, Section I - Oxygen, Basic Physiology of.

SAE ARP-171B Glossary of Technical and Physiological Terms Relating to Aerospace Oxygen Systems

Revised in 1976, this document defines over 300 terms used in oxygen system design and respiratory physiology and is a valuable aid to the understanding of oxygen equipment standards and governmental regulations on aircraft oxygen.

SAE AIR-505 Oxygen Equipment, Provisioning and Use in High Altitude (to 40,000 feet) Commercial Transport Aircraft

Originally drafted between December 1952 and December 1956, this document antedated formulation of specific requirements for oxygen equipment and provisioning by the FAA. The recommendations in this document, until issuance of requirements in Civil Air Regulations (CAR) 4b and subsequent applicable FAA regulations, were the only authoritative guide. Although historical in nature, these recommendations are still useful as reference and background data.

SAE AIR-1069 Crew Oxygen Requirements up to a Maximum Altitude of 45,000 Feet

This document reviews equipment capability and physiological research findings on the effectiveness of crew oxygen equipment following rapid decompression and recommends minimum oxygen concentrations for breathing prior to and following loss of cabin pressurization.

SAE AIR-847 Oxygen Equipment for Commercial Transport Aircraft Which Fly Above 45,000 Feet

The intent of this report is to provide minimum design criteria for oxygen equipment to be used on commercial transport aircraft that fly above 45,000 ft. To separate these requirements from those for spacecraft, the maximum flight altitude for aircraft defined by this report is limited to the maximum altitude obtainable by aircraft using air-breathing engines.

SAE AIR-861 Minimum General Standards for Oxygen Systems

This information report recommends minimum general standards for the design, fabrication, testing, and packaging of oxygen breathing equipment used in nonmilitary aircraft. Detailed SAE specifications exist for many oxygen system components. When a conflict exists between these general standards and specific component specifications, the specific component specifications take precedence.

SAE AIR-1133 Chemical Oxygen General Information

The historical background of the development of chemical oxygen generators is described. Chemical design parameters, physical properties, and applications of these systems are detailed in this information report. This document, issued in 1969, was reaffirmed in 1976.

British Standards Institution BS N.2 Requirements for Chemical Oxygen Generators for Aircraft

This British document defines specifications for chemical oxygen generators.

SAE AIR-1223 Installation of Liquid Oxygen Systems in Civil Aircraft

Requirements for the design and installation of liquid oxygen supply systems for breathing oxygen for crew and/or passengers of transport aircraft are detailed in this report.

SAE AIR-1176 Oxygen System and Component Cleaning and Packaging

This information report details the minimum requirements for work areas and for cleaning and packaging of aircraft oxygen systems and components, the normal working pressure of which is 5 psig or greater. Cleaning methods, test procedures, and specifications for oxygen clean parts and packaging materials are included.

SAE AIR-1392 Oxygen System Maintenance Guide

Issued in 1977, this information report provides general instructions and directions for personnel performing maintenance and modification work on oxygen systems.

SAE ARP-1320 Determination of Chlorine in Oxygen from Solid Chemical Oxygen Generators

This ARP describes a sensitive and accurate method to rapidly measure the minute quantities of chlorine evolved following chemical oxygen generator activation.

SAE ARP-1109 Dynamic Testing System for Oxygen Breathing Equipment

This recommended practice outlines a system and instrumentation for the dynamic testing of breathing oxygen regulators and/or demand or demand-regulator mask and hose assemblies using dynamic testing and simulation of human breathing capabilities to insure reliability and stability of crew oxygen breathing systems.

SAE AIR-1169 Bibliography of References Pertaining to the Effects of Oxygen on Ignition and Combustion of Materials

Over 125 references and scientific reports pertaining to oxygen and fire are listed by author in this AIR.

SAE AIR-910 Ozone Problems in High Altitude Aircraft

Issued in 1964, this AIR alerts the aviation industry to the problem of ozone (O_3) and provides information on its control in high-altitude aircraft environments. Sources of information and a selected bibliography are included in this report.

British Standards Institution BSI2N100 General Requirements for Aircraft Oxygen Systems and Equipment

This British Aerospace Series standard includes specifications for the design, materials, processes, and fabrication of oxygen systems. Test methods for the determination of material compatibility with oxygen in relation to fire hazard are also included in this document.

Air Navigation Order 1970 Scale K (ANO Scale K) Oxygen Supply

This British document sets forth the British regulatory requirements for passenger and crew oxygen.

OXYGEN SYSTEM COMPONENTS

OXYGEN REGULATORS

AS-1194 Regulator Oxygen, Diluter Demand Automatic Pressure Breathing

The purpose of this document is to establish standards for the design, construction, and performance of diluter-demand, automatic-pressure-breathing, oxygen regulators for use in civil aircraft.

TSO-C89 FAR Part 37.198 Oxygen Regulators, Demand

TSO-C89, published in Part 37 of the FARs, defines the minimum requirements that crewmember demand and pressure-demand regulators must meet to be granted approval under the TSO system.

MIL-R-83178 (USAF) Regulators, Oxygen, Diluter Demand, Automatic Pressure Breathing, General Specifications

Civil transport aircraft are frequently equipped, and type-certificated, with crewmember panel-mounted oxygen regulators designed and manufactured to this or similar military specifications.

SAE AS-1197 Oxygen Regulator, Continuous Flow

This standard establishes requirements for the construction, performance, and testing of continuous-flow oxygen regulators.

OXYGEN MASKS

SAE AS-452A Oxygen Mask Assembly, Demand and Pressure Breathing, Crew

This standard establishes design and performance requirements for oronasal and fullface demand and pressure-demand crew oxygen masks for use in civil aircraft.

TSO-C78, FAR Part 37.184 Crewmember Demand Oxygen Masks

TSO-C78 published in Part 37 of the FARs defines the minimum requirements crewmember demand and pressure-demand oxygen regulators must meet to be granted approval under the TSO system.

British Standards Institution - BSN.1 British Standard: Oxygen Masks for Use in Demand Systems

This British document defines the design and performance requirements for oronasal masks to be used with demand and pressure-demand regulators.

NAS (National Aerospace Standard) 1179 Oxygen Mask Assembly, Passenger

NAS 1179 is copyrighted (1975) by the Aerospace Industries Association and is published and distributed by the National Standards Association. This standard defines the minimum requirements for the design, construction, and performance of continuous-flow oxygen masks for passengers of civil aircraft.

TSO-C64, FAR Part 37.169 Oxygen Mask Assembly, Continuous Flow, Passenger

TSO-C64, published in Part 37 of the FARs, defines the minimum requirements that continuous-flow passenger oxygen masks must meet to be granted approval under the TSO system. This TSO is, with minor technical changes, an adoption of NAS 1179.

SAE AS-1224 Continuous Flow Aviation Oxygen Masks (Non-Transport Category Aircraft)

This standard defines the minimum requirement for the design, construction and performance of continuous-flow oxygen masks for crew and passengers of general aviation civil aircraft.

PORTABLE OXYGEN SYSTEMS

SAE AS-1046A Minimum Standard for Portable Gaseous, Oxygen Equipment

This standard defines the general minimum standards for design specifications, testing, and packaging of portable oxygen-breathing equipment that uses compressed gaseous oxygen. This standard applies to portable oxygen equipment used for the administration of supplementary and/or first aid oxygen to one or more occupants of either private or commercial transport aircraft.

SAE AS-1303 Portable Chemical Oxygen

General specifications, materials, performance, and test requirements for portable chemical oxygen generators are defined in this standard.

OXYGEN CYLINDERS, VALVES, AND INDICATORS

SAE AIR-1059 Transfilling and Maintenance of Oxygen Cylinders

Many airlines, aircraft manufacturers, and aircraft service stations transfill small portable and fixed oxygen cylinders. AIR-1059 advises the aviation industry of the hazards involved and of the personnel qualifications and facilities necessary to reduce the number of accidents to a minimum.

SAE AS-1065 Quality and Serviceability Requirements for Aircraft Cylinder Assemblies Charged with Aviators Breathing Oxygen

This specification covers the servicing of gaseous oxygen cylinders used for breathing purposes in civil aircraft.

SAE AS-1066 Minimum Standards for Valve, High Pressure Oxygen, Cylinder Shut-Off, Manual

General minimum specifications for designing, fabricating, testing, and packaging manually operated, high-pressure breathing oxygen cylinder shut-off valves are described by this standard.

SAE AS-1214 Minimum Standards for Valve, High Pressure Oxygen, Line Shut-Off, Manual

General minimum standards for designing, fabricating, testing, and packaging manually operated, high-pressure oxygen line shut-off valves are described.

SAE AS-1219 Aircraft Oxygen Replenishment Coupling for Civil Transport Aircraft

This AS defines a coupling installed in an aircraft high-pressure oxygen system of civil transport aircraft to mate with ground oxygen replenishment facilities.

SAE AS-1225 High Pressure Oxygen System Filler Valve

This AS defines the optimum standards of design, construction, and performance of one type of high-pressure oxygen system filler valve designed to automatically control the rate of fill such that temperature rise in the oxygen system caused by compression heating will be within acceptable limits.

SAE AS-1248 Minimum Standard for Oxygen Pressure Reducers

This AS defines general minimum requirements for designing, testing, and packaging pressure reducers designed specifically to diminish pressure from one level to another in oxygen systems.

SAE AS-916 Standard for Oxygen Flow Indicators

This AS establishes general material and design requirements for oxygen-flow-indicating devices for diluter-demand and continuous-flow oxygen systems.

SAE ARP-433 Liquid Oxygen Quantity Instruments

This ARP defines recommended design, materials, environmental tests, and performance of electrical liquid-oxygen quantity instruments for use with liquid-oxygen converters.

SAE ARP-611A Tetrafluorethylene Hose Assembly Cleaning Methods

Cleaning methods are described for each of four cleanliness levels of tetrafluorethylene hose assemblies for use in aerospace systems, including requirements for oxygen systems.

SAE AS-845 Minimum Design Standards for Smoke Protection Goggles for Air Transport Crew

Originally issued in 1964, AS-845 covers goggles to be used in conjunction with an oronasal oxygen mask and a demand regulator delivering "safety pressure" oxygen during cockpit smoke emergency situations on civil air transports. Regulatory action currently under consideration, if consummated, will take precedence as an authoritative guide.

SAE AS-8010 Aviators Breathing Oxygen Purity Standard

This AS defines the minimum degree of purity for aviators breathing oxygen at the point of manufacture and covers gaseous, liquid, and chemical aviators breathing oxygen.

APPENDIX 2

PERTINENT CAA AND FAA MEDICAL REPORTS

1. McFadden, Ernest B.: Time Factors in Passenger Utilization of Emergency Oxygen. Aeronautical Medical Research Laboratory, Columbus, Ohio, Office of Aviation Safety, CAA, U.S. Department of Commerce, May 19, 1955.

2. McFadden, Ernest B., James W. Raeke, and J. W. Young: An Improved Method for Determining the Efficiency of Crew and Passenger Oxygen Masks. CARI Report Number 62-21, November 1962.

3. McFadden, E. B., P. C. Tang, and J. W. Raeke: Continuous Functional Testing of Passenger Masks at Ground Level and During Rapid Decompression. Presented at the Survival and Flight Equipment Association National Symposium, San Diego, California, October 1964.

4. McFadden, E. B.: Evaluation of the Physiological Protective Efficiency of a New Prototype Disposable Passenger Oxygen Mask. OAM Report No. 66-7, April 1966.

5. McFadden, E. B. and M. T. Lategola: Evaluation of the Sierra, Hanging, Quick-Don, Crew, Pressure-Breathing, Oxygen Mask. OAM Report 66-20, June 1966.

6. McFadden, Ernest B.: Development of Techniques for Evaluating the Physiological Protective Efficiency of Civil Aviation Oxygen Equipment. OAM Report No. 67-3, April 1967.

7. McFadden, Ernest B., Hiley F. Harrison, and James Simpson: Performance Characteristics of Constant-Flow Phase Dilution Oxygen Mask Designs for General Aviation. OAM Report No. 67-9, May 1967.

8. McFadden, E. B.: Physiological Evaluation of a Modified Jet Transport Passenger Oxygen Mask. <u>Proceedings of the Survival and Flight Equipment Association</u>, Las Vegas, Nevada, September 1971. Also published as OAM Report No. 72-10, February 1972.

9. McFadden, E. B., D. deSteiguer, and J. M. Simpson: Physiological Evaluation of the MBU-8/P Passenger Oxygen Mask. Presented at the 11th Annual Survival and Flight Equipment Symposium in Phoenix, Arizona, October 1973.

10. deSteiguer, D., E. B. McFadden, and J. M. Simpson: Performance Characteristics of Portable First-Aid Chemical Oxygen Generators. <u>Proceedings of the 11th Annual Survival and Flight Equipment Symposium</u>, Phoenix, Arizona, October 1973.

11. McFadden, Ernest B., and Don deSteiguer: Physiological Considerations and Limitations in High-Altitude Operation of Small-Volume Pressurized Aircraft. Presented at the 47th Annual Scientific Meeting of the Aerospace Medical Association (May 1976), and published in the preprints of that meeting.

12. deSteiguer, D., E. B. McFadden, M. S. Pinski, and J. R. Bannister: The Use of n-Pentane as a Tracer Gas for the Quantitative Evaluation of Aircrew Protective Breathing Equipment. Presented at the 14th Annual SAFE Symposium (September 1976) and published in the proceedings of that meeting.

13. deSteiguer, D., M. S. Pinski, J. R. Bannister, and E. B. McFadden: The Objective Evaluation of Aircrew Protective Breathing Equipment: I. Oxygen Mask/Goggles Combinations. Presented at the 14th Annual SAFE Symposium (September 1976) and published in the proceedings of that meeting.

14. deSteiguer, D., M. S. Pinski, J. R. Bannister, and E. B. McFadden: The Objective Evaluation of Aircrew Protective Breathing Equipment: II. Fullface Masks and Hoods. Presented at the 14th Annual SAFE Symposium (September 1976) and published in the proceedings of that meeting.

15. deSteiguer, D., M. S. Pinski, and E. B. McFadden: An Assessment of Protective Breathing Devices for Use by Flight Attendants. Presented at the Annual Scientific Meeting of the Aerospace Medical Association in Las Vegas, Nevada, May 9-12, 1977, and published in the preprints of that meeting.

16. Research Studies on Investigation of the Effects of Slow and Rapid Decompression Upon Humans at 45,000 Feet. Lockheed-California Company, Burbank, California, Final Report, Federal Aviation Agency Contract FA-3082, May 31, 1963.

17. An Analysis of the Oxygen Protection Problem at Flight Altitudes Between 40,000 and 50,000 Feet. Webb Associates, submitted by Psychological Research Associates, Division of Matrix Corp., Arlington, Virginia, as final report on Federal Aviation Agency Contract FA-955, February 20, 1961.

APPENDIX 3

PERTINENT FOREIGN OXYGEN REGULATIONS

1. International Civil Aviation Organization - ICAO Annex 6, Chapter 4: Flight Operations -- Oxygen Supply and Use of Oxygen; Chapter 6: Aeroplane instruments, equipment and documents -- Oxygen dispensing apparatus.

2. French Ministry of Transport Order ("Arrete") of March 6, 1972.

3. British Air Navigation Order of 1974 -- principal regulations contained in Annex J, Scale K.

4. Federal Republic of Germany -- 1 DVO Luft BO Articles 18, 19, 20, and 21.

5. Danish regulations -- Combination of ICAO Annex 6 and FAR Part 25.

6. Swedish regulations -- Combination of ICAO Annex 6 and FAR Part 25.

7. Belgian regulations -- Order ("Arrete") of February 13, 1970.

8. Netherlands regulations -- DEEL 2105, Article 16.

9. Swiss regulations -- Order ("Arrete") November 23, 1973.

10. Spanish Regulations -- Air Traffic Regulations, Vol. 7.

11. Italian Regulations -- Technical Rules of the Registro Aeronautico Italiano (5-2) Part 30, Chapter B.