Federal Aviation
Administration

Memorandum

Date:	March 24, 2006
To:	See Distribution
From:	Manager, Transport Airplane Directorate, Aircraft Certification Service, ANM-100
Prepared by	Steve Happenny, ANM-112
Subject:	Interim Policy on High Altitude Cabin Decompression (Reference Amendment 25-87)
Memo No.:	ANM-03-112-16
Regulatory Reference:	§ 25.841(a)

Summary

The purpose of this memorandum is to provide Federal Aviation Administration (FAA) certification policy on cabin decompression issues associated with high altitude flight. Recognizing the apparent operating restrictions on new airplane designs, the FAA has begun rulemaking activity supported by an Aviation Rulemaking Advisory Committee (ARAC) recommendation. The FAA has decided to issue this memo, which provides applicants with information on how the FAA, during the rulemaking period, will evaluate petitions for exemption from § 25.841(a), as amended by Amendment 25-87. For airplanes with wing-mounted engines, this regulation effectively limits the maximum operating altitude of airplanes approved to this standard to 40,000 feet. This policy is only applicable for the subset of rapid decompression events due to uncontained engine failures (UEF). This policy does not allow any change in cabin pressure regulatory provisions for the more common failures, i.e., environmental systems and structural failures. We believe the course of action outlined in this memo results in reasonable passenger safety while enabling industry to develop and operate new airplanes above 40,000 feet. Our analysis shows that there is an average probability of an uncontained engine failure at cruise of approximately $1x10^{-7}$ per engine hour. New engine designs appear to provide an order of magnitude improvement to this risk. Because these events are rare the FAA considers that the benefits of operating at higher altitudes compensate for the added risk.

Current Regulatory and Advisory Material

The FAA issued Amendment 25-87 because of an increased number of applications for transport category airplanes seeking approval to operate at cruise altitudes over 40,000 feet. We believed it was appropriate to require cabin pressure limits to ensure that all occupants be protected from permanent physiological harm following a rapid decompression at these high altitudes. Before Amendment 25-87 the only limits for cabin decompression were about decompression resulting from probable system failures.

In drafting this regulation, the FAA believed that passenger cabins of large transport category airplanes would not experience rapid decompression because of the large cabin volume as opposed to smaller executive business jets. We did not envision how the growth of engine size, including engine fragment size resulting from an engine rotor burst, would compromise the integrity of the airplane fuselage or cause the cabin of a large transport airplane to rapidly depressurize. Large holes can be created in the fuselage following certain types of uncontained engine failures, which would then cause rapid decompression.

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.

Note there are provisions in § 25.1441(d) for the oxygen flow rate and oxygen equipment approval for flight above 40,000 feet. Also note that there must be a sufficient quantity of oxygen to satisfy the operating requirements (e.g., § 121.333) up to the service ceiling of the airplane.

FAA developed Amendment 25-87 using work that focused on a concept called, “Time of Safe Unconsciousness” (TSU) as applied to passengers [See Reference 2, Attachment 1] and on material that had been developed for the US Supersonic Transport program (SST). This author focused on TSU and provided some recommendations which were adopted as the basis for cabin altitude limitations given in the regulations. However, neither service history nor the results of several human and animal altitude chamber studies were considered in the development of this regulation. The FAA did not investigate these data until an Aviation Rulemaking Advisory Committee (ARAC) was tasked to review the regulation. The intent of the provisions promulgated by Amendment 25-87 was to provide complete protection to all occupants, even those unable to properly don an oxygen mask, from any permanent physiological harm. We believe it is neither practical nor physiologically possible to afford this level of protection to all occupants. It was not the intent of the regulation to limit airplane operating altitude but to limit the cabin environment following types of failures as a function of their probability of occurrence.

FAA concludes that it is not possible to provide complete protection to all occupants per the original goal of Amendment 25-87. Furthermore, there is nothing distinctive about 40,000 feet cabin limit in terms of the severity of the exposure and risk to the occupants. Occupants exposed to a 40,000 feet pressure altitude are only slightly less likely to suffer harm than those exposed to higher pressure altitudes if the exposure is limited to a short duration by the airplane's rapid descent. While FAA is unable to quantify the relative risk to the occupants from exposure at these two altitudes, it has been recognized by all cognizant medical authorities that this risk is a function of the altitude (higher altitude being more risky) and duration of exposure (longer duration being more risky). The FAA reviewed information from the National Aviation Safety Data Analysis Center, covering aircraft accidents and incidents from 1959 to the present. We found no records of deaths from hypoxia at any altitude due to the type of inflight rapid decompression events envisioned by Amendment 25-87.

Our review indicates that since 1959 there have been approximately 3,000 loss-of-cabin-pressure events. The vast majority of these (See Attachment 2) have been caused by system (e.g., cabin pressurization controller failures, valve failures, etc.) and structural failures (e.g., door seal failures, etc.) which have been typically recognized at low altitude within a few minutes after takeoff. Pilot error has also contributed to the number of events. The majority of these events have not subjected the occupants to exposures above 25,000 feet (an altitude considered physiologically significant). Indeed, the cabin pressure altitude in most events did not exceed 15,000 feet (the pressure altitude where passenger oxygen masks are deployed). Similarly, uncontained engine rotor burst failures tend to be very rare as noted in Attachment 3. A simple calculation shows that grouping all engines and transport airplanes together yields an average probability of an uncontained engine failure at cruise of approximately $1x10^{-7}$ per engine hour. New engine designs appear to provide an order of magnitude improvement to this risk. It is because these events are considered rare that the FAA considers the risk versus benefits to be acceptable.

Relevant Past Practice

Section § 25.841(a), as amended by Amendment 25-87, provides airworthiness criteria intended to afford complete protection to all occupants from permanent physiological harm following a cabin decompression event. However, based upon our subsequent review, this can not be fully achieved. Occupants, who are at increased risk levels because of age, pre-existing medical conditions, etc., may suffer permanent physiological harm because of exposure to hypoxic conditions during a sudden decompression.

As the maximum operating altitude of modern jet transports increases, so does the physiological risk associated with cabin depressurization. Some existing large commercial transport category airplanes type certificated prior to Amendment 25-87 are approved to operate up to 45,000 feet altitude (See Attachment 4). Special conditions were issued for operation up to 51,000 feet for several executive business jets and the Concorde (60,000 feet) to address cabin depressurization concerns.

Both the business jets and Concorde shared a common performance characteristic; specifically the ability to conduct a rapid descent following a sudden loss of cabin pressure. Also, business jets typically feature rear fuselage-mounted engines which incorporate an aft pressurized bulkhead located forward of the rotor burst zone which decreases the likelihood of experiencing a rapid cabin decompression following an engine failure. Amendment 25-87 incorporated criteria similar to the provisions of the special conditions into part 25 to ensure occupant safety following any failure scenario including uncontained engine failure.

The effect of Amendment 25-87 is to limit the maximum operating altitude of new type designs with wing-mounted engines to 40,000 feet. Holes in the fuselage, caused by uncontained engine failure (UEF), 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 or structural failures.

Impending Rulemaking

A revised cabin pressurization standard was the subject of an Aviation Rulemaking Advisory Committee (ARAC) task. The draft policy was presented to, and comments received from, the ARAC working group. This policy, while limited in scope, is consistent with the final ARAC recommendation and will serve as policy until a new regulatory standard is issued.

Interim Policy

Permitting airplanes to fly above 40,000 feet does offer real and tangible benefits to the aerospace industry, the traveling public and the U.S. economy by lowering congestion, improving fuel economy, and lowering pollution. If compliance with § 25.841 at Amendment 25-87 limited airplanes operations to a maximum altitude of 40,000 feet, this would impose a significant disadvantage on newly designed airplanes that have many safety advantages over older airplanes currently allowed to operate at higher altitudes. This would delay the introduction of these airplanes and the benefits of their more advanced technology.

This interim policy provides design approval holders (DAH) 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). This interim policy will enable DAH to develop new and amended airplane designs with wing-mounted engines without being limited to 40,000 feet maximum operating altitude. This interim policy will be eventually replaced by a new regulatory standard.

This policy describes a process that may be used to allow an airplane, which does not meet the current regulation, to operate up to maximum altitudes higher than that allowed by the current regulation. The intent of this policy, and the ARAC proposed revisions to § 25.841, is to afford reasonable protection to occupants if a sudden loss of cabin pressure occurs at high altitude. In assessing the risk of high altitude decompression, we used as noted earlier, (a) service history and reports on the rate of failures that lead to loss of cabin pressure (Attachments 2 and 3), (b) the available, although limited, altitude chamber data, and (c) a physiological model prepared by the FAA’s Civil Aerospace Medical Institute that approximates blood saturation level of oxygen.

We reviewed the results of earlier research material [See Reference 3 through 17, Attachment 1], service history, and a new theoretical model proposed by the ARAC tasking, none of which were included in consideration of the existing regulation. These have provided additional information that was used to approximate the severity of the decompression event and relate that severity to the risk to occupants.

We utilized a physiological model that approximates blood saturation level of oxygen to screen the historical database. The model incorporates known phenomenological relationships that describe the respiratory cycle, lung mechanics, lung, venous and arterial blood flows and calculates trans-alveolar oxygen. This model has not been the subject of a peer review but we compared predicted values versus measured levels from historical test data and believe that it is a valid tool for comparative purposes. As our physiological model has not been subject to peer review we will not describe it in detail here. However, we reviewed the historical data, generated comparative plots and generated data on simulated sudden loss of cabin events to provide information on the severity of such events to occupant survivability. While future analysis and research may result in further refinements to this model, the table below should be used to determine the maximum flight altitude and the maximum permitted time exposure above certain altitudes.

The primary means to ensure occupant survivability rests in quickly bringing the occupants to a cabin pressure where they can survive (i.e., a lower cabin pressure altitude as given in the table below). Airplane DAH should use design features that facilitate rapid airplane descent from high altitudes to ensure that the occupants will not be subjected to pressure altitudes for durations longer than those given in the following table. To be eligible for an exemption the applicant's design should show compliance with the time limits given in the table. The maximum airplane operating altitude, and maximum cabin pressure being considered under this interim policy is 45,000 feet until we have completed the pending rulemaking.

Cabin Pressure Altitude [feet]	**Maximum Total Exposure Time [minutes]**
Above 45,000	0
Above 40,000	1
Above 25,000	3
Above 10,000	6

Time noted in the second column is the maximum total time spent above the indicated altitude.

In analyzing system and structural damage caused by fragments from an UEF, additional structural damage can be assumed to be limited to that engine. Regarding engine powered systems, other than losing the thrust, engine air bleed, and engine accessory power on the engine suffering the UEF, the operation of other airplane systems can be assumed to be normal. Therefore, the airplane should be capable of performing a V_{MO}/M_{MO} emergency descent (i.e., spoilers fully deployed if appropriate, maximum descent rate, V_{MO}/M_{MO} speed.)

This policy takes into account operating rules in 14 CFR parts 91, 121 and 135 which require (a) that one pilot wear and use his oxygen mask when operating above 41,000 feet altitude and (b) that an adequate quantity of oxygen is provided for crew operations. This policy is also premised on the condition that—in the Airplane Maintenance Manual—the airplane manufacturer and the airline operator include any required maintenance and checks of supplemental oxygen systems prior to each flight. Furthermore, this policy is premised on the condition that—if dispatch is deemed appropriate with a malfunctioning system that is required to ensure that the airplane is capable of performing an emergency descent (i.e., spoilers fully deployed, if appropriate; maximum descent rate; maximum operating limit V_{MO}/M_{MO} speed)—then the Master Minimum Equipment List (MMEL) will limit dispatch to a maximum flight altitude of 40,000 feet, unless other regulations or limitations require a lower altitude. Though V_{MO}/M_{MO} is normally the best speed for a rapid decompression descent, the pilots should follow the recommended emergency descent procedures in the AFM.

Since occupant survival depends on immediate and rapid descent from high altitude, applicable rapid decompression procedures for the flightcrew must be included in the emergency procedures section of the Airplane Flight Manual. This information should also be included in the Flight Crew Operating Manual. This policy is premised on operators fulfilling the initial and recurrent emergency training provisions in accordance with §§ 121.397, 121.417, and 121.427 for all crewmembers, including training for a rapid decompression and donning of oxygen masks. This policy is also premised on operators and flight crewmembers complying with the requirements of §§ 91.211, 121.333 or 135.157, as applicable. Also, normal operating procedures should be included in the AFM to ensure that the quantity of supplemental oxygen before each flight is sufficient for the intended operation.

Exemption Process

Under the procedures set forth in § 11.81, the FAA will consider DAH petitions for exemption from § 25.841(a) regarding the worst-case failures caused by an uncontained engine failure. The petition should address the following:

- *The applicant must justify "Public Interest." The petitioner must present a case that shows that granting an 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 because of the increased fuel use and longer routes because of more congestion at lower altitudes. Other factors may be used to justify "public interest."

- *The applicant must show why granting such an exemption "would not adversely affect safety."* For new and amended type designs, the applicant should provide enough 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.

Besides 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 existing or new design features that provide enhanced airplane emergency descent rates and occupant survivability.

Note: If a new design feature is required to enable the application of this policy, that design feature becomes a requirement of the type design.

(3) The petitioner should demonstrate by flight test the emergency descent procedure that is recommended in the AFM, which is the basis for determining the maximum operating altitude. In addition, if dispatch is deemed appropriate with a malfunctioning system that is required to ensure that the airplane is capable of performing an emergency descent (i.e., spoilers fully deployed, if appropriate; maximum descent rate; maximum operating limit V_{MO}/M_{MO} speed)—then the Master Minimum Equipment List (MMEL) should limit dispatch to a maximum flight altitude of 40,000 feet, unless other regulations or limitations require a lower altitude. Though V_{MO}/M_{MO} is normally the best speed for a rapid decompression descent, the pilots should follow the recommended emergency descent procedures in the AFM.

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. Similarly, if the implementing office becomes aware of reasons that an applicant's proposal that meets this policy should not be approved, the office must coordinate its response with the policy issuing office.

Implementation

The compliance methods discussed in this policy should be applied to type certificate, amended type certificate, supplemental type certificate, and amended supplemental type certification programs whose application date is on or after the date the policy is finalized. For the certification programs whose date of application precedes the date this policy is effective and the methods of compliance have already been coordinated with and approved by the FAA or their designee, the applicant may continue to follow the previously acceptable methods of compliance or choose to follow the guidance contained in this policy.

Applicants should expect the certificating officials would 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, [Transport Airplane Directorate, Aerospace Engineer, (425) 227-2147 or stephen.happenny@faa.gov].

/s/

Ali Bahrami

Attachments

Attachment 1 - References
Attachment 2 - Service History Data
Attachment 3 - Engine Failure Data
Attachment 4 - Number of Airplanes Approved to Operate Above 40,000 feet

Attachment 1
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. “A Behavioural and Neuropathological Study of the Sequelae of Profound Hypoxia”, A.N. Nicholson, Susan A. Freeland, and J.B. Brierley”, Brain Research, 22 (1970) 327-345.

12. “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.

13. “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.

14. “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, January, 1990.

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

16. “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.

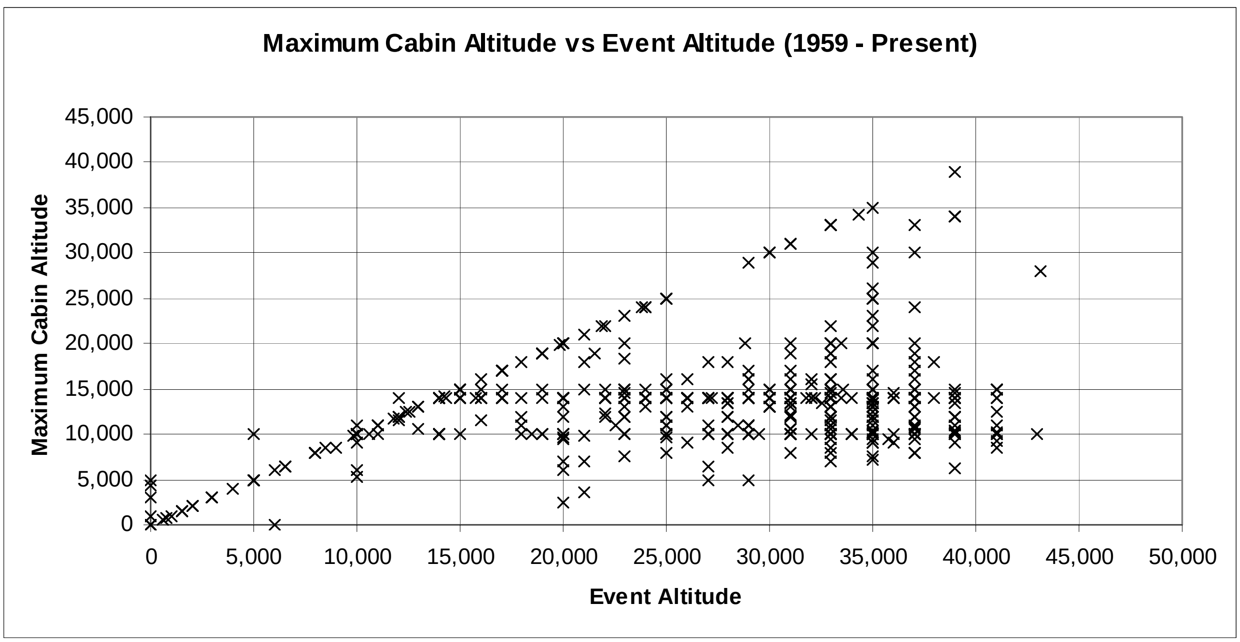
17. “Physiologically Tolerable Decompression Profiles for Supersonic Transport Type Certification”, Stanley R. Mohler M.D. and P.V. Siegel M.D., DOT/FAA/AM 70-12, July 1970.

18. Review of Interim Policy Regarding Amendment 25-87 Requirements (Altitude Rules), Memorandum from the Director, Civil Aerospace Medical Institute, to the Manager, Transport Airplane Directorate, March 30, 2004.

Attachment 2

Service History Data

The following figure [provided by the ARAC working group] contains reported events from 1959 through 2001 in transport category airplanes (over 60,000 pounds). These represent events where airplane cabin pressure was not maintained within the specifications and include cases attributed to failures that occurred within the environmental control system (e.g., pressure controller failures, valve failures, etc.), airplane structure (e.g., loss of door seal integrity), and engine (e.g., an uncontained engine failure). It depicts the maximum cabin altitude reached during a decompression event versus the airplane flight altitude. Note that no decompression event has resulted in a maximum cabin altitude above 40,000 feet, although it should also be noted that the vast majority of flight hours in transport category aircraft since 1959 have been at altitudes below 40,000 feet.

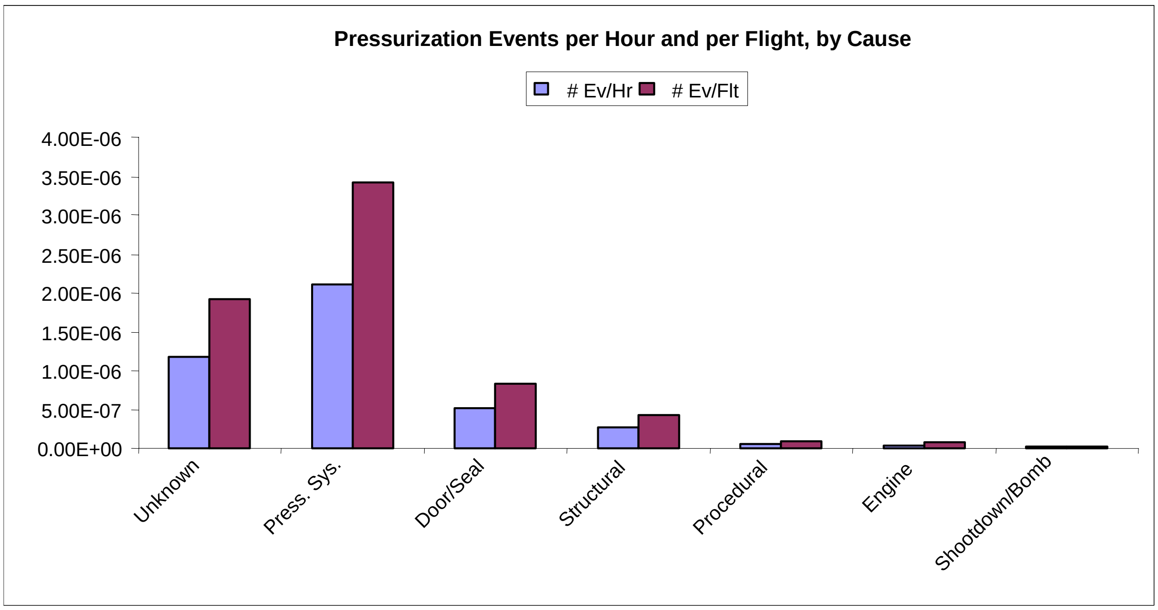


Most of the events shown in the preceding figure do not represent a severe threat to the airplane or the occupants. The reasons for this are many and include:

(1) Most loss of cabin pressure events occurs during the initial climb from an airport where the ambient pressure was below 15,000 feet pressure altitude. Most sedentary people can tolerate exposure to this pressure altitude with no permanent physiological harm.

(2) Most loss of cabin pressure events involve relatively slow leaks, which afford sufficient time for crew action to correct the situation or to limit airplane altitude and return to the airport.

The following figure [provided by the ARAC working group] depicts pressurization events by cause. From observation we conclude that loss of cabin pressure events are primarily caused by pressurization system failures. Maintenance and operational procedure errors are important contributors to the events (i.e., via loss of integrity of doors/seals or crew management of ECS). Decompressions due to uncontained engine failures are rare, albeit highly unpredictable events. It is in part due to their unpredictability as well as the uncertainty associated with the potential level of severity to the occupants that we conclude they must continue to be included in the design consideration of any airplane.



Attachment 3

Engine Failure Data

The worst-case loss of cabin pressure can occur from uncontained engine failures (UEFs). While we will not accept the use of probability as the sole means to comply with the rule we do acknowledge that these are rare events. Advisory Circular 20-128A, March 25, 1997, Section 5 (a) discusses the result of several Society of Automotive Engineers (SAE) studies engine failure events over a period of 28 years. These results include,

Report No.	Time Period	Total Number of Events	Events at Cruise
AIR1537	1962-75	275	
AIR4003	1976-83	237	
AIR4770 (draft)	1984-89	164	
TOTAL		676	95 (14% of total)

Utilizing the data presented above and the additional material included in AC 20-128A regarding the total number of engine operating hours during the 28 year time period (1089.6 million hours) leads to the conclusion that, the average probability of an uncontained engine failure at cruise was approximately $1x10^{-7}$ per engine hour. That is 1 event every 10,000,000 engine operating hours. We have information that the latest generation of engines will be less likely to experience UEFs. In addition, it should be noted that not all uncontained engine failures result in fuselage penetrations and loss of cabin pressure. This further lowers the likelihood of an occurrence. However, labeling the above events “cruise” may artificially lower the number of events because historically airplanes have performed a “step-climb” process (involving repetitive climb-cruise flight phases where airplanes fly at an altitude for a time until their weight permits them to climb to a higher altitude and cruise there for awhile) until they reach their final “cruise altitude” and some of the events listed as “climb” may be appropriate to consider.

Attachment 4

Number of Airplanes Approved to Operate Above 40,000 feet

The number of airplanes approved to fly above 40,000 feet, for which no high altitude special conditions were required, is approximately 6,000. For comparison purposes, the total number of airplanes in worldwide fleet are approximately 50,000 airplanes (but this includes general aviation, private airplanes, company owned and some military variants).

While FAA imposed special conditions for most executive business airplanes, no such requirements were levied on large transport category airplanes that fly above 40,000 feet. Approximately 2,000 of these airplanes have been approved to fly over 40,000 feet.

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