Memorandum

U.S. Department
of Transportation

**Federal Aviation
Administration**

Subject: INFORMATION: Interim Policy on Amendment 25-87 Requirements

Date: DRAFT

From: Manager, Transport Airplane Directorate, Aircraft Certification Service, ANM-100

Reply to Attn. of: ANM-03-112-16

To: SEE DISTRIBUTION LIST

Regulatory Reference: § 25.841(a)

Summary

The purpose of this memorandum is to provide Federal Aviation Administration (FAA) certification policy on the compliance issues associated with high altitude flight. This memo provides applicants with information on how the FAA will evaluate petitions for exemption from § 25.841(a), as amended by Amendment 25-87. For airplanes with wing-mounted engines, this regulation in effect limits the maximum operating altitude of airplanes approved to this standard to 40,000 feet. Several airframe manufacturers have asked the FAA to develop a new safety standard, which is being addressed in rulemaking activities. Those manufacturers have also asked for interim policy to provide relief because high altitude flight offers benefits to airplane performance in terms of reduced drag and lower fuel burn.

Current Regulatory and Advisory Material

Amendment 25-87 revised the ”pressurized cabin” airworthiness standards for subsonic transport airplanes. It created three new requirements governing the cockpit/cabin environment:

§ 25.841(a)(2)(i) - Cabin pressure not to exceed 25,000 feet for more than two minutes.
§ 25.841(a)(2)(ii) - Cabin pressure not to exceed 40,000 feet for any time.
§ 25.841(a)(3) – Fuselage, structure, engine and system failures are to be considered in evaluating the decompression.

The intent of these regulations is to provide suitable criteria for occupant survivability in the event of a rapid cabin decompression by establishing performance standards that ensure an adequate pressurization system and airplane design. However, the provisions adopted by Amendment 25-87 were based on limited high altitude physiological information [Reference 1], which resulted in the current restriction on maximum operating altitude. Published results from decompression research using human and non-human primates were not used to develop that regulation.

Amendment 25-87 was developed using one researcher’s work that focused on a concept called, “Time of Safe Unconsciousness” (TSU) as applied to passengers. Data described within this report is in relationship to the “Time of Useful Consciousness” (TUC) that is applicable to pilots or "time of consciousness." The author selects 25,000 feet pressure altitude as a reference state because most subjects can tolerate several minutes of hypoxia up to this altitude. The author concludes, "a relatively safe time may be considered as one minute and 40 seconds to two minutes" (above 25,000 feet). However the author also stated "plea must be made for the collection of better data on decompression events."

Relevant Past Practice

Section § 25.841(a), as amended by Amendment 25-87, provides airworthiness criteria to minimize the risks of incurring fatalities or permanent physiological damage (brain damage) following a cabin decompression event. As the maximum operating altitude of modern jet transports increases, so does the physiological risk associated with cabin depressurization. Prior to Amendment 25-87, special conditions were promulgated for flight above 41,000 feet for Business Jets (up to 51,000 feet) and the Concorde (60,000 feet) to address this safety concern. Amendment 25-87 attempted to incorporate similar criteria into part 25 to ensure occupant safety following an uncontained engine failure (UEF). In effect, Amendment 25-87 limits the maximum operating altitude of new type designs with wing-mounted engines to 40,000 feet, since in the event of a UEF, holes in the fuselage may be large enough to allow decompression of the airplane cabin to ambient pressure within seconds. Sudden cabin depressurization may also be caused by pressurization system failures.

Occupants, who are at increased risk level due to age, pre-existing medical conditions, etc., may suffer permanent physiological harm as a result of exposure to hypoxic conditions during a sudden decompression. Fatalities may also occur from uncontained engine debris impact.

Transport Canada and the Brazilian authority have adopted requirements similar to § 25.841(a). Joint Airworthiness Requirements (JAR)-25 does not address high altitude cabin decompression protection.

Impending Rulemaking

A revised cabin pressurization standard is the subject of an Aviation Rulemaking Advisory Committee (ARAC) task. The policy herein was presented to, and comments received from, the ARAC working group. This memorandum may be updated based on the final ARAC recommendation due September 2003 and will serve as policy until a new regulatory standard is issued.

Interim Policy

Manufacturers have asked the FAA to develop interim policy to address the relevant issues, though our intent is not to preempt the ARAC activity. This interim policy will enable manufacturers to develop new and amended airplane designs with wing-mounted engines, so that they are not limited to 40,000 feet maximum operating altitude. The interim policy herein provides the manufacturer with the FAA's methodology for evaluating the basis, under part 11, to exempt an applicant from the requirements of § 25.841(a)(2)(i) and (ii), and the policy will be eventually replaced by a new standard.

The FAA believes that the severity of the exposure to decompression is determined by the pressure field and the duration of the event. The medical community lacks definitive equations that can be utilized to predict human response to the rarified environment following decompression at high altitude. However, the medical community does have the results of experiments conducted to obtain information on the response of non-human primates to decompressions that could occur on supersonic airplanes flying at high altitudes.

This policy memorandum is based on flight physiological and medical experiments that were conducted during 1939, 1967 and 1969, which provide guidance as to the maximum exposure time an unprotected person (i.e., without supplemental oxygen and pressure garment) may be exposed to the rarefied environment without permanent physiological harm (i.e., neurological injury). Experimental data on humans and non-human primates have shown exposure times that have resulted in fatalities and/or permanent physiological harm or no resultant injuries. There are no corroborated data that establish the maximum safe exposure time (i.e., the maximum time that an unprotected individual may remain in the rarefied environment without incurring any permanent physiological harm). Certain reports have provided some guidance on exposure times that resulted in impairment of mental performance or loss of useful consciousness. However, these data are at lower altitudes than existing commercial airplanes maximum certified altitude and are not representative of the extreme environmental conditions that the cabin can be exposed to in the event of decompression at high altitude.

Research work on non-human primates and humans as reported in References 2, 3, and 4 form the basis for this policy. The FAA discovered that when the decompression data was evaluated via the use of an alveolar partial pressure of oxygen (i.e., a lung pressure) time integral, a trend became clear. There is a direct correlation of the integral in that as the value of the integral increases, there is an increasing likelihood of fatalities or permanent physiological damage being sustained by the subjects. [**See the link on the website for further information on the pressure-time integral.]**

The primary means to ensure occupant survivability rests in quickly bringing the occupants to a cabin pressure where they can survive. Airplane manufacturers should utilize design features that facilitate rapid airplane descent.

In lieu of performing the time-integral calculation the following chart utilizes average rate of emergency descent that would determine the highest flight level allowed for the maximum operating altitude. Table 1 (below) gives several average emergency descent rates with the corresponding maximum altitude that is allowed under this interim policy.

Descent Speed Versus Altitude	
Average Emergency Descent Speed ~ fpm (Not Less Than:)	**Maximum Operating Altitude ~ feet**
6,000	40, 000
7,000	42,250
8,000	45,000

The average rate of emergency descent given above is predicated on the airplane meeting the provisions of § 25.903(d) and that the airplane is designed such that in the event of an UEF the airplane structure, systems and other engine(s) function to enable an emergency (i.e., V_{mo}/M_{mo}) rate of descent. The FAA will utilize the applicant's information to make a determination as to the acceptability of the applicant's request for an exemption. Airplane and engine manufacturers continually seek to optimize airplane designs, which often means operating at higher altitudes. The FAA has identified the following design features as feasible and the applicant seeking the relief provided in this policy should incorporate these features into their design. The FAA believes automatic descent systems, redundant spoiler/speed brake deployment systems and improved engine fragment containment systems are feasible. The FAA expects that these pertinent design features should be incorporated into new and amended airplane type designs commensurate with the risks of decompression at high altitude flight. For example, an applicant seeking to cruise at 43,000 feet altitude would be expected to incorporate a redundant spoiler/speed brake deployment system. Those seeking cruise flight to 45,000 feet would be expected to incorporate an automatic descent system and redundant spoiler/speed brake deployment system. These design features would improve the survivability of passengers after a rapid cabin depressurization.

The ARAC working group is reviewing available physiological data to determine appropriate guidance regarding cabin decompression during high altitude flight operations, including altitudes above 45,000 feet. The maximum operating altitude being considered under this interim policy is 45,000 feet until that recommendation is received.

Technical Issues

The FAA acknowledges concern expressed by the medical community that these conclusions are controversial. The medical community has expressed their concern over the lack of sufficient theoretical basis for this approach, and as well as the paucity of available data. The medical community has cited concern over the fact that the human response to the rarified atmosphere following decompression is a dynamic multi-factorial situation including changes in the tracheal, alveolar, arterial and end-tidal partial pressure of oxygen, carbon dioxide, water vapor, pH of the blood, arterial blood pressure, cerebral vascular resistance and the local cerebral blood flow. In essence this is a time dependent, multi-variable, highly synergistic problem that is not amenable to simplistic methods of analysis.

While we acknowledge these concerns, we believe that, through the selection of the acceptance criteria to the alveolar partial pressure of oxygen time integral method and by gaining additional substantive data through a research program, this approach will permit a realistic numerical appraisal of the severity of the decompression environment.

Exemption Process

Under the procedures set forth in § 11.81, the FAA will consider manufacturers' petitions for exemption to the provisions of § 25.841(a), which should address the following criteria that will be used in evaluating a petitioner's request:

- **The applicant must justify "Public Interest."** The petitioner must present a case that shows that the granting of this exemption is in the "Public Interest." Since compliance with the current requirements may limit airplanes to a maximum operating altitude of no more than 40,000 feet, there could be an economic impact due to increased fuel use and longer routes due to more congestion at lower altitudes. Other factors may be used to justify "public interest."

- **The applicant should also show why granting such an exemption "would not adversely affect safety."** For new and amended type designs, the applicant should provide sufficient mitigation strategies that focus on those design features that provide some means to offset the inherent increased risk associated with exposure of occupants to high altitude conditions.

Conclusion In addition to addressing the "public interest" and "adverse safety" issues, the following process will be used in evaluating a petitioner's data:

(1) The petitioner should assume that rapid cabin decompression would occur at the maximum operating altitude for their airplane design.

(2) The petitioner should provide information about any design features that provide enhanced airplane emergency descent rates and occupant survivability.

(3) The petitioner demonstrates the emergency descent procedure that is recommended in the AFM, which is the basis for determining the maximum operating altitude.

Effect of Policy

The general policy stated in this document does not constitute a new regulation or create what the courts refer to as a "binding norm." The office that implements policy should follow this policy when applicable to the specific project. Whenever an applicant's proposed method of compliance is outside this established policy, it must be coordinated with the policy issuing office, e.g., through the issue paper or equivalent.

Applicants should expect that the certificating officials will consider this information when making findings of compliance relevant to new certificate actions. Also, as with all advisory material, this policy statement identifies one means, but not the only means, of compliance.

If you have questions, the person on my staff most familiar with this issue is Mr. Steve Happenny, [(425) 227-2147 or stephen.happenny@faa.gov].

Attachment

REFERENCES:

1. “Factors Influencing the Time of Safe Unconsciousness (TSU) for Commercial Jet Passengers Following Cabin Decompression”, James G. Gaume, Aerospace Medicine, April, 1970.

2. “Neurological Study of Simulated Decompression in Supersonic Transport Aircraft”, Aerospace Medicine, J.B. Brierley and A. N. Nicholson, August 1969.

3. “Neurological Sequelae of Prolonged Decompression”, Aerospace Medicine, A.N. Nicholson and J.R. Ernsting, April 1967.

4. “An Analysis of the Oxygen Protection Problem at Flight Altitudes Between 40,000 and 50,000 Feet, Final Report”, prepared for the Federal Aviation Agency, Contract FA-955, by Blockley and Hanifan, February 20, 1961.

cc: ANM-111, ANM-112, ANM-113, ANM-115, ANM-116, ANM-117

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Attachment

Supporting Information for Interim Policy regarding Amendment 25-87 Requirements (FAA Draft Memorandum ANM-03-112-116).

Summary:

The current regulation governing the cabin pressure following failure conditions is 14 CFR Part 25.841, as amended by Amendment level 25-87 [Reference 1]. This regulation was developed using one researcher's work [Reference 2] that focused on a concept called, "Time of Safe Unconsciousness"(TSU) as applied to passengers, and a relationship to the "Time of Useful Consciousness" (TUC) that is applicable to pilots. The author selected 25,000 feet pressure altitude as a reference state because most subjects can tolerate several minutes of hypoxia up to this altitude. The author concludes, "a relatively safe time may be considered as 1 minute and 40 seconds to 2 minutes" (above 25,000 feet). However the author also stated that a "plea must be made for the collection of better data on decompression events". There is no indication that the author utilized any of the data from the decompression studies that serve as the basis for the pressure-time integral method discussed in FAA Memo ANM-03-112-116.

In promulgating § 25.841(a), as amended by Amendment 25-87, the FAA did not consider the experimental data that was used to develop this policy memo (formulation of the pressure-time integral methodology). The criterion used to develop the interim policy relies upon the use of the alveolar partial pressure of oxygen time integral method (pAO_2-T). The foundation of the pAO_2-T method is that, while human physiological response to a rarefied environment is a dynamic multi-function problem, the two parameters of dominance are the pressure that the subject is exposed to and the duration of that exposure. Qualitative means could be utilized to assess risk to occupants but the uncertainty of the level of risk necessitates that specific features be incorporated into airplane designs to enhance survivability and lower the risk to the occupants.

An Aviation Rulemaking Advisory Committee (ARAC) has been tasked with reviewing the current regulation and providing recommendations for a new standard and means of compliance [Reference 3]. This interim policy will be superceded by the rulemaking activity.

Foundation of the FAA Analysis: The FAA believes that fundamentally the pressure field and the duration of the event determine the severity of the exposure to a decompression. The medical community lack definitive equations that can be utilized to predict human response to the rarified environment following a decompression at high altitude. However, data does exist from the results of experiments conducted to obtain information on the response of non-human primates to decompressions that could occur on supersonic airplanes flying at high altitudes. While direct comparisons of the altitude time history of the decompressions presented in the referenced papers proved inconclusive, the FAA observed that using an integral of the time history of the alveolar (i.e., relating to the air pockets in the lung) oxygen partial pressure did provide relevant information.

FAA studied the results of animal decompression studies, “Neurological Sequelae of Prolonged Decompression”, Aerospace Medicine, A.N. Nicholson and J.R. Ernsting, April 1967, and “Neurological Study of Simulated Decompression in Supersonic Transport Aircraft”, Aerospace Medicine, J.B. Brierley and A. N. Nicholson, August 1969 (References 4 and 5). Figure 1 shows the chamber pressure (in mmHg) time history from Reference 5 for both of these experiments [pressure altitude in feet versus time in minutes]. This data provided critical information needed to establish a measure of safety for the occupants of an airplane in the event of a decompression. In addition a relationship between the partial pressure of oxygen in the lung alveolar and atmospheric total pressure was determined from published data [Reference 6] and calculation, see Figure 2.

Figure 2 serves as a mathematical transfer function that converts input from Figure 1 [total atmospheric pressure versus time] into Figure 3 [alveolar partial pressure of oxygen versus time]. At altitudes equal to and/or less than, 25,000 feet (i.e., total atmospheric pressure at or greater than, 282 mmHg) data from Reference 6 was used directly. For altitudes greater than, 25,000 feet but less than 50,000 feet (i.e., total atmospheric pressure less than, 282 mmHg but greater than 87 mmHg) an extrapolation from the data point at 25,000 feet pressure altitude was used. Note that the FAA utilized the condition that at 50,000 feet (i.e., 87 mmHg total atmospheric pressure) the alveolar partial pressure of oxygen is equal to 0 mmHg (assuming normal water vapor tension and carbon dioxide tension of 47 mmHg and 40 mmHg, respectively).

Using the relationship in Figure 2, the FAA calculated alveolar partial pressure of oxygen time history for the experimental results given in Figure 1, as plotted in Figure 3. Several papers including Reference 7, reported 30 mmHg as being a critical value of alveolar partial pressure of oxygen in terms of impairment of performance following exposure to a decompression. Utilizing these data, the FAA formulated a methodology based upon an integral of the time history of the alveolar partial pressure of oxygen below 30 mmHg (pAO_2-T) as a means to provide a measure of the severity of the decompression event.

There is a direct correlation of the pAO_2-T integral in that as the value of the integral increases there is an increasing likelihood of fatalities or permanent physiological damage being sustained by the subjects [Figure 4]. For example, the experimental data resulted in values ranging from 9800 mmHg-seconds to 1900 mmHg-seconds for the integral below 30-mmHg. [Note that the magnitude of these values is dependent upon the functional relationship used between total pressure and alveolar partial pressure of oxygen [shown in Figure 2]. The values in Figures 3 and 4 are specific to the curve used by the FAA. Also note that the data in Figure 4 are presented in units of time in seconds.]

Those experiments that yielded values of 9800 mmHg-seconds experienced 100% fatalities, those at 7000 resulted in 25% fatalities or 50% with permanent physiological harm (i.e., neurological damage). Those below 6500 mmHg-seconds resulted in no fatalities or signs of permanent physiological harm. Selection of the critical integral value was made near 3000 mmHg-seconds to attempt to account for the paucity of, and uncertainty in the data. Although this value is still subjective and controversial, it represents a reasonable approach to this problem with consideration of the limited database available.

FAA acknowledges concern expressed by the medical community that these conclusions are controversial. However, as further corroboration, the FAA utilized the data from the experiment by Dr. Hans Clamann as reported in "An Analysis of the Oxygen Protection Problem at Flight Altitudes Between 40,000 and 50,000 Feet, Final Report", prepared for the Federal Aviation Agency, Contract FA-955, by Blockley and Hanifan, February 20, 1961 (Reference 8). Dr Clamann utilized a chamber to simulate a rapid decompression from 9,800 feet to 49,200 feet (pressure altitude) and then repressurized the chamber at a rate of 410 feet per minute (simulating an airplane rate-of-descent). He did not use supplemental oxygen but breathed air at the chamber pressure. It was reported that he retained consciousness during the entire, albeit short, event. The resulting integral for this exposure was 1215 mmHg-seconds and substantiates Dr Clamann's statement that consciousness was maintained throughout the decompression. (See Reference 8)

The alveolar partial pressure of oxygen time integral methodology provides the FAA and an applicant with a quantitative means to show the level of threat to the occupants exposed to such a decompression environment. While the available research material is difficult to assess, data is available that provides some definitive limits. FAA has reviewed this material and believes that an exposure to a pressure altitude slightly above the 40,000 foot maximum cabin pressure specified in Amendment 25-87 (i.e., < or = 41,000 feet) does not represent a significant increased physiological threat.

FAA reviewed references 1 through 16 and has concluded from observations of non-human primate and human studies and due to the paucity of data and the rarity of an engine induced decompression that,

- The pAO_2-T should be no greater than 3000 mmHg-seconds.
- For decompression events at high altitude, the time above 10,000 feet altitude should not exceed 6 minutes.
- The manufacturer should include emergency descent procedures that rely upon swift descent to an altitude of 10,000 feet. No increase in altitude is permitted once an

emergency decompression has occurred and AFM procedures should require that the crew land at the nearest available airport.

List of References

1. Amendment 25-87 Final Rule, Docket 26070, Federal Register Volume 61, Number 109, June 5, 1996.

2. “Factors Influencing the Time of Safe Unconsciousness (TSU) for Commercial Jet Passengers Following Cabin Decompression”, James G. Gaume, Aerospace Medicine, April, 1970.

3. Amendment 25-87 ARAC tasking notice, Federal Register, Volume 66, number 144, July 26, 2001.

4. “Neurological Study of Simulated Decompression in Supersonic Transport Aircraft”, Aerospace Medicine, J.B. Brierley and A. N. Nicholson, August 1969.

5. “Neurological Sequelae of Prolonged Decompression”, Aerospace Medicine, A.N. Nicholson and J.R. Ernsting, April 1967.

6. "Fundamentals of Aerospace Medicine", Roy L. DeHart, second edition, Williams & Wilkons, 1996, Table 5.12, Respiratory Gas Pressures and Gas Exchange Ratios, pg 91.

7. “Prevention of Hpoxia – Acceptable Compromises”, Aviation, Space, and Environmental Medicine, J. Ernsting, March 1978.

8. “An Analysis of the Oxygen Protection Problem at Flight Altitudes Between 40,000 and 50,000 Feet, Final Report”, prepared for the Federal Aviation Agency, Contract FA-955, by Blockley and Hanifan, February 20, 1961.

9. “Quick Response by Pilots Remains Key to Surviving Cabin Decompression”, Stanley R. Mohler, M.D., Human Factors & Aviation Medicine, Vol. 47, No. 1, Jan.-Feb., 2000

10. “Concepts Providing for Physiological Protection After Aircraft Cabin Decompression in The Altitude Range of 60,000 to 80,000 Feet above Sea Level”, Robert P. Garner, DOT/FAA/AM-99/4, Office of Aviation Medicine, February, 1999.

11. “Hypoxia and Performance Decrement”, William F. O’Connor, Ph. D., Jim Scow, M.D., George Pendergrass, Capt., USAF, DOT/FAA/AM 66-15, May, 1966.

12. “Performance of a Continuous Flow Passenger Oxygen Mask at an Altitude of 40,000 Feet”, Robert P. Garner, DOT/FAA/AM-96/4, February, 1996.

13. “Rapid Decompression of a Transport Aircraft Cabin: Protection Against Hypoxia”, H. Marotte, C.Toure, J.M. Clere, and H. Vieillefond, Aviation, Space and Env. Medicine, Jan., 1990.

14. “Effects of Decompression on Operator Performance”, William F. O’Connor, Ph. D., George E. Pendergrass, DOT/FAA/AM 66-10, April, 1966.

15. “Behaviour of Naïve Subjects During Decompression: An Evaluation of Automatically Presented Passenger Oxygen Equipment”, Chisholm DM, Billings CE, Bason R, Aerospace Medicine, February 1, 1974.

16. “Physiologically Tolerable Decompression Profiles for Supersonic Transport Type Certification”, Stanley R. Mohler M.D. and P.V. Siegel M.D., DOT/FAA/AM 70-12, July, 1970.

Figure 1 Decompression Profiles, "Neurological Study of Simulated Decompression in Supersonic Transport Aircraft", J.R. Brierley, and A.N. Nicholson, Aerospace Medicine, August 1969. [Reference 4]

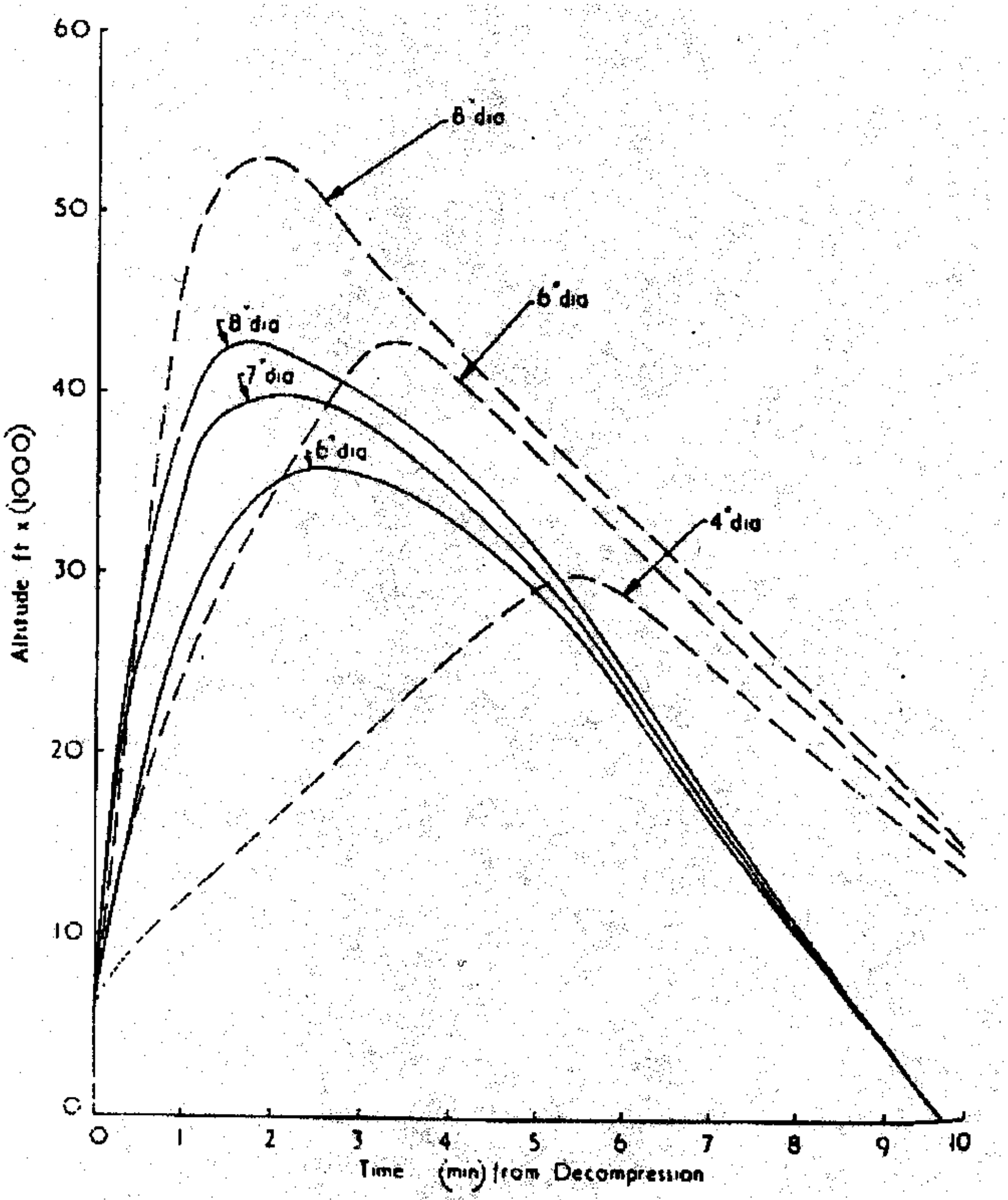

Fig. 1. Decompression profiles: The profiles investigated in the previous study (Nicholson and Ernsting 1967) are represented by broken lines. Continuous lines are the profiles investigated in the present study and are based on data given in Table I.

Figure 2 - FAA Analysis: Functional relationship between total atmospheric pressure and alveolar partial pressure of oxygen used in converting Figure 1 data into Figure 3. At altitudes equal to and/or less than, 25,000 feet (i.e., total atmospheric pressure at or greater than, 282 mmHg) data from Reference 6 was used directly. For altitudes greater than, 25,000 feet but less than 50,000 feet (i.e., total atmospheric pressure less than, 282 mmHg but greater than 87 mmHg) an extrapolation from the data point at 25,000 feet pressure altitude was used.

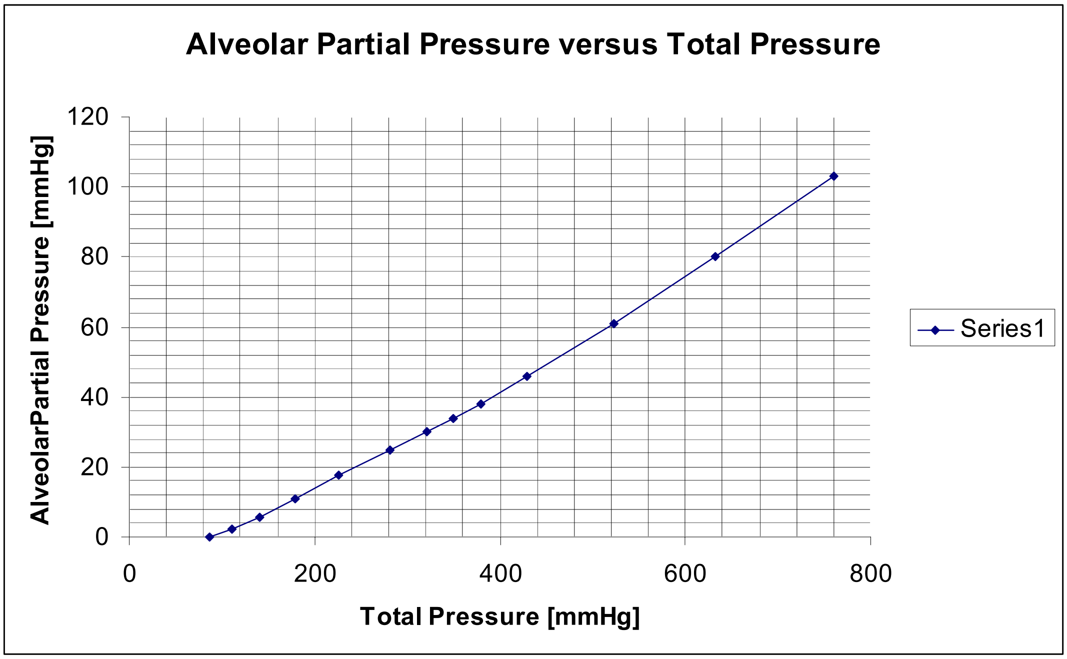

Figure 3 Partial pressure of oxygen in the lung alveolar time history was calculated from decompression profiles in “Neurological Study of Simulated Decompression in Supersonic Transport Aircraft”, J.R. Brierley, and A.N. Nicholson, Aerospace Medicine, August 1969

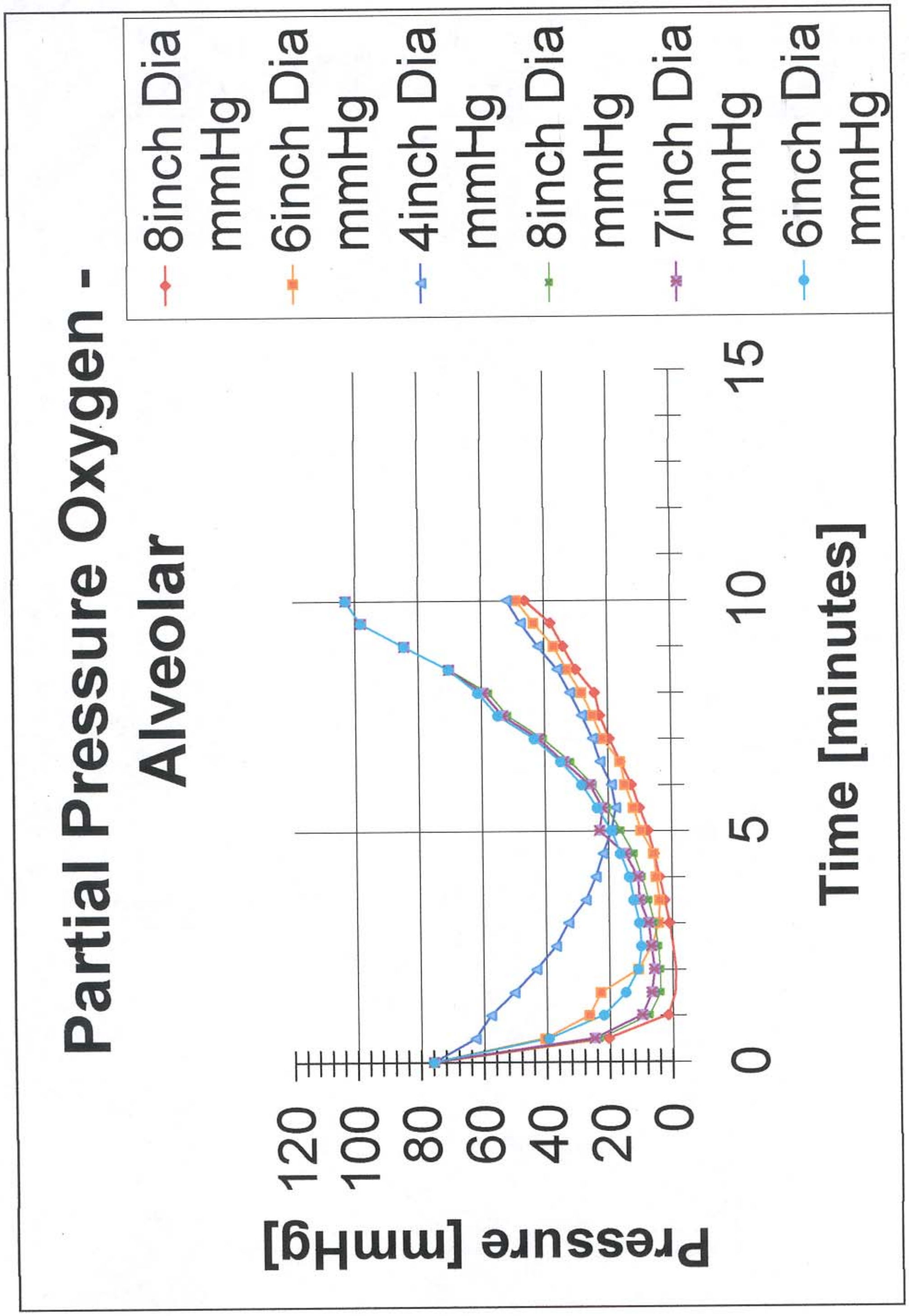

Figure 4. The integral values and the level of risk associated with high altitude decompression based upon the decompressions in Figure 3.

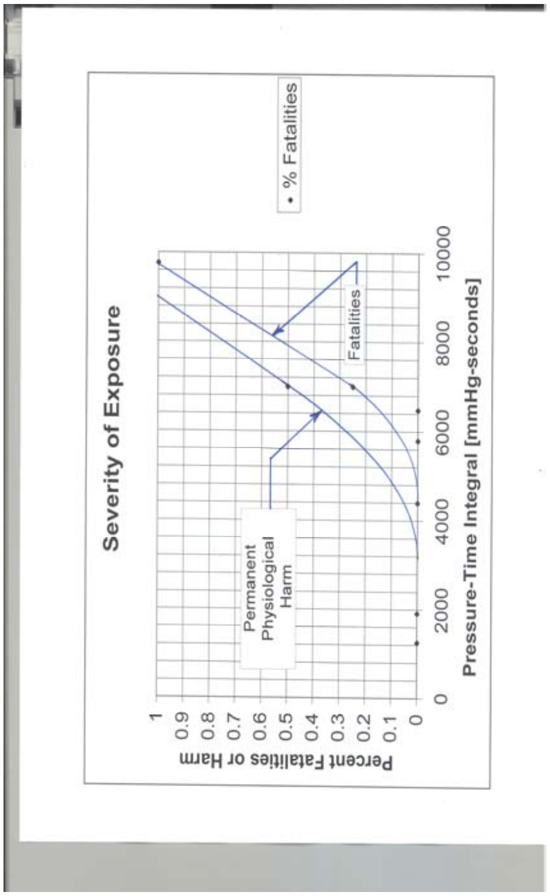

Figure 4. The integral values and the level of risk associated with high altitude decompression based upon the decompressions in Figure 3.

Integral [mmHg-seconds]	**% Fatalities**	**Source**
1215	0.	This point is from Blockley and Hanifan 1961 [Dr. H. Clamann,1939]
1908	0.	This point is from Ernsting & Nicholson 1967
4392	0.	This point is from Nicholson & Brierley 1969
5790	0.	This point is from Nicholson & Brierley 1969
6474	0.	This point is from Nicholson & Brierley 1969
6990	25 - 50	This point is from Ernsting & Nicholson 1967
9762	100	This point is from Ernsting & Nicholson 1967