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AEROSPACE INFORMATION REPORT

SAE AIR825/11

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Closed-Cycle Protective Breathing Devices

1. SCOPE:

Closed-cycle protective breathing apparatus, commonly referred to as rebreathers, or CCBA provide trained aircrew members or ground personnel with eye and respiratory protection from toxic atmospheres.

1.1 Purpose:

The purpose of AIR825/11 is to describe the static and dynamic characteristics of closed circuit breathing apparatus. Considerable design consideration must be given to ensure conservation of, or removal of, vital respiratory gases in closed cycle breathing apparatus. Descriptions and illustrations are included that represent the basic flow paths of respiratory gases during operation. For more specific information on certain topics, references are also cited in the text, where applicable.

1.2 Field of Application:

While the concept of closed circuit breathing apparatus applies to numerous industrial activities, AIR825/11 was prepared with special interest in the aviation industry. Apparatus detailed in this document are representative of those governed by FAA Technical Standard Order (TSO)-C116 and AS8047, and which meet or exceed the minimum prescribed duration of 15 minutes. Appendix A provides schematic representation of common types of TSO certified CCBA available today.

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2. REFERENCES:

2.1 Applicable Documents:

The following publications may be helpful in providing additional sources of information should the reader desire to do so. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the issue or revision date of this document. In the event of a 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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR1133	Chemical Oxygen General Information
ARP4259	Metabolic Simulator Testing Systems for Aviation Breathing Equipment
AS8010	Aviators Breathing Oxygen Purity Standard
AS8031	Personal Protective Devices for Toxic and Irritating Atmospheres, Air Transport Crew Member
AS8047	Performance Standard for Cabin Crew Portable Protective Breathing Equipment for Use During Aircraft Emergencies

2.1.2 FAR & FAA Publications: Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

TSO-C116	Crewmember Protective Breathing Equipment

2.2 Definitions:

REBREATHER: Common term for closed circuit breathing apparatus.

SCRUBBER: An apparatus for removing impurities, especially CO_2 from gases.

WORKLOAD: Reference to external work rates, defined as watts per unit body weight of the user.

HOODSHELL: Device that encompasses and protects users head, also may retain gases to be rebreathed.

VISOR: Transparent section of the hoodshell.

TOXIC ATMOSPHERE: Atmosphere containing either irritating or lethal substances.

3. EQUIPMENT DESCRIPTION:

Rebreathers provide a means to remove the exhaled carbon dioxide, replace the oxygen content, hold the exhaled breathing gas for the next breath and release excess volume. A stowage container is typically provided which will allow immediate access to the device in an emergency. The components that perform these functions are described below.

3.1 Carbon Dioxide (CO_2) Absorption Cartridge:

A CO_2 absorption cartridge, sometimes referred to as a scrubber, normally contains either Lithium Hydroxide (LiOH), Sodalime (NaOH & $Ca(OH)_2$), or potassium superoxide (KO_2) as the active ingredient. The reaction of these agents with CO_2 and water vapor (H_2O) either generates the necessary oxygen volume or removes sufficient CO_2 volume, or both. Some scrubbers in a pendulum or loop type device are downstream in the breathing circuit, driven by the users exhaled breath. Units may have passive scrubbers, where the scrubbing material lines the excess volume accumulator and relies on diffusion to absorb CO_2, or they may have an automatic system to circulate exhaled gas through the scrubber, independent of the users breathing.

TSO-C116 states that the concentration of CO_2 at mouth/nose shall not exceed 4 percent at sea level. CO_2 concentration may increase to 5 percent at sea level for a period not to exceed 2 minutes. These values are monitored during a performance evaluation prescribed in TSO-C116 for 15 minutes, under varying workloads. Appendix B lists common types of absorbing compounds, their associated chemical properties, and transformations.

3.2 Oxygen (O_2) Delivery System:

An oxygen delivery system can consist of one or more of the following. High-pressure aviators grade oxygen cylinder(s), or solid chemical oxygen generators (SCOGS). TSO-C116 requires the supply of breathable gas meet AS8010; furthermore, it states that upon donning, the unit shall be self purging by a sufficient supply of breathable gas to ensure one complete dead space volume displacement within 20 seconds of initial operation. Some devices incorporate a means for automatic oxygen delivery upon donning. This prevents donning without initiating oxygen flow.

In the case of high-pressure cylinders, delivery after activation can occur at either a decaying rate through a fixed orifice or at a constant mass flow through an orifice downstream from a pressure regulator. For long duration rebreathers used in industries other than Aviation, a minimal constant flow delivery can be coupled to a demand regulator when only small quantities of oxygen are necessary to support respiration.

Solid chemical oxygen generators, formerly referred to as oxygen candles, operate at low pressure, and tend to get very hot during operation, thus requiring a means to dissipate the heat produced by the exothermic reactions.

3.2 (Continued):

SCOGS such as KO_2 combine both CO_2 absorption and oxygen delivery. The reaction is as follows:

1) $2KO_2 + H_2O \rightarrow 2KOH + 3/2O_2$ + heat
2) $CO_2 + 2KOH \rightarrow K_2CO_3 + H_2O$ + heat

These equations combine to yield:

$2KO_2 + CO_2 \rightarrow K_2CO_3 + 3/2O_2$ + heat

The reaction is exothermic and proceeds slowly at initiation, hence, the device may need to incorporate another means to provide initial oxygen, such as a small cylinder of compressed oxygen or a chlorate starter candle.

Utilization of SCOGS, as a means of oxygen supply has been known for many decades. In its simplest form, the chemical core consists of a mixture of alkali metal chlorate, metallic fuel, contaminate removal system, and an inorganic binder. The pertinent chemical reactions are believed to be as follows:

1) $6NaClO_3 \rightarrow 3NaCl + 3NaClO_4 + 3O_2$
2) $3NaClO_4 \rightarrow 3NaCl + 6O_2$

The basic reaction is exothermic; however, heat must be applied to initiate the reaction. A phosphorous strike match or percussion cap may supply heat. For more general information about chemical oxygen, refer to AIR1133.

3.3 Rebreather Bag:

A rebreather bag provides a means of storing exhaled air. In some units the exhaled air is stored after it has passed the scrubber. Oxygen is then added to this volume of gas before it is rebreathed. The rebreather bag may either be separate from the hoodshell, or the dead space inside the hoodshell may act as the rebreathing bag.

3.4 Pressure Relief Valve:

A relief valve is located within the unit to prevent over pressurization of the unit due to incoming oxygen supply. Pressure buildup can also occur due to low workloads with high oxygen feed rates, or a decrease in the ambient pressure resulting from a change in cabin pressure. It is advantageous to maintain a degree of positive pressure around the head of the user to deter toxic gases entering from the outside.

3.5 Stowage Container:

Since these units are intended for emergency use only, it is extremely important that the stowage container protects the unit from environmental degradation during its shelf and/or service life, and holds the device in position to facilitate rapid access. Generally, the CO_2 scrubbers need to be protected from ambient air because sufficient moisture and ambient CO_2 can severely reduce the unit's performance once donned.

TSO-C116 requires the unit to have a means for any crewmember to determine the serviceability of the unit in its stowed condition. This may be accomplished using humidity indicating materials, tamper proof seals, or vacuum indicators.

4. ADVANTAGES/DRAWBACKS:

4.1 Advantages:

Closed circuit rebreathers have the smallest ratio of weight to duration, at a given rate of work.

Units have a typical useful life of ten years with minimal periodic inspection. Normally, they are otherwise maintenance free.

4.2 Disadvantages:

Breathing comfort is generally good, but inhaled gas temperature can be elevated with high humidity.

Visor defogging is normally provided, either by dried air directed over the visor or by special coating.

Closed circuit rebreathers are to be used by trained personnel only.

Exothermic reactions in SCOGS generate high temperatures.

5. CERTIFICATION:

In the United States, CCBA for Crewmember PBE must be certified to TSO-C116, a FAA governed document, before installation on commercial aircraft. Aerospace Standards (AS) 8031 and 8047 may be used as references, as applicable. Recommendations for test equipment used to simulate human respiration in testing of CCBA in compliance with TSO-C116 can be found in ARP4259; however, this does not preclude the need for human testing. The FAA provides guidelines for recordkeeping and design change approval, to insure all certified CCBA continue to meet performance requirements. Other countries have similar requirements, although their standard may differ slightly.

6. NOTES:

6.1 Key Words:

Absorption, apparatus, breathing, candle, carbon dioxide, CCBA, chlorate, closed circuit, closed-cycle, generators, hypoxia, lithium hydroxide, oxygen, PBE, protective, rebreather, scrubber, sodalime, starter candle, superoxide

PREPARED UNDER THE JURISDICTION OF
SAE COMMITTEE A-10, AIRCRAFT OXYGEN EQUIPMENT

APPENDIX A
COMMON TYPES OF CCBA

A.1 EXPLANATION OF FIGURE A1:

The following figure depicts four separate CCBA configurations. Each quadrant represents a different style of CCBA, and the general description of each is directly below the illustration in bold print.

The internal hood volume portions shown in Figure A1 are where the user's head would be in the donned position. In all but the lower-left illustration, the hood volume also serves as a reservoir for breathing gas.

In the lower-left illustration, the mechanism for scrubbing the exhaled breath resides outside the hood, though connected by means of flexible tubing. In this case, the exhaled breath is scrubbed twice before re-breathing along with supplemental oxygen. This method of scrubbing the exhaled gas is referred to as pendulum flow.

In the upper-right illustration, the method for scrubbing hood gas also resides outside the hood and is driven automatically by the gas flow from the generator and its associated pumping system. This provides oxygen and scrubs gas independent of the users breathing.