[4910-13]

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 25

[Docket No. FAA-2017-0717; Special Conditions No. 25-704-SC]

Special Conditions: The Boeing Company Model 777-8 and 777-9 Airplanes; Interaction of Systems and Structures

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Final special conditions; request for comments.

SUMMARY: These special conditions are issued for The Boeing Company (Boeing) Model 777-8 and 777-9 airplanes. These airplanes will have novel or unusual design features when compared to the state of technology envisioned in the airworthiness standards for transport-category airplanes. These design features include systems that, directly or as a result of failure or malfunction, affect airplane structural performance. The applicable airworthiness regulations do not contain adequate or appropriate safety standards for these design features. These special conditions contain the additional safety standards that the Administrator considers necessary to establish a level of safety equivalent to that established by the existing airworthiness standards.

DATES: This action is effective on Boeing on **[INSERT DATE OF PUBLICATION IN THE FEDERAL REGISTER]**. We must receive your comments by **[INSERT DATE 45 DAYS AFTER PUBLICATION IN THE FEDERAL REGISTER]**.

ADDRESSES: Send comments identified by docket number FAA-2017-0717 using any of the following methods:

- *Federal eRegulations Portal:* Go to http://www.regulations.gov/ and follow the online instructions for sending your comments electronically.
- *Mail:* Send comments to Docket Operations, M-30, U.S. Department of Transportation (DOT), 1200 New Jersey Avenue, SE., Room W12-140, West Building Ground Floor, Washington, DC, 20590-0001.
- *Hand Delivery or Courier:* Take comments to Docket Operations in Room W12-140 of the West Building Ground Floor at 1200 New Jersey Avenue, SE., Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.
- *Fax:* Fax comments to Docket Operations at 202-493-2251.

Privacy: The FAA will post all comments it receives, without change, to http://www.regulations.gov/, including any personal information the commenter provides. Using the search function of the docket Web site, anyone can find and read the electronic form of all comments received into any FAA docket, including the name of the individual sending the comment (or signing the comment for an association, business, labor union, etc.). DOT's complete Privacy Act Statement can be found in the **Federal Register** published on April 11, 2000 (65 FR 19477-19478).

Docket: Background documents or comments received may be read at http://www.regulations.gov/ at any time. Follow the online instructions for accessing the docket or go to Docket Operations in Room W12-140 of the West Building Ground Floor at 1200 New Jersey Avenue, SE., Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: Mark Freisthler, FAA, Airframe and Cabin Safety Branch, ANM-115, Transport Airplane Directorate, Aircraft Certification Service, 1601

Lind Avenue SW., Renton, Washington, 98057-3356; telephone 425-227-1119; facsimile 425-227-1320.

SUPPLEMENTARY INFORMATION:

The substance of these special conditions has been subject to the public-comment process in several prior instances with no substantive comments received. The FAA therefore finds it unnecessary to delay the effective date and that good cause exists for making these special conditions effective upon publication in the **Federal Register**.

Comments Invited

We invite interested people to take part in this rulemaking by sending written comments, data, or views. The most helpful comments reference a specific portion of the special conditions, explain the reason for any recommended change, and include supporting data.

We will consider all comments we receive by the closing date for comments. We may change these special conditions based on the comments we receive.

Background

On April 19, 2017 (for the Model 777-8 airplane), and May 12, 2015 (for the 777-9 airplane), Boeing applied for an amendment to Type Certificate (TC) No. T00001SE to include the new Model 777-8 and 777-9 airplanes. These airplanes are derivatives of the Model 777-300ER airplane currently approved under TC No. T00001SE. The Model 777-9 airplane is a stretched-fuselage, large, twin-engine airplane with seating for 408 passengers and a maximum takeoff weight of 775,000 pounds.

The Model 777-8 airplane, a shortened-body derivative of the Model 777-9 airplane, is a large, twin-engine airplane with seating for 359 passengers and a maximum takeoff weight of 775,000 pounds.

Type Certification Basis

Under the provisions of title 14, Code of Federal Regulations (14 CFR) 21.101, Boeing must show that the Model 777-8 and 777-9 airplanes meet the applicable provisions of the regulations listed in TC No. T00001SE, or the applicable regulations in effect on the date of application for the change, except for earlier amendments as agreed upon by the FAA.

If the Administrator finds that the applicable airworthiness regulations (i.e., 14 CFR part 25) do not contain adequate or appropriate safety standards for the Model 777-8 and 777-9 airplanes because of a novel or unusual design feature, special conditions are prescribed under the provisions of § 21.16.

Special conditions are initially applicable to the model for which they are issued. Should the type certificate for that model be amended later to include any other model that incorporates the same novel or unusual design features, or should any other model already included on the same type certificate be modified to incorporate the same novel or unusual design feature, these special conditions would also apply to the other model under § 21.101.

In addition to the applicable airworthiness regulations and special conditions, the Model 777-8 and 777-9 airplanes must comply with the fuel-vent and exhaust-emission requirements of 14 CFR part 34, and the noise-certification requirements of 14 CFR part 36.

The FAA issues special conditions, as defined in 14 CFR 11.19, in accordance with § 11.38, and they become part of the type certification basis under § 21.101.

Novel or Unusual Design Features

The Model 777-8 and 777-9 airplanes will incorporate the following novel or unusual design features:

These Boeing airplanes have full-time, digital, electronic flight-control systems (EFCS) affecting the pitch, yaw, and roll axes of the airplanes. In addition, the airplanes are equipped with on-ground load-alleviation systems to reduce braking loads. The current regulations are inadequate for considering the effects of these systems and their effects upon structural performance. These special conditions define the criteria to be used in the assessment of the effects of these systems on structures.

The general approach of accounting for the effect of system failures on structural performance would be extended to include any partial or complete system failure, alone or in combination with other partial or complete system failures, as would affect structural performance.

Discussion

Active flight-control systems are capable of providing automatic responses to external inputs from sources other than pilots. These systems have been expanded in function, effectiveness, and reliability such that fly-by-wire flight controls, without a manual backup system in the event of system failures, are becoming standard equipment on larger transport-category airplanes. As a result of these advancements in flight-control technology, the current safety standards contained in part 25 do not provide an adequate basis to address an acceptable level of safety for airplanes equipped with these advanced systems. Instead, certification of these systems has been achieved by issuance of special conditions under the provisions of § 21.16.

For example, stability-augmentation systems (SAS), and to a lesser extent load-alleviation systems (LAS), have been used on transport-category airplanes for many years. Past approvals of these systems were based on both special conditions and individual findings of equivalent level of safety with existing rules.

Although autopilots are also considered active control systems, typically their control authority has been limited such that the consequences of system failures could be readily counteracted by the pilot. Now, autopilot functions are integrated into the primary flight controls and are given sufficient control authority to maneuver the airplane to its structural design limits. This advanced technology, with its expanded authority, requires a new approach to account for the interaction of control systems and structures.

The usual deterministic approach to defining the loads envelope contained in part 25 does not fully account for system effectiveness and system reliability. These automatic systems may be inoperative or may operate in a degraded mode with less than full system authority. Therefore, it is necessary to determine the structural factors of safety and operating margins such that the joint probability of structural failures, due to application of loads during system malfunctions, is not greater than that found in airplanes equipped with earlier-technology control systems. To achieve this objective, it is necessary to define the failure conditions, with their associated frequency of occurrence, to determine the structural factors of safety and operating margins that will ensure an acceptable level of safety.

Earlier automatic control systems usually provided two states: either fully functioning, or a total loss of function. Flightcrew readily detected these conditions. The new, active, flight-control systems have failure modes that allow the system to function in the degraded mode without full authority. This degraded mode is not readily detectable by the flightcrew. Therefore, monitoring systems are required on these new systems to provide an annunciation of a condition of degraded system capability.

In these special conditions, and in the current standards and regulations, the term "any" requires the applicant to address all items covered by the term, rather than addressing only a portion of the items.

Applicability

As discussed above, these special conditions are applicable to Boeing Model 777-8 and 777-9 airplanes. Should Boeing apply at a later date for a change to the type certificate to include another model incorporating the same novel or unusual design feature, these special conditions would apply to that model as well.

Conclusion

This action affects only a certain novel or unusual design feature on one model of airplane. It is not a rule of general applicability.

List of Subjects in 14 CFR Part 25

Aircraft, Aviation safety, Reporting and recordkeeping requirements.

The authority citation for these special conditions is as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704.

The Special Conditions

Accordingly, pursuant to the authority delegated to me by the Administrator, the following special conditions are issued as part of the type certification basis for Boeing Model 777-8 and 777-9 airplanes.

Interaction of Systems and Structures

For airplanes equipped with systems that affect structural performance, either directly or as a result of a failure or malfunction, the influence of these systems and their failure conditions

must be taken into account when showing compliance with the requirements of part 25, subparts C and D.

For airplanes equipped with flight-control systems, autopilots, stability-augmentation systems, load-alleviation systems, fuel-management systems, and other systems that either directly, or as a result of failure or malfunction, affect structural performance, the following criteria must be used for showing compliance. If these special conditions are used for other systems, it may be necessary to adapt the criteria to the specific system.

1. The criteria defined herein only address the direct structural consequences of the system responses and performance. They cannot be considered in isolation, but should be included in the overall safety evaluation of the airplane. These criteria may, in some instances, duplicate standards already established for this evaluation. These criteria are only applicable to structure the failure of which could prevent continued safe flight and landing. Specific criteria that define acceptable limits on handling characteristics or stability requirements, when operating in the system-degraded or inoperative mode, are not provided in these special conditions.
2. Depending upon the specific characteristics of the airplane, additional studies that go beyond the criteria provided in these special conditions may be required to demonstrate the airplane's capability to meet other realistic conditions, such as alternative gust or maneuver descriptions for an airplane equipped with a load-alleviation system.
3. The following definitions are applicable to these special conditions.
    a. **Structural performance:** Capability of the airplane to meet the structural requirements of part 25.

b. **Flight limitations:** Limitations that can be applied to the airplane flight conditions following an in-flight occurrence, and that are included in the airplane flight manual (e.g., speed limitations, avoidance of severe weather conditions, etc.).

c. **Operational limitations:** Limitations, including flight limitations, that can be applied to the airplane operating conditions before dispatch (e.g., fuel, payload and master minimum-equipment list limitations).

d. **Probabilistic terms:** Terms such as probable, improbable, and extremely improbable, as used in these special conditions, are the same as those used in § 25.1309.

e. **Failure condition:** This term is the same as that used in § 25.1309. However, these special conditions apply only to system-failure conditions that affect the structural performance of the airplane (e.g., system-failure conditions that induce loads, change the response of the airplane to inputs such as gusts or pilot actions, or lower flutter margins).

Effects of Systems on Structures

1. **General.** The following criteria will be used in determining the influence of a system and its failure conditions on the airplane structure.
2. **System fully operative.** With the system fully operative, the following apply:
    a. Limit loads must be derived in all normal operating configurations of the system from all the limit conditions specified in part 25, subpart C (or defined by special conditions or findings of equivalent level of safety in lieu of those specified in subpart C), taking into account any special behavior of such a system or

associated functions, or any effect on the structural performance of the airplane that may occur up to the limit loads. In particular, any significant nonlinearity (rate of displacement of control surface, thresholds, or any other system nonlinearities) must be accounted for in a realistic or conservative way when deriving limit loads from limit conditions.

b. The airplane must meet the strength requirements of part 25 (static strength, residual strength), using the specified factors to derive ultimate loads from the limit loads defined above. The effect of nonlinearities must be investigated beyond limit conditions to ensure that the behavior of the system presents no anomaly compared to the behavior below limit conditions. However, conditions beyond limit conditions need not be considered when it can be shown that the airplane has design features that will not allow it to exceed those limit conditions.

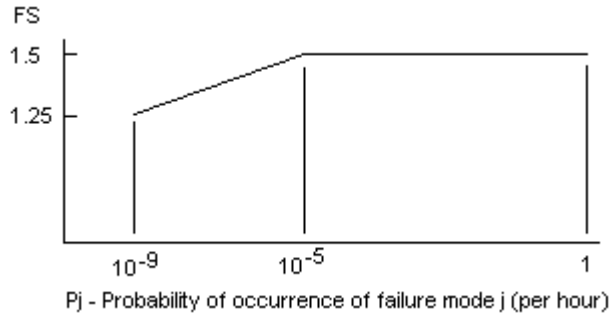
c. The airplane must meet the aeroelastic stability requirements of § 25.629.

3. **System in the failure condition.** For any system-failure condition not shown to be extremely improbable, the following apply:

    a. At the time of occurrence. Starting from 1g level flight conditions, a realistic scenario, including pilot corrective actions, must be established to determine the loads occurring at the time of failure and immediately after the failure.

        i. For static-strength substantiation, these loads, multiplied by an appropriate factor of safety that is related to the probability of occurrence of the failure, are ultimate loads to be considered for design. The factor of safety is defined in Figure 1, below.

Figure 1: Factor of safety (FS) at the time of occurrence



ii. For residual-strength substantiation, the airplane must be able to withstand two thirds of the ultimate loads defined in special condition 3.a.i. For pressurized cabins, these loads must be combined with the normal operating differential pressure.

iii. Freedom from aeroelastic instability must be shown up to the speeds defined in § 25.629(b)(2). For failure conditions that result in speeds beyond V_C/M_C, freedom from aeroelastic instability must be shown to increased speeds, so that the margins intended by § 25.629(b)(2) are maintained.

iv. Failures of the system that result in forced structural vibrations (oscillatory failures) must not produce loads that could result in detrimental deformation of primary structure.

b. For the continuation of the flight. For the airplane in the system-failed state, and considering any appropriate reconfiguration and flight limitations, the following apply:

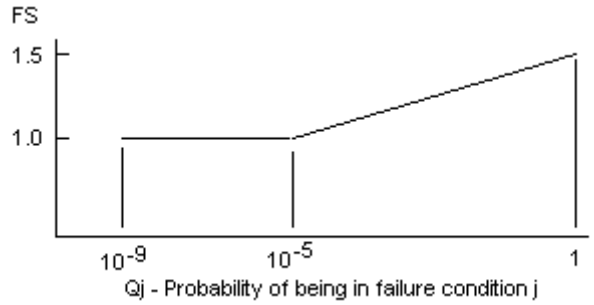
i. The loads derived from the following conditions (or defined by special conditions or findings of equivalent level of safety in lieu of the following

conditions) at speeds up to V_C/M_C (or the speed limitation prescribed for the remainder of the flight) must be determined:

1. the limit symmetrical maneuvering conditions specified in §§ 25.331 and 25.345.
2. the limit gust and turbulence conditions specified in §§ 25.341 and 25.345.
3. the limit rolling conditions specified in § 25.349, and the limit unsymmetrical conditions specified in §§ 25.367, and 25.427(b) and (c).
4. the limit yaw-maneuvering conditions specified in § 25.351.
5. the limit ground-loading conditions specified in §§ 25.473, 25.491, 25.493(d), and 25.503.

ii. For static-strength substantiation, each part of the structure must be able to withstand the loads in special condition 3.b.i., multiplied by a factor of safety depending on the probability of being in this failure state. The factor of safety is defined in Figure 2, below.

Figure 2: Factor of safety (FS) for continuation of flight



$Q_j = (T_j)(P_j)$ where:

T_j = Average time spent in failure mode j (in hours)

P_j = Probability of occurrence of failure mode j (per hour)

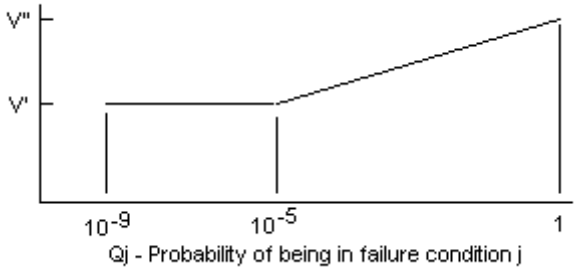
Note: If P_j is greater than 10^{-3} per flight hour, then a 1.5 factor of safety must be applied to all limit load conditions specified in part 25, subpart C.

iii. For residual-strength substantiation, the airplane must be able to withstand two-thirds of the ultimate loads defined in paragraph 3.b.ii. of these special conditions. For pressurized cabins, these loads must be combined with the normal operating differential pressure.

iv. If the loads induced by the failure condition have a significant effect on fatigue or damage tolerance, then their effects must be taken into account.

v. Freedom from aeroelastic instability must be shown up to a speed determined from Figure 3, below. Flutter clearance speeds V' and V" may be based on the speed limitation specified for the remainder of the flight using the margins defined by § 25.629(b).

Figure 3: Clearance speed



V' = Clearance speed as defined by § 25.629(b)(2).

V" = Clearance speed as defined by § 25.629(b)(1).

$Q_j = (T_j)(P_j)$ where:

T_j = Average time spent in failure mode j (in hours)

P_j = Probability of occurrence of failure mode j (per hour)

Note: If P_j is greater than 10^{-3} per flight hour, then the flutter clearance speed must not be less than V".

vi. Freedom from aeroelastic instability must also be shown up to V' in Figure 3, above, for any probable system-failure condition, combined with any damage required or selected for investigation by § 25.571(b).

c. Consideration of certain failure conditions may be required by other sections of part 25 regardless of calculated system reliability. Where analysis shows the probability of these failure conditions to be less than 10^{-9} per flight hour, criteria other than those specified in this paragraph may be used for structural substantiation to show continued safe flight and landing.

4. **Failure indications.** For system-failure detection and indication, the following apply:

a. The system must be checked for failure conditions, not extremely improbable, that degrade the structural capability below the level required by part 25, or that significantly reduce the reliability of the remaining system. As far as reasonably practicable, the flightcrew must be made aware of these failures before flight. Certain elements of the control system, such as mechanical and hydraulic components, may use special periodic inspections, and electronic components may use daily checks, in lieu of detection and indication systems, to achieve the objective of this requirement. These certification-maintenance requirements must be limited to components that are not readily detectable by normal detection-and-

indication systems, and where service history shows that inspections will provide an adequate level of safety.

b. The existence of any failure condition, not extremely improbable, during flight, that could significantly affect the structural capability of the airplane, and for which the associated reduction in airworthiness can be minimized by suitable flight limitations, must be signaled to the flightcrew. For example, failure conditions that result in a factor of safety between the airplane strength and the loads of part 25, subpart C below 1.25, or flutter margins below V", must be signaled to the crew during flight.

5. **Dispatch with known failure conditions.** If the airplane is to be dispatched in a known system-failure condition that affects structural performance, or that affects the reliability of the remaining system to maintain structural performance, then the provisions of these special conditions must be met, including the provisions of special condition 2 for the dispatched condition, and special condition 3 for subsequent failures.

   a. Expected operational limitations may be taken into account in establishing Pj as the probability of failure occurrence for determining the safety margin in Figure 1.

   b. Flight limitations and expected operational limitations may be taken into account in establishing Qj as the combined probability of being in the dispatched failure condition, and the subsequent failure condition, for the safety margins in Figures 2 and 3.

   c. These limitations must be such that the probability of being in this combined failure state, and then subsequently encountering limit load conditions, is

extremely improbable. No reduction in these safety margins is allowed if the subsequent system-failure rate is greater than 10^{-3} per flight hour.

Issued in Renton, Washington, on October 23, 2017.

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[FR Doc. 2017-23699 Filed: 10/31/2017 8:45 am; Publication Date: 11/1/2017]