Exemption No. 11082

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
RENTON, WASHINGTON 98057-3356

In the matter of the petition of **The Boeing Company** for an exemption from § 25.841(a)(2) and (a)(3) of Title 14, Code of Federal Regulations	**Regulatory Docket No. FAA-2013-0745**

PARTIAL GRANT OF EXEMPTION

By letter received August 14, 2013 (RA-13-03728), Mr. Douglas M Lane, Director, Regulatory Administration Deputy Lead Administrator, The Boeing Company, P.O. Box 3707, Seattle, WA 98124-2207, petitioned to exempt the 737-8, 737-9 and 737-7 derivative airplanes from the requirements of Title 14, Code of Federal Regulations (14 CFR) 25.841(a)(2) and (a)(3), as amended by Amendment 25-87. If granted, the exemption would provide relief, for the 737-8, 737-9, and 737-7 (a.k.a., 737 Max) derivative airplanes, from the requirement that, during a decompression caused by an uncontained failure of one of the engines, airplane cabin-pressure altitude not exceed 25,000 feet for more than two minutes, or exceed 40,000 feet for any duration. In addition, on February 21, 2014, the FAA received supplemental material proprietary to Boeing that provided additional information pertaining to their petition. This information was used in the FAA's analysis of this exemption.

The petitioner requests relief from the following regulations:

> **Section 25.841(a)(2), Amendment 25-87 –** requires that "The airplane must be designed so that occupants will not be exposed to a cabin pressure altitude that exceeds the following after decompression from any failure condition not shown to be extremely improbable:
>
> (i) Twenty-five thousand (25,000) feet for more than 2 minutes; or
>
> (ii) Forty thousand (40,000) feet for any duration."
>
> **Section 25.841(a)(3) at Amendment 25-87 –** requires that "Fuselage structure, engine and system failures are to be considered in evaluating the cabin decompression."

The petitioner supports its request with the following information:

This section summarizes, in pertinent part, the relevant information from the petitioner's request. The complete petition is available at the Department of Transportation's Federal Docket Management System, on the Internet at http://regulations.gov, in Docket No. FAA-2013-0745.

The Boeing 737-8, 737-9, and 737-7 derivative airplanes are designed to operate at a maximum cruise altitude of 41,000 feet pressure altitude. Should an uncontained engine rotor-burst event occur, it is possible that the cabin pressure could exceed the limits contained in current regulations. Boeing offers the following justification in support of its petition for exemption. Some of this justification is based on cabin decompression evaluations performed and reported by the Mechanical Systems Harmonization Working Group (MSHWG) under the auspices of the Aviation Rulemaking Advisory Committee (ARAC).[1]

The Boeing Company requests an exemption from compliance with § 25.841(a)(2) and (3) for cabin depressurization that can occur from uncontained engine-rotor failures that result in large holes in the fuselage (i.e., those holes with an effective area exceeding 149 $in.^2$ or approximately 14 in. diameter). Boeing states that, based on fleet service experience, these are rare events. The 737-8, 737-9, and 737-7 derivative airplanes comply with the latest FAA requirements and therefore offer a significantly higher basic level of safety than previously certified transport-category airplanes. Modern transport-category airplanes have a 53-year safety record with millions of hours at altitudes similar to the maximum cruise altitude proposed for the 737-8, 737-9, and 737-7 derivative airplanes. In addition, Boeing claims that neither the Joint Airworthiness Authorities nor the European Aviation Safety Administration has implemented similar restrictions.

Boeing notes that very few, if any, decompression incidents have exposed an airplane cabin to pressure altitude profiles that pose a risk of injury to passengers. Transport-category-airplane industry history reveals that few cases of catastrophic decompressions at high altitude have occurred, and those that have occurred have typically involved small business jets, according to Boeing. Also, Boeing states that the FAA has cited a few cases of rotor burst at cruise altitude. In one such instance, the crew of a DC-10 crossing New Mexico reported several cases of initial decompression sickness, apparently with no permanent injuries.

In addition, Boeing noted in its petition that a Helios Airways Flight HCY522 accident resulted in 121 additional fatalities related to hypoxia. However, Boeing correctly states that this accident was not due to a system, structural or engine failure event, but a failure of the flight crew to properly configure the pressurization system, and a subsequent failure to recognize that the airplane was not pressurized after takeoff.

[1] The Final Report of the MSHWG, dated August 2003, was approved by a majority of the members of ARAC's Transport Airplane Engine Issues Group (TAEIG). Seven members of TAEIG voted to submit the report as a recommendation to the FAA, two members voted against submitting the report, and one member abstained.

Boeing also supplied the results of analysis for the 737-8, 737-9, and 737-7 derivative airplanes and provided information on the likelihood of various engine-failure events. In its decompression analysis, Boeing included a measure of the severity of exposure for occupants, based on a Depressurization Exposure Integral (DEI) from the MSHWG report. Boeing used the relationship between cabin pressure and the Depressurization Severity Indicator (DSI), which is a measure of the partial pressure of oxygen, as was proposed by the MSHWG. Boeing showed that, for the failure modes reviewed for this exemption, the resultant DSI levels were much less than the critical value specified by the MSHWG. The analysis considers certain design and operational features of the 737-8, 737-9, and 737-7 derivative airplanes that would mitigate the effects of an increase in cabin-pressure altitude. These design features include redundancy of key systems such as electrical power, passenger oxygen, cabin-pressure control, and spoiler actuation.

The 737-8, 737-9, and 737-7 derivative airplanes are designed to fly at cruise altitudes that maximize fuel efficiency. The reduction in maximum cruise altitude resulting from compliance with § 25.841(a)(2) and (3), for uncontained engine failure, is a concern shared by other manufacturers of airplanes with wing-mounted engines seeking new or amended type certification. No transport-category airplane with wing-mounted engines certificated today for operation above 39,000 feet can meet the new cabin-altitude limits within the current § 25.841(a)(2) and (3) without an exemption.

The Boeing Company states that it mitigates risk to high cabin-altitude exposure by reasonable design requirements, proven design methodologies, and operational considerations regardless of the cause of the decompression event. It is intended that the proposed exemption addresses the intended concern for safety without imposing the operational economic penalties driven by § 25.841 (a)(2) and (3) as currently written.

Safety-enhancement initiatives with respect to critical rotating parts (inspecting for cracks in disks, and using continually updated maintenance data to refine disk-inspection criteria), as well as improvement in engine technology, lessons learned, and second- and third-generation engine-design practices, have resulted in a reduction in uncontained engine-failure events. The uncontained engine-failure rates of second- and third-generation engines, compared to first-generation engines, have improved by approximately 95 percent based on historical Boeing data on uncontained engine failures.

The materials Boeing submitted also note that restricting airplane operations to lower altitudes will increase traffic congestion. Limiting operation of new-generation airplanes to lower altitudes will result in higher traffic density, which in turn will result in higher cost of safety to maintain established air-traffic vertical and horizontal separation requirements.

The Boeing 737-8, 737-9, and 737-7 derivative airplanes will meet the latest amendments in effect at the time of application, except as noted within the Certification Basis for the 737-8, 737-9, and 737-7 derivative airplanes. The net result is that the 737-8, 737-9, and 737-7 derivative airplanes incorporate all the safety advancements as intended within these later amendments. Boeing states that any significant impact to the marketability of the 737-8, 737-9, and 737-7 derivative airplanes will, at a minimum, result in a reduced number of airplanes with this higher level of safety, as compared with the previous generation of airplanes, or at a maximum, preclude the manufacture of this new generation of airplanes. In either case, Amendment 25-87, according to Boeing, results in a reduced potential for overall aviation-safety improvements.

Boeing's petition reiterates that this request for exemption for § 25.841 (a)(2) and (3) is limited only to uncontained engine failures. For other sources of rapid depressurization, including system failures and specific structural failures, § 25.841 (a)(2) and (3) will be complied with as amended by Amendment 25-87, except as related to a specific structural-failure event as defined in the 737-8, 737-9, and 737-7 derivative airplanes' Certification Basis exception. All mechanical and/or functional interfaces that could potentially violate the physiological limits imposed by § 25.841(a) are considered. Robust structural and systems design, and the ability for the airplane to rapidly descend, are key to assuring the safety of airplane occupants, and are an inherent part of the 737-8, 737-9, and 737-7 derivative airplanes' design. The Boeing Company states that its design practices refine the requirements into sub-requirements for systems, structures, aerodynamics, and performance to assure airplane-level compliance.

Other threat-minimization designs employed in the 737-8, 737-9, and 737-7 derivative airplanes include separation and redundancy of key systems such as electrical power, passenger oxygen, cabin-pressure control, and spoiler actuation. Also, these airplanes incorporate emergency-descent improvements that result in a faster pitch-over maneuver, and reduced V_{MO}/M_{MO} margin during emergency descent. Both changes will improve descent capability when compared to older airplanes, for example, Model 737-700/800/900 airplanes.

The petitioner's statement of public interest

Boeing notes that, with respect to uncontained engine-failure events, the impact of § 25.841(a), Amendment 25-87, to the aviation industry and the flying public is significant. The "impact" of compliance takes three forms, as follows:

1. Increased air-traffic congestion. Restricting airplane operations to lower altitudes increases traffic congestion. Boeing cites three studies showing that the numbers of transport-category airplane operations above 37,000 feet are significant today, and the trend is for newer airplanes to cruise at these altitudes for even longer portions of their mission. Limiting operation of new-generation airplanes to lower altitudes will result in higher traffic density which, in turn, results in higher cost of safety to maintain established air-traffic vertical and horizontal separation requirements.

2. Reduced potential for overall safety improvements. Since the release of Amendment 25-87, a number of amendments to 14 CFR part 25 have been released. Each of these amendments has the intent of an increase in aviation safety.

   The Boeing 737-8, 737-9, and 737-7 derivative airplanes will meet the latest amendments in effect at the time of application, except as noted in the 737-8, 737-9, and 737-7 derivative airplanes' Certification Basis. The net result is that the 737-8, 737-9, and 737-7 derivative airplanes incorporate the safety advancements as intended within these later amendments. Any significant impact to the marketability of the 737-8, 737-9, and 737-7 derivative airplanes will, at a minimum, result in a reduced number of airplanes with this higher level of safety, as compared with the previous generation of airplanes, or at a maximum, preclude the manufacture of this new generation of airplanes. In either case, Amendment 25-87 results in a reduced potential for overall aviation-safety improvements.

3. The restriction to maximum cruise altitude imposed upon the 737-8, 737-9, and 737-7 derivative airplanes, due to compliance with § 25.841 (a)(2) and (3), Amendment 25-87, as relates to uncontained engine failure, has a significant adverse impact on 737-8, 737-9, and 737-7 airplane fuel burn. This additional fuel burn will increase engine emissions (e.g. CO2).

Federal Register publication

A summary of the petition was published in the Federal Register on September 9, 2013 [78 FR 55136]. Two substantial comments were received that oppose a grant of exemption.

Airline Pilot's Association (ALPA)

ALPA acknowledges that their comments opposing the petition are similar to those expressed regarding a variety of prior petitions for exemption (see docket nos. FAA-2005-20139, FAA-2010-0766, FAA-2008-0826, and FAA-2014-0202, located in regulations.gov).

ALPA states, "Although the requested exemption would allow operations to 41,000 ft., the highest altitude addressed by the cited research is 40,000 ft., the cited research indicates that serious physical harm will occur at exposure times of 10 seconds above 40,000 ft. … Many actual aircraft occupants may be more susceptible to the effects of hypoxia."

ALPA adds that the descent time required demands near-perfect pilot performance, and that airframe structural integrity could be compromised in a HIRF incident, thereby further affecting descent time. ALPA is additionally concerned that the petition "… not only cites amendment 14 CFR 25.841, 25-87 which established new requirements, which were based in part on special conditions that had been used on type certification of executive business airplanes, not Commercial airplanes, [but also] the Mechanical Systems Harmonization Working Group (MSHWG) Depressurization Exposure Interval/Depressurization Severity Index (DEI/DSI), and a number of research papers as support for the request but does not show specific DSI/DEI calculations."

ALPA concludes that "The research conducted since [ALPA last commented on similar petitions] does not support a change in our view. ALPA therefore cannot support the requested exemption with the current state of research into the overall effects of prolonged high cabin altitude exposures on humans."

Association of Flight Attendants (AFA)

The Association of Flight Attendants (AFA) submitted opposition comments which were similar to the comments submitted for docket nos. FAA-2005-20139, FAA-2010-0766, and FAA-2008-0826, all of which are considered in the FAA's analysis of the petition for this exemption.

AFA's comments state, "The primary reason AFA voted to reject the final MSHWG report was a lack of consensus within the working group over whether to allow cabin pressure altitude to exceed 40,000 ft following a rapid depressurization for any reason."

AFA says that key aspects of Amendment 25-87, published in 1996, were overturned 10 years later "… by a policy document developed and published in response to an industry-prompted ARAC effort, which was motivated apparently by a desire to correct the inability in 1996 to 'envision' future growth in engine sizes that could potentially lead to rapid depressurizations in large transport airplanes," adding that, "…human physiology never changed in those ten years, and the statement published by the FAA in the Amendment 25-87 preamble (and not refuted by the Interim Policy document) that 'persons not using supplementary oxygen are in serious peril' above 34,000 feet cabin altitude is as true today as it was then."

AFA concludes that "… a maximum cabin pressure altitude of 40,000 feet is an acceptable limit to ensure airplane occupant safety until additional, independent research is conducted that shows otherwise. AFA further concludes that the ARAC recommendation to FAA does not substitute for an equivalent level of safety finding; therefore, this exemption is not in the public interest and would adversely affect safety in the event of a sudden decompression."

The FAA's analysis

In general, FAA does not normally exempt various models of a particular airplane in one exemption because subsequent models may have different performance characteristics or design features which enable it to successfully meet some of the regulations which Boeing has requested an exemption. In addition, FAA review and approval of an exemption is predicated on the petitioner's good faith attempt to comply with the regulation in question. However, the certification basis of these models has been approved and subsequent information provided by Boeing for each model does support their petition.

The Boeing Company provided the following information to support its application for exemption from §§ 25.841(a)(2)(i) and (ii), and 25.841(a)(3):

1. A background of the current rule and recent activities to harmonize the part 25 regulations with the regulations of foreign authorities;
2. A review of the safety history of high-altitude commercial flight;
3. A discussion of hypoxia-physiology data upon which recent rulemaking activities are based;
4. A discussion of the impact of compliance with uncontained engine-rotor burst aspects of the existing rule;
5. Environmental and air-traffic considerations, and
6. Statements addressing public interest and no adverse impact to safety.

In response to FAA inquiries, Boeing provides estimated cabin-pressure altitude and airplane flight-altitude-time history plots that followed decompressions per emergency-descent procedures, and a description of the Boeing methodology of evaluating the threat from an uncontained engine rotor burst.

Need for exemption

Boeing requests relief from § 25.841(a)(2)(i), which specifies that cabin pressure altitude may not exceed 25,000 feet for more than two minutes after decompression from any failure condition not shown to be extremely improbable. A grant of exemption from this regulation would allow the 737-8, 737-9, and 737-7 derivative airplanes to take longer than two minutes to descend from 41,000 feet to 25,000 feet after such decompression.

Boeing also requests relief from § 25.841(a)(2)(ii), which specifies that cabin-pressure altitude may not exceed 40,000 feet for any duration after decompression from any failure condition not shown to be extremely improbable. A grant of exemption from this regulation would allow the 737-8, 737-9, and 737-7 derivative airplanes' cabin-pressure altitude to exceed 40,000 feet after such decompression.

Finally, Boeing requests relief from § 25.841(a)(3), which requires that an airplane manufacturer consider fuselage structure, engine, and system failures when evaluating the cabin-pressure altitude following a decompression due to one of these failure events.

Boeing has stated that the 737-8, 737-9, and 737-7 airplane designs will not meet the requirements of § 25.841(a)(2)(i) and (ii) for some types of engine failures. For some uncontained engine-rotor failures that result in pressure vessel penetration by fragments, the design of the 737-8, 737-9, and 737-7 derivative airplanes does not meet the requirements of § 25.841(a)(2)(i) and (ii). A grant of exemption from this regulation would allow the 737-8, 737-9, and 737-7 derivative airplanes to operate up to 41,000 feet, which could briefly expose cabin occupants to this altitude in the event of a worst-case decompression: an uncontained engine-rotor failure that would cause an approximately 14-in. diameter hole in the fuselage.

Analysis under FAA policy

The FAA reviewed this petition in the context of the MSHWG Final Report on § 25.841(a)(2) and FAA policy ANM-03-112-16 dated March 24, 2006, on Amendment 25-87 requirements. The policy applies only to decompression events that are due to uncontained engine-rotor failure. The basis of the policy is data from research on the response of humans and other primates to changes in ambient pressure. Evaluation of this data indicates a direct correlation between the alveolar partial pressure of oxygen time integral, and the likelihood of fatalities or permanent physiological damage to those exposed to such pressure changes. That is, as the value of the integral (the amount of time) increases, the likelihood of fatalities or permanent physiological damage also increases. The FAA policy contains a table of altitudes and cumulative exposure times in lieu of the pressure-time integral. The values of altitude and time in the table and the results of the pressure-time integral method are in agreement.

Accordingly, our policy focuses on minimizing the likelihood that, if a person is exposed to high-altitude cabin pressure from any failure not shown to be extremely improbable, they will suffer permanent physiological damage. To analyze petitions for exemption from

§ 25.841(a)(2), the FAA requires information about emergency descent rates, any design features that increase such rates, other design features that offset the inherent increased risk of exposure to high-altitude cabin pressure, and operational procedures.

As stated above and in the policy, the FAA acknowledges a lack of relevant data on the effects of exposure to high-altitude cabin pressure following decompression and, particularly, those effects on people of various ages, and on people with circulatory or respiratory diseases or certain other medical conditions. The FAA is pursuing physiological research to better understand the rapid-decompression risk to occupants.

Our review of the Boeing petition indicates that Boeing used the criteria recommended in the FAA's policy. Boeing's design incorporated these limits to ensure airplane descent performance. This methodology is conservative because it assumes a lower partial pressure of oxygen than would likely be present during decompression at 41,000 feet.

Boeing provided descent profiles for the 737-8, 737-9, and 737-7 derivative airplanes, based on conservative estimates of descent performance for failure scenarios, as described in the FAA's policy. The descent profiles indicate that the 737-8, 737-9, and 737-7 derivative airplanes can descend rapidly from 41,000 feet to below 25,000 feet and meet the requirements in FAA policy ANM-03-112-16.

Boeing also performed a depressurization analysis, which was based upon maximum cruise flight conditions. It provided an assessment of the vulnerability of passengers following failures that result in a decompression. In addition, Boeing identified design and operational features of the 737-8, 737-9, and 737-7 derivative airplanes that would mitigate the effects of an increase in cabin-pressure altitude.

The decompression analysis used several measures recommended in the MSHWG Final Report. Specifically, Boeing estimated the severity of exposure to high-altitude cabin pressure for occupants, based on calculation of a DEI. The analysis also considered the relationship between cabin pressure and the DSI, a measure of the partial pressure of oxygen. The analysis indicates that the physiological effect of an increase in the length of time spent above 25,000 feet, per FAA policy ANM-03-112-16, is within the uncertainty band of available physiological data. The Boeing analysis also shows that, for the failure modes reviewed for this exemption, resultant DSI levels were much less than the critical value recommended by the MSHWG.

The FAA has carefully considered the comments received from ALPA and AFA, and has taken them into account in our analysis of the petition for exemption Boeing submitted. As discussed in response to these comments that have been previously submitted by ALPA and AFA, in response to the previous petitions for exemption noted above, we acknowledge the need for additional research on the effects of exposure to high-altitude cabin pressure. We also acknowledge the need for validation of the DEI methodology recommended in the MSHWG's final report, and in our interim policy on 14 CFR part 25, Amendment 25-87 requirements. Although the FAA plans to conduct additional research on this subject, we find that sufficient data, including service history, is available to support this proposed exemption for the Model 737-8, 737-9, and 737-7.

Furthermore, we acknowledge ALPA's concern regarding the response of the flightcrew and the criticality of the flight maneuver, which ALPA also submitted in response to the previous petitions for exemption noted above. It was a consensus of the MSHWG that an uncontained engine-rotor-blade failure would result in sufficient structural integrity of the airplane to permit a rapid descent. The MSHWG also reviewed the delay in flight-crew initiation of the emergency descent, as noted in existing Advisory Circular 25-20, *Pressurization, Ventilation and Oxygen Systems Assessment for Subsonic Flight including High Altitude Operation*, and recommended that this delay represented a reasonable approach to addressing this concern. In summary, we have considered reasonable pilot-reaction times to don oxygen masks, recognize the failure event, and take appropriate action to configure the airplane for a swift descent.

The FAA reviewed information provided by Boeing about design features and operational procedures that would mitigate the threat of a high-altitude rapid decompression and maintain the descent capability of the 737-8, 737-9, and 737-7 derivative airplanes and/or ensure occupant survival. We concluded that the design features and operational procedures associated with rapid decompression, followed by an emergency descent, support a finding that granting the exemption would not adversely affect safety.

Review of historical data and research

The FAA reviewed databases from its National Aviation Safety Data Analysis Center, covering 1959 to the present. Approximately 3,000 instances of loss of cabin pressure have occurred since 1959. The vast majority of these have been caused by system failures (e.g., cabin-pressurization controller failures and valve failures) and structural failures (e.g., door-seal failures), both of which typically have been 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, regardless of their cause, 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 cabin-pressure altitude at which passenger oxygen masks are deployed).

Similarly, uncontained engine-rotor-burst failures tend to be very rare. 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 reduce this probability by an order of magnitude. We found, as noted in the MSHWG report on § 25.841(a), that no fatalities from hypoxia were due to in-flight rapid decompression events as envisioned by Amendment 25-87. The data indicate that decompression is not a significant cause of fatalities. It is because these events are so rare that the FAA considers the risk to be acceptable.

In addition, Boeing provided the FAA with proprietary data from its analysis of uncontained engine-rotor failures, and the size and number of holes in the fuselage resulting from such failures. Using historical service data and theoretical values, Boeing performed decompression analysis for several scenarios. Boeing analyzed the probability of uncontained engine-rotor failure and of penetration of the fuselage of the 737-8, 737-9, and 737-7 derivative airplanes from fragments of various sizes resulting from such failures. This analysis was used to assess the threat of such an event to occupants of the airplane. The

FAA did not agree with Boeing's exclusion of data in their analysis that concerned large holes in the fuselage causing decompression. These larger hole sizes were greater than 149 $in.^2$ effective area and occurred from two historical events. However, Boeing's analysis was conducted in a manner consistent with the recommendations within the MSHWG report, and their data showed that even for the largest survivable hole, the 737-8, 737-9, and 737-7 derivative airplanes would be able to meet the FAA's policy criteria.

The FAA concurs with the petitioner that uncontained engine-rotor failures are rare events, and this consideration had a bearing on the granting of the exemption. Our analysis in this case also considered our analysis of an earlier petition for exemption from a different applicant for an airplane with the same cruise altitude (41,000 feet). The petition submitted by this previous applicant also included estimates of the probability of occurrence of an uncontained engine-rotor failure. In that case, as in this petition, the altitude excursion above 40,000 feet was no more than 1,000 feet. We concluded that the risk associated with exposure of the occupants to the slightly higher altitude was essentially the same as the risk of exposure at 40,000 feet. In other words, the risk from exposure at altitude was essentially the same with or without the grant of the exemption. In that case as well as in this petition, the rarity of uncontained engine-rotor failures did not significantly enter into consideration regarding the grant of exemption.

Holes from uncontained engine-rotor failure

The FAA evaluated the Boeing methodology for determining the probable size of holes in the fuselage and/or wings caused by uncontained engine rotor failure. We concluded that the method makes some assumptions which one could question. However, this issue is not of great significance since the FAA required Boeing to assume a failure which produced a very large hole in the fuselage (i.e., 149 $in.^2$ effective area), causing a sudden decompression.

Use of supplemental oxygen

As discussed below, the FAA has analyzed the Boeing petition in the context of the MSHWG recommendations, the 14 CFR part 25 requirements pertaining to supplemental oxygen, and certain technical standards for supplemental oxygen equipment. Section 25.1441(d) requires approval of oxygen equipment for airplanes that are approved to operate above 40,000 feet altitude. Section 25.1443 specifies the minimum mass flow of supplemental oxygen for flightcrew and passenger oxygen systems up to a cabin altitude of 40,000 feet. Part 25 does not contain standards for oxygen systems above 40,000 feet. However, FAA Technical Standard Orders (TSOs) provide requirements for diluter demand pressure-breathing regulators (TSO-89) and demand oxygen masks (TSO-78) up to 45,000 feet. In addition, the Society of Automotive Engineers (SAE) Standard AS 8027 provides specifications for diluter demand pressure-breathing regulators up to 45,000 feet. It is the FAA's understanding that no diluter demand pressure breathing regulators available for commercial airplanes meet all the requirements of TSO-89 or AS 8027.

As part of the certification for the 737-8, 737-9, and 737-7 derivative airplanes, Boeing must substantiate the adequacy of the supplemental oxygen systems installed for the flightcrew exposed to cabin altitudes above 40,000 feet.

Flightcrew pressure-breathing equipment requires training to ensure effective use. Pressure breathing requires physical effort to exhale and minimal effort to inhale. This reversal of the normal breathing cycle can lead to hyperventilation. The FAA considers it impractical to train passengers to use pressure-breathing equipment safely. The FAA determined that an acceptable means of compliance for the fixed and portable oxygen systems used by flight attendants and passengers would be to install oxygen equipment that is certificated to 40,000 feet, and limit exposure to the reduced-pressure environment above 40,000 feet via airplane-descent performance. The FAA believes that, ultimately, occupant survival during a decompression event depends upon swift descent to a lower altitude. In its review of the petitioner's airplane descent profile, the FAA finds that the 737-8, 737-9, and 737-7 derivative airplanes can descend at acceptable rates.

Conclusion of FAA analysis

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 reducing congestion, improving fuel economy, and reducing pollution. If compliance with § 25.841 at Amendment 25-87 were to limit airplanes operations to a maximum altitude of 40,000 feet, it 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 safety benefits of their more advanced technology.

Based upon its evaluation of Boeing's data and analysis, the FAA has determined that granting this exemption would not adversely affect safety, and is in the public interest, and therefore that Boeing provides sufficient justification for a partial grant of exemption from § 25.841(a)(2)(i) and (ii).

This partial grant of exemption does not provide relief from 14 CFR 25.841(a) for any other system and structural failure events not shown to be extremely improbable. The petitioner will have to demonstrate compliance for those failure events, and this partial grant is predicated on the condition that the petitioner successfully demonstrates compliance for the Boeing 737-8, 737-9, and 737-7 derivative airplanes. As noted in the MSHWG report on § 25.841(a), a tire burst in-flight is not extremely improbable, as demonstrated by historic data. According to the preamble of § 25.729(f)(1) and historic data, tire bursts occur in-flight. It is very difficult to demonstrate that tires cannot be burst in case of overheating. It cannot be demonstrated that tires do not burst in high-altitude flight. Therefore, the tire-burst event must be considered in the depressurization analysis.

In addition, pressure-vessel openings resulting from loss of antennas or stall-warning vanes, or any system failure conditions that are not shown to be extremely improbable, must be considered. The effects of such damage while operating under maximum, normal, cabin-pressure differential must be evaluated. Also, structural cracks must be addressed as per the existing Amendment 25-87 preamble:

> The maximum pressure vessel opening resulting from an initially detectable crack propagating for a period encompassing four normal inspection intervals. Mid-panel

cracks and cracks through skin stringer and skin frame combinations must be evaluated.

In addition, this partial grant of exemption is predicated on the requirement that the Boeing 737-8, 737-9, and 737-7 derivative airplanes successfully demonstrate compliance to 14 CFR 25.1441, 25.1443, 25.1445, 25.1447 and 25.1449.

This partial grant of exemption 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.

The FAA recognizes that Boeing accounts for non-standard conditions, such as rapid decompression, in defining appropriate supplemental-oxygen-system maintenance and checks at appropriate intervals that they include in the Instructions for Continued Airworthiness (ICA). To facilitate each operator's incorporation of this information into their maintenance procedures, Boeing also helps operators understand the details of the ICAs.

Boeing typically accounts for non-standard conditions, such as rapid decompression and emergency descent, in developing appropriate dispatch criteria with a malfunctioning system in the Master Minimum Equipment List (MMEL). For example, if Boeing determines that dispatch is possible with a malfunctioning system that contributes to the airplane's ability to perform an emergency descent, Boeing could propose that the MMEL limit dispatch to a lower maximum flight altitude. Rather than identify an MMEL dispatch limitation as an explicit condition of granting the exemption, the FAA has determined that it is appropriate for the FAA Flight Operations Evaluation Board to evaluate the matter of dispatch with a malfunctioning system.

The applicable rapid decompression procedures for the flightcrew must be included in the emergency procedures section of the airplane flight manual (AFM). This information should also be included in the Boeing flightcrew operating manual. Note that initial and recurrent emergency training for all crewmembers, in accordance with 14 CFR 121.397, 121.417, and 121.427, must include training for a rapid decompression and donning of oxygen masks.

The partial grant of exemption from § 25.841(a)(2)(ii) permits cabin-pressure altitude to exceed 40,000 feet for one minute (but not to exceed 41,000 feet for any duration) after decompression from any uncontained engine-failure condition not shown to be extremely improbable. The partial grant of exemption from § 25.841(a)(2)(i) will permit cabin pressure altitude to exceed 25,000 feet for more than 2 minutes (but not more than 3 minutes) after decompression from any uncontained engine-failure condition not shown to be extremely improbable, allowing time for the airplane to descend from an altitude of 41,000 feet to 25,000 feet.

The FAA's decision

In consideration of the foregoing, I find that a partial grant of exemption is in the public interest. Therefore, pursuant to the authority contained in 49 U.S.C. 40113 and 44701, delegated to me by the Administrator, a partial grant of exemption is granted to Boeing for exemption from the requirements of 14 CFR 25.841(a)(2)(i) and (ii), and 25.841(a)(3), as amended by Amendment 25-87, for Boeing 737-8, 737-9, and 737-7 derivative airplanes.

This partial grant of exemption is subject to the following conditions:

1. The Boeing 737-8, 737-9, and 737-7 derivative airplane AFMs must indicate that the maximum indicated operating pressure altitude is 41,000 feet.
2. The AFM for each airplane must contain applicable flightdeck crew procedures for a rapid-decompression event. The section of the 737-8, 737-9, and 737-7 derivative airplane AFM that pertains to actions in the event of a decompression must state that the flightdeck crew should initiate a descent at the maximum rate of descent and safe descent speed, which is typically the maximum operating speed (V_{MO}/M_{MO}), assuming structural integrity of the airplane.
3. Boeing must submit certification flight-test data for the Boeing 737-8, 737-9, and 737-7 derivative airplanes simulating the loss of one engine (i.e., from an uncontained engine rotor-burst), and subsequent loss of systems associated with the loss of one engine that corroborate the descent profiles used in the analysis to show that, after decompression at an airplane-indicated operating pressure altitude of 41,000 feet, the cabin-pressure altitude will not exceed 25,000 feet for more than 3 minutes, or 40,000 feet for more than 1 minute.

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/s/ Jeffrey E. Duven

Jeffrey E. Duven
Manager, Transport Airplane Directorate
Aircraft Certification Service