



AEROSPACE INFORMATION REPORT

AIR1069**REV. B**

Issued	1968-10
Revised	2001-10
Reaffirmed	2012-10
Stabilized	2015-06

Superseding AIR1069A

Crew Oxygen Requirements Up to a Maximum Altitude of 45,000 Ft.

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE A-10 Aircraft Oxygen Equipment Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2015 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
<http://www.sae.org>

SAE WEB ADDRESS:

Full document details: **SAE AIR1069B**

**SAE values your input. To provide feedback
on this Technical Report, please visit
<http://www.sae.org/technical/standards/AIR1069B>**

Documents

Document Sharing Hub

TABLE OF CONTENTS

1. SCOPE 3

2. CONCLUSIONS 3

3. RECOMMENDED MEANS TO ACCOMPLISH.....3

4. A-10 COMMITTEE ACTION 4

5. DISCUSSION 4

5.1 Oxygen Concentration 4

5.2 British Air Ministry Specifications 5

5.3 Rapid vs. Slow Decompressions 6

5.4 Requirement for Use of 100% Oxygen Immediately on Decompression.....7

5.5 Means to Deliver 100% Oxygen on Decompression Summary A 7

5.6 Review of Decompression Incidents.....8

5.7 Additional Safety Requirements 12

5.8 Comparison of Features of References 6, 8 and 9 12

FIGURE 1 Recommended Oxygen Concentration vs Altitude 10

FIGURE 2 Comparison of Oxygen Concentration vs Altitude 10

FIGURE 3 Breathing Mixtures Before Decomposition.....11

FIGURE 4 Oxygen Hose Volume and Decompression 12

REFERENCES 13

TABLE OF CONTENTS (Continued)

APPENDIX I	Proposed Revision to AIR825	14
APPENDIX II	Abstracts of References 1-9.....	15
	1. Physiologic Effects of Cabin Pressure Failure in High Altitude Passenger Aircraft....	15
	2. IAM Report FPRC/1141: Anoxia Subsequent to Rapid Decompression	15
	3. IAM Report 183: The Relation Between the Capacity of the Regulator-Mask Hose and the Incidence of Anoxia Following Rapid Decompression	18
	4. Some Effects of Brief Profound Anoxia Upon the Central Nervous System.....	19
	5. The Ideal Relationship Between Inspired Oxygen Concentration and Cabin Altitude	20
	TABLE I: The Incidence of Hypoxia Following Rapid Decompression	21
	FIGURE 1: Oxygen Concentration to Prevent Hypoxia.....	22
	6. Ministry of Aviation-Specification RO 316/1	23
	7. IAM Report 313: The Physiological Effects of Failure of the Pressure Cabins of Passenger Aircraft Flying at Altitudes Between 35 000 Feet and 65 000 Feet	24
	TABLE I: Effects of Various Size Defects in the Cabin Wall Upon the Cabin Altitude	26
	8. Ministry of Aviation-Specification RO 316/2	27
	9. Ministry of Aviation-Specification RO 316/3	27

1. SCOPE:

- 1.1 Determine the required minimum oxygen concentration to be breathed prior to, during, and after a loss of cabin pressurization, and
- 1.2 Determine recommended means necessary to provide the required oxygen concentrations.

2. CONCLUSIONS:

- 2.1 To prevent impairment of consciousness caused by hypoxia after decompression oxygen must be used as follows:
 - A. Above 24,000 and up to 40,000 feet the system must provide, in accordance with Figure 1:
 - (1) An increased minimum oxygen concentration prior to a decompression,
 - (2) A schedule of increased oxygen concentration with increase in cabin altitude,
 - (3) 100% oxygen at an altitude not higher than 24,000 feet, and
 - (4) Safety pressure to begin simultaneously with delivery of 100% oxygen.
 - B. Between 40,000 and 45,000 feet the system must provide, in addition to the above,
 - (1) Delivery of 100% oxygen under positive pressure, increasing with altitude to maintain no less than the equivalent of 40,000 feet.
 - C. When cabin altitude can not exceed 25,000 feet
 - (1) No change in present requirements.

3. RECOMMENDED MEANS TO ACCOMPLISH:

- 3.1 Use of the oxygen regulator air mix (dilution) schedule controlled to Figure 1.
- 3.2 After the regulator goes to 100%, there should be not more than 2 seconds elapsed before 100% oxygen is delivered to the mask. The Reference 5 approach to the problem was to limit the volume of the part of the breathing system lying between the regulator air port and the mouth/nose to 150/ milliliters. This in effect requires the use of a regulator mounted on the mask or Helmet. The use of 400 ml as specified by the British Air Ministry permits the regulator to be mounted on the body or seat which represents an engineering compromise and produces reduced effectiveness.
- 3.3 Since the inspired gas must contain an increased concentration of oxygen prior to decompression, it will be necessary for the pilot in control of the aircraft to wear and use his oxygen mask above some stipulated flight altitude.

4. A-10 COMMITTEE ACTION:

4.1 Based on the results of the study, the following actions will be taken:

- 4.1.1 The crew oxygen regulator AS will include the oxygen concentration requirements of Figure 1 which increases the required minimum oxygen concentration below 19,000 feet and requires 100% oxygen no higher than 24,000 feet.
- 4.1.2 Since the results of the study indicate that remotely mounted regulators can not meet the minimum requirements for decompression to above 25,000 feet, revise the AS452 on crew oxygen masks to limit the altitude when used with a panel or remote mounted regulator to 25,000 feet, and to permit use to altitudes of 40,000 and 45,000 feet when provisions are included to ensure that after the regulator goes to 100% no more than 2 seconds will elapse before 100% oxygen is delivered to the mask, and suitable positive pressure is provided above 40,000 feet.
- 4.1.3 Revise AIR825 to include the necessary pertinent information as shown in Appendix I to this report.
- 4.1.4 Civil and military regulatory requirements are out of the scope of Committee A-10 activities, except for recommendation of changes. Since many documents are affected (HIAD, MIL specs., AFR's, FAR's, etc.), it is not practical to do more than make this report available to the FAA and the military suggesting that appropriate action be taken.
- 4.1.5 Give consideration to adopting requirements or recommendations for requirements for provision of mask pressure relief valves as has been done in the British specifications References 8 and 9.

5. DISCUSSION:

5.1 Oxygen Concentration:

Data on the required minimum oxygen concentration are found in References 1 through 9, and 11 through 13. Reference 5 appears to be the basic published report and appears to document the requirements by test data for cabin altitudes up to 40,000 feet. The Figure 1 Curve marked "38,000 feet" shows the Reference 5 recommended oxygen concentrations vs. altitude, provided 100% oxygen is immediately available on decompression. It will be noted that prior to decompression the inspired gas should contain a minimum of 38 to 40% oxygen at cabin altitudes of sea level to 8,000 feet whereas the "ideal" concentration for acrobatic, fighter, etc. aircraft is 50% when oxygen toxicity from long exposure and partial lung collapse from acceleration effects are considered.

5.1 (Continued):

For altitudes from 40,000 to 45,000 feet, Reference 5 states with regard to the oxygen concentration inspired prior to decompression that all decompressions to altitudes in excess of 40,000 feet may be considered as decompressions terminating at this pressure-altitude since the prevention of hypoxia in the steady state at these heights demands that the absolute pressure within the respiratory tract should not fall below that equivalent to 40,000 feet, i.e., oxygen must be delivered under positive pressure above 40,000 feet. However for civil, as opposed to military use, there is no assurance that this will occur (mask "on" and tightly secured) even though required by regulations and this has been considered in the preparation of Figure 3 from Figure 29 of Reference 11. This Figure (also shown in References 12 and 13) shows an estimate prior to confirmation by test at altitudes above 40,000 feet of the oxygen enrichment of the breathing mixture vs. final altitude in a cabin pressurized to 8,000 feet needed to prevent a critical fall in alveolar oxygen during decompressions to various altitudes. The critical level selected is an alveolar pO_2 of 33 mm Hg, below which transient mental deterioration would occur. It is assumed that 100% oxygen (under positive pressure above 40,000 feet) would be supplied immediately. These predecompression mixtures would be necessary to prevent a critically low alveolar pO_2 during the event, that is before the first breath is taken, and under these conditions, the estimated oxygen concentration required for a final altitude of 45,000 feet is 60%.

The means used to achieve the required oxygen enrichment would appear to include the use of crew regulators with dilution characteristics based on the relationship of Figure 1. This Figure shows a family of curves developed from Figure 3 for varying maximum altitudes. Further wide range decompressions to altitudes greater than 40,000 feet are needed to test the prediction that no degradation will occur if the alveolar oxygen tension reached during the transient fall of oxygen tension produced by a rapid decompression is not lower than 30 mm Hg. It should be noted that the criterion of 33 mm Hg pO_2 alveolar tension used in Figure 3 assumes that in civil use oxygen masks will not be secured tightly to the face to prevent leakage whereas Reference 5 assumes no leakage since the investigation is dealing with controlled military equipment and personnel. Slightly modified recommendations by the Subcommittee could result from receipt and review of test results not now available covering the higher altitudes.

Since the final recommendation will be an increased oxygen concentration over ambient, the pilot in control will be required to wear and use his mask. This in turn would require a change in regulations.

5.2 British Air Ministry Specifications:

The British specifications for miniaturized crew oxygen system, References 2 through 4 have been reviewed and compared with Reference 5 in Figure 2. It was anticipated that Ernsting's recommendations in Reference 5 would be reflected in References 6, 8 and 9. However, Figure 2 shows that neither Reference 6 nor 8 requires increased oxygen concentration in the sea level to 19,000 feet cabin altitude range while the Reference 9 approaches but is slightly below the Reference 5 minimum. The explanation of the differences is as follows:

5.2 (Continued):

The oxygen requirements in Specifications 316/1, /2, and /3 are based on the referenced data Specification RO316/1, which is now obsolete, was written in relation to one specific aircraft, and in fact no regulator has been developed to it. Specification 316/2 was written to define the oxygen equipment required in RAF and RN interceptor aircraft. Since all these aircraft have relatively low differential cabins (a maximum of the order of 4 lb/sq in) the cabin altitude will be greater than 15,000 feet when the aircraft altitude exceeds 30,000 feet. The very small differences in the concentration of oxygen required to prevent hypoxia following rapid decompression to an altitude above 30,000 feet (eg, 43% at a cabin altitude of 15,000 feet by these criteria) and that required to provide a sea level equivalent mixture (eg, 39% at 15,000 feet) in these circumstances was ignored in defining the minimum acceptable oxygen concentration in Specification 316/2. Furthermore, the primary object in relation to these aircraft was to keep the inspired oxygen concentration as low as possible in order to reduce the incidence of lung collapse during positive maneuvers.

It is Specification 316/3 which applies to aircraft with high differential pressure cabins such as those which carry passengers. The oxygen requirements in this Specification embody the results of the referenced experiments. The discrepancy between the shape of the minimum concentration curve in Reference 5 and that in Specification 316/3 is related to the schedule of pressurization of the military transport and bomber aircraft. In these, the cabin altitude is of the order of 5,000 to 6,000 feet when the aircraft altitude exceeds 30,000 feet. Hence it is only above a cabin altitude of 5,000 feet that is only above a cabin altitude of 5,000 feet that the oxygen system is required to give the higher concentration of oxygen. The airmix schedule below 5,000 feet would theoretically allow some economy in the use of oxygen, but in practice it is not believed that any manufacturer would attempt to follow the shape of curve given in 316/3.

5.3 Rapid vs. Slow Decompressions:

Most of these tests reported have involved rapid decompressions, generally 1.5 - 2.0 seconds. However, when the duration of decompression was lengthened to 20 seconds by Ernsting in Reference 5 and 26 - 30 seconds by Ohio State University in Reference 11 or to 9 seconds as in Figure 4 and in Reference 3 essentially identical results were obtained.

5.4 Requirement for Use of 100% Oxygen Immediately on Decompression:

The referenced data indicate that 100% oxygen must be inspired immediately on decompression. Delays of up to 8 seconds resulted in profound impairment of performance when breathing air before decompression to 38,000 feet, and when breathing 40% oxygen, the decrement in performance was moderated but reduced to a level which is unacceptable for the members of the crew of an aircraft. In decompressions to 30,000 feet breathing air with 100% oxygen immediately available, there was no decrement in performance; but with delays up to 8 seconds, performance was reduced to an unacceptable level. Possibly a higher percentage of oxygen in the inspired gas would permit an acceptable delay in terms of seconds for the inspiration of 100% oxygen and thus permit consideration to establish a relationship between percent oxygen in the inspired gas and mask-to-regulator hose length. However, until test data are available to support this it must be required that, in addition to supplying increased minimum oxygen concentrations at cabin altitudes of sea level to 8,000 feet, 100% oxygen be immediately available on decompression. Refer to Figure 4 for results of available test data on the effect of hose length. This appears to require the use of regulators mounted as close to the face as practicable, and to limit the use of panel or remote mounted regulators to an altitude less than 30,000 feet. The limiting altitude would be determined by mask-to-regulator hose length and final cabin altitude if different than the flight altitude. However, since a final decompression cabin altitude less than flight altitude cannot practically be assured (unless pressure suits are worn) and data on the effect of hose length, or delay in breathing 100% oxygen below 30,000 feet are not available, it is recommended that 25,000 feet be the upper limit.

5.5 Means to Deliver 100% Oxygen on Decompression:

The means recommended by which 100% oxygen can be supplied immediately are:

- (1) to keep to an absolute minimum the volume of the breathing system trapped between the regulator air port and the mask,
- (2) to minimize the breathing equipment (mask) dead space,
- (3) to close the air port as quickly as possible on decompression,
- (4) reduce the altitude where 100% oxygen is delivered,
- (5) require safety pressure simultaneously with delivery of 100% oxygen, and
- (6) require that the pilot in control wear and use his mask.

On the subject of trapped volume References 8 and 9 require a maximum regulator to mouth volume of 400 ml (milliliters). The following breakdown shows how restrictive this is. The panel mounted regulator air port-to-outlet volume is estimated to be 1.5 cubic inches or 25 ml. The typical crew mask cavity provides an estimated 150 ml, and the conventional regulator-to-mask hose provides a volume of approximately 10 ml per inch of length. Restricting the total to 400 ml results in a hose length of 22.5 inches (regulator 25 + mask 150 = 175, or 225 ml remaining for hose length.) Ernsting in Reference 5 made no specific recommendation for maximum trapped volume but did recommend 150 ml max. for dead space of the breathing compartment.

5.5 (Continued):

It will be noted in Summary A that the maximum trapped volumes of Reference 8 and 9 systems are limited to 400 ml, and that the Reference 6 system does not list a specific number for the maximum volume but instead requires that "the composition and quantity of gas trapped between the regulator and mouth shall not cause impairment of consciousness after explosive decompression." Use of 400 ml in References 8 and 9 is based on a compromise established by the British Air Ministry and does permit the regulator to be man-or-seat-mounted, the permissible hose length in this case being approximately 22 inches. An additional indication of the value of the use of the small volume is that 400 ml at 8,000 feet becomes 1600 ml (or 1.6 liters) at 40,000 feet. This compares with 4 to 5 liters produced by use of the conventional 6 to 8 feet hose, the use of the smaller volume substantially reducing the trapped gas pressure relief problem, by reducing the time required for relief as well as reducing the maximum transient pressure level.

It is obviously desirable that the regulator air port be closed instantaneously but is not possible in a barometrically (bellows) controlled mechanism, since there is an inherent lag in the sensing and closing operation. This probably can best be minimized if not overcome by initiating the closing action at the lowest practicable altitude. It will be noted in Table I that in Reference 8, the maximum altitude for dilution is 24,000 feet. This compares with approximately 32,000 feet for current regulators.

Requiring 100% oxygen at no higher than 24,000 feet provides no significant operational penalty since unpressurized emergency flight will normally be limited to 18,000 feet because of decompression sickness. Therefore, from a practical standpoint, the maximum altitude for dilution could be reduced below 24,000 feet. However, since an altitude range or tolerance of at least 2,000 feet is required, it is concluded that the 22,000 to 24,000 feet range of Reference 9 is acceptable. An additional advantage of supplying 100% oxygen at the recommended level is that when the decompression is relatively slow the crew member may well breathe in during the decompression and will receive 100% all the sooner.

An additional means of assuring delivery of 100% oxygen is to provide safety pressure (1-2 inches H₂O) to begin simultaneously with delivery of 100% oxygen. Since masks when worn will not be worn tightly secured to the face it is very likely that during an emergency decompression the mask would leak until properly adjusted. Thus inboard mask leakage is likely to occur without the presence of an effective safety pressure.

5.6 Review of Decompression Incidents:

Having come to the conclusion above based on altitude chamber tests, a review of decompression incidents in Reference 13, compiled from FAA records, seems in order. In the period April 1956 through July 1964, there were 18 reported incidents occurring between 30,000 and 41,000 feet altitude. Of these seven were voluntary and pressure controlled to prevent excessive cabin altitude. Of the eleven involuntary decompressions, the records indicate that the maximum cabin altitude:

- (1) has been reached relatively slowly
- (2) has been relatively low, physiologically, and
- (3) duration has been a minimum consistent with emergency descent procedures.