SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
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AEROSPACE INFORMATION REPORT

SAE AIR825/4

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Chemical Oxygen Systems

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1. SCOPE:

This SAE Aerospace Information Report (AIR) provides an orientation regarding the general technology of chemical oxygen generators to aircraft engineers for assistance in determining whether chemical oxygen generators are an appropriate oxygen supply source for hypoxia protection in a given application and as an aid in specifying such generators. Information regarding the details of design and manufacture of chemical oxygen generators is generally beyond the scope of this document.

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 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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR825/8	Continuous Flow Oxygen Systems
AIR825/11	Closed Cycle Breathing Apparatus
AIR1133	Chemical Oxygen General Information
AS1303	Portable Chemical Oxygen
AS1304	Continuous Flow Chemical Oxygen Generators
ARP1894	Useful Life Determination for Chemical Oxygen Generators
AS8010	Aviators Breathing Oxygen Purity Standard

2.2 Definitions:

CHEMICAL CORE: An object, composed of sodium chlorate or an analogous alkali metal chlorate or perchlorate, formulated with fuels, catalysts, and other modifiers and additives as required by the particular design, which evolves oxygen by a controlled chemical decomposition reaction, when actuated. Also sometimes called a chlorate candle.

CHEMICAL OXYGEN GENERATOR: A device comprising a chemical core and its surrounding mechanical enclosure, insulating material, actuation means for the chemical core, and any necessary filtering means. A means of conveying evolved oxygen to the masks is also frequently included, although that function can also be fulfilled by an external manifold.

CHLORATE CANDLE: An alternate term sometimes applied to a chemical core, possibly because the progress of the organized decomposition reaction along the length of the core can be likened to the burning of a candle. This term is also sometimes loosely applied to the entire chemical oxygen generator.

2.2 (Continued):

DESCENT PROFILE: A curve relating altitude to elapsed time following a decompression, which can be utilized in determining the flow rate of oxygen which should be supplied by a chemical oxygen generator at each point in time following initiation of an emergency descent. This curve is established by the aircraft designers, based on the performance features of the aircraft under various operating conditions. It sometimes is modified to reflect assumptions about height of local terrain which might be encountered in operating the aircraft over a given route.

OXYGEN GENERATOR: Generally, any device or system which generates oxygen. For the purposes of this document, the term is a shortened form of chemical oxygen generator, unless the context clearly implies the more general meaning.

OXYGEN MODULE: A structure or assembly, frequently in the form of a box or container, in which an oxygen generator is installed. Such containers typically contain the oxygen mask assemblies and a solenoid latch which is employed to deploy the masks in the event they are needed. In some cases, oxygen generator installations do not include a distinct, separate oxygen module, but rather the generator and other components are installed directly into an integrated Passenger Service Unit.

PASSENGER SERVICE UNIT (PSU): A structure or assembly frequently mounted above a row of passenger seats, which typically includes individual reading lights and fresh air vents for the use of the passengers, and a door behind which the passenger oxygen mask assemblies are stowed. Passenger information signs are often included, as well.

REACTION ZONE: The area or region of a chlorate candle within which oxygen is being released at a given point in time. Typically, this region is somewhat molten, while the unreacted material ahead of this region and the residue behind it are solid. As the candle operates, this region travels along the length of the candle.

3. PRINCIPLE OF OPERATION:

A chemical oxygen generator produces oxygen when actuated by means of a chemical reaction involving the decomposition of sodium chlorate (or an analogous compound) to evolve oxygen. A solid chemical residue is left behind. The basic chemical reaction is shown in Equation 1.

$$NaClO_3 \rightarrow NaCl + 3/2\ O_2 \qquad \text{(Eq. 1)}$$

This chemical reaction is exothermic, meaning that there is net evolution of heat.

The melting point of pure sodium chlorate is about 260 °C and the decomposition reaction occurs at about 500 °C. Thus, if a chemical core were made of pure sodium chlorate, it would melt and run into a puddle at a temperature far below that at which oxygen would be produced, and no organized reaction zone could form. Practical chemical cores contain a variety of additives, such as fuels, catalysts, and modifiers, which enable the decomposition reaction to take place in an organized manner, so that a reaction zone can travel along the chemical core in a steady way.

3. (Continued):

The chemical reaction is initiated by input of thermal energy to the end of the chemical core. This is frequently accomplished by use of a percussion primer, as would be used in small arms cartridges. It can also be accomplished electrically.

The flow rate of oxygen from a chlorate candle can be controlled by proper selection of additives, in combination with selection of a suitable physical size and shape. This flow rate is normally programmed to change as a function of time following actuation, to match the rate of oxygen production which is needed for each point in the aircraft descent profile.

The rates of chemical reactions vary as a function of reaction temperature. For this reason, the rate of oxygen production from a chemical core depends on the environmental temperature under which the chemical core is operated. Because the flow rate is lower under colder conditions, the nominal flow rate at ambient must typically be higher than the specified requirement. Because the duration is shorter under hotter conditions, the nominal duration at ambient temperature must typically be longer than the specified requirement. AIR1133 gives added information about the operation of chemical oxygen generators.

Another chemical technology which can be employed to produce oxygen is the reaction of potassium superoxide (KO_2) with moisture and carbon dioxide exhaled by the user.

Use of this technology requires the use of a closed rebreather type of apparatus. While such equipment lies outside the scope of this document, it is discussed in AIR825/11, and the chemistry is reviewed in AIR1133.

4. CHARACTERISTICS OF CHEMICAL OXYGEN SYSTEMS:

4.1 Hardware Configuration:

A typical chemical oxygen system is made up of a set of boxes which each contain an oxygen generator and from one to five constant flow phase dilution passenger mask assemblies, along with an electrically operated latch which is operated to open the door of the box and allow deployment of the masks following a decompression. These oxygen modules are installed adjacent to each group of seats in the passenger cabin, and at flight attendant stations, and in galleys and lavatories. The electrically operated latches are usually connected to the central control system on the flight deck.

When an increase in cabin pressure altitude beyond a preset value occurs, an aneroid switch sends a signal which causes power to be supplied to the latched, opening the doors of the boxes. The masks are then presented within reach of the passengers. Each generator may be actuated by means of a lanyard, when a passenger grasps any one of the masks and pulls it towards his face. Alternatively, actuation may be accomplished by an electrical current, as the masks are presented. The performance requirements for chemical oxygen generators are addressed in AS1304.

4.2 Maintenance:

Chemical oxygen generators are sealed, single use devices. They require no maintenance during their stated useful life which is typically in the range of 12 to 15 years or more. ARP1894 furnishes a basis for determining useful life and evaluating the possibility of extending useful life.

4.3 Oxygen Flow Rates:

One limitation of a chemical oxygen generator is its lack of flexibility in oxygen flow rates. Once the generator is actuated, flow will continue until the core is completely reacted. The rate of oxygen production has been previously programmed at the time of design. To change duration or conform to a different descent profile, one must change the generator to a different model. Since oxygen flow requirements at a given altitude also depend on mask efficiency, changing the type of mask used may also require a change in generator performance. AIR825/8 gives some information about nominal flow requirements.

4.4 Heat Evolution:

Because the oxygen producing reaction is exothermic, chemical oxygen generators emit heat, and their external surfaces are hot enough to burn unprotected human skin. Depending on the design, external temperatures of as much as 250 to 300 °C (482 to 572 °F) are sometimes observed when a generator is operated in the open air at 21 °C (70 °F) ambient temperature. Manufacturers of chemical oxygen modules use various types of shields, insulating materials, and design features to control the heat which is released. It is also necessary to consider the heat dissipation capabilities and thermal tolerance of adjacent structures when designing chemical oxygen installations.

Over time, installed generators sometimes become coated with dust, residues from cigarette smoke, and similar contaminants. When the generator is operated, the heating of these contaminants may result in a noticeable odor, somewhat similar to the "hot" odor experienced when an electrical heater is operated after a long period of storage. Crew training should include an awareness of this possibility so that passengers can be reassured this odor is not a cause for alarm.

Since oxygen has a relatively small heat capacity, the gas which reaches the passenger is cooled sufficiently between the generator outlet and the mask so that it is safe to breath. Typically the inhaled gas temperature is within 5 °C (9 °F) of the surrounding environmental temperature.

4.5 Purity:

Chemically produced oxygen may contain traces of other gases which are produced by the chemical reaction. However, these impurity levels are below the values considered hazardous in the physiological literature, and conform to the required purity levels stated in oxygen source standards. AS8010 establishes purity requirements for oxygen sources, including chemical sources.