U.S. Department
of Transportation

Federal Aviation
Administration

Advisory Circular

AC 25-22

DATE: 3/14/00

CERTIFICATION OF TRANSPORT AIRPLANE MECHANICAL SYSTEMS

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject:	**CERTIFICATION OF TRANSPORT AIRPLANE MECHANICAL SYSTEMS**	**Date:**	3/14/00	**AC No:**	25-22
		Initiated by	ANM-110	**Change:**	

1. **PURPOSE**. This advisory circular (AC) provides methods acceptable to the Administrator for showing compliance with the type certification requirements for transport airplane mechanical systems and equipment installations. This AC is intended to provide guidance to airplane manufacturers, modifiers, foreign regulatory authorities, Federal Aviation Administration (FAA) transport airplane type certification engineers and their designees. The methods and procedures described herein have evolved over many years and represent current certification practice. Like all advisory material, these guidelines are not mandatory and do not constitute regulations. They are derived from previous FAA experience in finding compliance with the airworthiness requirements and represent methods and procedures found to be acceptable by that experience. Although mandatory terms such as “shall” and “must” are used in this AC, because the AC method of compliance is not in itself mandatory, these terms apply only to applicants who seek to demonstrate compliance by use of the specific method described in this AC.

2. **CANCELLATION.** Advisory Circular 25-14, High Lift and Drag Devices, dated May 4, 1988, is cancelled.

3. **APPLICABILITY**. This advisory circular contains guidance for the latest amendment of the regulations and applies to all transport category airplanes approved under the provisions of part 25, for which a new, amended, or supplemental type certificate is requested.

4. RELATED DOCUMENTS.

a. Related Federal Aviation Regulations. Sections which prescribe requirements for the design, substantiation, and certification of transport airplane mechanical systems are for most part in Title 14 Code of Federal Regulations (14 CFR) part 25, subpart D - Design and

Construction, and subpart F - Equipment. Additional sections (and their associated advisory circulars where applicable) that prescribe requirements which can have a significant impact on the overall design and configuration of mechanical systems are in subpart B- Performance, subpart C - Structure, subpart E - Powerplant, and subpart G - Operating Limitations and Information. Five advisory circulars are planned. Each AC will address primarily one area of regulations for transport category airplanes. They are: Certification of Transport Airplane Mechanical Systems (AC 25-XX), Certification of Electrical Equipment Installations (AC 25-XX), Transport Airplane Propulsion Engine and Auxilliary Power Unit Installation Certification Handbook - The Propulsion Mega-AC (AC 25-XX), Certification of Transport Airplane Structure (A 25-21), and Transport Airplane Cabin Interiors Handbook (AC 25-17A). Each AC will cross reference the other four AC's, as necessary, for coverage of the related regulations. A cross reference index is provided as item 7 in appendix 4 of this AC.

b. Advisory Circulars (AC’s). This AC can be found and downloaded from the Internet at http://www.faa.gov/avr/air/airhome.htm, at the link titled "Advisory Circulars."

Copies of advisory circulars referenced in this AC may be obtained from the US Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341Q 75th Avenue, Landover, MD 20785. The help line number is 301-322-4961, and the fascimile number is 301-386-5394 DOT Warehouse.

5. BACKGROUND.

a In the past, advisory and guidance information applicable to transport airplane mechanical systems and equipment installations has been formally published within AC's. However, in many instances, policy has been developed and applied to specific certification projects without formal publication. This policy appeared in the form of policy memorandums and issue papers (or certification review items) which were distributed to the Aircraft Certification Offices. In many instances this information was not organized in a way that allowed easy access. This AC formalizes existing policy so that the public, FAA personnel, and their designees may have access to this information, and contains policy extracted from existing FAA communications used to provide guidance to applicants and other aircraft certification organizations.

b. The guidance contained in this document is presented in a format that lists the regulatory text, intent of the rule, background of the rule, acceptable compliance methods, and references. This AC is considered to be a "living document." As such, it will be revised to maintain currency, such as with the issuance of part 25 rule changes, or the development of substantive new guidance. An index of all references listed in this AC is included as an appendix to this document.

c. The methods and procedures described in this AC are only one acceptable means of compliance. Any alternative means proposed by the applicant should be given due consideration. Applicants are encouraged to use their technical ingenuity and resourcefulness in order to develop more efficient and less costly methods of achieving the objective of part 25.

<u>/s/ Donald L. Riggin</u>
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Chapter 1. DESIGN AND CONSTRUCTION

Section 1. CONTROL SYSTEMS

1. SECTION 25.671 - GENERAL.

a. Rule Text.

(a) Each control and control system must operate with the ease, smoothness, and positiveness appropriate to its function.
(b) Each element of each flight control system must be designed, or distinctively and permanently marked, to minimize the probability of incorrect assembly that could result in the malfunctioning of the system.
(c) The airplane must be shown by analysis, tests, or both, to be capable of continued safe flight and landing after any of the following failures or jamming in the flight control system and surfaces (including trim, lift, drag, and feel systems), within the normal flight envelope, without requiring exceptional piloting skill or strength. Probable malfunctions must have only minor effects on control system operation and must be capable of being readily counteracted by the pilot.
(1) Any single failure, excluding jamming (for example, disconnection or failure of mechanical elements, or structural failure of hydraulic components, such as actuators, control spool housing, and valves).
(2) Any combination of failures not shown to be extremely improbable, excluding jamming (for example, dual electrical or hydraulic system failures, or any single failure in combination with any probable hydraulic or electrical failure).
(3) Any jam in a control position normally encountered during takeoff, climb, cruise, normal turns, descent, and landing unless the jam is shown to be extremely improbable, or can be alleviated. A runaway of a flight control to an adverse position and jam must be accounted for if such runaway and subsequent jamming is not extremely improbable.
(d) The airplane must be designed so that it is controllable if all engines fail. Compliance with this requirement may be shown by analysis where that method has been shown to be reliable.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-23, 35 FR 5674, Apr. 8, 1970]

NOTE: This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group may recommend revisions to §§ 25.671 and 25.672. The ARAC working group is developing Advisory Circular (AC) 25.671-1.

2. SECTION 25.672 - STABILITY AUGMENTATION AND AUTOMATIC AND POWER-OPERATED SYSTEMS.

a. Rule Text.

If the functioning of stability augmentation or other automatic or power-operated systems is necessary to show compliance with the flight characteristics requirements of this part, such systems must comply with § 25.671 and the following:
(a) A warning which is clearly distinguishable to the pilot under expected flight conditions without requiring his attention must be provided for any failure in the stability augmentation system or in any other automatic or power-operated system which could result in an unsafe condition if the pilot were not aware of the failure. Warning systems must not activate the control systems.
(b) The design of the stability augmentation system or of any other automatic or power-operated system must permit initial counteraction of failures of the type specified in § 25.671(c) without requiring exceptional pilot skill or strength, by either the deactivation of the system, or a failed portion thereof, or by overriding the failure by movement of the flight controls in the normal sense.
(c) It must be shown that after any single failure of the stability augmentation system or any other automatic or power-operated system-
(1) The airplane is safely controllable when the failure or malfunction occurs at any speed or altitude within the approved operating limitations that is critical for the type of failure being considered;
(2) The controllability and maneuverability requirements of this part are met within a practical operational flight envelope (for example, speed, altitude, normal acceleration, and airplane configurations) which is described in the Airplane Flight Manual; and
(3) The trim, stability, and stall characteristics are not impaired below a level needed to permit continued safe flight and landing.
[Amdt. 25-23, 35 FR 5675, Apr. 8, 1970]

NOTE: This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group may recommend revisions to §§ 25.671 and 25.672. The ARAC working group is developing AC 25.671-1.

NOTE: For policy and guidance on compliance with this requirement, refer to AC 25.672-1, Active Flight Controls.

3. SECTION 25.699 - LIFT AND DRAG DEVICE INDICATOR.

a. Rule Text.

(a) There must be means to indicate to the pilots the position of each lift or drag device having a separate control in the cockpit to adjust its position. In addition, an indication of unsymmetrical operation or other malfunction in the lift or drag device systems must be provided when such indication is necessary to enable the pilots to prevent or counteract an unsafe flight or ground condition, considering the effects on flight characteristics and performance.
(b) There must be means to indicate to the pilots the takeoff, en route, approach, and landing lift device positions.
(c) If any extension of the lift and drag devices beyond the landing position is possible, the controls must be clearly marked to identify this range of extension.
[Amdt. 25-23, 35 FR 5675, Apr. 8, 1970]

b. Intent of Rule. This rule prescribes standards for providing visual indication to the pilot of the high lift and drag device(s) surface positions for the takeoff, enroute, approach, and landing conditions.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR), to replace part 4b of the Civil Air Regulations (CAR). Sections 4b.323(e) and 4b.323(f) of the CAR basically covered trailing edge devices. These sections became §§ 25.699(a) and 25.699(b) of 14 CFR for wing flap position indicator.

(1) Amendment 25-23 (April 8, 1970) expanded the rule to specifically cover all high drag devices or high lift devices (such as slots, spoilers, and slats), and added the requirement for position indication for all lift and drag devices with separate cockpit controls. The title was revised accordingly.

d. Policy/Compliance Methods. Indicators that show the position of the lift or drag devices must be provided. If asymmetric extension of lift or drag devices could result in an unsafe condition, an indication of each individual control surface is required. The indication must clearly identify each position setting. The controls should be designed so that inadvertent extension beyond the landing position is not possible. For guidance on compliance with this requirement, refer to AC 25-14, dated 5/4/88, which is incorporated below.

AC No.: AC 25-14 HIGH LIFT AND DRAG DEVICES

Initiated by: ANM-110 Date: 5/4/88

1. PURPOSE. This advisory circular (AC) sets forth an acceptable means of compliance with the provisions of part 25 of the Federal Aviation Regulations (FAR) dealing with the certification requirements for high lift and drag devices. Guidance information is provided for showing compliance with structural and functional safety standards for high lift and drag devices and their operating systems. The intent of the requirements and some acceptable means of compliance are discussed. Other means are acceptable if they meet the intent of the regulations.

2. RELATED FAR SECTIONS. The contents of this AC are considered by the FAA in determining compliance of flaps, slats and drag devices with part 25. Related sections are 25.301, 25.303, 25.333(e), 25.345, 25.457, 25.571, 25.671, 25.672, 25.697, 25.699, 25.701, 25.703, and 25.1309.

3. BACKGROUND. For several years, special consideration has been given to high lift and drag devices to ensure that malfunction or failure will not result in an unsafe condition. These considerations are consolidated and incorporated in this AC.

4. STRUCTURAL REQUIREMENTS. The structure of high lift and drag devices must be designed to comply with the damage tolerance requirements of § 25.571, Amendment 25-45, of the FAR. The design should incorporate features which would provide a high probability of detection of any damage before the damage causes loss of the surface from the airplane. High lift and drag components to be evaluated under the requirements of § 25.571 typically include all structure which contributes significantly in reacting applied flight and actuation loads. Examples of such structure are the flap or slat surfaces, support linkages or tracks, hinges, fittings and attachments.

5. CONTROL SYSTEM REQUIREMENTS. The control system for high lift and drag devices must be designed to comply with the requirements of § 25.671. For the purpose of compliance with § 25.671, the control system ends where the control surface attaches to fixed structure such as the wing or fuselage. Examples of elements to be evaluated under the requirements of § 25.671 are linkages, hinges, cables, pulleys, quadrants, valves, actuator components, track rollers, movable tracks, bearings, and hydraulic or electrical systems. In accordance with § 25.671, the airplane must be shown to be capable of continued safe flight and landing without requiring exceptional pilot skill or strength following the failure of any single mechanical element or any combination of failures not shown to be extremely improbable, excluding jamming. Following this failure or combination of failures, the remaining structure

must be able to withstand the loads defined by §§ 25.333 and 25.345. These are considered ultimate loads for this condition. If the surfaces are automatically or power operated, the control system must also be designed to meet the requirements of § 25.672.

6. DETAIL DESIGN CONSIDERATIONS.

a. Unless the airplane has safe flight characteristics with the functionally related high lift or drag devices retracted on one side and extended on the other, the motion of the devices opposite sides of the plane of symmetry must be synchronized by a mechanical interconnection or approved equivalent means as required by § 25.701. The criteria of § 25.701 are considered equally applicable to high lift and drag devices.

(1) The surface interconnection must be designed for the loads resulting when the surfaces on one side of the plane of symmetry are jammed and immovable while the surfaces on the other side are free to move and the full power of the surface actuating system is applied. The flight loads from § 25.345 acting on the surface must be considered in combination with the actuating system loads (including system inertia loads). This is considered a limit load condition.

(2) In showing compliance with the interconnection requirements of § 25.701, all possible jam locations in the drive and support system should be considered. The surface mechanical interconnection must be able to withstand the jam condition and preclude any unsafe asymmetrical condition. The interconnection system is comprised of all elements which react the drive output from the actuator source to the jam point. These elements may include structures, interconnection linkages, and drive system components. When the interconnection is the only means to prevent an unsafe asymmetrical condition, the loads associated with the jam conditions are considered limit loads and require a 1.5 factor of safety. A factor of safety less than 1.5 may be used when a reliable (i.e., a probability of failure of 10^{-3} or less) and independent means is used, in addition to the mechanical interconnection, to prevent unsafe asymmetry of a high lift system. The alternate system should detect the jam and shut down the drive system before the loads from any jam condition are reacted by the mechanical interconnection. The factor of safety may be as low as 1.25 if the probability of failure of the alternate system is 10^{-5} or less; however, it should not be less than 1.25 unless the alternate system is found to be equivalent to a mechanical interconnection. When a torque limiter is used, the torque tolerance limit should be used to react the required load rather than the nominal or set torque. A torque limiter should not be located in the drive system in a position where the limiter itself would allow an unsymmetrical configuration if a jam occurred.

(3) An equivalent means of compliance with the requirements for a mechanical interconnection system may be substantiated using a systems safety analysis. Guidelines for performing a systems safety analysis are given in AC 25.1309-1, System Design Analysis.

b. Where failures in the drive system can result in uncommanded extensions or retractions of the high lift or drag devices, a positive means should be provided to limit the movement of the affected surfaces. This may be accomplished through irreversible drive actuators, no-back devices, redundancy in the drive system, or other equivalent means.

c. In determining loads on high lift devices during actuation, it may be necessary to consider friction loads in the actuating system, which may be reasonably expected to occur in service. Flap tracks and rollers for instance, are often subjected to ice and slush which may offer high resistance to flap actuation. Each design should be evaluated to determine its susceptibility to friction in the mechanism and any loads associated with such resistance should be accounted for and applied in combination with normal operating loads.

d. In evaluating the effects of failures or jamming of high lift surfaces, the effects of skewed surfaces on the operation of adjacent surfaces should be evaluated. Damage to adjacent structures and systems due to skewing of the surface should also be evaluated.

7. INDICATING AND WARNING SYSTEMS.

a. Indicating systems for high lift and drag devices must provide visual indication to the pilot of the surface positions for the takeoff, enroute, approach, and landing conditions. The position sensors should be located such that they show a direct indication of failure conditions. There should be independent monitoring of each functionally related set of surfaces (i.e., a set of surfaces on each side of the plane of symmetry that is driven by a common actuator, or is synchronized by some other means to ensure symmetric actuation) for which a failure will require an action or procedural change by the flightcrew. For instance, a functionally related flap set which is in an unsymmetrical configuration about the fuselage centerline would require an indication to the pilot of the unsymmetrical condition before takeoff. The indication to the flightcrew need not indicate the specific surface which has failed, but must clearly reflect the abnormal configuration (§ 25.699). The cockpit surface position display must also clearly distinguish a fault which was caused by a high lift "asymmetrical" deployment from a high lift "disagree" condition. A "disagree" condition exists when the high lift surface is stopped at a position different than the position commanded-by the pilot through the flap selection switch or handle. This distinction will aid the pilot in using proper procedures to further deploy, retract, or leave the high lift or drag devices for continued flight.

b. The takeoff warning system required by § 25.703 should sense the position of each functionally related set of high lift devices (symmetric about the airplane centerline) and provide aural warning during the initial portion of the takeoff roll if any set is not in an approved takeoff position.

8. FLIGHT LOADS MEASUREMENT. Notwithstanding the advancements in analytical methods used in predicting loads on airplane structures, accurate prediction of loads on wing leading edge and trailing edge high lift devices continues to be a problem. It is, therefore, advisable to verify the loads on these surfaces by conducting flight loads surveys regardless of the level of confidence in the overall loads program.

9. AIRPLANE CONTROLLABILITY. It should be shown by analysis, and where necessary by ground, simulation or flight tests, that the airplane has adequate stall margins and controllability to sustain the failure conditions addressed in paragraphs 4, 5, and 6 of this AC without requiring exceptional flightcrew skill or strength. It should also be demonstrated that no hazardous change in altitude or attitude will develop during transition to the unsymmetric condition considering likely transition rates.

END OF ADVISORY CIRCULAR 25-14

e. Reference. None.

4. SECTION 25.701 - FLAP INTERCONNECTION.

a. Rule Text.

(a) Unless the airplane has safe flight characteristics with the flaps or slats retracted on one side and extended on the other, the motion of flaps or slats on opposite sides of the plane of symmetry must be synchronized by a mechanical interconnection or approved equivalent means.
(b) If a wing flap or slat interconnection or equivalent means is used, it must be designed to account for the applicable unsymmetrical loads, including those resulting from flight with the engines on one side of the plane of symmetry inoperative and the remaining engines at takeoff power.
(c) For airplanes with flaps or slats that are not subjected to slipstream conditions, the structure must be designed for the loads imposed when the wing flaps or slats on one side are carrying the most severe load occurring in the prescribed symmetrical conditions and those on the other side are carrying not more than 80 percent of that load.
(d) The interconnection must be designed for the loads resulting when interconnected flap or slat surfaces on one side of the plane of symmetry are jammed and immovable while the surfaces on the other side are free to move and the full power of the surface actuating system is applied.
[Amdt. 25-72, 55 FR 29777, July 20, 1990]

NOTE: For policy and guidance on compliance with this requirement, refer to Advisory Circular (AC) 25-14, High Lift and Drag Devices, incorporated into this AC in § 25.699 paragraph d.

5. SECTION 25.703 - TAKE OFF WARNING SYSTEM.

a. Rule Text.

A takeoff warning system must be installed and must meet the following requirements:
(a) The system must provide to the pilots an aural warning that is automatically activated during the initial portion of the takeoff roll if the airplane is in a configuration, including any of the following, that would not allow a safe takeoff:
(1) The wing flaps or leading edge devices are not within the approved range of takeoff positions.
(2) Wing spoilers (except lateral control spoilers meeting the requirements of § 25.671), speed brakes, or longitudinal trim devices are in a position that would not allow a safe takeoff.
(b) The warning required by paragraph (a) of this section must continue until-
(1) The configuration is changed to allow a safe takeoff;
(2) Action is taken by the pilot to terminate the takeoff roll;
(3) The airplane is rotated for takeoff; or
(4) The warning is manually deactivated by the pilot.
(c) The means used to activate the system must function properly throughout the ranges of takeoff weights, altitudes, and temperatures for which certification is requested.
[Amdt. 25-42, 43 FR 2323, Jan. 16, 1978]

b. Intent of Rule. This rule prescribes a requirement for a takeoff warning system to warn the pilots during the initial portion of the takeoff roll if the airplane is in a configuration that would prevent successful completion of the takeoff.

c. Background. This section was not addressed in either part 4b of the Civil Air Regulations (CAR) or part 25 of Title 14, Code of Federal Regulations (14 CFR) when it was originally codified. This rule was introduced with Amendment 25-42, dated January 16, 1978. It was realized that wing flaps and associated leading edge devices posed a special problem because some airplanes have take off flap settings that vary with weight, altitude, temperature, and runway length. A warning system that accounts for these variables would be extremely complex, and would still require the pilot to enter the proper data. In the interest of reliability, the rule requires the system to give a warning when the flaps or leading edge devices are not within the approved range of takeoff positions, e.g., when the pilot has not placed the flaps in an approved takeoff position or has retracted the flaps inadvertently, or if the flaps fail to move from the retracted position in response to a control input. Additionally, longitudinal trim devices (such as movable stabilizers) and drag devices (such as ground and flight spoilers) may be positioned inadvertently or due to failure conditions in a configuration that may prevent successful completion of a takeoff. The regulation applies to the stabilizer, speed brake systems, and rudder trim as well.

d. Policy/Compliance Methods. For policy and guidance on compliance with this requirement, refer to Advisory Circular (AC) 25-14, High Lift and Drag Devices, incorporated into this AC in § 25.699 paragraph d.

e. Reference. The address for ordering the latest revision of the advisory circular listed below can be found in the Appendix to this AC.

AC 25.703-1, Takeoff Configuration Warning Systems.

6-10. [RESERVED]

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Section 2. LANDING GEAR

11. SECTION 25.729 - RETRACTING MECHANISM.

a. Rule Text.

(a) General. For airplanes with retractable landing gear, the following apply:
(1) The landing gear retracting mechanism, wheel well doors, and supporting structure, must be designed for-
(i) The loads occurring in the flight conditions when the gear is in the retracted position,
(ii) The combination of friction loads, inertia loads, brake torque loads, air loads, and gyroscopic loads resulting from the wheels rotating at a peripheral speed equal to 1.3 V_s *(with the flaps in takeoff position at design takeoff weight), occurring during retraction and extension at any airspeed up to 1.6* V_{S1} *(with the flaps in the approach position at design landing weight), and*
(iii) Any load factor up to those specified in § 25.345(a) for the flaps extended condition.
(2) Unless there are other means to decelerate the airplane in flight at this speed, the landing gear, the retracting mechanism, and the airplane structure (including wheel well doors) must be designed to withstand the flight loads occurring with the landing gear in the extended position at any speed up to 0.67 V_C*.*
(3) Landing gear doors, their operating mechanism, and their supporting structures must be designed for the yawing maneuvers prescribed for the airplane in addition to the conditions of airspeed and load factor prescribed in paragraphs (a)(1) and (2) of this section.
(b) Landing gear lock. There must be positive means to keep the landing gear extended, in flight and on the ground.
(c) Emergency operation. There must be an emergency means for extending the landing gear in the event of-
(1) Any reasonably probable failure in the normal retraction system; or
(2) The failure of any single source of hydraulic, electric, or equivalent energy supply.
(d) Operation test. The proper functioning of the retracting mechanism must be shown by operation tests.
(e) Position indicator and warning device. If a retractable landing gear is used, there must be a landing gear position indicator (as well as necessary switches to actuate the indicator) or other means to inform the pilot that the gear is secured

in the extended (or retracted) position. This means must be designed as follows:
(1) If switches are used, they must be located and coupled to the landing gear mechanical systems in a manner that prevents an erroneous indication of "down and locked" if the landing gear is not in a fully extended position, or of "up and locked" if the landing gear is not in the fully retracted position. The switches may be located where they are operated by the actual landing gear locking latch or device.
(2) The flightcrew must be given an aural warning that functions continuously, or is periodically repeated, if a landing is attempted when the landing gear is not locked down.
(3) The warning must be given in sufficient time to allow the landing gear to be locked down or a go-around to be made.
(4) There must not be a manual shutoff means readily available to the flightcrew for the warning required by paragraph (e)(2) of this section such that it could be operated instinctively, inadvertently, or by habitual reflexive action.
(5) The system used to generate the aural warning must be designed to eliminate false or inappropriate alerts.
(6) Failures of systems used to inhibit the landing gear aural warning, that would prevent the warning system from operating, must be improbable.
(f) Protection of equipment in wheel wells. Equipment that is essential to safe operation of the airplane and that is located in wheel wells must be protected from the damaging effects of-
(1) A bursting tire, unless it is shown that a tire cannot burst from overheat; and
(2) A loose tire tread, unless it is shown that a loose tire tread cannot cause damage.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-23, 35 FR 5676, Apr. 8, 1970; Amdt. 25-42, 43 FR 2323, Jan. 16, 1978; Amdt. 25-72, 55 FR 29777, Jul. 20, 1990; Amdt. 25-75, 56 FR 63762, Dec. 5, 1991]

b. Intent of Rule. This rule provides minimum design and certification requirements for landing gear actuation systems to address:

(1) Structural integrity for the nose and main landing gear, retracting mechanism(s), doors, gear supporting structure for actuation loads, maneuvering loads, and yawing flight condition loads.

(2) Emergency means to extend gear under certain failure conditions.

(3) Downlock and uplock design.

(4) Gear up-and-locked and down-and-locked position indications and aural warning.

(5) Protection of essential equipment located in the wheel well from a bursting tire or loose tire tread.

(6) Function demonstration.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Sections 4b.334 and 4b.334-2 of the CAR, became § 25.729 of 14 CFR for landing gear retracting mechanism.

(1) Amendment 25-23 (April 8, 1970) added a wheel rotational speed based on a factored takeoff speed of 1.3 V_s to be used for load computations under § 25.729(a)(1)(ii) and changed the reference from § 25.345 to § 25.345(a) under § 25.729(a)(1)(iii).

(2) Amendment 25-42 (January 16, 1978) clarified the rule and made minor editorial changes to § 25.729(e)(3).

(3) Amendment 25-72 (July 20, 1990) amended the rule. It made editorial changes and deleted reference to § 25.67(e) under § 25.729(e)(4), since § 25.67 no longer existed.

(4) Amendment 25-75 (December 5, 1991) revised § 25.729(e)(2) through (e)(6) to state objectives without stating how the requirements were to be met; thus allowing manufacturers to use their ingenuity in designing systems to minimize the occurrence of nuisance and inappropriate aural warnings.

d. Policy/Compliance Methods. Guidance addressing flight testing used to demonstrate compliance with this section may be found in Advisory Circular (AC) 25-7A, Flight Test Guide for Transport Category Airplanes, chapter 4, section 4, paragraph 52, issued March 31, 1998. Also see AC 25.963-1, Fuel Tank Access Covers, section 4, for compliance to § 25.729(f)(2)

(1) Protection of Equipment in wheel wells, § 25.729(f)(1). The following is extracted from an FAA memorandum dated December 4, 1997, which addresses whether wheel/tire assemblies containing thermal fuse plugs are sufficient to comply with the requirements of § 25.729(f)(1).

(a) The intent of the regulation is to protect essential equipment from the effects of a tire burst, regardless of the cause of the burst; overheat is just one way of causing a tire burst. Other ways a tire burst may be caused are:

1 foreign object damage.
2 under-inflation.
3 over-inflation.
4 overload.
5 an abnormal wheel component such as a melted/defective fuse plug.

Additionally, compliance with § 25.1309(b) is required for a continued safe flight and landing. A tire burst must be considered regardless of its probability of occurrence.

(b) As cited in the preamble to Amendment 25-78: "A tire burst, as referred to in § 25.729(f), is a sudden, sometimes violent, venting of the pressure from within a tire, usually associated with a flaw in the tire, foreign object damage, or tire overheat/overload. The FAA assumes that tire bursts will occasionally occur, given the severe operating environment of airplane tires, and the fact that certain tire damage may go undetected until tire failure. With this in mind, equipment installed in wheel wells is evaluated at the time of certification to determine its ability to withstand the effects of a bursting tire. Analyses and laboratory tests are performed to identify critical areas, and design changes are often made to ensure that a single tire burst will not cause loss of critical functions."

(2) Landing Gear Position Indication System - "Backup Requirement" (Section 25.729(e)). The following is extracted from an FAA memorandum dated July 12, 1988, which addresses whether a backup gear position system is always required.

(a) The failure of the landing gear position indicating system does not prevent the continued safe flight and landing of the airplane. Further, service history has shown that gear-up landings on transport category airplanes are not catastrophic. Compliance with the requirements of § 25.729 may be accomplished by a straightforward engineering assessment of the design. A numerical probability analysis is not required.

(b) If a review of the certification basis of the airplane reveals that a second method of landing gear position indication (e.g., a viewing port) was required due to the characteristics of the design, a replacement for the now-unusable viewing ports would have to be provided. The replacement system could be of any type (electrical, mechanical, etc.), as long as it provided a back-up with reliability and functionality not less than that of the system approved under the original type certification basis.

(c) If the back-up indication system was installed at the manufacturer's option, and was not required by the type certification basis, removing the system now could result in crew confusion or other operational problems. Although it is not recommended to remove an optional backup system (to avoid confusion in the cockpit), it would be acceptable provided the airplane continues to meet the original type certification basis requirements. Replacing the viewing ports with a system that would be similar in function to the original is encouraged, i.e., a redundant means of determining that the landing gear is indeed down if there is any uncertainty from using the primary system. The determination of the reliability of the system need not be as rigorous as in (b), above, as long as the replacement system can be shown to perform its intended function.

(d) Service difficulty reports relating to the landing gear indication system should be reviewed, and if the primary electrical system has required the use of the back-up viewing system to an inordinate degree, the back-up system would then become more important to the overall reliability of the indication system, and would be considered to be necessary under the provisions of § 21.21(b)(2).

(3) Flap System/Landing Gear Warning System Tie-In. The following is extracted from an FAA memorandum dated December 19, 1983. The memo addressed whether it was an acceptable design to provide two approach flap settings and two landing flap positions without including the “landing gear-up” warning required by § 25.729(e)(4), redesignated as § 25.729(e)(2), effective at Amendment level 25-72.

(a) The FAA originally determined that providing no warning in this configuration was unacceptable. However, it was noted that there were transport category aircraft already certificated with approved alternate "selectable" means of changing the gear-up warning onset for alternate approach/landing flap configurations and that "uniformity" of certification warranted that this concept be approved if the proposed alternate means was judged acceptable by the cognizant Aircraft Certification Office. The concept was the use of a guarded, manually operated selection switch (location not specified) and the associated proposed Airplane Flight Manual procedures for the use of this system be provided.

(b) FAA flight test personnel evaluated this proposed alternate design and found it acceptable. Based on these events, it was determined that the proposed installation is acceptable, meets the intent of § 25.729(e)(4), and provides an acceptable equivalent level of safety.

(4) Landing Gear Position Indication System. The following policy is extracted from an FAA memorandum dated June 3, 1983, which addresses whether other regulations need to be considered when finding compliance with § 25.729(e) (e.g., §§ 25.1301 and 25.1309).

(a) Section 25.729(e) provides standards for landing gear position indicating systems. This section is necessary, but not sufficient, for certification of these systems. This section only establishes the requirement for such a system; however, it is necessary to consider the requirements of § 25.1301 (that requires the system to be of a kind and design appropriate to its intended function and function properly when installed), and §§ 25.1309(a) and 25.1309(b) (that require failures which reduce the capability of the aircraft or crew to cope with adverse operating conditions to be "improbable" and those that prevent the continued safe flight and landing of the airplane to be "extremely improbable"). In summary, all sections of part 25 contained in the certification basis should be reviewed for applicability.

(b) In addition, failures that result in presenting hazardously misleading indication to the crew must be improbable. An example of a hazardously misleading failure condition would be if the gear indicating portions of the landing gear system indicate that all gear are down/locked when in actuality, all gear are not fully down and locked.

(c) If the failure evaluation process of the landing gear system (including the gear position indication) shows that a gear-up landing will have catastrophic consequences, then the occurrence of this condition should be shown to be extremely improbable. However, if the evaluation shows that a gear up landing would only result in a hazardous condition, then the occurrences of this condition would fall in the improbable category.

(d) Reviews of transport category accident/incident reports from the FAA files covering the five years prior to this memorandum have not listed a catastrophic result due to failures in the landing gear and/or indicating system. Further, providing a second independent landing gear position indicating system may not improve the overall safety of' the aircraft and may, in some instances, lead to a more confused condition on the part of the crew in trying to sort out which indicating system should be used.

(5) Landing Gear Slush Tests. The following policy is extracted from an FAA memorandum dated April 22, 1983. This memo addresses the need for slush tests to ensure that the landing gear can be extended for an aircraft with a single hydraulic system and no auxiliary power source.

(a) There is no specific certification requirement for slush tests to evaluate landing gear retraction/extension systems during wet, freezing conditions. Service history indicates this can be a problem, even on large transport category airplanes with multiple hydraulic systems. The FAA has not made such tests a certification requirement because there is no practical means of preventing accumulation of slush in the wheel well area, short of prohibiting operation during slushy conditions. Slush tests on a new airplane maintaining original design tolerances and properly lubricated joints would be of questionable value since the problem is often associated with poor maintenance practices.

(b) In several reported instances of failure of the landing gear to extend, even with hydraulic pressure applied, the problems were usually corrected by lubrication of rotating joints. During slushy runway operation, water can enter rotating joints and freeze after cold soaking at altitude. The problem is usually reported during cold winter months and during low surface temperatures.

(c) The design should be evaluated for possible accumulation of ice on the uplock mechanism and rotating joints, which could prevent manual operation of the emergency extension system. If, after careful review of a particular landing gear design, it appears that slush testing is necessary, such tests could be required under §§ 21.21(b)(2) and 25.729(d). If tests are deemed necessary, the tests should be conducted with little or no lubrication in all rotating joints.

e. References. The addresses for ordering the latest revision of advisory circulars and other referenced documents listed below can be found in the Appendix to this AC.

AC 20-34D, Prevention of Retractable Landing Gear Failures.
AC 23.729-1, Landing Gear Doors and Retraction Mechanism. (For information only).
AC 25-7A, Flight Test Guide for Transport Category Airplanes.
AC 43.13-1A, Acceptable Methods, Techniques and Practices - Aircraft Inspection and Repair.
AC 25.963-1, Fuel Tank Access Covers.
SAE AIR-4566 - Crashworthiness Landing Gear Design.
SAE ARP-1311A - Landing Gear- Aircraft.

f. Definitions. For definitions of V_S, V_{S1}, and V_C, see 14 CFR part 1, section 1.2, titled Abbreviations and symbols.

12. SECTION 25.731 - WHEELS.

a. Rule Text.

(a) Each main and nose wheel must be approved.
(b) The maximum static load rating of each wheel may not be less than the corresponding static ground reaction with-
(1) Design maximum weight; and
(2) Critical center of gravity.
(c) The maximum limit load rating of each wheel must equal or exceed the maximum radial limit load determined under the applicable ground load requirements of this part.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-72, 55 FR 29777, Jul. 20, 1990]

b. Intent of Rule. This rule requires use of approved wheels, either approved under an applicable Technical Standard Order (TSO) e.g., TSO-C26c, or approved as part of the type design for the airplane. Wheels must satisfy both a design static (1g) load and design limit landing or taxiing load determined under the applicable ground load requirements (§§ 25.471 through 25.511). Standards for a tire installed on a wheel are contained in § 25.733. Standards for a brake installed on a wheel are contained in § 25.735. A TSO approval is not an approval to install wheels on the airplane. If the airframe manufacturer decides to install equipment approved under a TSO, they must conduct the applicable airplane certification tests and obtain FAA approval for the installation.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Sections 4b.335(a) and 4b.335(b) of the CAR became §§ 25.731(a) and 25.335(b) of 14 CFR for wheels.

(1) Amendment 25-72 (July 20, 1990) amended the rule to become compatible with § 25.25 (which had been amended). This amendment provides for weights that are in excess of takeoff weight, such as ramp weights, provided that the compliance with applicable structural requirements, including wheel strength, is demonstrated at the higher weights.

(2) Harmonization. This regulation is the subject of a Federal Aviation Regulation/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group is revising §§ 25.731 and 25.735, and is developing a new advisory circular AC 25.735-1, and a new TSO-C135 for transport category airplanes, replacing the applicable parts of the existing TSO-C26c.

d. Policy/Compliance Methods. For guidance on compliance, the following material is extracted from Advisory Circulars (AC) 27-1, Certification of Normal Category Rotorcraft, and AC 29-2B, Certification of Transport Category Rotorcraft. It is applicable to certification of transport category airplanes. While not specifically prepared for transport category airplanes, this policy material has been used for demonstrating compliance with § 25.731. For additional guidance, see AC 25-7A, Flight Test Guide for Transport Category Airplanes, chapter 4, section 4, par 53, issued March 31, 1998.

(1) The structural design loads data shall contain both a static load and a landing and taxiing load for each wheel. These loads are determined by virtue of compliance with the standards of §§ 25.731(b) and 25.731(c). The ratings of the wheel shall not be exceeded. TSO-C26c contains minimum performance standards for TSO approval of aircraft wheels and wheel-brake assemblies. Ratings are assigned in accordance with this performance standard.

(2) If a wheel selected for an aircraft design has TSO-C26c approval, the wheel manufacturer will supply the rating to the aircraft manufacturer. Each wheel shall be marked as prescribed which includes a listing of the TSO number. Even though a wheel is TSO approved, the application on the aircraft (loads imposed on the wheel) requires proof that the rating is not exceeded. Wheel rating must not be less than airplane maximum radial load limits.

(3) If a wheel selected for an aircraft design is not approved under TSO-C26, the necessary data, both detail design and assembly drawings and qualification tests and test report data, will be required to comply with the standards contained in part 25. Design control and inspections will be accomplished as a part of the aircraft type design. Structural substantiation and any appropriate qualification tests shall be accomplished. See §§ 25.471 through 25.497 for the ground load conditions.

(4) The Tire and Rim Association Inc., issues a yearbook listing aircraft tire and rim sizes and ratings. The dimensions and contours for aircraft wheel rims are contained in the yearbook.

e. References. The addresses for ordering the latest revision of advisory circulars, technical standard orders, and other referenced documents listed below can be found in the Appendix to this AC.

Section 25.731 Wheels and § 25.735 Brakes, part 25 of 14 CFR.
AC 25-7A, Flight Test Guide for Transport Category Airplanes.
AC 27-1, Certification of Normal Category Rotorcraft.
AC 29-2A, Certification of Transport Category Rotorcraft.
AC 43.13-1A, Acceptable Methods, Techniques and Practices-Aircraft Inspection and Repair, Chap. 8, L. G. Equipment.
TSO-C26, was an acceptable standard to Civil Aeronautics Administrator, but was not part of the regulations.
TSO-C26a, was a part of the regulations, under part 514 of the Regulations of the Administrator, as § 514.72.
TSO-C26b, was part of the regulations as § 37.172 of 14 CFR.
TSO-C26c, was part of the regulations as § 37.172 of 14 CFR.
TSO-C26c with Addendum I. The TSO was removed from regulations (§ 37.172, Amendment 25-52, 1980) and became a voluntary standard.
SAE AIR-811B, Disposition of Wheels which have been Overheated.
SAE ARP-1322, Overpressurization Release Devices.
SAE ARP-1786, Wheel Roll on Rim Criteria for Aircraft Application.
SAE AS-707B, Thermal Sensitive Inflation Pressure Release Devices for Tubeless Aircraft Wheels.

13. SECTION 25.733 - TIRES.

a. Rule Text.

(a) When a landing gear axle is fitted with a single wheel and tire assembly, the wheel must be fitted with a suitable tire of proper fit with a speed rating approved by the Administrator that is not exceeded under critical conditions and with a load rating approved by the Administrator that is not exceeded under-
(1) The loads on the main wheel tire, corresponding to the most critical combination of airplane weight (up to maximum weight) and center of gravity position, and
(2) The loads corresponding to the ground reactions in paragraph (b) of this section, on the nose wheel tire, except as provided in paragraphs (b)(2) and (b)(3) of this section.
(b) The applicable ground reactions for nose wheel tires are as follows:
(1) The static ground reaction for the tire corresponding to the most critical combination of airplane weight (up to maximum ramp weight) and center of gravity position with a force of 1.0g acting downward at the center of gravity. This load may not exceed the load rating of the tire.
(2) The ground reaction of the tire corresponding to the most critical combination of airplane weight (up to maximum landing weight) and center of gravity position combined with forces of 1.0g downward and 0.31g forward acting at the center of gravity. The reactions in this case must be distributed to the nose and main

wheels by the principles of statics with a drag reaction equal to 0.31 times the vertical load at each wheel with brakes capable of producing this ground reaction. This nose tire load may not exceed 1.5 times the load rating of the tire.
(3) The ground reaction of the tire corresponding to the most critical combination of airplane weight (up to maximum ramp weight) and center of gravity position combined with forces of 1.0g downward and 0.20g forward acting at the center of gravity. The reactions in this case must be distributed to the nose and main wheels by the principles of statics with a drag reaction equal to 0.20 times the vertical load at each wheel with brakes capable of producing this ground reaction. This nose tire load may not exceed 1.5 times the load rating of the tire.
(c) When a landing gear axle is fitted with more than one wheel and tire assembly, such as dual or dual-tandem, each wheel must be fitted with a suitable tire of proper fit with a speed rating approved by the Administrator that is not exceeded under critical conditions, and with a load rating approved by the Administrator that is not exceeded by-
(1) The loads on each main wheel tire, corresponding to the most critical combination of airplane weight (up to maximum weight) and center of gravity position, when multiplied by a factor of 1.07; and
(2) Loads specified in paragraphs (a)(2), (b)(1), (b)(2), and (b)(3) of this section on each nose wheel tire.
(d) Each tire installed on a retractable landing gear system must, at the maximum size of the tire type expected in service, have a clearance to surrounding structure and systems that is adequate to prevent unintended contact between the tire and any part of the structure or systems.
(e) For an airplane with a maximum certificated takeoff weight of more than 75,000 pounds, tires mounted on braked wheels must be inflated with dry nitrogen or other gases shown to be inert so that the gas mixture in the tire does not contain oxygen in excess of 5 percent by volume, unless it can be shown that the tire liner material will not produce a volatile gas when heated or that means are provided to prevent tire temperatures from reaching unsafe levels.
[Amdt. 25-23, 35 FR 5676, Apr. 8, 1970; Amdt. 25-38, 41 FR 55467, Dec. 20, 1976; Amdt. 25-49, 44 FR 68745, Nov. 29, 1979; Amdt. 25-72, 55 FR 29777, Jul 20, 1990, as amended by Amdt 25-78, Mar 29, 1993]

b. Intent of Rule. This rule specifies type certification requirements for both design and performance of tires used on transport category airplanes. The tire must be of proper fit and have approved speed and load ratings for a particular airplane application. The maximum static ground reaction for the condition specified must not exceed the maximum static load rating of each tire. Retractable gear system tires must have adequate clearance from surrounding structure and systems. The tire inflation medium is to be an inert gas to avoid explosions. Tires installed on landing gear axles with multi-wheels (main wheel tires only), must have a 7% load margin included in their rating. Tire performance standards are contained in Technical Standard Order (TSO) TSO-C62. A TSO approval is not approval to install tires on the airplane. The airframe manufacturer/user must conduct the applicable airplane certification tests and receive FAA approval for installation.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Sections 4b.336(a) and 4b.336(b) of the CAR became §§ 25.733(a) and 25.733(b) of 14 CFR for tires.

(1) Amendment 25-23 (April 8, 1970) added tire speed rating as a limitation governing the acceptance of tires for use on particular airplanes, identified the FAA Administrator to approve load and speed ratings in lieu of The Tire and Rim Association, and added the term "suitable" to "the tire of proper fit."

(2) Amendment 25-38 (December 20, 1976) added § 25.733(c) to require that for retractable landing gear, the design must account for tire production tolerances and size increases expected in service. The tire should have adequate clearance to prevent jamming or interference of landing gear mechanisms and equipment/structure.

(3) Amendment 25-49 (November 29, 1979) improved minimum performance standards applicable to landing gear main and nose wheel tires (by revising § 37.167/TSO-C62b to TSO-C62c) and added more comprehensive design standards covering tire loads and speed ratings (§ 25.733). This amendment also specified a date (December 31, 1979) after which tire manufacturers could no longer identify their tires as approved under earlier standards (TSO-C62, C62a, C62b).

(a) This amendment evolved as follows: The minimum performance standards for tires were set forth in the technical standard order (§ 37.167 "Aircraft Tires," TSO-C62b) which was unchanged since it became effective in 1962. A series of accidents and incidents involving large commercial jet airplanes, particularly wide body types, in the mid 1970's involved failures of tires, wheels, brakes, and antiskid devices. The FAA intensified its surveillance efforts with respect to aircraft tires and began an analysis of the failures and potential corrective actions. This led to joint FAA-Industry meetings in 1976 and 1977 that resulted in a proposed set of revised and updated standards (Notice 79-7) to reflect the latest technology and to meet operating conditions.

(b) This amendment was a response to recommendations from the National Transportation Safety Board (NTSB). The NTSB issued a series of recommendations and advisory actions affecting tires in the areas of design standards, qualification testing, quality control during manufacture, and operational limits.

(4) Amendment 25-52 (June 2, 1980) revoked part 37, § 37.167 Aircraft Tires - TSO-C62c. Subpart A of 14 CFR part 37 became Subpart O of 14 CFR part 21. Subpart B of 14 CFR part 37 was eliminated, and the technical performance standards were made available at FAA Headquarters.

(5) Amendment 25-72 (July 20, 1990) deleted the requirement to consider the effects of inertia, from § 25.733(a)(1) because such effects were determined to be negligible for constant speed taxi and takeoff conditions. In addition, § 25.733(c)(1) changed from a reference to § 25.733(a)(1) to a direct statement of the loading conditions for the sake of clarity.

(6) Amendment 25-78 (March 29, 1993) added paragraph § 25.733(e) to require that for airplanes with a maximum certified takeoff weight of more than 75,000 pounds, the tires mounted on braked wheels be inflated with dry nitrogen or other inert gases so that the tire does not contain oxygen in excess of 5 percent by volume to prevent tire explosions. The 75,000 pounds weight limit was based on a review of the service difficulty reports indicating that tire explosions, as opposed to tire bursts, tend to occur on the larger, heavier airplanes. The 5 percent by volume limit for oxygen content was based on a series of laboratory tests indicating that an abrupt auto-ignition could occur for oxygen concentrations of 10 percent or more.

(a) There had been several cases where tire explosions had occurred in transport category operations. A tire explosion differs from a tire burst, which can occur when an overheated or over inflated tire fails and releases the high pressure air contained therein. Protection against tire burst is required under § 25.729(f). A tire explosion is the result of a chemical reaction occurring when gases released from overheated tire material mix with oxygen in the inflation air and ignite. In 1987, the FAA issued an airworthiness directive (AD 87-08-09) requiring use of nitrogen for tire inflation to ensure that the tires on braked wheels of airplanes do not contain more than 5 percent oxygen. Amendment 25-78 was intended to accomplish the same purpose for new airplanes.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Approval of Retreaded Tires by Similarity. The following is extracted from an FAA memorandum dated March 1, 1995, that addresses whether "qualification by similarity" basis could be used for approving the production of retreaded aircraft tires, using a modified tread compound, in various sizes.

(a) Background. A tire manufacturer had qualified several retreaded tires of different sizes in accordance with the stipulations of advisory circular (AC) 145-4, Inspection, Retread, Repair, and Alteration of Aircraft Tires (dynamometer testing). The manufacturer wished to produce other retreaded tires of different sizes and ratings, based on similarity. In the past, every tire size had to be tested for such an approval.

(b) Supportive Information. The following supportive information was provided:

1 Nature of the Change The formulation for the tread compound used to retread commercial aircraft tires had been modified as follows:

(aa) Polymer: A proprietary description of the change.

(bb) Filler: A proprietary description of the change.

2 Test Results. The change in tread compound had been proven by dynamic qualification testing on a sample of tire sizes. The various tire sizes were representative of the tire sizes listed for production approval in the applicant's letter. Qualification Test Reports (QTR's) were submitted to the FAA. The QTR's were approved by the cognizant Flight Standards District Office.

3 Physical Properties of the Tread Material. The physical properties measured in a laboratory showed that the new compound had a specific percent lower hysteresis value, an indicator of heat generation. This characteristic provided an indication of tread durability, and related to the qualification of tires that had been retreaded using the new compound. Also, this lower modulus and a lower hardness of the new compound indicated a better resistance to scuffing and tearing actions to which the tire is subjected in service.

4 Static Test Results per AC 145-4. Because the tire design remained the same, all static measurements (overall diameter, section width, static-loaded radius, skid depth, and static unbalance) were not affected by this change. Tread weight remained within the retread process capability.

5 In-Service Evaluation. Tires retreaded with this new material had been evaluated in service with several different airlines. No problems had been reported by the operators and no tires had been prematurely removed from service due to tread-related conditions, such as chunking or tread separation. Field inspection and examination of returned worn casings, performed by qualified personnel, had indicated good tread integrity and wear characteristics. Based on cycle data gathered (number of landings per retread), the length of the maintenance interval remained within a reasonable percentage of the baseline tire.

6 Rationale Summary. The tire sizes selected to demonstrate the continuation of performance were representative of the tire sizes for which production approval was requested. At least one tire size was qualified in each of the tire design types presently in service. For each tire application (nose and main landing gear), at least one tire was dynamically qualified. With one tire size, the highest speed rating in the list of proposed tire sizes was successfully qualified. With another tire size, the tested sample included the highest rated pressure tire. With yet another tire size, the largest skid depth in the list of proposed sizes was

dynamically tested. Within their own class of tires, these were, historically, the most difficult sizes to meet the qualifications of the AC 145-4 requirements. They had often been used in the past to prove process or material changes.

7 In view of the substantiating factors detailed above, it was requested that all of the additional tire sizes listed in their letter be authorized for production on the basis of "qualification by similarity."

(c) Approval. The FAA carefully considered the information provided above, and determined that there was sufficient merit to authorize production of the additional tire sizes for retreading, based on "qualification by similarity."

(2) Approval of Nonretreadable Tires - Qualification Testing. The following is extracted from an FAA memorandum dated August 18, 1988, which addresses the definition and application of "major and minor" changes as they relate to products with a TSO versus aircraft installation approval.

(a) TSO tire dynamometer testing, alone, is not considered acceptable for installation approval except for the most straightforward changes. This memorandum also addresses a potentially unsafe condition that may have resulted from retreading tires that were designed and approved as nonretreadable.

1 Based on evidence presented, including the adverse service history, it appears that the development of the lightweight and nonretreadable tires should have been classified as a "major change," which would have necessitated flight testing on the candidate airplane(s) prior to approval.

(b) It was noted that the TSO was granted based on dynamometer testing, and that the tire was presumably shown to meet the required load-speed-time curve, and other airplane weight and load parameters. However, FAA policy has been that dynamometer testing is not a suitable substitute for airplane tests for any but the most straightforward changes.

(c) The memorandum recommended that a suitable test program be implemented as soon as possible that would demonstrate that these tires are appropriate for their intended application. The test program that was established in January 1984, for the introduction of radial tires, presented later in paragraph (4)(b), is also appropriate in this case since the effect of these tires on airplane performance, landing gear dynamics and antiskid operation, wheel/fuse plug integrity, brake energy absorption, and wheel-well tire burst, is unknown. These lower weight, and therefore lower strength, tires may have a profound effect on the airplane performance, the wheel/brake integrity, or the life of the tires. The documentation that accompanies nonretreadable tires, once they are approved, must clearly show that the tires are not to be retreaded.

(d) There is concern that there have been many changes to wheels, tires, and brakes that have been considered to be "product improvements," and approved under the TSO system as "minor changes," that should have been demonstrated on the airplane prior to their approval.

(3) Approval Method for Substitute Tires. The following is extracted from an FAA memorandum dated April 14, 1988, which addresses the certification considerations that should be taken into account when the installation approval of a new tire on a type certificated aircraft is requested.

(a) A substitute tire must be shown to be adequate for its intended use. In some cases, the proposed tire will be listed in the airframe manufacturer's specification documents, and can be installed without further investigation. The airframe manufacturer should be contacted to determine if data exist regarding the acceptability of the proposed tire to be substituted on the airplane.

(b) If the replacement tires are of the same basic type and construction as the currently approved tires, but they have not been previously approved on the airplane, the following items should be considered. This list is not meant to imply that flight tests would be mandatory; rather, that the items should be discussed with the applicant and any discrepancy or concerns addressed.

1 The TSO load-speed-time curves should be compared to the airplane envelope to establish the suitability of the proposed tire for installation on the airplane. If the tire is not TSO authorized, it would be the applicant's responsibility to demonstrate that the tire meets all TSO requirements.

2 The physical dimensions of the mounted tire should allow adequate clearance to the wheel well and its contents, landing gear structure, gear doors, etc. Consideration should be given to new tires as well as retreads and possible growth effects of retreading.

3 If the weight of the proposed tire is significantly different from the original, or from other tires approved on the airplane, landing gear retraction times or emergency gear extension operation may be affected. A flight test should be conducted if there is a concern that any weight difference would be large enough to affect gear actuation times.

4 The spring rates for the proposed tire should be compared to other tires approved for the specific airplane at the expected load and deflection, to determine any adverse effect on the loads on the landing gear or any adverse dynamic coupling between the landing gear and tires.

5 The tire rolling radius, tire pressure, tire deflection, and tire footprint should be compared to other tires approved on the airplane, to determine the effect on water spray patterns or tire heating. If the tire pressure is adjusted to obtain a certain deflection, the effect on tire load carrying capability should be investigated.

6 Uninstrumented functional landings should be conducted. If antiskid is installed, these functional landings should be conducted on both wet and dry runways to determine if any adverse effects on the system have been introduced by the proposed tire.

7 If comparison of the proposed tire to other tires approved on the airplane reveals any significant differences in the factors noted above, or if there is evidence of significantly increased or decreased tire rolling resistance or tire μ, performance landings should be conducted. Increased tire rolling resistance could impact takeoff performance, decreased rolling resistance could affect fuse plug integrity, and a different tire μ could affect stopping performance.

(4) Replacement of Bias Ply Tires with Radial Ply Tires. The following is extracted from an FAA memorandum dated February 7, 1984.

(a) This memorandum provided certification criteria for installation of radial tires on type certificated aircraft which only had bias tire approval. The radial tire had obtained TSO approval and this memorandum outlined the installation considerations.

(b) Certification Program for Replacing Bias Tires with Radial Tires, part 25 Transports; All weight Categories, dated Jan. 12, 1984. A bias ply to radial ply tire change is not considered minor. The following certification program is designed for a TSO approved radial tire that is to replace a bias tire of equivalent rating.

1 The tire must be TSO-C62c approved, or equivalent as stated in § 25.733(c), and rated for the speed and gross weight under consideration. The radial tire must have been tested to the equivalent of the TSO, i.e., loads, speeds, and energies, etc.

2 The vertical spring rate for the radial tire should be determined and compared to the original bias tire in order to assess the difference in energy absorption characteristics. The airplane vertical load factors should not exceed the original design values with the radial tire installed. Also, spin-up and spring-back loads should be evaluated if there are significant differences in the weight and moments of inertia of the two tire and wheel assemblies. (For guidance on compliance refer to §§ 25.479, 25.723, and 25.725.)

3 The protection of the equipment in the wheel wells should be reassessed as the radial tire will have different failure burst characteristics than the bias tire. This assessment should cover tire air blast, as well as loose tread. (For guidance on compliance refer to § 25.729(f).)

4 Emergency gear extension should be reviewed and, if necessary, reassessed if tire size or weight changes are involved. (For guidance on compliance refer to § 25.729(c).)

5 A maximum Rejected Takeoff (RTO) energy stop using the 3 mile taxi, 3 full stops criteria of AC 25-7A, Flight Test Guide for Transport Category Airplanes, chapter 4, section 4, paragraph 55, should be conducted.

(aa) The tire pressure is to be set to the highest value appropriate for the maximum takeoff weight for which approval is being sought. Pressure should be set before taxi and with cold tires. This test is specified to confirm (at maximum takeoff weight) acceptable tire structural integrity, tire anti-skid dynamics, airplane braking performance, effectiveness of the fuse plugs, and to assess the directional control compatibility of the airplane if the fuse plugs melt late in the RTO run. In addition, the fire limitations of AC 25-7A, paragraph 55c(ii), or latest revision, are to be observed.

6 A sufficient number of RTO's and landings should be conducted to substantiate that the aircraft performance with radial tires is as good as, or better than, originally demonstrated with bias tires. Tests should be conducted in accordance with AC 25-7A, paragraph (2)(ii)(c), or latest revision.

7 The fuse plug integrity no-melt tests should be conducted in accordance with AC 25-7A, paragraph 55c(7), unless the applicant demonstrates the energies absorbed by the brake with a radial tire are no greater than the energies absorbed in the same brake when using the bias tire when comparing equivalent flywheel energies on the dynamometer. The fuse plug integrity test should also be run if the brake or tire temperatures of the radial tire/wheel/brake assembly are greater than the brake or tire temperatures of the bias tire/wheel/brake assembly when comparing equivalent flywheel energies on the dynamometer.

8 A sufficient number of flight tests should be conducted on wet and dry runways to establish that the anti-skid and/or autobrakes will function compatibly and acceptably with the radial tires.

9 A high speed takeoff at the highest speed for which approval is being sought, and sufficient taxi and turn tests to assess dynamic stability should be conducted.

10 If the airplane is approved for unimproved runways, additional evaluations should be conducted if there is an appreciable change in the tire footprint.

11 Water spray characteristics should be reviewed and, if necessary, reassessed.

12 Tire intermix, radial/bias, should be considered based on an evaluation on a case by case basis. For example, some of these items (1-11) may not apply for a nose tire

intermix. Any additional considerations deemed necessary by the cognizant ACO should be addressed.

13 If there is a significant tire tread change from one radial tire to another radial tire, the airplane performance should be considered and if necessary reassessed.

14 Additional testing may be required if certification for an increase in airplane weight or kinetic energy is requested.

(5) Certification of Radial Tire Installation. The following is extracted from an FAA memorandum dated March 28, 1984, which addresses as to why is it necessary to consider items (4)(b)1. through (4)(b)14. addressed in the preceding paragraph, and provides historical information on the reasons for certain items contained in the radial tire certification program. It also explains some of the reasons why dynamometer testing alone is not considered adequate for installation approval of replacement tires.

(a) The "Certification Program for Replacing Bias Tires with Radial Tires" dated January 12, 1984, is still the FAA recommended program. A bias ply tire to radial ply tire change is not considered minor. Dynamometer tests are not an acceptable substitute for airplane tests for tires, wheels, and brakes. This position, which is supported by FAA certification experience, is taken in AC 25-7A, chapter 4, section 4, paragraph 55.

1 For example, the FAA was requested to certificate a medium transport with three sets of tire/wheel/brake combinations for an increased gross weight. The manufacturer wished to certificate these combinations based on extrapolated data from existing lower energy data of one set, and to the higher TSO authorized energy levels of all three sets; however, the FAA insisted a full testing program be done. All three sets failed to achieve the projected braking coefficient of friction (μ). In addition, the set that was supposed to have the greatest margin, the set designated for future growth potential, almost failed due to shearing of the brake rotor lugs. The wheels, tires and fuseplugs functioned properly.

(b) Another example was the certification of a new model large transport. The tires had received TSO authorization, but were failing at the high speed takeoffs within the TSO performance envelope. Going further back, the FAA has had similar experiences relative to fuseplugs, anti-skid brake lock-up, and so forth. These experiences confirm that the dynamometer is not a satisfactory tool in predicting performance, compatibility, fuseplug melt/no-melt, etc., for tires, wheels, and brakes. The dynamometer is even questionable when it is used for trend data, as demonstrated by the medium transport example above. It is, however, useful as background information.

(c) That the dynamometer does not accurately simulate actual conditions may be due to its inherent inability to adequately simulate the following:

1 Actual runway conditions (i.e., round versus the flat surface of the runway, surface conditions and so forth).

2 Thermodynamic interaction (i.e., conduction. radiation, and convection between adjacent tires, wheels, and brakes, between the tire and the runway surface, and the effects of the air).

3 Airplane/System dynamics (i.e., the interaction between the airplane and supporting gear and systems, control systems and so forth).

(d) Adequate means of simulation could probably be developed with new test criteria (if comparisons are to be made) and new techniques. The end result would most likely be a test fixture on a track with a complete landing system including supporting structure, systems duplicating the number of landing gear, and so on, which would be capable of intricate simulations of takeoff, landing and braking dynamics. However, it would probably be less expensive to test the airplane as is currently the practice.

(e) Another problem is establishing the adequacy of the tire relative to the TSO data and to additional tests. The airframe manufacturer may request that the tire, wheel, and brake manufacturers conduct specific tests beyond the scope of the TSO. Side loading and overloading are good examples of additional tests. We can never be sure after completing the airplane tests that the tire (wheel or brake also) reliability is dependent totally on the TSO tests or on the TSO test and the additional tests specified. We are aware of at least one case where two tires manufactured by two different companies were installed on the same airplane and operated within the same TSO envelopes, yet one tire type failed while the other passed. The successful tire type had additional side loads specified which were not part of the TSO testing. As a repetitive statement, the FAA position is that TSO data is not a satisfactory substitute for tire wheel or brake tests on the airplane.

(f) If the radial ply tire is heavier than the bias tire, it must be determined whether that is significant. Lighter tire weight can affect some emergency extension systems as some of these systems use the landing gear weight to overcome the unlocking residual forces to provide enough inertia to extend the gear down, over center, and to lock the gear in place. Heavier weight may have an effect on retraction times. Radial tires may weigh as much as 1/4 less than the bias tires they would replace.

(g) Rejected takeoff tests are not only to prove the capability of the brakes, but also to prove the landing gear system and its interaction with associated components as well. These tests are to evaluate performance, dynamics, and system adequacy. As stated earlier, the dynamometer tests of the TSO are not an acceptable equivalent or substitute for the airplane tests. We also note that an applicant has stated that: "The radial tire exhibits less drag, and would therefore result in a slightly longer stopping distance at the same brake pressure (i.e., brake torque)." The maximum RTO is conducted at the maximum brake pressure, therefore, the braking distance would appear to be longer, based on an applicant's comment. In addition to other considerations, the maximum RTO and other performance tests should help establish how much longer the braking distance is going to be.

(h) Note that for the same bias tire dynamometer test energy, the brake energy increases with a decrease in energy absorbed by the radial tire; therefore, the heat being delivered to the fuseplug through the wheel will probably increase. It is not known how much or how significant that increase will be. How the fuseplugs are going to act (no-melt/melt) should be established on the airplane prior to certification.

(i) A sufficient number of flight tests should be conducted on wet and dry runways to establish that the anti-skid and the landing gear system will function compatibly and acceptably with the radial tires.

(j) It should be established prior to certification that the airplane tire will behave structurally and dynamically on the airplane as well as it did on the dynamometer at high speed conditions. Because dynamic stability may be more of a function of gear dynamics coupled to the tire dynamics, airplane tests should be conducted, as the dynamometer is insufficient in simulating airplane and landing gear system dynamics.

(6) Critical Conditions & Maximum Ramp Weight Definitions. The following is extracted from an FAA telegraphic message dated January 26, 1981, which addresses definitions of "critical conditions" and "maximum ramp weight" as they relate to § 25.733.

(a) Section 25.733(a) Critical Conditions. The critical conditions are those conditions where the takeoff or landing speed extremes that have been established by evaluating takeoff or landing performance for temperature, altitude, aircraft weight, aircraft configuration, runway conditions, engine performance, etc., may approach the tire speed rating. The critical conditions in this case are the takeoff or landing performance conditions that establish maximum tire speed.

(b) Section 25.733(a)(1); (b)(1); (b)(3);Maximum ramp weight. The maximum ramp weight is the maximum weight allowed on the airplane (includes airplane weight, fuel, oil, baggage, etc.). This definition is used interchangeably with maximum taxi weight.

e. References. The addresses for ordering the latest revision of advisory circulars, technical standard orders, and other referenced documents listed below can be found in the Appendix to this AC.

AC 20-97A, High-Speed Tire Maintenance and Operational Practices.
AC 43.13-1A, Acceptable Methods, Techniques and Practices - Aircraft Inspection and Repair, chap. 8, L. G. Equipment.
AC 145-4, Inspection, Retread, Repair and Alterations of Tires.
FAA Order 8000.54, Process Specifications for Retreading Tires and Inspection Procedures Manuals for Tire Retreaders.
FAA Order 8000.64, Qualification of Aircraft Radial Tires for Use on Aircraft and for Retreading.
FAA's Tire Approval Process Video, MTS 422/422.1, 42:15 Minutes.
TSO-C62c, of § 37.167 14 CFR. This TSO was removed from regulations (§ 37.167, Amendment 25-52, 1980), and became a voluntary standard.
TSO-C62c, With Addendum I. This TSO was removed from regulations (§ 37.167, Amendment 25-52, 1980), and became a voluntary standard.
TSO-C62d, Tires.
SAE AIR-1904 - Tire Spray Suppression - Airplane, Design Consideration and Testing.
SAE ARP-1322 - Overpressurization Release Devices.
SAE ARP-4834 - Recommended Practice for Retreaded Aircraft Tires - Radial and Bias.
SAE AS-707B - Thermal Sensitive Inflation Pressure Release Devices for Tubeless Aircraft Wheels.
SAE-AS 1188 - Aircraft Tire Inflation-Deflation Equipment.
SAE AS-4833 - Aircraft New Tire Standard- Bias and Radial.

14. SECTION 25.735 - BRAKES.

a. Rule Text.

(a) Each brake must be approved.
(b) The brake system and associated systems must be designed and constructed so that if any electrical, pneumatic, hydraulic, or mechanical connecting or transmitting element (excluding the operating pedal or handle) fails, or if any single source of hydraulic or other brake operating energy supply is lost, it is possible to bring the airplane to rest under conditions specified in 25.125, with a mean deceleration during the landing roll of at least 50 percent of that obtained in determining the landing distance prescribed in that section. Subcomponents within the brake assembly, such as brake drum, shoes, and actuators (or their equivalents), shall be considered as connecting or transmitting elements, unless it is shown that leakage of hydraulic fluid resulting from failure of the sealing elements in these subcomponents within the brake assembly would not reduce the braking effectiveness below that specified in this paragraph.
(c) Brake controls may not require excessive control force in their operation.

(d) The airplane must have a parking control that, when set by the pilot, will without further attention, prevent the airplane from rolling on a paved, level runway with takeoff power on the critical engine.
(e) If antiskid devices are installed, the devices and associated systems must be designed so that no single probable malfunction will result in a hazardous loss of braking ability or directional control of the airplane.
(f) The design landing brake kinetic energy capacity rating of each main wheel-brake assembly shall be used during qualification testing of the brake to the applicable Technical Standard Order (TSO) or an acceptable equivalent. This kinetic energy rating may not be less than the kinetic energy absorption requirements determined under either of the following methods:
(1) The brake kinetic energy absorption requirements must be based on a rational analysis of the sequence of events expected during operational landings at maximum landing weight. This analysis must include conservative values of airplane speed at which the brakes are applied, braking coefficient of friction between tires and runway, aerodynamic drag, propeller drag or power-plant forward thrust, and (if more critical) the most adverse single engine or propeller malfunction.
(2) Instead of a rational analysis, the kinetic energy absorption requirements for each main wheel-brake assembly may be derived from the following formula, which must be modified in cases of designed unequal braking distributions.

$$KE = 0.0443 \frac{WV^2}{N}$$

where-
KE = Kinetic energy per wheel (ft.-lb.);
W = Design landing weight (lb.);
V = Airplane speed in knots. V must be not less than V_{S0}, the power off stalling speed of the airplane at sea level, at the design landing weight, and in the landing configuration; and
N = Number of main wheels with brakes.
(g) The minimum stalling speed rating of each main wheel-brake assembly (that is, the initial speed used in the dynamometer tests) may not be more than the V used in the determination of kinetic energy in accordance with paragraph (f) of this section, assuming that the test procedures for wheel-brake assemblies involve a specified rate of deceleration, and, therefore, for the same amount of kinetic energy, the rate of energy absorption (the power absorbing ability of the brake) varies inversely with the initial speed.
(h) The rejected takeoff brake kinetic energy capacity rating of each main wheel-brake assembly that is at the fully worn limit of its allowable wear range shall be used during qualification testing of the brake to the applicable Technical Standard Order (TSO) or an acceptable equivalent. This kinetic energy rating may not be less than the kinetic energy absorption requirements determined under either of the following methods:

(1) The brake kinetic energy absorption requirements must be based on a rational analysis of the sequence of events expected during an accelerate-stop maneuver. This analysis must include conservative values of airplane speed at which the brakes are applied, braking coefficient of friction between tires and runway, aerodynamic drag, propeller drag or powerplant forward thrust, and (if more critical) the most adverse single engine or propeller malfunction.
(2) Instead of a rational analysis, the kinetic energy absorption requirements for each main wheel brake assembly may be derived from the following formula, which must be modified in cases of designed unequal braking distributions:

$$KE = \frac{0.0443\ WV^2}{N}$$

where-
KE = Kinetic energy per wheel (ft.-lb.);
W = Design landing weight (lb.);
V = Airplane speed (knots);
N = Number of main wheels with brakes; and
W and V are the most critical combination of takeoff weight and ground speed obtained in a rejected takeoff.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-23, 35 FR 5676, Apr. 8, 1970; Amdt. 25-48, 44 FR 68742, Nov. 29, 1979; Amdt. 25-72, 55 FR 29777, Jul. 20, 1990, as amended by Amdt. 25-78, 58 FR 11781, Feb. 26, 1993; Amdt. 25-92, 63 FR 8320, Feb. 18, 1998]

b. Intent of Rule.

(1) This rule requires use of approved brakes and wheel assemblies, either approved under an applicable technical standard order (TSO) e.g., TSO-C26c, or approved under the type certificate for the airplane. The existence of TSO approval with the article displaying required markings does not automatically constitute the authority to install and use the article on an airplane.

(2) It is the responsibility of those desiring to install this article to determine that the aircraft operating conditions are within the TSO standards. Additional requirements may be imposed based on airplane specifications, wheel and brake design, and quality control specifications. The airframe manufacturer/user must conduct the applicable airplane certification tests and receive FAA approval.

(3) In addition to brake performance and safety requirements, the rule provides standards for systems and equipment associated with brakes, e.g., control mechanisms and anti-skid systems. The brake and wheel assembly must have proper energy and load ratings for taxi, takeoff, refused takeoff, and landing. The braking system must have acceptable pilot-control forces, adequate parking brake capability, emergency braking capacity and directional control, and protection against overpressure, overtemperature, and fire.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Sections 4b.337 (a)(1), 4b.337(a)(2) and 4b.337(a)(3), 4b.337(b), 4b.337(c), 4b.337(d), 4b.335(c), and 4b.335(d) of the CAR, respectively became §§ 25.735(a), 25.735(b), 25.735(c), 25.735(d), 25.735(e), 25.735(f) and 25.735(g) of 14 CFR, for brakes/braking systems.

(1) Amendment 25-23 (April 8, 1970) deleted reference to a military specification (MIL-B-8075) as the means of compliance for antiskid devices under § 25.735(e) to allow any other acceptable means of compliance. In addition, proper units of "knots" were added to stall speed under § 25.735(f)(2).

(2) Amendment 25-48 (November 29, 1979) revised the technical standard order TSO-C26b for aircraft wheels and wheel-brake assemblies and related type certification requirements for airplane brakes. The revised standards in § 37.172 - TSO-C26c incorporated an updated and improved minimum performance standard for the design and construction of aircraft wheels and brakes. Under § 25.735(b), the incorrect reference to § 25.75 was replaced by a correct reference to § 25.125. Under § 25.735(f)(2), the numerical constant 0.0442 was corrected as 0.0443, and the letter "N" was appropriately redefined as the number of main wheels with brakes. Under § 25.735(f)(2), the term V_{SO} in the formula was replaced with "V" such that V must not be less than V_{SO}. Under § 25.735(g), the term V_{SO} was replaced by V to be consistent with terminology used under § 25.735(f)(2).

(3) Amendment 25-52 (June 9, 1980) eliminated § 37.172 Aircraft wheels and brakes - TSO-C26c from the regulations. TSO-C26c was made available at FAA Headquarters in the Office of Airworthiness.

(4) Amendment 25-72 (July 20, 1990) revised the text of the last sentence in § 25.735(b) to clarify the intent.

(5) Amendment 25-92 (February 18, 1998) added § 25.735(h) requiring that the maximum rejected takeoff kinetic energy capacity rating of the aircraft brakes be determined with the brake at the fully worn limit of its allowable wear range. The requirement evolved from an National Transportation Safety Board (NTSB) recommendation as follows: In 1988, a large transport category airplane experienced an 86% maximum kinetic energy (KE) rejected takeoff (RTO) in a dispatch configuration in which eight of the ten brakes were worn close to the maintenance limits. The eight brakes failed early in the braking run and the airplane overran the runway. As a result, the FAA reviewed the methodology used in the determination of allowable brake wear limits for transport category airplanes. It was determined that brake wear limits should be established during certification to ensure that fully worn brakes will function properly during a maximum KE RTO. A series of airplane specific airworthiness directives were issued between 1989 and 1994 to establish brake wear limits using the new criteria. These criteria were applied to transport category airplanes that exceeded a gross weight of 75000 pounds. The test criteria to establish brake wear limits are discussed later under Policy/Compliance item d.(6). The regulation was updated to reflect this new criteria.

(6) Harmonization. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group has recommended revisions to §§ 25.731 and 25.735, and has developed a new advisory circular (AC) 25.735-1. A new TSO-C135 for transport category airplanes, replacing the applicable parts of the existing TSO-C26c, was also developed. The proposed rule change, the proposed AC, and the proposed TSO package were published in the Federal Register, August 10, 1999, inviting public comments. The proposed harmonized AC 25.735-1 will not, however, replace all policy matter contained in this AC because several issues are not addressed in AC 25.735-1.

d. Policy/Compliance Methods. Flight and ground testing procedures for demonstrating compliance with the requirements of § 25.735 may be found in AC 25-7A, Flight Test Guide for Transport Category Airplanes.

(1) Carbon Brake Refurbishment (redensification). The following is extracted from an FAA memorandum, dated April 11, 1996, which provides guidance regarding approval of an alternate process for redensification of carbon brake disks during brake overhaul. The redensification process involves a 2-for-1 brake disk refurbishment. The term 2-for-1 is associated with a re-building of the brake where two worn rotors are resurfaced, placed in an oven to have the carbon "redensified" and riveted together to form a new rotor, which is then placed in the brake as part of the re-building of the assembly. An approved repair shop that overhauls brakes in accordance with the original equipment manufacturer (OEM) overhaul procedures, requested the FAA to approve, as a minor change, the option of using a different carbon brake redensification process developed by the shop and its associates. The only redensification option presently available is to return the brake components to the OEM. The proposed process was initially applied to carbon brake disks used on a military aircraft.

(a) Due to continued in-service problems associated with carbon brakes and their complex processing techniques, the FAA contacted major U.S. manufacturers to solicit background information regarding carbon brake overhaul procedures including the 2-for-1 refurbishment and redensification process. All brake manufacturers consider carbon brake redensification a complex and proprietary process which can affect brake performance. Experience at three (3) brake manufacturers of original equipment has shown that a very minor carbon processing change (heat treat operation) can have a significant effect on brake performance and airplane structural compatibility. By the criteria established in AC 25-7A, Flight Test Guide for Transport Category Airplanes, paragraph 55, it has been determined that redensification is a major change.

(b) For additional guidance on compliance with this requirement, refer to the latest revision of AC 25-7A, chapter 4, section 4, paragraph 55.

(c) The typical dynamometer test program conducted by an OEM for an overhauled brake configuration can be quite substantial. An airplane manufacturer usually requires that the OEM conduct testing to obtain FAA TSO-C26c approval and re-qualify the brake before airline introduction and retrofit. This full scale brake requalification effort depends on the type and degree of modification(s) done to the brake to obtain the overhauled configuration.

(d) An airplane manufacturer pays particular attention to potential differences in brake torque, energy capacity, vibration, brake sensitivity, dynamic response, and structural strength. A brake requalification test program including the conditions below would be accomplished using a wheel/brake assembly in the most adverse service condition.

1 Design Landing Stops (Normal and Overload Energy levels).
2 Wet Brake Landing Stops (effect of moisture content in carbon).
3 New Brake Rejected Takeoffs (RTO's) at 60%, 80%, and 100% of maximum brake kinetic energy).
4 Worn Brake RTO's.
5 Wet Brake RTO's.
6 High Power/Torque Repeatability RTO.
7 Torque Sensitivity Testing.
8 Service Landing Wear Testing.
9 Fuse Plug No-Melt RTO series to evaluate disk warpage and thermal characteristics.
10 Brake Rolling Drag.
11 Brake Peak Torque Survey.
12 Static Low Speed Torque.
13 Vibration Testing.
14 Frequency Response.
15 Torque Recovery.
16 Hysteresis.
17 Static Structural Torque.
18 Dynamic Structural Torque Test.
19 Static Brake Torque to evaluate park brake hold capability.
20 Carbon Disk Oxidation Resistance.
21 Heat Sink Contamination Testing.
22 Intermix of New and Overhauled disks.
23 Brake Thermal Modeling.

(e) The test results are then compared to the original new brake qualification test results to determine equivalence of the overhauled brake configuration. When changes include different heat sink material processing or are done by a supplier other than the OEM, it may be necessary to perform airplane/brake system flight testing. This will validate the Airplane Flight Manual performance and the brake control system compatibility for the overhauled brake configuration.

(f) Some additional considerations are as follows:

1 The FAA does not accept military airplane equipment test data for compliance with transport category airplane regulations.

2 The applicant has not conducted any tests whatsoever on the modified brakes.

3 The applicant may need to apply for a new TSO and possibly a supplemental type certificate (STC).

(2) FAA/JAA certification requirements: steel/carbon brakes. The following is extracted from an FAA letter dated April 9, 1996, which addresses obtaining parts manufacturer approval (PMA) for manufacturers located outside of the United States, TSO procedures, and brake certification requirements for steel and carbon brakes.

(a) There are no differences in the certification requirements between carbon and steel brakes. The TSO-C26c and AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes, are still applicable. In addition, each airframe manufacturer has specific vibration control criteria in their wheel and brake specification. This criteria is crucial to the brake dynamics, the particular airplane installation, and structural integrity of the airplane.

(b) There are no known differences on the carbon brake certification requirements between the FAA and the Joint Aviation Authorities (JAA). You are, however, advised to verify this with the JAA.

(3) Certification of Replacement Brakes. The following is extracted from an FAA letter dated May 19, 1992, which addresses policy on aircraft brake replacement. The information was requested by a foreign airworthiness authority and is provided in the advisory circular format.

ADVISORY INFORMATION FOR BRAKE REPLACEMENT

(a) Purpose. To provide advisory information and guidance for a non-U.S. manufacturer concerning an acceptable means of showing compliance with Title 14, Code of Federal Regulations (14 CFR), applicable to the replacement of brakes for part 25 airplanes.

(b) Related Regulations and Documents.

1 Sections. The related sections of 14 CFR, part 25, are as follows:

§ 21.305	Approval of materials, parts, process, and appliances.
§ 21.502	Approval of materials, parts, and appliances.
§ 21.607	General rules governing holders of TSO authorizations.
§ 21.609	Approval for deviation.
§ 21.617	Issue of letters of TSO design approval: import appliances.
§ 25.109	Accelerate-stop distance.
§ 25.125	Landing.
§ 25.143	Controllability and maneuverability.
§ 25.231	Longitudinal stability and control.
§ 25.233	Direction stability and control.
§ 25.493	Braked roll conditions.
§ 25.735	Brakes.
§ 25.1301	Function and Installation.
§ 25.1309	Equipment, systems, and installations.

2 Advisory Circulars (AC's). The addresses for ordering the latest revision of the advisory circulars and technical standard orders listed below can be found in the Appendix to this AC.

AC 21-23, Airworthiness Certification of Civil Aircraft Engine, Propellers, and Related Products.

AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes.

TSO-C26c, Aircraft Wheels and Wheel-Brake Assemblies with Addendum I.

3 Industry Documents. These documents provide additional information, guidance, and/or standards. The address to order the documents listed below can be found in the Appendix to this AC.

SAE ARP-597C, Wheels and Brakes, Supplementary Criteria for Design Endurance - Civil Transport Aircraft.

SAE ARP-813A, Maintainability Recommendations for Aircraft Wheels and Brakes.

SAE ARP-1064B, Brake Dynamics.

SAE AS-1145A, Aircraft Brake Temperature Monitor System (BTMS).

SAE ARP-1619, Replacement and Modified Brakes and Wheels.

(c) Airworthiness Requirements.

1 Applicable Requirements. Replacement of brakes must be evaluated against the applicable part 25 airworthiness requirements. They are §§ 25.109, 25.125, 25.143, 25.231, 25.233, 25.493, 25.735, 25.1301, 25.1309, of Title 14 Code of Federal Regulations (14 CFR), and TSO-C26c.

2 Substantiation Procedures:

(aa) The design and its design deviations should be substantiated by conducting the necessary analytical investigations, laboratory testing, and airplane testing to ensure that the change can be made without impairing airplane braking or rolling performance. The recommended substantiation procedures for replacement brakes are based on parts approval and their impact on the prior certification. Depending upon the type and extent of change and the certification basis of the airplane, engineering judgment will be used to determine which of the substantiation procedures discussed in AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes, chapter 4, section 4, paragraph 55, should be considered for replacement brake installations in addition to the laboratory tests required by the TSO.

(bb) Aircraft brakes are approved under the Technical Standard Order (TSO) system (TSO-C26c). A TSO-C26c authorization indicates that the brake and its associated wheel have met certain requirements relating to strength, energy absorption, durability, construction, performance, and manufacture. In addition, the holder of a TSO authorization has demonstrated certain quality control procedures and the ability to produce duplicate parts from approved drawings.

(cc) A TSO authorization, by itself, is generally considered adequate to show that the wheel/brake combination is satisfactory for flight testing on an airplane, and would be safe for use during subsequent certification testing. However, it is not sufficient to show satisfactory performance within the operational envelope of the airplane, due to the well-documented differences (load distribution on the landing gear, heat dissipation, brake efficiency, runway crown, etc.) between laboratory dynamometer testing and full-scale airplane testing.

(d) Continued Airworthiness/Brake Wear Limits.

1. During previous certification activity, the determination of airplane performance and the demonstration of maximum brake kinetic energy capability was based on testing brakes at or near their new state. In 1988, a transport category airplane experienced a rejected takeoff (RTO) at 86% of the brake's maximum kinetic energy capability. The airplane went off the end of the runway. An investigation determined that eight of the ten brakes were near the maximum allowable wear limits before the RTO and were unable to absorb the required energy, thus contributing to the accident.

2 Since this accident, the FAA has reviewed the methodology used in the determination of allowable wear limits and airplane performance for transport category airplanes.

The FAA has issued airworthiness directives (AD's) that require more conservative brake wear limits on various models of US and foreign transport category airplanes having a U.S. type certificate.

(4) Parking Brake Testing. The following is extracted from an FAA message dated March 20, 1992, which addresses the intent and application of § 25.735(d).

(a) The parking brake requirement was added to the CAR under § 4b.397 of the CAR on September 1, 1949, and changed to § 4b.337(c) on July 20, 1950. Section 4b.337(c) of the CAR became § 25.735(d) of Title 14, Code of Federal Regulations (14 CFR). The guidance material in § 4b.337-1 indicated this was to be a demonstration to determine that sufficient braking was maintained to prevent the airplane from rolling on a paved runway while takeoff power was applied on the most critical engine.

(b) The FAA certification offices agree that the test is intended to demonstrate that the parking brake will hold with the power of the critical engine at takeoff power and the other engine(s) at idle. The effects of propeller wash or propeller/engine torque, in addition to asymmetric thrust and aircraft weight, should be used in determining the critical engine and vertical loads on the main landing gear. The vectored thrust point can be outside the propellers axis of rotation. Therefore, propeller rotation and engine inclination are a factor in determining the critical engine.

(c) To test the maximum torque for the parking brake, the airplane should be configured at its highest gross weight with the flaps retracted. The critical engine for a four engine airplane is usually one of the outboard engines. For a two engine executive jet airplane with near centerline engines, or a twin engine propeller airplane with propellers rotating the opposite direction, it may not make a difference which is the critical engine. For some executive jets, where there wasn't considered to be a critical engine relative to § 25.735(d), the manufacturers tested by putting both engines at takeoff power. This is not being tested according to the rule, but it should lead to the same conclusion.

(d) For consistency, the following test procedure is recommended:

Paint a radial stripe(s) on the wheels. With the airplane sitting on dry pavement at the airplane's maximum takeoff weight, the tires pressurized normally for this weight, the flaps retracted and control surfaces centered (neutral), conduct the parking brake test as follows:

1 Set the parking brake.

2 Apply takeoff power to the critical engine (critical relative to § 25.735(d)) leaving the other engine(s) at idle.

3 An external observer, looking at the white stripe(s) on the wheels, verifies the wheels are not turning, i.e., the brakes are locked. The airplane may skip or shear tire tread or the tire may slip around the wheel, but the wheels must not rotate.

(e) If it has not been established which engine is critical, conduct a separate test for each engine. If it has been determined there isn't a critical engine for a twin engine airplane, a test with either engine at takeoff power will suffice.

(5) Worn Brake Requirements for Non-Original-Equipment Parts. The following is extracted from an FAA letter dated February 18, 1992, which addresses an original equipment manufacturer (OEM) inquiring whether a non-OEM was required to follow the same procedures and conduct the same tests as the OEM. The FAA response was affirmative and explained below.

(a) An FAA issued AD proposes brake wear limits for specific series airplanes. This proposal required that all landing gear brakes be inspected for wear and be replaced if the wear limits prescribed in this proposal are not met, and that the new wear limits be incorporated into the FAA-approved maintenance inspection program. An original equipment manufacturer asked that the AD require the following for non-original equipment (NOE) certified parts:

1 NOE manufacturers submit worn brake RTO test results for all brake assemblies using their parts.

2 Brake assemblies containing NOE parts be given new part numbers and TSO markings.

3 Installation approval and notification of all operators and overhaul shops be required concerning these approvals, and

4 Compliance with the terms of the AD be required for anyone using or furnishing parts for brakes.

(b) The FAA position was that regulations, orders and advisory material provide guidance concerning changes to approved parts, components and assemblies and that events 1, 2, 3, and 4 occur. As an example, a brake assembly was approved with NOE rotors under a supplemental type certificate (STC) project. The Aircraft Certification Office, which issued the STC, required the company manufacturing the brake assembly meet all applicable worn brake RTO requirements.

(6) Determination of Allowable Worn Brake Limits. The following is extracted from an FAA memorandum dated February 23, 1990, which provides guidance regarding worn brake capability determination. A policy letter dated March 2, 1990, contained the same information. Issue papers were used to administer the same policy for new certification programs until Amendment 25-92 was issued in February 1998.

(a) This memorandum established criteria for worn brake testing for in-service transport category airplanes. Worn-brake accountability determination was intended to validate brake wear limits with respect to brake energy capacity only, and was not meant to account for any reduction in brake force due solely to the wear state of the brake. This criteria is intended for transport category airplanes used in part 121 operation, and which have a certificated maximum takeoff weight in excess of 75,000 pounds.

(b) It should be noted that this worn-brake accountability determination will validate brake wear limits with respect to brake energy capacity only, and is not meant to account for any reduction in brake force due solely to the wear state of the brake. Any reduction in brake force (or torque) that may develop over time as a result of brake wear is to be evaluated and accounted for as part of the rulemaking project described in (c) below. The accident that prompted this investigation into brake wear is believed to have been caused by inadequate brake energy-absorbing capability. The issue of loss of brake effectiveness with brake wear, and the resulting increase in runway lengths required for a RTO is addressed under Amendment 25-92.

(c) The following dynamometer test guidelines are the result of a series of meetings. These test procedures may be used for the determination of acceptable airplane brake wear limits.

1 Acceptable Test Brakes.

(aa) Either airplane-worn or mechanically-worn brakes may be used. Mechanically-worn is defined as not being airplane-worn, e.g., machined or dynamometer-worn. If mechanically-worn brakes are used, it must be shown that they can be expected to provide similar results to airplane-worn brakes.

(bb) Each test brake shall be subjected to a sufficient number and type of stops to ensure that the brake's performance is representative of in-service use.

2 Wear State of the Test Brake.

(aa) Degree of Wear. The degree of wear of the test brake shall be 100 percent. One hundred percent worn is defined as that degree of wear which the applicant intends to allow before the brake is to be removed for overhaul. At the overhaul limit the brake will not be fully worn out, but will contain sufficient braking capability to meet the energy absorption requirements discussed below. The chosen test brake shall be such that the wear-in conditions produce a brake ready to perform the RTO test at the correct wear setting. If a brake to be tested is worn less than 100 percent, an acceptable method of extrapolation to the fully worn state must be provided prior to test.

(bb) Definition of Degree of Wear. The degree of wear shall be defined in terms of the linear, axial direction dimension relating to the allowable wear of the brake as commonly determined by noting wear pin extension.

(cc) Distribution of Wear (Applicable only to mechanically-worn brakes). The proportioning of the wear through the brake for the various friction pairs shall be based on either: Service experience on the test brake or an appropriate equivalent brake, or Dynamometer wear test data.

3 Brake Energy Level to Set 100 Percent Wear Limits.

(aa) It will be necessary to conduct the dynamometer test with an initial energy value prior to the RTO test that is analogous to that generated during the airplane certification flight test of that brake (e.g., energy due to taxi stops).

(bb) The dynamometer RTO maximum energy level may be based on the Airplane Flight Manual limiting conditions, including, if desired by the applicant, the effects of:

Engine reverse thrust, following normal procedures for power setting, cutback speed, and

The recommended number of reversers to be used with a critical engine inoperative, and the demonstrated transition times achieved in or equivalent to an RTO flight test.

(cc) The dynamometer test should be conducted to duplicate the airplane's speed versus time performance as closely as practicable.

(dd) The use of reverse thrust shall be limited to a determination of the energy to be absorbed by the brake during the dynamometer test. No thrust reverser credit shall be given for the purpose of determining runway distance requirements or airplane stopping performance.

4 Power Level. The test shall be conducted at either of the conditions below, provided that the test is conducted at the condition which more closely represents the actual braking conditions obtainable on the airplane. The intent of these procedures is to simulate actual airplane conditions as closely as possible:

(aa) The maximum brake pressure, or

(bb) The maximum tire drag or brake torque consistent with the airplane's hydraulic system and any antiskid and/or torque limiter pressure limitations that would occur on the airplane during an equivalent RTO operation.

(cc) In order to assure that the test results are accurate, repeatable, and simulate actual airplane conditions as closely as possible, the dynamometer tests must be conducted on an inertial-wheel type dynamometer, using a suitable tire/wheel/brake assembly. If use of a shaft-type dynamometer is desired, it must be shown prior to any testing, that the shaft-type dynamometer will provide results equivalent to that provided by the inertial-wheel type dynamometer.

5 Final Condition Definition.

(aa) A full-stop demonstration is not required for the worn-brake RTO test. The test brake pressure may be released at a dynamometer speed of up to 20 knots to facilitate a detailed post-test inspection of the brake. The dynamometer test may be started at a slightly higher speed so that the test may be terminated at 20 knots or less, provided that the data submitted for each test show that the energy absorbed by the brake during a test that is terminated at 20 knots or less, is equal to the energy that would have been absorbed if the test had been started at the proper speed and continued to zero ground speed.

(bb) There shall be no wheel burst as a result of this test.

6 Data Requirements.

(aa) As a minimum, the following technical data shall be obtained for each dynamometer test conducted:

Brake torque (or force).
Brake pressure.
Time.
Road wheel speed.
Road wheel distance.
Dynamometer inertia equivalent.

(bb) The absorbed dynamometer kinetic energy shall be computed based on measured data. Additional data may also be obtained to aid in interpolating and extrapolating test results.

(cc) A test report shall be prepared which, as a minimum, shall include:
A detailed description of the test article (e.g., component part numbers, individual disk measurements, wear pin measurements, etc.),
The test procedures,
The test results, and
If possible, photographs of brake rotors/stators before and after the dynamometer test.

(dd) In order to receive credit for the effects of (N-1) thrust reversers, where N is the number of reversers available at dispatch, thrust reverser effectiveness must be substantiated. Any existing validated reverser performance data are to be submitted for FAA review and approval. This is required for each engine family for each airplane model.

7 Interpretation of Data. Any adjustment of energy levels or allowable wear from the dynamometer test shall be based on a review of the test data, inspection of brake hardware after test, and subsequent analysis.

(aa) An extrapolation of wear data or energy data up to 5 percent of the test values shall be permissible.

(bb) An interpolation of data up to 20 percent of the test values shall be permissible to establish energy levels from multiple dynamometer tests which are within this range from the target condition.

8 Acceptance of Prior Tests.

(aa) Worn-brake RTO tests which have been conducted successfully prior to the adoption of these procedures may be acceptable. These tests need not be repeated solely to gather test data specified here.

(bb) These worn-brake dynamometer test guidelines are a recommended test procedure, and, as such, represent one means, but not necessarily the only means, of determining acceptable maximum brake wear. The FAA would consider deviations from these guidelines if it can be shown that the proposed procedure is appropriate and would produce equivalent results.

(cc) The dynamometer guidelines listed above indicate that credit for reverse thrust, using the recommended number of thrust reversers with a critical engine inoperative, is to be allowed in the determination of the maximum brake energy on the dynamometer. The effect of inoperative thrust reversers due to Minimum Equipment List (MEL) dispatch must also be accounted for.

(dd) If a particular brake is affected by the Airworthiness Directive (AD), and is later tested on the dynamometer and shown to require a different wear pin cut-back than that specified in the AD, then the AD should be amended at that time to reflect the correct wear pin length. The continued airworthiness aspects of this statement apply to all brakes whether or not an AD was issued.

(ee) On any given airplane model there may be many different brake configurations that are quite similar, and identified by different dash numbers. It may be acceptable for the manufacturer to demonstrate acceptable brake wear limits on one brake representative of a brake family, and extend that brake wear limit to others of the same family by analysis. Each case will have to be evaluated on its own merits.

(ff) There may be situations in which a brake modification or brake installation is proposed by someone other than the airframe manufacturer or the original brake manufacturer. In these cases, if the brake modification is judged to be a major change involving the friction couple (rotor/stator), or in any way could affect brake energy capacity, a determination of the effects of brake wear in accordance with these procedures must be accomplished. The applicant may claim the same brake wear limit as the original brake manufacturer, and this may be acceptable, but this would have to be demonstrated by analysis or test.

(gg) A project to amend part 25 to include a determination of the effects of brake wear on brake force has been initiated. At this time it has not been determined what the format for this determination will be. For the present time, any certification project involving new brakes or a substantial redesign of existing brakes (major change) should be conducted as described in AC 25-7A (formerly Order 8110.8), i.e., airplane flight tests should be conducted using new brakes. An adjustment to the allowable brake wear limits should then be made, if applicable, using the procedures described above.

(7) <u>Credit for Reverse Thrust in Worn Brake Testing.</u> The following is extracted from an FAA memorandum dated April 28, 1989, which established the acceptability of reverse thrust credit for the purposes of establishing worn brake limits only.

(a) During certification of aircraft brake systems, a demonstration of stopping performance at the maximum takeoff weight and speed expected in service is conducted. This RTO test shows that the brake has the capacity to absorb the required kinetic energy, and may limit certain performance information in the Airplane Flight Manual. This test is conducted with new brakes and without reverse thrust or other deceleration means other than spoilers.

(b) Accident data has shown that the brake-wear limits and brake design in general may be inadequate to provide the required stopping performance at maximum RTO energy levels with worn brakes.

(c) An adopted rule AD that reduces allowable brake wear prior to overhaul on the XYZ model airplane has been issued. This AD was based on dynamometer testing, and provides for a brake overhaul interval such that sufficient brake mass remains at overhaul to absorb the certificated RTO energy and allow the airplane to stop on the runway.

(d) FAA/Industry meetings were held to develop a dynamometer test protocol prior to any testing, so as to minimize costs and delays. A major issue, which arose during these meetings, is credit for the effects of reverse thrust on the kinetic energy that must be absorbed by the brakes. Because of the way brake energy for the initial dynamometer tests was calculated, the initial AD included credit for (N-1) thrust reversers, i.e., 2-engine reverser credit for the 3-engine aircraft. As you know, the FAA has been reluctant in the past to grant credit for reverse thrust relating to braking performance or brake kinetic energy determination. We remain unconvinced that reverse thrust credit should be granted in the case of airplane braking performance, because reverse thrust has not been shown to be sufficiently reliable for this purpose. However, the FAA has no valid reason to deny the use of reverse thrust in the determination of brake kinetic energy for brake wear limit tests. Reverse thrust will certainly be used in any RTO (if available), and the probability of a high-energy, field-length-limited RTO combined with an inoperative reversers is sufficiently low to allow relief in this area. It will be acceptable to allow credit for the effects of (N-1) thrust reversers in the determination of allowable wear limits in dynamometer tests discussed above.

(e) It should be noted that this use of reverse thrust applies to kinetic energy determination for the purpose of establishing worn brake limits only. The FAA will not consider allowing credit for reverse thrust in the determination of accelerate-stop distances or braking performance.

(8) Certification of Brake Replacement Components. The following is extracted from FAA letters and memorandums dated March 16, 1989, December 27, 1988, and March 16, 1988, which address the certification data/testing required for obtaining FAA approval for replacement parts of an existing FAA approved brake installation.

(a) In early 1989, the FAA issued an STC to provide replacement brake parts for certain part number brakes on a specific airplane. Throughout the STC review process, the FAA was acutely aware that granting this STC would be precedent-setting. Brakes to date had been designed and approved as a system, involving the wheel/brake assembly, the tire, and the airplane landing gear and brake systems. This approval involved a component of a previously approved system, and as such, the approval method for this modification was necessarily different from that applied to the original manufacturer.

(b) The key issue to be addressed was the amount of product development and testing that must be conducted in order to demonstrate that the proposed parts are satisfactory for their intended use. An original brake manufacturer must perform considerable research and development in order to design an aircraft brake with the best compromise of low weight, durability, useful life, and performance. The interface between the airplane structure and systems and the proposed brake must be investigated, and this sometimes requires much dynamometer and airplane flight testing. Early in-service experience with the new brake may reveal the need for minor "fine tuning" in the brake design.

(c) If another manufacturer later desires to produce any of the components of an approved assembly under an STC or a Parts Manufacturer Approval (PMA), he or she must show that the airplane, as modified to incorporate the new components, continues to comply with the regulations incorporated by reference in the type certificate for that airplane. This does not necessarily entail following the same approval path as that of the original manufacturer. In many cases, he or she need only duplicate the part in question, and if the part can be shown to be "identical" to the original part, FAA approval can be granted on that basis. This method of approval of replacement parts has a long, successful history and will continue to be used when appropriate. The original manufacturer of a TSO-authorized part does enjoy certain advantages over another manufacturer that seeks to modify that part. He may make modifications to the part based on the experience gained during the product development without extensive testing, and have the change approved as a "minor" change. The same change proposed by another applicant might be judged to be a "major" change, which would necessitate considerably more testing.

(d) In this case, the STC applicant originally sought approval of their part based on identicality with the original part. A finding of identicality could not be made, however, due to some small differences between the parts. The differences existed and could not be ignored, but were judged to be so insignificant as to obviate the need for the full spectrum of ground and flight tests discussed in AC 25-7A, Flight Test Guide for Transport Category Airplanes (formerly Order 8110.8), chapter 4, section 4, paragraph 55. It was agreed by the FAA and the STC applicant that a back-to-back comparison of the original brake and the company's modified brake on a flywheel-type dynamometer at the ultimate energy capacity of the original brake would be an acceptable test to show equivalent performance. New OEM brakes would be tested at successively higher energies until brake failure occurred, or was imminent; the applicant's modified brake would then be tested at this energy, with a second modified brake tested for a demonstration of repeatability.

(e) Although, by its very nature this dynamometer test alone could not support a "major" brake change (as discussed in AC 25-7A, formerly Order 8110.8), it would demonstrate that the ultimate kinetic energy (KE) capacity of the replacement brake part and the OEM brake part were equivalent under identical laboratory test conditions. This, together with the near identicality of the two components, was the basis for the FAA approval. No attempt was made to duplicate any conditions relating to on-airplane brake testing. The well-documented differences between dynamometer testing and airplane testing prevented any such comparison. It is possible that this series of dynamometer tests was a more severe test than a single RTO, since the brake was tested to destruction in the laboratory under controlled conditions, and its behavior could be more closely monitored than on the airplane. The FAA was aware of the torque and deceleration window mentioned by the OEM, and the replacement part was shown to perform within that envelope satisfactorily.

(f) The OEM was concerned that the friction couple was a key factor in the determination of the performance of the brake, and the FAA concurred. In future applications for similar approvals, either by the STC applicant or other manufacturers, the FAA expects to apply the test regimen discussed in FAA Order 8110.8. The dynamometer test used in this case would only be used if the situation were essentially the same as this case ; i.e., a part that is so nearly identical with the original that there is little question that the part would perform the same as the original, and the FAA was satisfied with a demonstration of manufacturing competence by the STC applicant.

(g) Another issue raised by the OEM was the unilateral FAA approval of the replacement part without the concurrence of the airframe manufacturer. This is the normal method of FAA approval for STC applications. Data supplied to the FAA by the STC applicant is, in most cases, proprietary to the applicant, and the FAA is obliged not to reveal details of the application to another manufacturer. The FAA is in a position to have access to pertinent data from the original airframe manufacturer, and questions of compatibility can be answered without involving the original manufacturer. It is unreasonable to expect assistance from a manufacturer if that assistance would benefit a competitor or interfere with their own interests. There are numerous examples of major modifications to airplanes that have been completed without the assistance or cooperation of the original airframe manufacturer. In this particular case, the replacement part manufacturer unsuccessfully attempted to obtain technical data from both the airframe and brake manufacturer, as well as from the FAA, under the Freedom of Information Act.

(h) During a meeting between the OEM and the FAA, the issues of product support, configuration management, and product maintenance were discussed at some length. Product improvements are a normal part of any manufactured product, and we expect the OEM brake that was the basis for the STC approval will continue to evolve as the market changes and service history dictates. In each case, the burden will be on the STC holder to demonstrate that their STC is satisfactory as a replacement for any new OEM brake part numbers, if they choose to make such an application, and that applicability must be demonstrated, either by the dynamometer test method discussed above, or other test requirements dictated by the particular situation under consideration. It is possible that future changes to the OEM brake under consideration here may make the replacement part STC obsolete.

(i) We concur with the OEM’s statement that the performance of the proposed replacement brake component must necessarily be identical to the original. In many other areas, the FAA will accept a demonstration of performance that is "equal to or greater than" the original, since many of our requirements are intended to be minimum performance standards. In this case, improved brake performance may actually be a detriment, because landing gear structure, and brake and antiskid systems are often tuned to brake performance, and a change in braking μ or other brake characteristics may have an adverse affect on the airplane itself. If the performance of the replacement part is shown to be different in any way from the original, the applicant would be required to show that the effect on the airplane would be acceptable.

(j) In 1987 the FAA convened a special technical review team to examine the facts surrounding the original application for approval of replacement brake components. The team reviewed the brake approval procedures that had been applied in the past, including TSO approvals, dynamometer testing, and airplane flight testing. The team also considered information presented by the STC applicant. The consensus of the team is as follows:

1 The distinction between “major” and “minor” changes to brakes and brake systems, as discussed in AC 25-7A, chapter 4, section 4, paragraph 55, (formerly FAA Order 8110.8), is valid, and should continue to be followed. The discussion and examples given in paragraph 55 are generally adequate to determine the proper course of testing to be followed in the certification of brake changes.

2 The applicant had failed to establish identicality of the proposed replacement part with the originally approved brake component. There was also the possibility that the change could impact the airplane stopping performance, or the kinetic energy absorption characteristics of the brake. Such a design change would normally lead to a classification as a major change requiring a demonstration of brake performance on the airplane, including a maximum energy RTO.

3 The review team concluded, however, that the proposed replacement brake part could be properly considered a minor change, on the basis of demonstrated equivalency, as supported by additional analysis and tests. This means that the testing requirements of a major change need not apply, if functional airplane landings and comparative dynamometer tests could be successfully completed. Given the close similarity of the replacement part and the original, the inherent simplicity of the brake part (as compared to the stator with its friction linings, for example), and the applicant's long experience in producing acceptable brake rotors for the U. S. Air Force, it was determined that the procedure proposed by the FAA for dynamometer testing of the applicants part was acceptable. This procedure contains the following items:

(aa) Use of new stator and rotor parts in both the applicant's and OEM’s brakes for each test will be required, in order to minimize test configuration variables. If rebuilt or in-service components other than these fail during testing, it should be realized that the results of the test may be questionable. Suspect tests would be carefully scrutinized by the FAA and retesting may then be necessary.

(bb) A series of tests may be necessary to find the ultimate KE level of the OEM brake, as agreed upon in the original test plan. For each succeeding run, the KE will be increased by 5% over the previous run until the ultimate KE level is determined, i.e., brake failure has occurred, or is imminent. The initial kinetic energy level for this series of tests will be at the discretion of the applicant. After each test run, the brake will be examined and a determination will be made whether additional tests at higher energies are necessary.

(cc) A minimum of two test runs at this ultimate energy level must be conducted on the OEM brakes for validation of this level prior to conducting the applicant's comparison tests. These two runs must show similar results. This provides confidence similar to that obtained from multiple brake assemblies on actual airplane tests.

(dd) At least one run at this ultimate energy level must then be run on the applicant's brake assembly, i.e., a back-to-back demonstration of the two brakes. The need for additional test runs on the applicant's brake will be determined after the first test. If the applicant's brake shows good correlation to the OEM brake, additional tests will not be necessary.

(ee) The correlation factor between the OEM and the applicant's tests must be such that the results of the applicant's tests can be shown to be equivalent to or better than the OEM tests.

(ff) Constant maximum braking force pressure appropriate to the airplane braking system must be applied during the tests.

(gg) Fuse plugs may be released or the tire deflated after each test run, to reduce the risk to test personnel.

(hh) The functional landings already completed were also a required part of this approval.

4 This additional dynamometer testing in lieu of actual airplane testing was applied in this case due to the unusual circumstances relating to the applicant's application. The applicant had considerable manufacturing experience with brake parts, indicated by long and trouble-free service history in the Air Force inventory. While this Air Force service history was not directly applicable to commercial operations, and would not in itself be a basis for FAA approval, it did indicate that the applicant's parts performed adequately in service. This gave a measure of confidence that the ultimate energy dynamometer testing to be performed would be successfully completed.

5 It should not be inferred from this action taken on this specific brake part proposed by this applicant that this dynamometer test procedure will be applicable to any other application, either from this applicant or other manufacturers. Each request for approval should be judged on its own merits.

(9) Ground Equipment - Brake Cooling Unit. The following is extracted from an FAA letter dated December 27, 1988, which addresses certification of an aircraft wheel/brake cooling unit.

(a) This type of equipment is not approved as part of the aircraft type certificate. The FAA does not impose any technical standards on most ground-support equipment that is used to support airline operations. Ground service trucks, baggage carts, and the device proposed by the applicant fall into this category. The only exception to this is if the particular item of ground equipment performs a critical function, or could cause damage to the airplane if used incorrectly. Examples of the latter include portions of jacking equipment which must mate with jacking fittings on the airplane, towing bars that attach to the nose gear, and fuel systems on fuel trucks to ensure cleanliness of the fuel.

(b) Airlines that choose to use the wheel/brake cooling device proposed by the applicant would be responsible for showing that the device is appropriate for its intended use in their operations and would not pose a hazard to their personnel or the airplane. In addition, performance credit for reduced ground turn-around time (required time for brake cooling prior to the next takeoff) cannot be granted without an evaluation of the effectiveness of the device by the appropriate FAA Aircraft Certification office.

(10) Certification Requirements for Asbestos-Free Brake Linings. The following is extracted from an FAA letter dated December 16, 1987, which addresses guidance for certification of replacement brakes with asbestos-free linings, based only on dynamometer and TSO testing.

(a) The testing requirements in AC 25-7A, Flight Test Guide for Transport Category Airplanes (formerly FAA Order 8110.8, paragraph 89(b)), relate to the addition of a highly modified brake design to an existing type certificated airplane. A highly modified brake is defined in this section as one which contains new or modified parts which in turn will cause a significant variance in the kinetic energy absorption characteristics of the brake. It has been our experience that airplane performance cannot be adequately predicted from the dynamometer testing specified in the TSO. While it may be satisfactory to assign some performance penalty to compensate for this, there remains the question of the effect of the change in friction materials on fuse plug performance, ground handling, and brake sensitivity. AC 25-7A, chapter 4, section 4, paragraph 55, issued March 31, 1998, contains relevant portions of canceled FAA Order 8110.8, and additional information.

(b) In addition, the coefficient of friction wear rates of the new materials may prove to be different from the original. In order to adequately demonstrate the performance of a major change to the brakes or brakes control system, a maximum kinetic energy RTO, as described in AC 25-7A (formerly Order 8110.8), would normally be required, as well as six functional takeoffs and landings. In addition, fuse plug substantiation test (melt and no-melt) would be required (if applicable), unless it can be demonstrated that heat transfer from the brake stack to the wheel is identical to the original. Also, antiskid-on and antiskid-off tests (if applicable), qualitative taxi tests, and wet runway tests (antiskid-on, if applicable) would be required. These test procedures are described in AC 25-7A (formerly Order 8110.8, paragraph 89(f)).

(c) It is noted that numerous older airplanes may use these new asbestos-free brakes. The intent of the test program discussed above is to validate the brake change, as it affects each type design under consideration. It is important to note that each airplane type which uses these brakes provides a different operating environment, considering landing gear geometry, dynamic response, weight, rate of energy absorption, etc. As stated in AC 25-7A (formerly Order 8110.8, paragraph 89(b)), a sufficient number of conditions to verify the existing approved performance levels on each type design would be required. The actual content of the test program would depend on many factors, including the similarity of the old and new designs, the relative performance envelopes of the demonstrated brake and candidate airplane, effect of the new brake design on fuse plug performance (if applicable), presence or absence of antiskid systems, and possible effects of the change on ground handling. It is also possible that the addition of these new brakes to certain existing airplanes could be considered to be a minor change, in which case AC 25-7A (formerly Order 8110.8, paragraph 89(b)) would apply, and only uninstrumented functional landings would be required. It was recognized that it may be impossible to duplicate test data that may have been created over 20 years ago, especially if the airplane in question is not equipped with an antiskid system. In this case, it may be appropriate to apply a suitable performance penalty to allow for this uncertainty. In any event, engineering judgment should be applied to each individual situation so that the intent of the test program discussed above will be followed.

(d) While the performance of the new brake must be no less than that of the originally approved brake, it also should not be greater; e.g., a higher brake torque is desirable for reducing stopping distance but may be undesirable for structural integrity of other components of the landing gear. Original landing gear designs are based on structural analysis, which could be adversely affected by a brake system change.

(11) Certification Requirements for Brake Components - Performance. The following is extracted from an FAA letter dated October 26, 1987, which addresses "major" and "minor" changes to aircraft brake components and explains FAA policy on this subject.

(a) Measured accelerate-stop distance, landing distance, and functional flight tests may be required depending upon an evaluation of the individual characteristics of each brake system change and in order to establish aircraft landing and RTO certification performance levels for a replacement or modified brake. The type and magnitude of flight tests required will depend on whether or not a requested change to the brake involves a change in heat sink capacity or torque requirements of the original certificated brake. In addition, such tests will also depend on whether or not an increase in the FAA certificated performance level is desired by the applicant, and whether the proposed change to the brake would affect the landing gear static or dynamic loads.

(b) The flight test procedures applicable to brake certification, among others, are contained in AC 25-7A, Flight Test Guide for Transport Category Airplanes (formerly FAA Order 8110.8). The testing requirements in AC 25-7A (formerly Order 8110.8, paragraph 89(b)), relate to the addition of a highly modified brake design to an existing type certificated airplane. A highly modified brake is defined in this section as one which contains new or modified parts which in turn will cause a significant variance in the kinetic energy absorption characteristics of the brake. The FAA concurs that a change to either the rotors or stators in a previously approved brake could meet this definition, and be considered a major change. In order to adequately demonstrate the performance of a major change to the brakes or brake control system, a maximum kinetic energy RTO, as described in AC 25-7A (formerly Order 8110.8), would normally be required, as well as six functional takeoffs and landings. In addition, fuse plug substantiation tests (melt and no-melt) would be required (if applicable), unless it can be demonstrated that heat transfer from the brake stack to the wheel is identical to the original. Also, antiskid-on and antiskid-off tests (if applicable), qualitative taxi tests, and wet runway tests (antiskid-on, if applicable) would be required. Order 8110.8 has been canceled. Relevant portions of Order 8110.8 and additional information have been included in AC 25-7A, chapter 4, section 4, paragraph 55.

(c) Minor brake changes that cannot affect airplane braking performance may require functional landings. This may be required to verify airplane-pilot-brake-antiskid combination compatibility. Normally, five non-instrumented functional landings are considered sufficient to verify this compatibility. A change to thicker friction material, heavier heat sink elements, or other structural improvements generally fall into this minor change category, and the effect of the weight change on landing gear performance and other airplane effects would be evaluated. If the change to the brake resulted in a lighter weight heat sink, the effects of this change would be carefully evaluated to ensure that the thermal characteristics of the brake, wheel, axle, fuse plugs, or other landing gear structure is not adversely affected.

(d) Technical Standard Order (TSO) approval of a modification to a brake is only the first step towards approval for the brake to be installed on an airplane. In each case, the modification must be shown to have no adverse effect on airplane performance. Depending on the magnitude of the proposed change, this demonstration may consist of functional tests only, a full test program, or a selection of the various test procedures described in AC 25-7A (formerly Order 8110.8). Enough flexibility exists in FAA procedures to allow for a thorough evaluation of a proposed brake change without causing undue burden on the applicant. In any event, if there is a question whether or not a given modification to a brake will result in a change to the certificated performance of the airplane, FAA policy has been to demonstrate the performance change on the airplane, or, at the very least, to impose a suitable performance penalty so as to cover any eventuality. There are no plans to relax this requirement.

(12) Approval of Brake Components Utilizing New Brake Friction Material. The following is extracted from an FAA memorandum dated July 27, 1987, which addresses guidance regarding certification of brake components utilizing new brake friction material.

(a) This is in response to questions regarding an approval for new replacement brake pads. For the purpose of approving a replacement brake pad, the FAA may issue a design approval by either a Parts Manufacturer Approval (PMA) or a Technical Standard Order Authorization (TSOA) followed by a Supplemental Type Certificate (STC) for installation, or a procedure using an STC followed by a PMA for production. Each of these approval methods is discussed below. Once a PMA approval is given, the applicant could then mark the brake assembly with his own nameplate, indicating the method of approval (STC number), without altering the existing TSO nameplate.

(b) Issuance of a PMA. If the applicant intends to show identicality with existing TSO-authorized parts, he must consider not only the form and fit of the parts, but also the chemical and/or metallurgical characteristics (including microstructure, surface and crosssectional hardness, and material spectrum analysis), and process and manufacturing specifications. Previous experience with various brake manufacturers has shown that it is extremely difficult to duplicate the physical and chemical characteristics of brake lining materials. For example, two linings with similar hardness or other measurable characteristics could have been produced using different process specifications. If the applicant satisfactorily shows that his parts are indeed identical to the originals, the change could then be considered to be a "minor change," as discussed in AC 25-7A (formerly Order 8110.8, paragraphs 89(b, (c)). Five non-instrumented landings would be sufficient to demonstrate compatibility between the airplane, pilot, brake, and anti-skid systems on the airplane. With respect to the TSO, a statement of conformance and submittal of the data showing identicality would be sufficient. Order 8110.8 has been canceled. Relevant portions of Order 8110.8 and additional information have been included in AC 25-7A, chapter 4, section 4, paragraph 55.

(c) Issuance of a TSOA+STC or an STC+PMA. If the applicant is unable to demonstrate identicality, the change must then be considered to be a major change, since the coefficient of friction and wear rates may be different, and the new parts could, therefore, cause a significant variance in the heat sink capacity, the torque characteristics, or the kinetic energy absorption characteristics of the brake. It would be necessary, therefore, for the applicant to demonstrate compliance with the pertinent parts of TSO-C26c, including the 100 landing stops and 1 accelerate-stop described in Table III of § 4.2 of the TSO.

(d) In addition to the TSO requirements, a maximum kinetic energy Rejected Takeoff (RTO), as described in AC 25-7A (formerly Order 8110.8), must be conducted in the airplane, as well as six functional takeoffs and landings. In addition, fuse plug substantiation tests (melt and no-melt) must be conducted, unless the applicant can demonstrate that heat transfer from the brake stack to the wheel is identical to the original. Also, antiskid-on and antiskid-off tests, qualitative taxi tests, and wet runway tests (antiskid-on) must be conducted. These test procedures are described in AC 25-7A (formerly Order 8110.8, paragraph 89), and are required to adequately demonstrate the performance of the new lining material .

(e) If the applicant successfully demonstrates that the performance of the brake with his parts installed is identical to the original, he may mark the brake as described above. If the demonstrated performance is greater than that of the original, however, an FAA evaluation by the cognizant ACO is essential, since original landing gear designs are based on structural analysis which could be adversely affected by a brake system change.

(13) <u>Maximum Quick Turnaround Times.</u> The following is extracted from an FAA letter dated August 19, 1983, which addresses a request to intermix brakes from different manufacturers for testing of the fuse plug integrity and receive certification credit for each brake/wheel system.

(a) It is fundamental FAA policy to test the complete configuration of an airplane system that is to be certificated for transportation service. In this case the applicant proposed to certificate two unmixed configurations, the Original Equipment Manufacturer 1(OEM1) and the Original Equipment Manufacturer 2 (OEM2) wheel/brake systems. In general, the FAA does not certificate unmixed configurations based solely on a test of mixed configurations. Further, certification of the mixed configuration requires extensive testing, beyond the test outlined in AC 25-7A (formerly FAA Order 8110.8). Order 8110.8 has been canceled. However, the relevant portions of the Order and additional information have been included in AC 25-7A, chapter 4, section 4, paragraph 55.

(b) Precedent tests previously accepted by the FAA have been cited. These cases were judged on their merits, as must be done here. Approval of the eutectic melt temperature reduction was based on dynamometer tests and an analysis. In that case, wherein the wheel/brake configuration was fixed and test date/analysis were provided, the FAA judged equivalency in a single system element (fuse plugs). The FAA did not consider it appropriate to compare the equivalency finding in the foregoing case to that of mixing wheel/brake configurations for establishing new turnaround limitations.

(c) The OEM1 and OEM2 wheel/brake configurations are “similar in design and performance" was cited as justification to allow mixed wheel/brake fuse plug turnaround testing. The FAA noted that the wheel brake designs were intended to mount on the same axle using the same hydraulic and antiskid/autobrake systems and brake torque reaction rods. Both wheel/ brake assemblies have double heat shields and the tolerance of the OEM1 fuse plug is inside the tolerance of the OEM2 fuse plug. The nominal difference is not considered significant.

(d) The structural arrangement in detail, however, is different in a number of places, including in and around the fuse plugs. The FAA must assume the variations in metal mass and configuration will affect heat transfer. Also, there are differences in the hydraulic actuators. The brakes themselves are made up of proprietary materials that will exhibit different thermal reactions. The wheels are similar in appearance because they have to be interchangeable; however, it has not been established that they are similar relative to the fuse plug performance.

(e) "Significant margin exists for higher certificated no melt energy levels" is also proposed. It is the FAA's understanding that the applicant intends to use this margin, derived from dynamometer tests minus airplane test data available, to increase the fuse plug "no melt" energy. The FAA has determined this increase is a valid reason to substantiate by test both configurations, i.e., OEM1 and OEM2, with the wheels and brakes in the unmixed state.

(f) The applicant proposed that twice as many fuses be instrumented as in the basic certification. This would give useful empirical data, although the FAA does not require fuse plug instrumentation. In the final analysis, the success of the test is judged by whether the fuse plug integrity is maintained.

(g) In light of the foregoing, the FAA has determined that each wheel/brake configuration should be tested separately for the "no melt" condition to provide a technically defensible minimum wheel/brake fuse plug sample size. This decision is consistent with FAA policy published in AC 25-7A, Flight Test Guide for Transport Category Airplanes, chapter 4, section 4, paragraph 55. This information was in Order 8110.8, paragraphs 89(a), (b), and (c), which has been canceled. However, the relevant portions of the Order and additional information have been included in AC 25-7A,

(h) It has been suggested that the proposed intermix and test procedure ensures minimal data scatter between brakes. If this statement means that the test data scatter between the two tire/wheel configurations will be minimized because all the data will be collected on one test run versus two, which may occur at separate times of the day or different days under varying conditions, then we can concur. However, this does not lend credence to the selection of an inadequate sample size. The proposal does not address what occurs if differences in brake performance are observed; or how to establish a significant difference (which could affect turnaround times), when comparing one brake system to another.

e. References. The addresses for ordering the latest revision of advisory circulars, technical standard orders, and other referenced documents listed below can be found in the Appendix 4 to this AC.

TSO-C26, was an acceptable standard to CAA but not part of the regulations.
TSO-C26a, was part of regulations as § 514.72 of the CAR.
TSO-C26b, was part of regulations as § 37.172.
TSO-C26c, was part of regulations as § 37.172 of 14 CFR.
TSO-C26c with Addendum I, was removed from regulations (§ 37.172, Amendment 25-52, 1980) and became a voluntary standard.
AC 25-7A, Flight Test Guide for Transport Category Airplanes (formerly FAA Order 8110.8).
AC 43.13-1A, Acceptable Methods, Techniques and Practices- Aircraft Inspection and Repair; L. G. Equipment.
FAA Letter, Dynamometer Test Guidelines to Establish Brake wear Limits.
FAA's Wheels and Brakes Approval Process Videos, parts 1 and 2.
SAE AS-1145A - Aircraft Brake Temperature Monitor System.
SAE ARP-1907 - Automatic Braking Systems Requirements.
SAE AIR-1064C - Brake Dynamics.
SAE ARP-1070B - Design and Testing of Antiskid Brake Control.
SAE AIR-1739 - Information on Antiskid Systems.
SAE ARP-813B - Maintainability Recommendations for Aircraft Wheels and Brakes.
SAE ARP-1619 - Replacement and Modified Brakes and Wheels.
SAE AS-483A - Skid Control Equipment.
SAE ARP-862A - Skid Control Performance.
SAE AIR-1934A - Use of Carbon Heat Sink Brakes on Aircraft.
SAE ARP-597C - Wheels and Brakes, Supplementary Criteria for Design Endurance.

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Section 3. PERSONNEL AND CARGO ACCOMMODATIONS

15. SECTION 25.773 - PILOT COMPARTMENT VIEW.

a. Rule Text.

(a) Nonprecipitation conditions. For nonprecipitation conditions, the following apply:
(1) Each pilot compartment must be arranged to give the pilots a sufficiently extensive, clear, and undistorted view, to enable them to safely perform any maneuvers within the operating limitations of the airplane, including taxiing, takeoff, approach, and landing.
(2) Each pilot compartment must be free of glare and reflection that could interfere with the normal duties of the minimum flight crew (established under § 25.1523). This must be shown in day and night flight tests under nonprecipitation conditions.
(b) Precipitation conditions. For precipitation conditions, the following apply:
(1) The airplane must have a means to maintain a clear portion of the windshield, during precipitation conditions, sufficient for both pilots to have a sufficiently extensive view along the flight path in normal flight attitudes of the airplane. This means must be designed to function, without continuous attention on the part of the crew, in –
(i) Heavy rain at speeds up to 1.6 V_{S1} with lift and drag devices retracted; and
(ii) The icing conditions specified in § 25.1419 if certification with ice protection provisions is requested.
(2) The first pilot must have –
(i) A window that is openable under the conditions prescribed in paragraph (b)(1) of this section when the cabin is not pressurized, provides the view specified in that paragraph, and gives sufficient protection from the elements against impairment of the pilot's vision; or
(ii) An alternate means to maintain a clear view under the conditions specified in paragraph (b)(1) of this section, considering the probable damage due to a severe hail encounter.
(c) Internal windshield and window fogging. The airplane must have a means to prevent fogging of the internal portions of the windshield and window panels over an area which would provide the visibility specified in paragraph (a) of this section under all internal and external ambient conditions, including precipitation conditions, in which the airplane is intended to be operated.
(d) Fixed markers or other guides must be installed at each pilot station to enable the pilots to position themselves in their seats for an optimum combination of

outside visibility and instrument scan. If lighted markers or guides are used they must comply with the requirements specified in § 25.1381.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-23, Apr. 8, 1970; Amdt. 25-46, Oct. 30, 1978; Amdt. 25-72, Jul. 20, 1990]

b. Intent of rule. The intent of this rule is for the flight deck windshield to provide sufficient external vision to permit the pilot to safely perform any maneuvers within the operating limits of the aircraft and, at the same time afford an unobstructed view of the flight instruments and other critical components and displays from the same eye position.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Section 4b.351 of the CAR became § 25.773 of 14 CFR for pilot compartment view.

(1) Amendment 25-23 (April 8, 1970) added a new § 25.773(c) to require means to prevent fogging of the internal portions of the windshield and window panels which can occur under certain temperature and humidity conditions and create a hazardous situation.

(2) Amendment 25-46 (October 30, 1978) added a new § 25.773(d) requiring means (such as fixed markers) to guide the pilot to determine an optimum seat position for proper visibility.

(3) Amendment 25-72 (July 20, 1990) revised § 25.773(b)(1)(i) for clarity and consistency with actual certification practice by specifying that all lift and drag devices, e.g., slats and spoilers as well as flaps, must be retracted. In addition, section 25.773(b)(2) was revised to allow alternate means of compliance to maintain clear vision as opposed to an openable sliding window being the only means.

(4) Harmonization. Parts of this regulation (§ 25.773(b)(2) and (b)(4)) will be the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC harmonization working group may adopt parts of both FAR and JAR as well as revise AC 25.783-1.

d. Policy/Compliance Methods. For guidance with this requirement, refer to the preamble of this rule and Advisory Circular (AC) 25-7A, Flight Test Guide for Certification of Transport Category Airplanes, and AC 25.773-1, Pilot Compartment View for Transport Category Airplanes.

e. References. None.

16 - 25. [RESERVED]

26. SECTION 25.783 - DOORS.

a. Rule Text.

(a) Each cabin must have at least one easily accessible external door.
(b) There must be a means to lock and safeguard each external door against opening in flight (either inadvertently by persons or as a result of mechanical failure or failure of a single structural element either during or after closure). Each external door must be openable from both the inside and the outside, even though persons may be crowded against the door on the inside of the airplane. Inward opening doors may be used if there are means to prevent occupants from crowding against the door to an extent that would interfere with the opening of the door. The means of opening must be simple and obvious and must be arranged and marked so that it can be readily located and operated, even in darkness. Auxiliary locking devices may be used.
(c) Each external door must be reasonably free from jamming as a result of fuselage deformation in a minor crash.
(d) Each external door must be located where persons using them will not be endangered by the propellers when appropriate operating procedures are used.
(e) There must be a provision for direct visual inspection of the locking mechanism to determine if external doors, for which the initial opening movement is not inward (including passenger, crew, service, and cargo doors), are fully closed and locked. The provision must be discernible under operational lighting conditions by appropriate crewmembers using a flashlight or equivalent lighting source. In addition, there must be a visual warning means to signal the appropriate flight crewmembers if any external door is not fully closed and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed and locked indication is improbable for doors for which the initial opening movement is not inward.
(f) External doors must have provisions to prevent the initiation of pressurization of the airplane to an unsafe level if the door is not fully closed and locked. In addition, it must be shown by safety analysis that inadvertent opening is extremely improbable.
(g) Cargo and service doors not suitable for use as emergency exits need only meet paragraphs (e) and (f) of this section and be safeguarded against opening in flight as a result of mechanical failure or failure of a single structural element.
(h) Each passenger entry door in the side of the fuselage must meet the applicable requirements of §§ 25.807 through 25.813 for a Type II or larger passenger emergency exit.
(i) If an integral stair is installed in a passenger entry door that is qualified as a passenger emergency exit, the stair must be designed so that under the following conditions the effectiveness of passenger emergency egress will not be impaired:
(1) The door, integral stair, and operating mechanism have been subjected to the inertia forces specified in 25.561(b)(3), acting separately relative to the surrounding structure.

(2) The airplane is in the normal ground attitude and in each of the attitudes corresponding to collapse of one or more legs of the landing gear.
(j) All lavatory doors must be designed to preclude anyone from becoming trapped inside the lavatory, and if a locking mechanism is installed, it be capable of being unlocked from the outside without the aid of special tools.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-15, 32 FR 13262, Sep. 20, 1967; Amdt. 23-23, 35 FR 5676, Apr. 8, 1970; Amdt. 25-54, 45 FR 60173, Sep. 11, 1980; Amdt. 25-72, 55 FR 29780, Jul. 20, 1990; Amdt. 25-88, 61 FR 57956, Nov. 8, 1996]

b. Intent of Rule. The intent of the term "reasonably free" is to provide proper dimensional clearances around door structure and seals. The requirement is also defined under § 25.809(g): "There must be provisions to minimize the probability of jamming of the emergency exits resulting from fuselage deformation in a minor crash landing."

c. Background. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group is tasked to recommend revisions to § 25.783 and related crashworthiness regulations and to recommend revisions to AC 25.783-1A.

d. Policy/ComplianceMethods. For policy and guidance on compliance with this requirement, refer to Advisory Circular (AC) 25-783-1, Fuselage Doors, Hatches, and Exits; AC-25-21, Certification of Transport Airplane Structure, paragraph 85; and AC 25-17A, Transport Airplane Cabin Interiors Crashworthiness Handbook.

e. Reference. None.

27 - 29. [RESERVED]

Section 4. VENTILATION AND HEATING

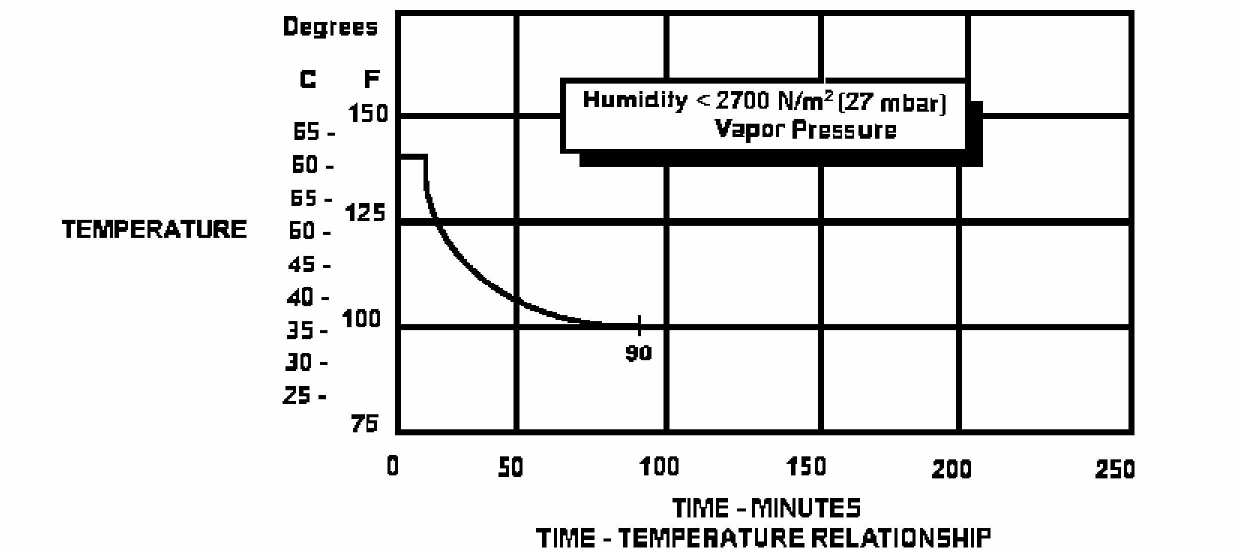
36. SECTION 25.831 - VENTILATION.

a. Rule Text.

(a) Under normal operating conditions and in the event of any probable failure conditions of any system which would adversely affect the ventilating air, the ventilation system must be designed to provide a sufficient amount of uncontaminated air to enable the crewmembers to perform their duties without undue discomfort or fatigue and to provide reasonable passenger comfort. For normal operating conditions, the ventilation system must be designed to provide each occupant with an airflow containing at least 0.55 pounds of fresh air per minute.
(b) Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapors. In meeting this requirement, the following apply:
(1) Carbon monoxide concentrations in excess of 1 part in 20,000 parts of air are considered hazardous. For test purposes, any acceptable carbon monoxide detection method may be used.
(2) Carbon dioxide concentration during flight must be shown not to exceed 0.5 percent by volume (sea level equivalent) in compartments normally occupied by passengers or crewmembers.
(c) There must be provisions made to ensure that the conditions prescribed in paragraph (b) of this section are met after reasonably probable failures or malfunctioning of the ventilating, heating, pressurization, or other systems and equipment.
(d) If accumulation of hazardous quantities of smoke in the cockpit area is reasonably probable, smoke evacuation must be readily accomplished, starting with full pressurization and without depressurizing beyond safe limits.
(e) Except as provided in paragraph (f) of this section, means must be provided to enable the occupants of the following compartments and areas to control the temperature and quantity of ventilating air supplied to their compartment or area independently of the temperature and quantity of air supplied to other compartments and areas:
(1) The flight crew compartment.
(2) Crewmember compartments and areas other than the flight crew compartment unless the crewmember compartment or area is ventilated by air interchange with other compartments or areas under all operating conditions.
(f) Means to enable the flight crew to control the temperature and quantity of ventilating air supplied to the flight crew compartment independently of the temperature and quantity of ventilating air supplied to other compartments are not required if all of the following conditions are met:
(1) The total volume of the flight crew and passenger compartments is 800 cubic feet or less.

(2) The air inlets and passages for air to flow between flight crew and passenger compartments are arranged to provide compartment temperatures within 5 degrees F. of each other and adequate ventilation to occupants in both compartments.
(3) The temperature and ventilation controls are accessible to the flight crew.
(g) The exposure time at any given temperature must not exceed the values shown in the following graph after any improbable failure condition.

temperature curve from Amdt. 25-87



[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-41, 42 FR 36970, Jul. 18, 1977; Amdt. 25-87, 61 FR 28695, Jun. 5, 1996; Amdt. 25-89, 61 FR 63956, Dec. 2, 1996]

b. Intent of Rule. The intent of this rule is to supply passengers and crewmembers with enough uncontaminated air to provide reasonable comfort during normal operating conditions and also after any probable failure of any system that would adversely affect the cockpit or cabin ventilation air.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The majority of the requirements from section 4b.371 of the CAR were carried over directly to § 25.831 of 14 CFR for ventilation.

(1) Amendment 25-41 (July 18, 1977) revised the rule to clarify the requirements for the means by which crewmembers can control the temperature and quantity of ventilating air in the flight crew compartment and compartments occupied by other crew members.

(2) Amendment 25-87 (June 5, 1996) revised the rule to codify special conditions that had been used to certify certain airplanes for high altitude operation (maximum altitudes up to

45,000 or 51,000 feet). The amendment added the requirement that each occupant be provided with 0.55 pounds (equivalent to 10 cubic feet) per minute of fresh air, reference § 25.831(a). The amendment also specifies limits for interior temperatures after specific failures, reference § 25.831(g). Compliance to Amendment 25-87 is required for only those airplanes whose certification basis includes this amendment. Most of the airplanes that are currently produced do not fall into this category. An accompanying advisory circular, AC 25-20, Pressurization, Ventilation, and Oxygen Systems Assessment for Subsonic Flight including High Altitude Operation, was also issued to provide one means, but not the only means, of compliance to the regulations affected by Amendment 25-87.

(3) Harmonization. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group will be tasked to recommend revisions to §§ 25.831, 25.841, and related regulations and to recommend revisions to AC 25.20.

(4) Amendment 25-89 (December 2, 1996) revised § 25.831(b)(2) to change the carbon dioxide requirements from three percent by volume to 0.5 percent by volume (sea level equivalent). The following information is extracted from an FAA letter dated May 18, 1999, to the Society of Automotive Engineers (SAE) Committee AC-9, Aircraft Environmental Systems, to acknowledge an error in the preamble to Amendment 25-89, page P-610, 3rd paragraph. It states that ". . . sea level equivalent (SLE) for a cabin altitude of 8,000 feet would be 0.5 percent multiplied by 0.74 . . ." The word "multiplied" should have read "divided." The FAA does not feel that an increase in carbon dioxide concentration from 0.5 percent SLE to 0.68 percent at altitude will introduce an appreciable discomfort or hazard to passengers and maintains a concentration level well below industry recommendations for carbon dioxide exposure.

d. Policy/Compliance Method. For guidance on compliance with this requirement, refer to the preambles of this rule and the following information.

(1) Ventilation rates are determined by tests and/or analyses. For compliance with § 25.831(b) and (c), carbon monoxide and carbon dioxide levels may be measured with hand held samplers or gas measurement devices for the various flight conditions, such as takeoff, cruise, and landing. Measurements are made at "head" level in the cockpit, other compartments occupied by crewmembers, and in the passenger cabin.

(2) Smoke Evacuation. For compliance with § 25.831(d), cockpit smoke evacuation test methods are addressed in AC 25-9A, Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures. The AC 25-9A also provides guidance regarding lavatories, galleys, crew rest areas, equipment cooling bays, and cargo compartments smoke detection/penetration/evacuation.

(3) Ventilation System Design. The ventilation system design should be reviewed and tests or analyses conducted to ensure compliance with § 25.831(e) and (f), which address control of temperatures and ventilating air quantity in compartments occupied by crewmembers.

(4) Airplane Operation with Airconditioning Packs Off. The following policy is extracted from an FAA memorandum dated September 3, 1999, in response to questions regarding compliance with § 25.831 while operating with the airconditioning packs off.

(a) Background. The following summarizes some key elements that are necessary to understand in determining the certification policy regarding cabin ventilation, smoke detection and evacuation, and equipment cooling.

(b) The provisions of § 25.831(a), as amended by Amendment 25-41, state: "Each passenger and crew compartment must be ventilated, and each crew compartment must have enough fresh air (but not less than 10 cu. ft. per minute per crewmember) to enable crewmembers to perform their duties without undue discomfort or fatigue".

(c) A 1983 memo addressing airconditioning packs-off operation provides additional guidance to the regulatory provisions of § 25.831(a), as amended by Amendment 25-41.

1 The memo states: "The proposed environmental control system (ECS) takeoff procedure for the Model ABC should be processed for certification by an exemption to 25.831(a)."

2 The memo also states: "Analysis and tests have been used to substantiate that operating without the required 10 cubic feet per minute per pilot (§ 25.831(a)) for short duration will not impair pilot performance or significantly affect equipment reliability. This is not to say that the pilots need be comfortable. These ECS 'off' approvals were made in accordance with adequate criteria, but not all were made in accordance with correct certification procedures (i.e., equivalency or exemption)."

(d) Subsequently, Amendment 25-87, effective April 30, 1998, amended several of the airworthiness provisions concerning cabin ventilation. Section 25.831(a) was changed to require that ". . . the ventilation system must be designed to provide a sufficient amount of uncontaminated air to enable the crewmembers to perform their duties without undue discomfort or fatigue and to provide reasonable passenger comfort. For normal operating conditions, the ventilation system must be designed to provide each occupant with an airflow containing at least 0.55 pounds of fresh air per minute."

1 The preamble to Amendment 25-87 adds the following additional information. "One commenter recommends allowing the fresh air requirements proposed to be required under § 25.831(a) to remain a crewmember requirement only. The FAA does not concur with this recommendation. It has been determined that this level of airflow is required for several reasons. Members of the flightcrew performing their functions in the passenger cabin are not sedentary and must perform their duties without undue discomfort or fatigue. In addition, fresh airflow has been determined to be necessary to provide adequate smoke clearance in the event of smoke accumulation due to a system failure or fire. However, it is clear that the

additional airflow is not required at all times and under all operating conditions. Therefore, the wording in the final rule has been changed to state that the ventilation system must be designed to provide the fresh airflow. This also addresses concerns regarding the low fresh airflow capability that occurs during descent at low power levels."

(e) Advisory Circular 25-20 was developed concurrent with Amendment 25-87. Paragraph 5d states: "Takeoff with airconditioning or bleed air system 'off' may be an acceptable procedure provided the ventilation system continues to provide an acceptable environment in the passenger cabin and cockpit for the brief period when the ventilation system is not operating normally."

(f) The Draft Version of this AC (dated November 30, 1998) was issued for public comment as well as coordinated for directorate comments. This AC includes a statement that recommends that the exemption process be used to approve the cabin ventilation system for operation with airconditioning packs-off operation. However, the Aerospace Industries Association (AIA) has questioned the need for an exemption and stated that the no packs takeoff procedures already exist; that as the transient for this condition is short, this is an accepted practice; and that it does not cause the cabin environment to be unsafe. In addition, the Los Angeles Aircraft Certification Office (ACO) commented that an equivalent safety finding was more appropriate than an exemption.

(g) Analysis. The Transport Standards Staff's (TSS) interpretation of the provisions of § 25.831(a), as amended by Amendment 25-41, is that the prescribed airflow for the flightcrew is required to be provided during normal operation. However, the certification records do not show that any such equivalent safety finding or exemption for airconditioning packs-off operation (i.e., no fresh air for crewmembers) was issued for the model ABC or for any other transport category airplane. Therefore, the TSS assumes that any transport category airplane for which the AFM allows packs-off operation, does not strictly comply with the provision of § 25.831(a), as amended by Amendment 25-41.

<u>1</u> Recognizing that the cabin ventilation provisions of Amendment 25-41 were overly restrictive, the FAA, in Amendment 25-87, changed the requirement of § 25.831 so that the regulatory provision now reads: *" . . . the ventilation system must be designed to provide a sufficient amount of uncontaminated air to enable the crewmembers to perform their duties without undue discomfort or fatigue . . ."*

<u>2</u> The preamble discussion quoted above states that the reason for this change is that ". . . it is clear that the additional airflow is not required at all times and under all operating conditions."

<u>3</u> Therefore, provisions of § 25.831, as amended by Amendment 25-87, specify a <u>design</u> requirement and allow for limited interruptions of the specified design airflow. However, this interruption may not result in "<u>undue</u>" discomfort or fatigue to the crewmembers. Advisory Circular (AC) 25-20, which was developed concurrently with Amendment 25-87, supports this interpretation (see excerpt above).

4 Furthermore, an airplane accident heightened FAA awareness to the need to address smoke penetration and include cargo compartment fire protection (detection and suppression) throughout the flight, including taxi, takeoff and climb. When determining compliance with the sections of part 25 relating to flight crew compartment air quality, ventilation, smoke penetration/evacuation, cargo compartment fire protection (detection and suppression) and equipment cooling, all the impacts related to operating with the airconditioning packs off for a limited time must be determined. The TSS considers the failure to document any consideration of these issues in previous compliance findings an oversight by the FAA.

5 While direct compliance to § 25.831(a), as amended by Amendment 25-87, for airconditioning packs-off operation is possible without using an equivalent safety finding; an equivalent safety finding (§ 21.21(b)(1)) may be used for showing compliance with the provisions of § 25.831(a), as amended by Amendment 25-41, for airconditioning packs-off operation.

(h) Conclusion. The TSS has determined that while direct compliance to § 25.831(a), as amended by Amendment 25-87, for airconditioning packs-off operation is possible without using an equivalent safety finding, an equivalent safety finding (§ 21.21(b)(1)) may be used for showing similar compliance with the provisions of § 25.831(a), as amended by Amendment 25-41. The equivalent safety finding must document that the ventilation system continues to provide an acceptable environment in the passenger cabin and cockpit for the brief period when the ventilation system is not operating normally. The degradation of crewmember air quality must not reach the level that would cause undue discomfort and fatigue to the point that it could affect the performance of their duties.

(i) Advisory Circular (AC) 25.1581-1, Airplane Flight Manual, issued in 1997, states in paragraph 2b(11), Systems and Equipment Limitations, that; *"all limitations applicable to systems and equipment installations that are considered necessary for safe operation must be included."* Airconditioning packs-off operation is intended to be a short duration operation. Therefore, the maximum period of operation in this configuration should be defined by the applicant and specified in the AFM, along with any related operating procedures necessary to maintain compliance with the regulatory issues discussed above. An example of establishing "the maximum period of operation (short duration) for takeoff" would be an operational phase beginning with turning packs off when cleared into position for takeoff, and ending when packs were turned back on after takeoff thrust was reduced to climb thrust or when accomplishing the "after-takeoff" checklist.

(j) Packs-On and Packs-Off. In accordance with §§ 25.855 and 25.857, there must be a means to exclude hazardous quantities of smoke, flames, or extinguishing agent from any compartment occupied by crew or passengers. The FAA has historically found compliance to these requirements for packs-on operation but has not recognized the need to assess compliance with requirements for limited duration packs-off operation. A change in precedent set by historical practice is beyond the scope of this informational memorandum. The Transport Standards Staff (TSS) recognizes that service experience to date has not demonstrated that packs-off operations have resulted in hazardous quantities of smoke. Therefore, at this time, determination that packs-off operation is acceptable can be predicated on an FAA finding that no unsafe condition due to limited duration packs-off operation would result should a cargo compartment fire occur. Criteria that should be considered include: (1) packs-on operation will not allow any smoke from the cargo compartment to penetrate the passenger compartment; and (2) during limited duration packs-off operations the cargo compartment smoke detection system is effective and the aircondition packs can be turned on and returned to the approved packs-on configuration to exclude hazardous quantities of smoke. The local ACO may make a determination of compliance to the aforementioned criteria based upon available test data, analysis and extrapolation of these data, as has been historically accepted to demonstrate compliance to these and other sections of part 25.

(5) Fresh Air and Normal Operating Conditions. The following policy is extracted from an FAA memorandum dated September 10, 1997, in response to questions regarding the terms "fresh air" and "normal operating conditions" as it applies to compliance with § 25.831.

(a) The term "fresh air" was first documented with the ventilation requirements in § 4b.371 of the CAR. Section 4b.371(a) of the CAR required that all crew compartments be ventilated with a sufficient amount of fresh air. It was specified that "an outside air supply of approximately 10 cubic feet per minute is considered a minimum for each crewmember." This requirement was later codified into 14 CFR § 25.831(a).

(b) Notice of Proposed Rulemaking (NPRM) 89-31 first proposed that § 25.831(a) be amended to include additional minimum airflow requirements for both crew and passengers. NPRM 89-31 and Amendment 25-87 proposed that the minimum fresh airflow of 10 cubic feet per minute per crewmember be provided to each occupant during normal operation. Both the "Discussion" section of NPRM 89-31 and the "Background" section of Amendment 25-87 state that some airplanes "incorporate ventilation systems in which fresh air is augmented with conditioned and recirculated air." It was specified that the rule change would permit a ventilation system that uses a mixture of the minimum amount of fresh air and any desired quantity of recirculated air that is shown to be uncontaminated by odors, particulates, or gases. It is stated that the "minimum amount of fresh air is specified by weight. . . ." Ten cubic feet of standard air at a typical cabin altitude of 8,000 feet weighs approximately 0.55 pounds, which is how the final rule was stated. This provides a clear distinction that the minimum amount of fresh air (outside air) is 0.55 pounds per minute per person, but may be augmented by additional conditioned and recirculated air.

(c) Requests have been made that "normal operating conditions" as used in § 25.831(a) be interpreted to mean normal cruise conditions with this interpretation excluding ground, climb, descent, and holding operations. The FAA does not agree. Ground, climb, descent, and holding operations are considered normal operating conditions. However, it should be noted that the wording in the preamble to the final rule stated that for normal operating conditions, the ventilation system must be *designed* to provide the fresh airflow. This was a change from the NPRM that which stated that each occupant must be *provided* the fresh airflow. The preamble to Amendment 25-87 states that it is clear that the additional airflow is not required at all times and under all operating conditions. The change in wording reflects the need to express certification rules in terms of design requirements rather than operating restrictions and addresses concerns regarding potential low airflow capability that occurs during descent at low power levels. If an applicant proposes not to *provide* the minimum required fresh airflow during phases of flight using low power levels, the applicant must show that the cabin air quality is not compromised for that period of time.

(6) Ventilation During Takeoff with the Environmental Control System Turned Off. The following policy is extracted from an FAA memorandum dated May 20, 1983, in response to questions regarding compliance with § 25.831 while conducting takeoff with the environmental control system (ECS) off.

(a) Proposals for takeoff procedures with the ECS off should be processed for certification by an exemption to § 25.831(a). [See paragraph (h) Conclusion, above for a 1999 update] Transient ventilation conditions have been required to be analyzed for current transport aircraft in the past. Analysis and tests should be used to substantiate that operating without the required 10 cubic feet per minute per occupant (§ 25.831(a)) for short durations will not impair pilot performance, passenger safety, or significantly affect equipment reliability.

(b) Both equipment and the pilot environment should be evaluated during taxi and takeoff to ensure pilot performance and equipment reliability are not impaired. This evaluation should cover the extremes of ambient hot air temperatures in which the airplane is expected to operate. The temperatures evaluated should be no less than the maximum ambient hot air temperature limits of engine or equipment, whichever is more limiting. Analysis may be used to extrapolate test temperatures.

e. References. The address for ordering the latest revision of the advisory circulars listed below can be found in the Appendix to this AC.

AC 25-9A, Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Procedures.
AC 25-20, Pressurization, Ventilation, and Oxygen Systems Assessment for Subsonic Flight Including High Altitude Operation.
AC 20-32B, Carbon Monoxide (CO) Contamination in Aircraft-Detection and Prevention.
AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes.

31. SECTION 25.832 - CABIN OZONE CONCENTRATION.

a. Rule Text.

(a) The airplane cabin ozone concentration during flight must be shown not to exceed-

(1) 0.25 parts per million by volume, sea level equivalent, at any time above flight level 320; and
(2) 0.10 parts per million by volume, sea level equivalent, time-weighted average during any 3-hour interval above flight level 270.
(b) For the purpose of this section, "sea level equivalent" refers to conditions of 25° C and 760 millimeters of mercury pressure.
(c) Compliance with this section must be shown by analysis or tests based on airplane operational procedures and performance limitations, that demonstrate that either-
(1) The airplane cannot be operated at an altitude which would result in cabin ozone concentrations exceeding the limits prescribed by paragraph (a) of this section; or
(2) The airplane ventilation system, including any ozone control equipment, will maintain cabin ozone concentrations at or below the limits prescribed by paragraph (a) of this section.
[Amdt. 25-50, 45 FR 3883, Jan. 1, 1980, as amended by Amdt. 25-56, 47 FR 58489, Dec. 30, 1982]

b. Intent of Rule. Ozone is an odorless, colorless gas that can be irritating to the respiratory tract and eyes when present in high enough concentrations. This rule was formulated to limit the ozone concentrations in the occupied areas of transport category airplanes. Because the level of discomfort is proportional to the level of activity of the parties exposed, cabin attendants are more likely to be adversely affected. The ozone limits embodied in this section will prevent crew members and passengers from being exposed to concentrations high enough to be hazardous. There is a parallel requirement in the operating rules (§ 121.578).

c. Background. Following complaints from crewmembers regarding various adverse health effects associated with ozone in the airplane cabins, and a petition for rulemaking, parts 25 and 121 were amended at Amendments 25-50 (January 1, 1980) and 121-154 (January 1, 1980), to add standards for maximum ozone concentration in transport category airplanes.

(1) Amendment 25-56 (December 30, 1982) raised the flight levels at which compliance must be demonstrated, and excluded certain airplanes from the requirements of the part 121 rule.

(2) The Operating Rule, § 121.578, allows route and altitude adjustments to be used, in conjunction with global ozone concentration data and airplane ozone retention factors, to avoid exceeding safe ozone levels. Part 25 requirements were intended to be addressed through design features, e.g., ozone filters or catalytic converters, to ensure that ozone limits would not be exceeded regardless of altitude, latitude, and time of year for the operation. However, some manufacturers have requested that they be allowed to comply with § 25.832 by placing limitations in the airplane flight manual that would stipulate altitude limits for operations at specific latitudes during certain times of the year.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Sea Level Equivalent. The following guidance is extracted from an FAA letter dated May 18, 1999. It was developed in response to inquiries regarding a definition of the term "sea level equivalent" and to acknowledge an error in the preamble to Amendment 25-89 with reference to AC 120-38. The following guidance will demonstrate that for cabin air concentration the FAA intended to maintain constant parital pressures; however, the concentrations may change with altitude.

(a) Confusion still exists pertaining to the term "sea-level equivalent." This term has been used as far back as 1953 in the Civil Air Regulations (CAR) part 4b, § 4b.371, Ventilation, to address carbon dioxide concentrations. This later became Title 14, Code of Federal Regulations (14 CFR), part 25, § 25.831(b)(2). Amendments 121-154 (Operations) and 25-50 (Certification), effective February 20, 1980, introduced §§ 121.578 and 25.832, Cabin Ozone Concentration. These regulations defined the term sea level equivalent in §§ 121.578(a)(2) and 25.832(b) as follows: "Sea level equivalent (SLE) refers to conditions of 25^0 C and 760 millimeters of mercury pressure." The preamble to these amendments further states that ozone concentration is stated in parts per million by volume (ppmv) and expressed as a sea level equivalent, i.e., the ratio of ozone to air that would exist at 760 millimeters of mercury (mm Hg) pressure and 25^0 C.

(b) The NPRM that originally proposed ozone limitations, (NPRM No. 78-15), introduced an ozone limit of 0.3 ppmv at any given time. During the comment period, confusion was expressed as to what was meant by the proposed cabin ozone concentrations. The ratios proposed were those that would be expected at the air pressure which is normally maintained in the passenger cabins of the affected aircraft (it was considered to be 6,000 feet). This original proposal was modified, however, since concentration limits are typically expressed at standard sea level pressure (760 mm Hg) and temperature (25^0 C), including those adopted by the Occupational Safety and Health Administration (OSHA).

(c) The FAA adjusted the final rule, Amendment. Nos. 121-154 and 25-50, to be expressed based on the sea level criteria. The preamble states, "Since there is more air in a given volume at sea level, the proposed 0.3 ppmv limit converts to 0.25 as a ppmv, sea level equivalent." The intent was not to allow a higher ozone concentration at altitude, but to take the proposed cabin ozone concentration and express it in standardized terms based on published OSHA limits.

(d) Advisory Circular (AC) 120-38, provides illustrations for determining a sea level equivalent concentration. Per the AC, the terms OZSLE and O_3 are concentrations in ppmv. OZSLE is the sea level equivalent absolute ozone concentration and O_3 is the absolute concentration at a given altitude (assuming a cabin temperature of 25^0 C). The AC provides the following equation to relate O_3 and OZSLE based on a pressure ratio (P/P_o), which will always be less than zero for altitudes higher than sea level.

$\underline{1}$ $\quad$ OZSLE = $(P/P_o)(O_3)$

P/P_o is the ratio of the total cabin pressure (P) to total sea level pressure (P_o). This equation is nothing more than a conversion of a concentration value at altitude back to sea level.

(e) Dalton's Law states that the total pressure of a gas mixture is the sum of the individual pressure (or partial pressures) that each gas would exert if it alone occupied the whole volume. Each kind of gas exerts its own pressure depending on the percentage of that gas in the mixture; thus, even though the percentage or concentration of oxygen in the atmosphere is nearly constant (around 20.9%), its partial pressure will decrease proportionately as atmospheric pressure decreases. If c is the concentration of a gas, P is the absolute pressure, and P_p is the partial pressure, they are related by the following equation.

$\underline{2}$ $\quad$ $c = (P_p/P)$

Advisory Circular (AC) 120-38 uses SLE to essentially provide a constant partial pressure requirement independent from the cabin pressure. Substituting the concentrations of ozone at sea level (OZSLE) and of ozone under cabin pressure (O_3) into equation (1) you get:

$\underline{3}$ $\quad$ $P_{p,OZSLE}/P = (P/P_o)(P_{p,O3}/P)$

At sea level, $P = P_{o,}$ therefore, equation $\underline{3}$ becomes

$\underline{4}$ $\quad$ $P_{p,OZSLE}/ P_o = (P/P_o)(P_{p,O3}/P)$

which reduces to $P_{p,OZSLE} = P_{p,O3}$.

(f) This exercise demonstrates that the FAA intended to maintain constant partial pressures; however, the concentrations may change with altitude. It was not the intent of the FAA to allow higher partial pressures of a gas at low cabin pressures. In fact, the partial pressures are intended to be independent of the cabin altitude. With this in mind, the sea level equivalent of a gas can be considered the gas concentration (volume %) at sea level for which the partial pressure of the gas matches the ambient partial pressure of the gas at a given cabin altitude.

(g) Based on this interpretation of the preamble to Amendment. Nos. 121-154 and 25-50, and AC 120-38 material, the preamble to Amendment. No. 25-89 should be corrected to read as shown in paragraph 36(c)(4)(a) above.

(2) <u>Ground test</u>. Applicants have demonstrated compliance with this rule by conducting a ground test to establish the ozone retention of the aircraft. This should be accomplished by inducing a known ozone concentration into the engine inlet/bleed air system, representative of the worst case concentration predicted for the atmospheric environment, and measuring the concentration in the passenger cabin and cockpit. Alternatively, ground tests could be conducted utilizing ambient ozone (vs. machine generated ozone) in regions with high

levels of ozone provided the cognizant ACO finds them acceptable. The airplane engines and ventilation systems by themselves reduce the concentration without any additional filtering. Using the ratio of the ozone introduced to the amount of ozone retained in the cabin environment (the retention ratio), the airplane operating characteristics in terms of the ozone concentration to be expected in the occupied areas can be determined. If an ozone filter or catalytic converter is installed, the manufacturer may perform a similar ground test (or an equivalent laboratory test acceptable to the cognizant ACO) to demonstrate that the ozone concentration in the airplane will never exceed the ozone limits in service, regardless of the atmospheric concentration. Typically, a maintenance manual limit is established for removing and cleaning the units. The maintenance interval ensures that the converters will be removed when the efficiency of the converter degrades to the point that the airplane would no longer be in compliance with § 25.832.

(3) Use of Default Retention Ratio. The following guidance is extracted from an FAA letter dated February 18, 1999. It was developed in response to an inquiry regarding certification of cabin ozone limits to satisfy § 25.832:

(a) One letter requested FAA concurrence that for future certification programs a value of 0.7 be accepted as a default value for the ozone retention ratio when demonstrating compliance to 14 CFR § 25.832.

(b) An applicant for a type certificate under part 25, or a part 121 operator, must demonstrate compliance with the maximum ozone concentration requirements of § 25.832 or § 121.578, respectively. These two regulations were introduced per Amendments 25-50 and 121-154. Amendments No. 25-56 and 121-181 made revisions stipulating these ozone concentration limits be applicable at revised flight levels. Section 25.832 stipulates a limit for a time weighted average during any three hour interval above flight level 270. Section 121.578 stipulates a limit for a time weighted average for each flight segment that exceeds four hours and includes flight above flight level 270 during that segment. The time difference is referenced in the preamble material in Notice No. 78-15 and ensuing Amendments No. 25-50 and 121-154. As explained in the notice, approximately one hour of the scheduled flight segment would not be at higher altitudes. This was based on conservative times for start, taxi, takeoff, climb, descent, approach, and landing. The operating rule considers the entire flight segment involving time at lower altitudes.

(c) Certification for ozone concentration limits under both parts 25 and 121 entails demonstrating that the cabin and cockpit ozone concentration will not exceed the limits mandated by the regulations. In either case, the testing and/or analysis for showing compliance utilizes a retention ratio. This ratio is the fractional value of the cabin interior ozone concentration compared with the ambient concentration.

(d) The FAA published a table of previously measured transport airplane retention ratios in Notice No. 81-15. The notice also stipulated that the FAA would accept a retention ratio of 0.7 to facilitate compliance to § 121.578 when computing cabin ozone concentrations, even when a retention ratio has not been measured for that particular airplane. The final rule preamble (Amendment Nos. 25-56 and 121-181) incorporating the proposed changes to both part 25 and part 121 states that the FAA considers it reasonable to accept the value of 0.7.

(e) Since that notice was published, retention ratios have been determined for a number of airplanes. The retention values that have been demonstrated on turbine-powered aircraft indicate that 0.7 continues to be a reasonable value. The FAA accepts a default value of 0.7 for the ozone retention ratio when demonstrating compliance to both §§ 25.832 and 121.578. If you propose to use a retention value of less than 0.7, the FAA will require certification testing to validate the proposed retention level.

(4) Use of Operational Limitations. The following guidance is extracted from an FAA memorandum dated March 31, 1997. It was developed in response to inquiries regarding certification of cabin ozone limits to satisfy § 25.832:

(a) The cabin ozone limits specified in § 25.832 were first introduced in Amendment 25-50, and were simultaneously placed into part 121. When the part 25 rule went into effect, it was expected that many of the existing airplanes in the fleet would not be modified with ozone filters; since § 25.832 was not part of their type design, these airplanes did not have to comply with this rule. Most operators of these airplanes chose, instead, to comply with the ozone limits required by § 121.578 by way of operational considerations, i.e., reduced cruise altitudes, amended routes of flight, etc. For the existing airplanes at that time, this solution was deemed the most economical method of compliance, and Advisory Circular (AC) 120-38 was developed to provide guidance on acceptable methods of operational compliance to § 121.578.

(b) Compliance with § 25.832 requires a demonstration (by test or analysis) that the cabin ozone concentration will not exceed the stated limits at the maximum atmospheric ozone concentration expected in service. If an ozone filter or other device is installed, it must be shown that this device, plus the natural ozone dissociation which occurs in the engines and in the airplane air conditioning system, will meet the requirements of the rule at the airplane's certificated altitude ceiling. If an ozone filter or other device is not used, however, certification testing may reveal that the cabin ozone concentration may exceed the limits at the airplane's certificated altitude ceiling, and this would cause the certificated ceiling of the airplane to be lowered to whatever altitude would allow compliance with § 25.832. Proposals have been made to comply with § 25.832 by applying operational limitations to the Airplane Flight Manual in lieu of installing ozone control equipment. These limitations would restrict the airplane to certain maximum altitudes based on the latitude and time of year. Such data is currently considered acceptable in finding compliance to § 121.578. This concept could be an option for compliance to § 25.832, but a part 25 approval is not geographically limited. Therefore, charts need to be available for ozone limitations globally for this method of complying with § 25.832. This type of compliance would have to be approved by the Manager of the responsible Aircraft Certification Office.

(5) Meaning of the Term Time-Weighted Average in § 25.832. The following policy material is extracted from an FAA letter dated October 26, 1987. It was in response to a request

for information on the calculation of time-weighted-average ozone exposure for compliance with § 25.832(a)(2).

(a) Time-weighted-average (TWA) ozone exposure, as described in AC 120-38, is calculated for flight segments that occur in different atmospheric ozone concentrations by averaging the individual exposures and the duration of each exposure over the entire flight. This concept can be explained by an example.

(b) Assume a 2 hour flight in zero parts per million (PPM) atmospheric ozone concentration, and then a 4 hour segment in a 1.3 ppm concentration. Assume also a cabin ozone retention ratio of 0.7, a cabin altitude of 7,000 feet, and no ozone filter installed.

(c) The time-weighted-average (TWA) atmospheric ozone concentration is calculated as follows:

$$\frac{(0.0\text{ppm})(2\text{ hrs}) + (1.3\text{ppm})(4\text{ hrs})}{6\text{ hrs}} = 0.867 \text{ ppm time-weighted-average (TWA) atmospheric ozone concentration}$$

(d) The 7,000-foot cabin altitude results in a ratio of cabin altitude/sea level pressure of 0.77 (the allowable cabin ozone concentration is corrected to sea level conditions). The ozone retention ratio of 0.7 is a value that the FAA will accept without a test to determine the actual value.:

<u>1</u> This is equation 6 from Appendix 1 of AC 120-38:

$$0Z16 = (l\text{-}E)(R)(P/P_O)\left[\sum_{i=1}^{N}(OZ16)_i Ti \,/\, T_{F\,S}\right]$$

<u>2</u> Using equation 6 from Appendix 1 of AC 120-38, the calculation of the resultant cabin ozone concentration for this sample flight is as follows:

TWA = 0.77 x 0.7 x 0.867 = 0.467 ppm cabin ozone concentration.

(e) In this example, the cabin ozone concentration exceeds the 0.1 ppm limit in § 121.578, and the flight could not be made under these conditions. Either the altitude, route of flight, or duration of exposure would have to be changed to make the flight acceptable. This procedure is explained, with several examples, in AC 120-38.

(f) The calculation of the TWA ozone exposure for compliance with § 25.832(a)(2) is done in the same way except that the TWA value would be based on the 4-hour segment, not the 6-hour segment used in the example.

(6) <u>Example of Compliance with § 25.832.</u> The following is extracted from an applicant's letter in response to the FAA’s request for an example of the calculation methods used to certify previous models under § 25.832, Cabin Ozone Concentration. Included below are

generic examples of the calculations used to show compliance to the maximum and time-weighted average ozone concentration limits.

(a) For this example, extracted from report no. FAA-EQ-78-03 (reference (b) of applicant's letter), the maximum certified flight level of the airplane will be FL430. The highest ambient ozone concentrations at flight level 430 are at 80° N latitude, Eastern North America during the month of January (atmospheric ozone concentration, confidence level of 84%). The minimum ozone converter efficiency required for southern and northern hemisphere flights are the same; however, while the worst seasons for high ambient ozone concentrations in the southern hemisphere are the summer and fall, the worst seasons for the northern hemisphere are the winter and spring.

(b) In lieu of an experimentally based retention factor, a retention factor of 0.7 will be used in the following analysis extracted from Docket No. 22438, Notice No. 81-15 (reference (c) of applicant's letter). The FAA will accept a retention factor of 0.7 when computing cabin ozone concentrations if a retention factor has not been measured for the airplane being analyzed.

(c) To comply with § 25.832, an airplane must be designed so that the cabin ozone concentration does not exceed a maximum ozone concentration level of 0.25 parts per million by volume (ppmv), sea level equivalent (SLE), at any time above flight level 320; and time weighted average (TWA) limit 0.1 ppmv, SLE, during any three hour time interval above flight level 270. Compliance will be shown by statistical analysis as described in Advisory Circular 120-38 (reference (d) of applicant's letter).

(d) The following is the calculation of the minimum ozone converter efficiency required to meet the maximum cabin ozone concentration limit (OZMAX) of § 25.832 during a worst case flight. Using equation 1 from Appendix 1 of AC 120-38, the calculation of the resultant cabin ozone concentration is as follows:

1 Given:

Month:	January
Latitude:	80° N
Flight Level:	430
Flight Time:	3 Hours Cruise; 4 Hours Total

$$OZMAX = R * \frac{P}{P_o} * (1 - E) * OZ16$$

where:

OZMAX = Maximum Cabin Ozone Concentration Limit = 0.25 ppmv (§ 25.832)
R = Airplane Ozone Retention Factor = 0.7

$\frac{P}{P_o}$ = Ratio of Cabin Pressure to Sea Level Atmospheric Pressure = 0.74

E = Efficiency of Ozone Converter
OZ16 = Ambient Ozone Concentration = 1.6 PPMv (From report no. FAA-EQ-78-03)

Solving:

$$E = 1 - \frac{OZMAX}{R * \frac{P}{P_o} * OZ16}$$

$$E = 1 - \frac{0.25}{0.7 * 0.74 * 1.6} = 0.70$$

E = 70 % CONVERTER EFFICIENCY; minimum converter efficiency required to comply with § 25.832 OZMAX limit.

(e) The following is the calculation of the minimum ozone converter efficiency required to meet the time-weighted average cabin ozone concentration limit (OZTWA) of § 25.832 during a worst case flight. Using equation 6 from Appendix 1 of AC 120-38, the calculation of the resultant cabin ozone concentration for is as follows:

1 Given:

Month:	January
Latitude:	80° N
Flight Level:	430
Flight Time:	3 Hours Cruise; 4 Hours Total

$$OZTWA = (1 - E) * R * \frac{P}{P_o} * \sum_{i=1}^{N} (OZ16)_i * \frac{T_i}{T_{FS}}$$

where:

OZTWA = Time-Weighted Average Cabin Ozone Concentration Limit = 0.10 ppmv (§ 25.832)
E = Efficiency of Ozone Converter
R = Airplane Ozone Retention Factor = 0.7

$\frac{P}{P_o}$ = Ratio of Cabin Pressure to Sea Level Atmospheric Pressure =0.74

N	= Number of Individual Flight Segments = 3		
OZ16	= Ambient Ozone Concentration	= 1.6 ppmv	(from report no. FAA-EQ-78-03)
T_i	= Time of Individual Flight Segment	= 1 Hour	
T_{FS}	= Total Time of Flight	= 4 Hours	

Solving:

$$E = 1 - \frac{OZTWA * T_{FS}}{R * \frac{P}{P_o} * \sum_{i=1}^{N} (OZ16)_i * T_i}$$

$$E = 1 - \frac{0.10 * 4}{0.70 * 0.74 * [(1.6 * 1) + (1.6 * 1) + (1.6 * 1)]} = 0.84$$

E = 84 % CONVERTER EFFICIENCY; minimum converter efficiency required to comply with § 25.832 OZTWA limit.

(f) When calculating the minimum ozone converter efficiency required to satisfy the 14 CFR time-weighted average limit of 0.1 ppmv, a four-hour flight was assumed, taking a half-hour each for takeoff and landing and three hours for cruise.

(g) Based on the above calculations, the minimum required ozone converter efficiency for the airplane to comply with § 25.832 of 14 CFR is 84%.

e. References. The addresses for ordering the latest revision of the advisory circulars and other referenced documents listed below can be found in the Appendix to this AC.

AC 120-38, Transport Category Airplanes Cabin Ozone Concentrations.

FAA Report FAA-AM-79-20, Effects of Ozone on Exercising and Sedentary Adult Men and Women Representative of the Flight Attendant Population.

FAA Report FAA-AEQ-77-13, Ozone Concentration by Latitude, Altitude, and Month, Near 80^{o} West.

FAA Report FAA-AM-80-9, Effects of Ozone (0.30 Parts Per Million, ~ 600µg/m^3) on Sedentary Men Representative of Airline Passengers and Cockpit Crewmembers.

FAA Report FAA-AM-80-16, Effects of Long-Term Exposure to Low Levels of Ozone: A Review.

32. SECTION 25.833 - COMBUSTION HEATING SYSTEMS.

a. Rule Text.

Combustion heaters must be approved.
[Amdt. 25-72, 55 FR 297783, Jul 20, 1990]

b. Intent of Rule. The intent of this rule is that combustion heaters installed on transport category airplanes must be approved. Technical Standard Order (TSO) C-20 provides standards for approval of these devices.

c. Background. Combustion heaters were common in airplanes certificated to parts 3 and 4b of the Civil Air Regulations (CAR). These airplanes, usually powered by reciprocating engines, supplemented various engine exhaust heating systems by separate combustion heaters. There are few combustion heaters in use in modern part 25 airplanes, but their use is not prohibited. The certification requirements for combustion heaters appeared in § 4b.372 of the CAR, entitled “Heating Systems,” which stated: "Combustion heaters shall be of an approved type and shall comply with the fire protection requirements of § 4b.386. Engine exhaust heaters shall comply with the provisions of § 4b.467(c) and (d)." Section 4b.386 contained extensive standards for combustion heater fire zones, ventilating air ducts, combustion air ducts, heater controls, air intakes, and exhaust systems.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Standards for Certification of Combustion Heaters. The following policy material is extracted from an FAA memorandum dated March 14, 1948, in response to questions regarding standards for certification of combustion heaters to § 4b.372 of the CAR.

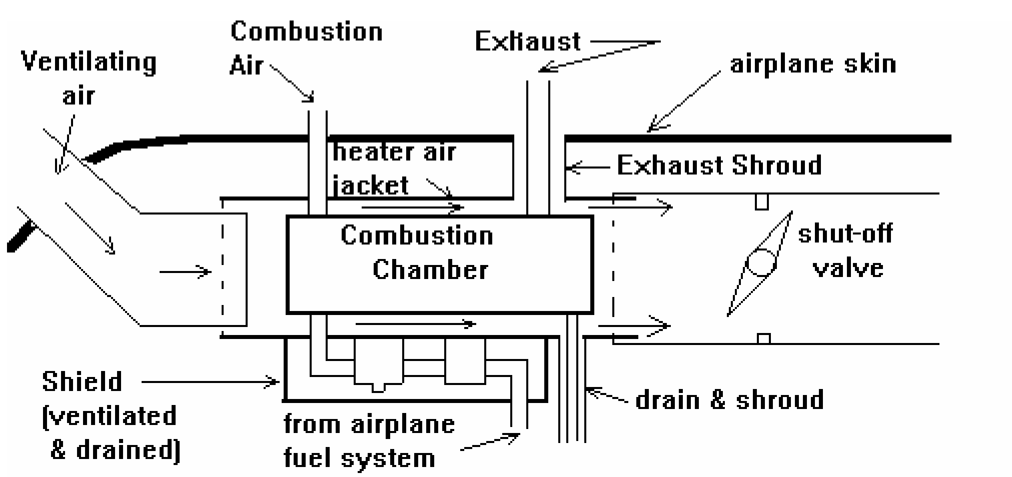
(a) Heater Approval. The approval of heater units is considered essential to safety in all cases. In this regard two separate classes of approval are evidently in order to cover the various applications that can be foreseen.

1 The first class of approval will cover units which will be considered eligible for use only as space heaters. In the case of such units, the criteria for acceptance will involve the general airworthiness of the unit under vibration and operating temperatures and considerations of safety from the standpoint of fire and carbon monoxide contamination only. Heater performance, i.e., the ability of the heater to deliver a given output between normal overhaul periods, ability to start under all expected conditions of altitude and temperature, etc., will not enter into such approvals as this does not normally constitute a safety item in the case of space heaters.

2 The second class of approval will involve heater performance in addition to the criteria for the first class of approval. This type of approval will cover units that are to be used for de-icing purposes since heater performance obviously becomes a safety consideration when the heater is to be used for windshield, surface, or propeller de-icing.

3 Technical Standard Order TSO-C-20 provides standards for combustion heaters and should be used for new installations.

(b) Heater Isolation. Heaters must be isolated from the remainder of the airplane. However, this need not necessarily mean a complete shield around the entire heater unit (although this would be satisfactory) since in many heater designs, the air jacket largely surrounds the flame chamber. Thus, the heater design itself practically provides a steel shield between the combustion unit and the remainder of the airplane. In such cases, it is acceptable to provide isolation for the fuel system components mounted on the heater, and for the heater exhaust system and combustion chamber drains. The following schematic sketch shows an example of an installation which should be satisfactory:



1 The shut-off valve shown in the sketch should be provided if there are fuel system components within the ventilating air shroud which may be subject to leakage or failure. In such cases, that portion of the ventilating air duct up to the valve, as well as the valve itself, should be of fire resistant construction and the valve should provide as flame tight a seal as possible. If the fuel system is so arranged that there are no fittings or connections within the

ventilating air shroud, the downstream air shut-off valve and fire resistant duct between the heater and the valve may be dispensed with.

2 For shrouds for the combustion chamber drain lines, the necessity for these will generally depend upon the location of the drain in the heater. If the drain outlet from the combustion chamber is so located that products of combustion can issue through the drain line, it will no doubt become hot and require isolation. However, drains are sometimes connected in such a manner that they do not carry exhaust gases and remain relatively cool. In such cases, shrouds are not necessary.

(c) Fire Detector and Extinguisher Equipment.

1 For transport category airplanes, extinguishers and detectors will normally be required, in addition to isolation provisions.

2 Detectors and extinguishers should be provided wherever potential sources of fuel leakage and sources of ignition are in close proximity. In the foregoing sketch, the space within the shield would require such protection. In addition, detectors and extinguisher nozzles should be installed in the ventilating air passages of the heater if this chamber contains fuel system fittings or connections that may be subject to leakage. Hand fire extinguishers should be considered equivalent to a fixed fire extinguisher installation only when the heater is located in such a manner that it is readily accessible to the crew and when all fire zones in the installation can easily be reached with a hand extinguisher. All extinguishers may also be dispensed with when the heater is so shielded and located that a fire could be permitted to burn itself out without danger of damage to any important structural members or otherwise endangering the safety of the airplane.

3 Detectors may be dispensed with only when the heater is so located that the occurrence of fire would immediately be noted by the crew.

(d) Heater Fuel System. The heater fuel system should comply with airworthiness standards for the engine fuel system as regards fuel lines, fittings and accessories. While in flight, valves should be provided for shutting off the flow of fuel at its source, unless equivalent provisions in the form of a separate heater fuel pump are available. In the case of transport category airplanes, fuel lines located in fire zones should, in addition, be of fire resistant construction. In the foregoing sketch, this would apply to that portion of the fuel line within the shield and in the heater ventilating air compartment. All pressure lines should comply with the provisions of §§ 03.4211 and 04.4211 of the CAR, regarding pressure cross feed arrangements.

e. Reference. The address for ordering the latest revision of the referenced document listed below can be found in the Appendix to this AC.

Technical Standard Order No. TSO-C-20, Combustion Heaters.

33. SECTION 25.841 - PRESSURIZED CABINS.

a. Rule Text.

(a) Pressurized cabins and compartments to be occupied must be equipped to provide a cabin pressure altitude of not more than 8,000 feet at the maximum operating altitude of the airplane under normal operating conditions.
(1) If certification for operation above 25,000 feet is requested, the airplane must be designed so that occupants will not be exposed to cabin pressure altitudes in excess of 15,000 feet after any probable failure condition in the pressurization system.
(2) 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.
(3) Fuselage structure, engine and system failures are to be considered in evaluating the cabin decompression.
(b) Pressurized cabins must have at least the following valves, controls, and indicators for controlling cabin pressure:
(1) Two pressure relief valves to automatically limit the positive pressure differential to a predetermined value at the maximum rate of flow delivered by the pressure source. The combined capacity of the relief valves must be large enough so that the failure of any one valve would not cause an appreciable rise in the pressure differential. The pressure differential is positive when the internal pressure is greater than the external.
(2) Two reverse pressure differential relief valves (or their equivalents) to automatically prevent a negative pressure differential that would damage the structure. One valve is enough, however, if it is of a design that reasonably precludes its malfunctioning.
(3) A means by which the pressure differential can be rapidly equalized.
(4) An automatic or manual regulator for controlling the intake or exhaust airflow, or both, for maintaining the required internal pressures and airflow rates.
(5) Instruments at the pilot or flight engineer station to show the pressure differential, the cabin pressure altitude, and the rate of change of the cabin pressure altitude.
(6) Warning indication at the pilot or flight engineer station to indicate when the safe or preset pressure differential and cabin pressure altitude limits are exceeded. Appropriate warning markings on the cabin pressure differential indicator meet the warning requirement for pressure differential limits and an aural or visual signal (in addition to cabin altitude indicating means) meets the warning requirement for cabin pressure altitude limits if it warns the flight crew when the cabin pressure altitude exceeds 10,000 feet.

(7) A warning placard at the pilot or flight engineer station if the structure is not designed for pressure differentials up to the maximum relief valve setting in combination with landing loads.
(8) The pressure sensors necessary to meet the requirements of paragraphs (b)(5) and (b)(6) of this section and 25.1447(c), must be located and the sensing system designed so that, in the event of loss of cabin pressure in any passenger or crew compartment (including upper and lower lobe galleys), the warning and automatic presentation devices, required by those provisions, will be actuated without any delay that would significantly increase the hazards resulting from decompression.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-38, 41 FR 55466, Dec. 20, 1976; Amdt. 25-87, 61 FR 28696, Jun. 5, 1996]

b. Intent of Rule. This rule provides standards for pressurized compartments in transport category airplanes. The requirements for various controls and pressure relief valves are addressed. Testing required for demonstrating compliance with many of the requirements of this section are addressed in § 25.843.

c. Background. The rules in this section originated in sections 4b.373 through 4b.376 of the Civil Air Regulations, and were carried over essentially unchanged when part 25 was codified.

(1) Amendment 25-38 (December 20, 1976) added § 25.841(b)(8). This amendment requires pressure sensors and systems designed so the indicators (and automatic oxygen mask presentation required in § 25.1447(c)) will be actuated without any delay that would significantly increase the hazards resulting from decompression.

(2) Amendment 25-87 (June 5, 1996) changed section 25.841(a) based largely on special conditions that had been applied to aircraft operating at high altitudes. The objective of the amended § 25.841(a) (when applied in conjunction with amended § 25.1447(c)) was to provide airworthiness standards that allow subsonic airplanes to operate at their maximum achievable altitudes. This is the highest altitude for which an applicant chooses to demonstrate that, after decompression caused by a single failure or combination of failures that are not shown to be extremely improbable: (1) the flightcrew will remain alert and be able to fly the airplane; (2) the cabin occupants will be protected from the effects of hypoxia; and (3) in the event that some occupants do not receive supplemental oxygen, they nevertheless will be protected against permanent physiological damage. Compliance to Amendment 25-87 is required for only those airplanes whose certification basis includes this amendment. Most of the currently produced airplanes do not fall into this category.

(3) Harmonization. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group will be tasked to recommend revisions to §§ 25.831, 25.841 and related regulations as well as a revised AC 25.20.

d. Policy/Compliance Methods. Flight tests for demonstrating compliance with the requirements of the section are addressed in § 25.843. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information. Advisory Circular (AC) 25-7A, Flight Test Guide for Certification of Transport Category Airplanes, provides additional guidance on tests to verify the 8,000 feet and 15,000 feet cabin altitude requirements as well as tests for high altitude (i.e., greater than 8,000 feet) airports.

(1) Rapid Equalization of Pressure. The following policy is extracted from an FAA memorandum dated June 21, 1982, in response to an inquiry about the intent of, and need for, § 25.841(b)(3).

(a) Section 25.841(b)(3) ensures that a means exists to provide rapid equalization of pressure in the event that (1) a plug type door must be opened for an emergency, and (2) a windshield cracks (§ 25.775(d)). Part 25 manufacturers typically have complied with this regulation by providing a manual position indication and control for the outflow valves. Later certification documents reference, in addition to the manual control, the ability to shut off cabin air inflow as a means of meeting this requirement.

(b) The FAA does not recommend a specific depressurization rate other than the pilot being able to control the rate. In other words, in the manual pressure control mode, he should be able to set the rate as fast or as slow as the pilot judges the emergency requires or as the flight manual specifies. Typical maximum rates for large aircraft will open the outflow valve in 30 seconds, and the depressurization that follows will occur in two minutes or less (with the air conditioning packs on).

(c) From a design and certification standpoint, the need to establish a rate of equalization of pressure can be assessed from failure analyses, abnormal procedures, and the need to prevent a failure from becoming a disaster.

(2) Access to a Pressurized Cargo Compartment in the Engine Burst Zone During High Altitude Operation. The following policy is extracted from an FAA memorandum dated June 25, 1986, in response to an inquiry regarding access to a cargo compartment located in the engine burst zone during operation above 10,000 feet.

(a) Section 25.841(a)(2) requires that the cabin pressure altitude not exceed 40,000 feet for any duration, or 25,000 feet for more than two minutes after any failure not shown to be extremely improbable. Section 25.841(a)(3) states that engine failures are to be considered in evaluating the cabin decompression, this includes rotor burst. Prior to Amendment 25-87, these stipulations were made through special conditions on several aircraft. Compliance has been shown for many airplanes by locating the pressure bulkhead forward of the aft mounted engines for aft fuselage mounted engines.

(b) In some cases, the primary pressure bulkhead of the airplane is located aft of the engines; however, an additional pressure bulkhead installed forward of the cargo compartment, forward of the engine, and forward of the aft pressure bulkhead was proposed to meet these requirements. The additional pressure bulkhead is likely to have a door that is used for access to the cargo compartment from the main passenger compartment. Should a depressurization of the cargo compartment occur, the integrity of this pressure bulkhead is dependent on the door being closed. This arrangement is considered satisfactory for compliance with the above requirements, provided there is a means of ensuring that the door is not opened during high altitude flight.

(c) Allowing the door to the aft cargo compartment of the airplane to be opened at high altitudes would not ensure the level of safety established by the high altitude special conditions and subsequent rule change. Preventing access to the cargo compartment to ensure that the door is always closed and latched at the higher altitudes is an inconvenience. Most present day airplane designs provide overhead storage bins or limited underseat storage in the main cabin. With some forethought, the limited baggage needed during flight can be stored in these locations prior to operation at high altitudes without exposing the airplane and occupants to possible catastrophic decompression. For these reasons, the FAA has determined that these conditions do not impose an undue burden on the applicant.

(d) In view of the above, the applicant must provide a positive means of ensuring that: (1) The cargo compartment is inaccessible and unoccupied for high altitude flight; (2) There is an indication in the cockpit to warn the flight crew when the cargo compartment door is not closed and latched; and (3) There is a means to automatically close the door. A flight manual limitation should specify that the cargo compartment door must be closed and latched during any operation above 10,000 feet.

(3) <u>Cabin Altitude Limit; § 25.841(a).</u> The following policy is extracted from an FAA memorandum dated January 12, 1994, in response to the question: Is the 8,000 foot cabin altitude limit in § 25.841(a) an absolute limit?

(a) Background. The pressurization systems on the airplanes of interest allow cabin altitudes to exceed the 8,000 feet maximum allowed by § 25.841(a). The manufacturer states that the systems currently used on these airplanes allow 8,000 feet plus or minus 200 feet. It is also noted that the cabin altitude display employs a tolerance of an additional plus or minus 250 feet. The applicant states that this design does not result in an unsafe condition, and while the system does not literally comply with the 8,000 feet limit, the intent of § 25.841(a) is met.

(b) The preamble to both the Notice of Proposed Rulemaking (NPRM) and the final rule associated with part 4b of the Civil Air Regulations (CAR) have been reviewed. Amendment 4b-6, effective August 12, 1957, changed the requirements in section 4b.374 of the CAR to limit cabin altitude to 8,000 feet. Prior to that amendment, the limit was 10,000 feet. This limit was carried over into § 25.841 of 14 CFR. The NPRM states, ". . . it is proposed to change § 4b.374 to require on airplanes intended for operation over 25,000 feet to maintain under normal conditions a pressure altitude of no more than 8,000 feet. . ." The wording adopted was similar to that found in § 25.841(a). When deciding on the interpretation of a rule, the policy of the FAA has been to determine the intent of the parties preparing the rule. The use of the words "no more than 8,000 feet" indicates that the rule was intended to mandate a cabin altitude limit of 8,000 feet. There is nothing in either preamble to indicate that 8,000 feet plus some equipment tolerance was the goal. Further, the pressurization systems on many other airplanes are designed to limit cabin altitude to 7,950 feet including equipment tolerances.

(c) It is recognized that the difference in the partial pressure of oxygen at 8,000 versus 8,450 feet is not significant. There is, of course, a difference, and if a passenger has a breathing impairment, there could be some effect on their health. There is no adverse effect associated with the cabin altitude indicator tolerance because oxygen partial pressure is a function of actual cabin altitude.

(d) Based on the above review, the FAA has determined that issuing a new or amended Type Certificate (TC) for an airplane which does not meet the criteria <u>as written</u> is not in the public interest. When a maximum (or minimum) value of a parameter is provided in a section of 14 CFR, the airplane should be shown to meet that limit in normal operation, including expected equipment and sensor manufacturing tolerances. This applies to the actual measured value as determined in FAA flight or ground tests, but does not apply to tolerance in the display device, such as the cabin altitude indicator. A displayed value of 50 or 100 feet above the 8,000 feet limit would not be considered unacceptable, as long as the actual pressure altitude in the cabin does not exceed 8,000 feet.

(e) For airplanes that are already certificated, it is not necessary to require a modification to revise the pressurization control system. That action would be required only if an unsafe condition warranting mandatory action is identified.

e. <u>References</u>. The addresses for ordering the latest revision of the advisory circular (AC) listed below can be found in the Appendix to this AC.

AC 25-20, Pressurization, Ventilation and Oxygen Systems Assessment for Subsonic Flight Including High Altitude Operation.
AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes.

34. <u>SECTION 25.843 - TESTS FOR PRESSURIZED CABINS.</u>

a. <u>Rule Text:</u>

(a) Strength test. The complete pressurized cabin, including doors, windows, and valves, must be tested as a pressure vessel for the pressure differential specified in 25.365(d).
(b) Functional tests. The following functional tests must be performed:
(1) Tests of the functioning and capacity of the positive and negative pressure differential valves, and of the emergency release valve, to simulate the effects of closed regulator valves.

(2) Tests of the pressurization system to show proper functioning under each possible condition of pressure, temperature, and moisture, up to the maximum altitude for which certification is requested.
(3) Flight tests, to show the performance of the pressure supply, pressure and flow regulators, indicators, and warning signals, in steady and stepped climbs and descents at rates corresponding to the maximum attainable within the operating limitations of the airplane, up to the maximum altitude for which certification is requested.
(4) Tests of each door and emergency exit, to show that they operate properly after being subjected to the flight tests prescribed in paragraph (b)(3) of this section.

b. Intent of Rule. This rule provides specific tests that must be conducted in demonstrating compliance with the cabin pressurization requirements contained in § 25.841.

c. Background. The standards in this section originated in section 4b.376 of the Civil Air Regulations (CAR), and were carried over essentially unchanged when part 25 was codified.

(1) Amendment 25-87 (June 5, 1996) added another factor to § 25.365(d), referred to in § 25.843(a). Airplanes operating up to 45,000 feet use a factor of 1.33; airplanes operating over 45,000 feet use a factor of 1.67. Compliance to Amendment 25-87 is required for only those airplanes whose certification basis includes this amendment. Most of the currently produced airplanes do not fall into this category.

(2) Harmonization. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group will be tasked to recommend revisions to §§ 25.365, 25.831, 25.841, and related regulations as well as revisions to AC 25.20.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information. While flight tests to demonstrate compliance are not specifically required in this section, the functional tests identified are usually conducted during flight tests because the pressurization system, including the positive and negative pressure relief valves, can be exercised during other flight test activities, and many of the tests are more meaningful when conducted in flight. The functional tests involving environmental factors (temperature and humidity) are generally conducted on the ground under laboratory conditions.

(1) Pressure Tests For Compliance with § 25.843(a): The following policy is extracted from an FAA memorandum dated February 21, 1990, in response to concerns regarding cabin test pressures for demonstrating compliance with § 25.843(a).

(a) Some manufacturers conduct cabin pressure vessel tests to a pressure corresponding to the maximum relief valve setting, while others test to 1.33 times the maximum relief valve setting. Effective June 5, 1996, if the airplane certification basis includes Amendment 25-87, the factor 1.33 (ref. § 25.365(d)) applies for operation to 45,000 feet while a factor of 1.67 applies for operation above 45,000 feet. While there is not a regulatory requirement to test each and every production airplane to the 1.33 times maximum relief valve setting, many major manufacturers test to this pressure to enhance the fatigue characteristics of the structure. The FAA recommends that modifiers follow the lead of these major manufacturers. If the airframe was originally tested to the 1.33 times relief valve setting, then the modified airplane should also be tested to the same pressure.

e. Reference. The address for ordering the latest revision of the advisory circular listed below can be found in the Appendix to this AC.

AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes.

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Section 5. FIRE PROTECTION

35. SECTION 25.851 - FIRE EXTINGUISHERS.

a. Rule Text.

(a) Hand fire extinguishers.
(1) The following minimum number of hand fire extinguishers must be conveniently located and evenly distributed in passenger compartments:

Passenger Capacity	*Number of extinguishers*
7 through 30	*1*
31 through 60	*2*
61 through 200	*3*
201 through 300	*4*
301 through 400	*5*
401 through 500	*6*
501 through 600	*7*
601 through 700	*8*

(2) At least one hand fire extinguisher must be conveniently located in the pilot compartment.
(3) A least one readily accessible hand fire extinguisher must be available for use in each Class A or Class B cargo compartment and in each Class E cargo or baggage compartment that is accessible to crewmembers in flight.
(4) At least one hand fire extinguisher must be located in, or readily accessible for use in, each galley located above or below the passenger compartment.
(5) Each hand fire extinguisher must be approved.
(6) At least one of the required fire extinguishers located in the passenger compartment of an airplane with a passenger capacity of at least 31 and not more than 60, and at least two of the fire extinguishers located in the passenger compartment of an airplane with a passenger capacity of 61 or more must contain Halon 1211 (bromochlorodifluoromethane CBrC1F2), or equivalent, as the extinguishing agent. The type of extinguishing agent used in any other extinguisher required by this section must be appropriate for the kinds of fires likely to occur where used.
(7) The quantity of extinguishing agent used in each extinguisher required by this section must be appropriate for the kinds of fires likely to occur where used.
(8) Each extinguisher intended for use in a personnel compartment must be designed to minimize the hazard of toxic gas concentration.
(b) Built-in fire extinguishers. If a built-in fire extinguisher is provided-
(1) Each built-in fire extinguisher system must be installed so that--

(i) No extinguishing agent likely to enter personnel compartments will be hazardous to the occupants; and
(ii) No discharge of the extinguisher can cause structural damage.
(2) The capacity of each required built-in fire extinguishing system must be adequate for any fire likely to occur in the compartment where used, considering the volume of the compartment and the ventilation rate.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-54, 45 FR 60173, Sep. 11, 1980; Amdt. 25-72, 55 FR 29783, Jul. 20, 1990; Amdt. 25-74, 56 FR 15456, Apr. 16, 1991]

b. Intent of Rule. This rule prescribes the standards for both hand held and built-in fire extinguishers. Section 25.851(a), which addresses hand fire extinguishers, is addressed in Advisory Circular (AC) 25-17. Section 25.851(b) is intended to ensure that the built-in fire extinguishing system does not introduce a hazard to occupants or the airplane structure, and that the system is adequate to control any fire likely to occur.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the of the Civil Air Regulations (CAR). The standards in section 4b.380(b) of the CAR were carried over essentially unchanged to § 25.851 of 14 CFR. While § 25.851 has been amended several times, the standards for built-in fire extinguishers have not been not changed.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information. Flight tests are conducted, in which the fire extinguishing system is activated and the extinguishent concentration is measured. The common method is to utilize a gas spectrum analyzer to sample the extinguishent concentration in real time at several locations in the compartment. An advisory circular is being written that will provide guidance on certification of cargo compartment fire extinguishing or suppression systems. Guidance related to compliance with § 25.851(b)(2) is included under §§ 25.855 and 25.857 of this AC.

e. References. None.

36. SECTION 25.854 - LAVATORY FIRE PROTECTION.

a. Rule Text.

For airplanes with a passenger capacity of 20 or more:
(a) Each lavatory must be equipped with a smoke detector system or equivalent that provides a warning light in the cockpit, or provides a warning light or audible warning in the passenger cabin that would be readily detected by a flight attendant; and
(b) Each lavatory must be equipped with a built-in fire extinguisher for each disposal receptacle for towels, paper or waste, located within the lavatory. The

extinguisher must be designed to discharge automatically into each disposal receptacle upon occurrence of a fire in that receptacle.
[Amdt. 25-74, 56 FR 15456, Apr. 16, 1991]

b. Intent of Rule. This section provides standards for certification of lavatory smoke detection and waste chute fire extinguishing systems.

c. Background. Prior to the adoption of § 25.854, part 121 was amended in March 1985, by the addition of § 121.308, to require that each lavatory be equipped with smoke detectors, and that each lavatory trash receptacle be equipped with a fire extinguisher that discharged automatically when a fire occurs in the receptacle. Amendment 25-74, April 1991, added § 25.854 to require the same provisions for newly certificated airplanes.

d. Policy/Compliance Methods. For guidance concerning lavatory smoke detection testing plus an acceptable smoke generator, see AC 25-9A. For compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Approval of Lavatory Smoke Detectors. The following policy is extracted from an FAA memorandum dated October 28, 1991, in response to an inquiry regarding certification of smoke detectors in transport category airplane lavatories.

(a) The following guidance provides policy for determining approval criteria for the lavatory smoke detectors that are required by Amendment 25-74 to 14 CFR. This amendment added § 25.854, which requires the installation of lavatory smoke detectors on all transport category airplanes with a passenger capacity of 20 or more. The preamble to the amendment contains a statement that "a commercially available smoke detector, such as the type commonly used in residential buildings, which is demonstrated to serve its intended function as installed, could be considered adequate under the proposal of Notice 89-1." When the economic evaluation was performed in support of the rule change, the cost impact was based in part on costs associated with inexpensive smoke detectors such as those noted above.

(b) When § 25.854 was added by Amendment 25-74, the justification used followed that contained in the preamble to the relevant part 121 amendment that was already in force. Section 121.308, effective March 29, 1985, requires lavatory smoke detectors for all airplanes operating under part 121. The original intent of the part 121 rule was to discourage passengers from smoking in the lavatories, and the smoke detectors were perceived as a cost-effective way to provide that deterrent. This concern has become even greater now that virtually all US, and many international, commercial flights are "smoke free." The incentive to smoke in the lavatory is even greater because passengers cannot smoke at their seats.

(c) The primary FAA concern is to detect smoke from a lavatory fire in a timely manner, and the most likely location for a fire in the lavatory is in the waste bin containing paper towels. For that reason, the smoke detectors currently in use in lavatories are tested using burning paper towels, and are not necessarily optimized for the particulate size contained in tobacco smoke. The detectors continue to be effective as a deterrent to smokers, however, because tobacco smoke is also detected, as evidenced by continuing reports of lavatory smoke alarms due to smoking in lavatories. To the extent that smoke detectors do not detect cigarette smoke, there is a perception that they are not properly designed and/or functioning. Therefore, it is the FAA position that industry be encouraged to do all they can to ensure that lavatory smoke detectors not only function well to detect smoke from lavatory fires, but also function to effectively deter lavatory smoking by efficiently detecting cigarette smoke as well.

(d) When the airframe manufacturers were approached by their customers to install smoke detectors as part of the type design, the FAA was requested to provide certification requirements covering the installation. The guidance provided was the following:

1 The detectors had to meet §§ 25.1301(a) and (d) and 25.1309(a). This meant that environmental, as well as performance, standards had to be considered.

2 Testing was to be performed in flight, and the combustible material used for testing was to be representative of what would be expected to burn in a lavatory waste bin, e.g., paper towels.

3 As a design goal, the detector was to provide a warning within one minute after a fire started.

4 If unpressurized flight was to be allowed, testing under those conditions had to be performed.

(e) It has been suggested that Technical Standard Order (TSO) TSO-C1c might be appropriate for use in approving lavatory smoke detectors. TSO-C1c provides standards for approval of detectors to be used in cargo compartment smoke detection systems. The TSO requirements are not considered appropriate for lavatory smoke detection, as the environment and products of combustion to be detected are both different from that to be expected in a cargo compartment fire. This is not to imply, however, that a TSO-C1c detector would be unacceptable. With appropriate testing, and recognizing that the environment in a lavatory is different than a cargo compartment, a detector authorized under the TSO might be an acceptable choice.

(f) TSO-C1c authorization should not be a requirement for lavatory smoke detector certification. The certification basis for the lavatory smoke detector installation must include §§ 25.1301 and 25.1309, as discussed above, plus any other appropriate sections such as those addressing structural or electrical supply requirements. If application for certification occurs after the effective date of Amendment 25-74 (April 15, 1991), § 25.854 would also be applicable. For these installations, the intended function is to detect smoke resulting from a fire occurring in a lavatory.

(2) Approval of Lavatory Fire Extinguishers Containing Agents Other Than Halon. The following policy is extracted from an FAA memorandum dated March 31, 1997, to distribute a minimum performance standard for use in certifying lavatory fire extinguishers.

(a) Sections 25.854(b) and 121.308(b) require that each lavatory on passenger-carrying transport category airplanes with a passenger capacity of 20 or more, be equipped with a built-in fire extinguisher for each disposal receptacle for towels, paper, or waste located within the lavatory. The fire extinguisher must be designed to discharge automatically into each disposal receptacle upon occurrence of a fire in the receptacle. Currently, although not required by airworthiness regulations, the typical aircraft lavatory disposal receptacle fire extinguisher uses Halon as the fire extinguishing agent.

(b) Halon production was banned as of January 1, 1994, under the provisions of the Montreal Protocol for those subscribing nations, due to its identification as an ozone destroying compound. The Environmental Protection Agency has exempted the aviation industry from the ban on the use of Halon. However, the FAA established the International Halon Replacement Working Group to help identify acceptable replacements for halons. A key aspect of this work is to define minimum performance standards which can be used to assess the performance of candidate replacement agents to assure that they will provide protection equivalent to Halon. Standards are being developed for fire extinguishers used in: lavatory trash receptacles; cargo compartments; engines and auxiliary power units; and hand held extinguishers. The first of these minimum performance standards is published in report number DOT/FAA/AR-96/122, titled "Development of a Minimum Performance Standard for Lavatory Trash Receptacle Automatic Fire Extinguishers," dated February 1997.

(c) The minimum performance standard in report DOT/FAA/AR-96/122 provides guidance on acceptable methods of compliance to § 25.854. The performance of an alternative agent needs to be measured against a standard test method. This document establishes fire load, trash disposal receptacle test article, test procedures, and pass/fail criteria for built-in extinguishers for lavatory disposal receptacles.

e. References. The addresses for ordering the latest revision of advisory circulars (AC), technical standard orders (TSO), and other referenced documents listed below can be found in the Appendix to this AC.

AC 25-9A, Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures.

Technical Standard Order TSO-C1c, Cargo and Baggage Compartment Smoke Detection Instruments.

FAA Report DOT/FAA/AR-96/122, Development of a Minimum Performance Standard for Lavatory Trash Receptacle Automatic Fire Extinguishers.

37. SECTION 25.855 - CARGO OR BAGGAGE COMPARTMENTS.

a. Rule Text.

For each cargo and baggage compartment not occupied by crew or passengers, the following apply:
(a) The compartment must meet one of the class requirements of 25.857.
(b) Class B through Class E cargo or baggage compartments, as defined in 25.857, must have a liner, and the liner must be separate from (but may be attached to) the airplane structure.
(c) Ceiling and sidewall liner panels of Class C compartments must meet the test requirements of Part III of appendix F of this Part or other approved equivalent methods.
(d) All other materials used in the construction of the cargo or baggage compartment must meet the applicable test criteria prescribed in Part I of appendix F of this Part or other approved equivalent methods.
(e) No compartment may contain any controls, wiring, lines, equipment, or accessories whose damage or failure would affect safe operation, unless those items are protected so that-
(1) They cannot be damaged by the movement of cargo in the compartment; and
(2) Their breakage or failure will not create a fire hazard.
(f) There must be means to prevent cargo or baggage from interfering with the functioning of the fire protective features of the compartment.
(g) Sources of heat within the compartment must be shielded and insulated to prevent igniting the cargo or baggage.
(h) Flight tests must be conducted to show compliance with the provisions of 25.857 concerning-
(1) Compartment accessibility,
(2) The entries of hazardous quantities of smoke or extinguishing agent into compartments occupied by the crew or passengers, and
(3) The dissipation of the extinguishing agent in Class C compartments.
(i) During the above tests, it must be shown that no inadvertent operation of smoke or fire detectors in any compartment would occur as a result of fire contained in any other compartment, either during or after extinguishment, unless the extinguishing system floods each such compartment simultaneously.
[Doc. No. 5066, 29 FR 18291. Dec. 24, 1964, as amended by Amdt. 25-15, 32FR 13266, Sep. 20, 1967; Amdt. 25-32, 37 FR 3972, Feb. 24, 1972; Amdt. 25-60, 51 FR 18242, May 16, 1986; Amdt. 25-72, 55 FR 29784, Jul. 20, 1990; Amdt. 25-93, 63 FR 8048, Feb. 17, 1998]

b. <u>Intent of Rule.</u> This rule contains the material standards and design considerations for cargo compartment interiors; the statement that each cargo compartment must meet one of the class requirements of § 25.857; and the flight tests which must be conducted for certification.

c. <u>Background.</u> Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The standards in section 4b.382 of the CAR, cargo and baggage compartments, and section 4b.384, proof of compliance, of the Civil Air Regulations (CAR), and were carried over essentially unchanged to

§ 25.855 of 14 CFR. This section contains the standards related to those requirements that must be demonstrated by flight test.

(1) Amendment 25-15 (September 20, 1967) added reference to the requirements of § 25.853 for materials, rather than stating the materials must be at least flame resistant.

(2) Amendment 25-32 (February 24, 1972) specifically addressed insulation blankets and cargo covers meeting the requirements of § 25.853(b-3).

(3) Amendment 25-60 (May 16, 1986) added more stringent flammability standards for cargo compartment materials.

(4) Amendment 25-72 (July 20, 1990) made editorial changes and relocated the material flammability requirements to § 25.853 and Appendix F of part 25.

(5) Amendment 25-93 (February 17, 1998) revised §§ 25.855(c) and 25.857(c)(2) to eliminate reference to Class D cargo compartments. . These amendments upgraded the fire safety standards for cargo or baggage compartments in certain transport category airplanes by eliminating Class D compartments as an option for future type certification. Compartments that can no longer be designated as Class D must meet the standards for Class C or Class E compartments, as applicable. The Class D compartments in certain transport category airplanes manufactured under existing type certificates and used in passenger service must meet the fire or smoke detection and fire suppression standards for Class C compartments by early 2001 for use in air carrier, or most other commercial service. The Class D compartments in certain transport category airplanes manufactured under existing type certificates and used only for the carriage of cargo must also meet such standards or the corresponding standards for Class E compartments by that date for such service. These improved standards are adopted to increase protection from possible in-flight fires.

(6) Harmonization. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group is recommending revisions to §§ 25.855 and 25.857, and a new advisory circular may evolve from that process. As a result of this process, Class B compartments may be revised and a new Class F compartment may be proposed.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preambles of this rule and the following information. In accordance with § 25.855(h), flight tests must be conducted to show compliance with the standards concerning: compartment accessibility, smoke and extinguishing agent penetration into occupied areas, and the dissipation of extinguishing agent. Cargo compartment smoke detection testing should be conducted in flight, and is usually accomplished concurrently with the smoke penetration tests. Advisory Circular 25-9A contains guidance regarding smoke detection and penetration testing. Where suitable data is available from previous certification flight test programs of the same airplane model, the cognizant ACO may review an applicant's proposal on a case by case basis and, if satisfactory, may accept certification ground tests for smoke detection purposes.

(1) Halon Concentration. The following policy is extracted from an FAA memorandum dated March 9, 1998, regarding the adequacy of Halon concentration levels needed for certification of cargo compartments in loaded vs. empty configurations.

(a) Traditionally cargo fire extinguishing systems have been certified by demonstrating five percent initial Halon concentration levels and subsequent concentration levels of three percent, when the cargo compartment has been in the empty configuration. The majority of applicants in previous certification programs have not tested or analyzed a loaded cargo compartment configuration.

(b) Recent tests and analyses have raised concern regarding the adequacy of Halon concentrations in a loaded cargo compartment. Regardless of this concern, the Transport Airplane Directorate does not currently have any written guidance, stating that applicants must test or analyze the loaded configuration. Requiring testing or analysis to show Halon concentration levels remain at or above three percent in the loaded cargo compartment may be considered beyond the scope of what the FAA can require without public comment. Although some applicants have previously considered loaded cargo compartments, we do not require testing or analysis for the loaded cargo condition at this time.

NOTE: This may be considered a safety issue that the Transport Airplane Directorate may address in future policy.

(2) Class D to Class C Conversion. The following guidance is extracted from an FAA memorandum dated October 29, 1997, regarding criteria for certification of cargo compartments to be converted from Class D to Class C.

(a) On June 9, 1997, the FAA issued a Notice of Proposed Rulemaking, Docket No. 28937, Notice 97-10 (62 FR 32412, dated June 13, 1997), that proposes to upgrade the fire safety standards for cargo or baggage compartments in certain transport category airplanes by eliminating Class D compartments as an option for future certification. This notice also proposes that Class D compartments in certain transport category airplanes manufactured under existing type certificates and used in passenger service would have to meet the fire detection and suppression standards for Class C compartments by early 2001 for use in air carrier, commuter, on demand, or most other commercial service.

(b) A policy memorandum, dated August 18, 1997, was issued in response to questions concerning what guidance was available regarding the certification of smoke detection/penetration and fire suppression system evaluations in anticipation of the final rule associated with Notice 97-10. After considering industry objections to our memorandum of August 18, 1997, the information in our memorandum is revised to read: Fire Suppression Tests. Several companies have objected to the guidance provided under "Fire Suppression Tests" in the memorandum dated August 18, 1997, even though some recent certification projects have been approved using that guidance. Some manufacturers argued that they used a number of techniques to establish a minimum Halon concentration, including a volumetric averaging technique. The certification criteria contained under “Fire Suppression Tests” in our memorandum of August 18, 1997, is considered new policy for Class D to C conversions. Therefore, the manufacturers may continue to use the certification techniques they have been using, including volumetric averaging, to establish the minimum concentration of Halon for fire suppression.

(aa) At the FAA/Industry workshop of April 22-24, 1997, the FAA’s Technical Center expressed concern that the current Halon measuring technique using volumetric averaging may allow a concentration of Halon insufficient to suppress a fire. The FAA Technical Center tests have shown that Halon, having a higher density than air, settled in the cargo compartment. Further, the tests showed that fires may reignite at the higher water lines in the cargo compartment due to insufficient Halon concentration even though the average volumetric concentration of Halon was considered adequate. There was no subsequent measured increase in Halon concentration near the fire due to convective stirring. This information was presented to and discussed with Industry at the April 22-24,1997, workshop and is the basis of the “Fire Suppression Tests” guidance provided in our memorandum of August 18, 1997.

(bb) The use of the technique of volumetric averaging to determine the minimum Halon concentration is questionable in light of the testing accomplished by the FAA’s Technical Center. Therefore, establishing minimum Halon concentrations near the ceiling should be considered. Applicants may elect to take advantage of this information in measuring the Halon concentration in their tests even though the FAA will not require this technique at this time. Furthermore, the Transport Standards Staff will develop an Advisory Circular (AC) that addresses measuring the minimum acceptable level of Halon in all cargo compartments.

(c) The rest of the memorandum, dated August 18, 1997, was revised as follows, and may be used for guidance:

(d) System Reliability. Use advisory material appropriate to the certification basis. When applying AC 25.1309-1A, the following is suggested: Detection and suppression systems are considered complex in terms of paragraph 6d of the AC. A failed detection system and/or a failed suppression system in conjunction with a fire should be considered a catastrophic event. Therefore, utilizing figure 2 of AC 25.1309-1A, knowing the system is complex and the failure event is a catastrophic event, the depth of analysis should include both a qualitative and quantitative assessment (reference paragraphs 8d, 9, and 10 of the AC).

(e) Dispatch. For dispatch relief, the systems should be tested in the proposed Master Minimum Equipment List (MMEL) configurations. Dispatch may be allowed with detection or suppression systems inoperative in a cargo compartment provided the AFM prohibits the carriage of cargo in the affected compartment.

(f) Smoke Detection/Penetration/Evacuation Tests. Use AC 25- 9A, “Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency

Procedures," supplemented by ANM-100 memorandum, dated June 18, 1997, and the referenced video. The supplemental memorandum elaborates on a small smoldering fire for use in detection tests.

(g) If the applicant disagrees with any of the guidance above, then an issue paper can be created identifying the disagreement as an issue and coordinate it with the FAA.

(3) Protection of Critical Equipment in Class E Cargo Compartments. The following guidance is extracted from an FAA Generic Issue Paper regarding protection of critical equipment in Class E cargo compartments.

(a) Statement Of Issue.

1 A specific requirement to protect critical systems and equipment in Class E cargo compartments from fire damage does not exist. Both Class B and Class E cargo compartments are similar in that they do not have fire suppression systems. On Class B compartments, it is assumed that the fire can be controlled manually. On Class E compartments, the fire is controlled by shutting off ventilating airflow. In both types of cargo compartments fires can quickly reach dangerous proportions because no fast-acting suppression system is installed. In a Class E compartment, an uncontrolled fire could damage critical systems and equipment to compromise flight safety before ventilating airflow could be effectively shut off. For this reason, protection of these critical systems and equipment must be ensured.

(b) Background.

1 The FAA has issued Airworthiness Directives (AD) 91-10-02, which requires certain design, equipment, and operational changes to maximize fire protection on "Combi" Class B cargo compartments. One of these requirements is to ensure appropriate protection of cockpit voice and flight data recorders, windows, primary flight control systems (unless it can be shown that a fire could not cause jamming or loss of control), and other equipment within the compartment that is required for safe flight and landing. If protective covers are used, they must be constructed of materials that meet the flame penetration resistance requirements of § 25, 14 CFR, appendix F, part III [Amendment 25-60].

2 The generic model airplane main deck Class E cargo compartment is similar to the main deck Class B cargo compartment on generic model "Combis." Therefore, similar protection must be afforded to the affected systems on the generic model aircraft.

(c) FAA Position.

1 Section 21.21(b)(2) of 14 CFR requires that no feature or characteristic of an airplane make it unsafe for the category in which certification is requested. Based on the similarities of the generic model aircraft Class E cargo compartment to the generic model aircraft "Combi" Class B cargo compartment, a concern exists that the unsafe conditions identified on "Combis" will also exist on the generic model aircraft.

2 Prior to issuance of the Generic Model Airplane Type Certificate, it must be shown by design or analysis that adequate fire protection has been provided to the cockpit voice and flight data recorders, windows, primary flight controls (unless it can be shown that a fire could not cause jamming or loss of control), and other systems and equipment within the compartment that is required for safe flight and landing. If protective covers are used, they must be constructed of materials that meet the flame penetration resistance requirements of 14 CFR part 25, appendix F, part III [Amendment 25-60].

e. Reference. The address for ordering the latest revision of advisory circulars and other referenced documents listed below can be found in the Appendix to this AC.

AC 25-9A; Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures.

38. SECTION 25.857 - CARGO COMPARTMENT CLASSIFICATION.

a. Rule Text.

(a) Class A. A Class A cargo or baggage compartment is one in which-
(1) The presence of a fire would be easily discovered by a crewmember while at his station; and
(2) Each part of the compartment is easily accessible in flight.
(b) Class B. A Class B cargo or baggage compartment is one in which-
(1) There is sufficient access in flight to enable a crewmember to effectively reach any part of the compartment with the contents of a hand fire extinguisher;
(2) When the access provisions are being used, no hazardous quantity of smoke, flames, or extinguishing agent, will enter any compartment occupied by the crew or passengers;
(3) There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station.
(c) Class C. A Class C cargo or baggage compartment is one not meeting the requirements for either a Class A or B compartment but in which-
(1) There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station;
(2) There is an approved built-in fire-extinguishing or suppression system controllable from the cockpit;
(3) There are means to exclude hazardous quantities of smoke, flames, or extinguishing agent, from any compartment occupied by the crew or passengers;
(4) There are means to control ventilation and drafts within the compartment so that the extinguishing agent used can control any fire that may start within the compartment.
(d) [Reserved]

(e) Class E. A Class E cargo compartment is one on airplanes used only for the carriage of cargo and in which-
(1) (Reserved)
(2) There is a separate approved smoke or fire detector system to give warning at the pilot or flight engineer station;
(3) There are means to shut off the ventilating airflow to, or within, the compartment, and the controls for these means are accessible to the flight crew in the crew compartment;
(4) There are means to exclude hazardous quantities of smoke, flames, or noxious gases, from the flight crew compartment; and
(5) The required crew emergency exits are accessible under any cargo loading condition.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-32, 37 FR 3972, Feb. 24, 1972; Amdt. 25-60, 51 FR 18243, May 16, 1986; Amdt. 25-93, 63 FR 8048, Feb. 17, 1998]

b. Intent of Rule. This rule provides the standards for the various classes of transport category airplane cargo compartments. It does not cover closets and stowage compartments (See § 25.787). Cargo compartment liner standards and required flight tests to demonstrate compliance are addressed in § 25.855.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The requirements in section 4b.383 of the CAR were carried over essentially unchanged to § 25.857 of 14 CFR.

(1) Amendment 25-32 (February 24, 1972) moved the liner requirements for Classes B through E to § 25.855.

(2) Amendment 25-60 (May 16, 1086) limited the volume of Class D compartments to a maximum of 1,000 cubic feet.

(3) Amendment 25-93 (February 17, 1998) revised paragraph (c)(2) to add reference to suppression systems as well as extinguishing systems, and eliminated reference to Class D compartments and reserved paragraph (d). Also see the explanation under § 25.855, Amendment 25-93.

(4) Harmonization. This regulation is the subject of a Federal Aviation Regulation/Joint Aviation Requirement (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group has provided the FAA with a fully harmonized draft notice of proposed rulemaking (NPRM) and an accompanying draft proposed advisory circular (AC) for regulatory evaluation. The NPRM and the AC provide the criteria for corrective action(s) that, if implemented, would be acceptable to the FAA for showing compliance with the airworthiness directive AD 93-07-15, or any new "combi" designs for Class B or the new proposed Class F cargo compartments. The NPRM proposes to revise §§ 25.855 and 25.857, and the proposed AC provides one means but not the only means of

compliance. Should an applicant not desire to comply with the requirements for Class B or class F compartments as stipulated above, then the main deck cargo compartments should comply with requirements for a Class C compartment as defined in current §§ 25.855 and 25.857.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preambles of this rule and the following information.

(1) Main Deck Cargo Compartment Fire Protection Certification Procedures. The following policy is extracted from an FAA letter dated June 6, 1997, and addresses requirements for "combi" airplanes. The letter is in response to a request from an applicant for information regarding certification of "combi" airplanes. The FAA refers to airplanes that can carry both passengers and cargo on the main deck as "combi's." The guidance is based on proposed rulemaking and advisory material being developed through the ARAC process.

(a) Information was requested concerning Federal Aviation Administration (FAA) requirements for certification of "combi" airplanes. The minimum design requirements for issuance of a Type Certificate for large transport airplanes are identified in 14 CFR part 25. The FAA was specifically asked to identify the criteria against which the FAA would evaluate the main deck fire protection features for FAA certification.

(b) The passenger and cargo compartments are separated by a partition that is either fixed or movable to accommodate various passenger/cargo combinations. Some "combi's" can also accommodate all passenger or all cargo configurations. In most cases, the main deck cargo compartments on these airplanes are identified as Class B cargo compartments, which meet the fire protection requirements specified in § 25.857(b). Class B cargo compartments rely on manual firefighting as the primary method of controlling fires.

(c) In 1987, a South African Airways 747-200 "combi" crashed in the Indian Ocean following a fire in it's main deck Class B cargo compartment. Following the investigation, the FAA concluded that manual firefighting in large Class B cargo compartments was not effective, and that the certification requirements identified in § 25.857(b) were inadequate. As a result, the FAA issued Airworthiness Directive (AD) 93-07-15, which required operators of existing large "combi" airplanes manufactured by Boeing or McDonnell Douglas to make significant modifications to their airplanes and operations. Operators were offered four options: (1) convert the Class B cargo compartment to Class C, (2) carry all cargo in the Class B cargo compartment in containers that meet the requirements for Class C cargo compartments, (3) use fire containment covers or containers for all main deck cargo, along with other airplane and operational changes, or (4) incorporate a 90 minute duration fire suppression system, along with other airplane and operational changes.

(d) To address new "combi" designs, the FAA, through the Aviation Rulemaking Advisory Committee (ARAC) process, is proposing a revision to §§ 25.855 and 25.857 which would require Class B cargo compartments to be small enough that a crewmember with a hand held fire extinguisher can extinguish a fire anywhere within the compartment without entering it. The FAA is also proposing a new cargo compartment classification, Class F. The proposed

Class F compartment would not be size-limited, and would require incorporation of a means to extinguish or control the fire without the need for a crewmember to enter the compartment. This includes not reaching in to move something in order to have full access to the fire extinguisher.

(e) The FAA has identified the criteria against which the FAA would evaluate main deck fire protection features on new "combi's." Although AD 93-07-15 provides an adequate level of safety for existing airplanes, the FAA recommends that all new "combi's" meet the intent of the proposed changes to §§ 25.855 and 25.857. In addition, the effectiveness of the third and fourth options of AD 93-07-15 depends heavily on the FAA-monitored procedures, maintenance, and training at individual airlines, whereas the proposed part 25 changes rely on the airplane design, rather than airline operations. The FAA recognizes that the limited size of the proposed Class B cargo compartment would not meet operational needs. The FAA recommends that the main deck cargo compartment on the "combi" meet either the requirements for Class C cargo compartments identified in §§ 25.855 and 25.857, or the proposed requirements for Class F cargo compartments. The FAA and the ARAC are proposing that Class F cargo compartments meet the general cargo compartment requirements of § 25.855, and the following:

1 A Class F cargo compartment must have a liner that is separate from, but may be attached to, the airplane structure, unless it can be shown that other means for containing the fire and protecting critical systems and structure are provided.

2 The ceiling and sidewall panels of the liner in the Class F cargo compartment, if required, must meet the test requirements of part 25, Appendix F, part III, or other FAA-approved equivalent methods. This includes windows and window shades/covers in combi airplanes.

3 A means to extinguish or control the fire in the Class F cargo compartment, without requiring a crewmember to enter the compartment, must be provided.

4 A means to prevent hazardous amounts of smoke, flames, or suppression agent in the Class F cargo compartment from entering any occupied compartment must be provided.

5 A separate, FAA-approved smoke or fire detector system to alert the pilot or flight engineer station in the event of a fire must be provided.

(2) Class A Cargo Compartments: The following policy is extracted from an FAA memorandum dated February 8, 1996, to provide FAA policy regarding certification of passenger airplanes converted to all-cargo Class A or unclassified cargo compartment configurations.

(a) The FAA Transport Airplane Directorate has become aware of a number of transport category airplanes that have been reconfigured as all-cargo airplanes with cargo compartments classified as Class A, or with the cargo compartment classification not addressed at all.

(b) An FAA memorandum , dated September 13, 1988, states that " . . . the agency policy has always been, and still is, that cargo compartments larger than that stated in Order 8110.27A(5)(b) are to be classified as Class B through E, whichever is applicable, and that operators comply with all requirements relative to each class." The aforementioned order describes the Class A compartment as " . . . small open compartments used for storage of crew luggage and located in the cockpit area where a fire can be easily discovered by a crewmember." The order goes on to state that: "During the 74/75 Airworthiness Review, it was mentioned that full cabins or other large cargo compartments were presented for approval under Class A category, and that these compartments were consistently rejected on the basis that their volume was outside the intent of the Class A category where a fire must be rapidly detected and extinguished. Since the Class A compartment has no liner, large cargo areas have been considered to be outside the intent of the Class A category. It was recommended to limit the volume to 200 cubic feet."

(c) Advisory Circular (AC) 25-18, issued January 6, 1994, Transport Category Airplanes Modified for Cargo Service, addresses this subject. In the AC, Class A compartments are defined as follows:

1 "A Class A compartment is one that is located so close to the station of a crewmember that the crewmember would discover the presence of a fire *immediately*. In addition, each part of the compartment is easily accessible so that the crewmember could quickly extinguish a fire with a portable fire extinguisher. A Class A compartment is not required to have a liner.

2 "Typically, a Class A compartment is a small open compartment in the cockpit area used for storage of crew luggage. A Class A compartment is not, however, limited to such use; it may be located in the passenger cabin and used for other purposes provided it is close to a crewmember's station. Typically, the crewmember would be a member of the flightcrew; however, the compartment could be located adjacent to the station of any other crewmember.

3 "Because a Class A compartment does not have a liner, it is *absolutely essential* that the compartment be small and located close enough to a crewmember that any fire that might occur could be discovered and extinguished immediately. Without a liner to contain it, an undetected or uncontrolled fire could quickly become catastrophic by burning out of the compartment and spreading throughout the airplane. There is no specific limit on the volume; however, all portions of the compartment must be virtually within arms length of the crewmember in order for any fire to be detected immediately and extinguished in a timely manner. Although there may be some exceptions, such as a 'U-Shaped' compartment for example, a Class A compartment greater than 50 cubic feet in volume would not typically have the accessibility required by § 25.857(a)(2) for fighting a fire."

(d) Advisory Circular 25-17, Transport Airplane Cabin Interiors Crashworthiness Handbook, dated July 15, 1991, or latest revision, notes that a Class A compartment was envisioned as a small, open compartment located in the cockpit area.

(e) It is clear from reviewing the above policy, and noting the chronology, that the intent of Class A compartments is not consistent with the conversion of an entire passenger cabin to a cargo compartment and identifying it as Class A. A number of issues support this view. In order to exit the airplane in the event of an uncontrollable fire, the only path may be through the fire zone. Access to emergency exits often does not exist with the compartment fully loaded. Further, there are no means to protect the flightcrew from the effects of toxic gasses that can be generated in a smoldering fire. In cargo compartments classified Class B through Class E, the cargo and crew areas are separated and certification tests are conducted to ensure that no hazardous quantities of smoke or fumes will penetrate occupied areas, including the cockpit. In addition, other factors that are frequently not addressed in these modifications are: lack of a cargo restraint system, compartment liners, and a second emergency exit.

(f) The FAA has determined, for the reasons discussed above, that it is inappropriate to classify full cabin or other large areas as Class A compartments. For future certification projects (whether new, amended, or supplemental), the above guidance must be considered.

(3) <u>Class E Cargo Compartments.</u> The following policy is extracted from an FAA memorandum dated March 21, 1991, in response to a request for guidance on compliance relating to the installation of a Class E cargo compartment.

(a) Smoke detection capability must be demonstrated in any flight condition contemplated by the operator. This usually means a flight test must be performed at the maximum contemplated cabin altitude.

(b) Smoke penetration from Class E compartment into cockpit tests must be conducted starting in a cruise configuration and continuing into a descent to sea level landing. If any other procedures, such as attempting to suppress the fire by going to higher altitudes, involve other operating altitudes, these must also be addressed.

(c) An Airplane Flight Manual (AFM) supplement is needed which addresses crew action following smoke annunciation, i.e., crew shuts off ventilating air to the cargo compartment, dons oxygen equipment, and proceeds to the nearest adequate airport.

(d) The protective breathing equipment requirement in § 25.1439(a) must be addressed.

(4) <u>Access to Class E Cargo Compartments.</u> The following policy is extracted from an FAA letter dated July 3, 1990, in response to a request for guidance on compliance on the carriage of dangerous goods, and the need for access, in Class E compartments.

(a) The International Civil Aviation Organization regulations for hazardous goods carried in Class E compartments require adequate access to these goods. Section 25.857 of 14 CFR does not preclude access to Class E compartments in flight. Sections 25.851(a)(3) and 121.309(c)(2) require that one hand fire extinguisher must be provided for use in each Class E cargo compartment that is accessible to crewmembers in flight.

(b) Although part 25 does not require in-flight access to Class E cargo compartments, in-flight access to the compartment can be accommodated with proper design if operational requirements result in the carriage of hazardous goods in a Class E compartment.

(5) Freighter Aircraft with Accessible Class E Compartment. The following is extracted from an issue paper dated March 10, 1995, titled "Accessible Class E Cargo Compartment."

(a) The following applies to certification of a freighter aircraft with an accessible Class E Cargo Compartment, which would allow the operator to carry hazardous material. The following would allow the crew and "persons" access to the entire cargo compartment.

(b) Access by one cargo handler will be allowed during flight to a Class E cargo compartment carrying hazardous material provided that one Portable Breathing Equipment (PBE) meeting TSO C-116 is available in the flight deck. The cargo handler in the Class E cargo compartment must carry the portable oxygen at all times while in the cargo compartment. A placard must state that the portable oxygen must be carried at all times. In addition, there must be a readily detectable means to alert the cargo handler to don oxygen equipment and/or return to the flight deck. Further, two Halon fire extinguishers of adequate size must be installed near the cargo compartment entrance with procedures for their use. Finally, there must be a means to prohibit smoking. Compliance with the above will meet §§ 25.855(e)(1), (e)(2), and 25.857(e)(4), taking into consideration the opening caused by a person exiting the cargo compartment.

(c) The applicant should show by test or by analysis that with the access door open in flight the positive ventilation with only one pack operating is capable of excluding smoke, flames, or noxious gasses in compliance with § 25.857(e)(4). In addition, the additional fire extinguisher that was kept on the flight deck was required to be a 16-pound Halon extinguisher to comply with § 121.309(c)(2).

e. References. The addresses for ordering the latest revision of referenced documents listed below can be found in the Appendix to this AC.

Advisory Circular, 25-XX, Cargo Compartment Fire Extinguishing or Suppression Systems, date TBD.

Advisory Circular, 25-XX, Class B and F Cargo Compartments, date TBD.

Two methods of determining the leakage rate for Class D compartments that have been approved for certification are contained in:

Appendix I of CAA Technical Development Report No. 146, Evaluation of Flight Fire Protection Means for Inaccessible Aircraft Baggage Compartments, dated June 1951, and

FAA Technical Center Report DOT/FAA/CT-83/1, Analysis of Dissipation of Gaseous Extinguisher Agents in Ventilated Compartments, dated May 1983.

39. SECTION 25.858 - CARGO OR BAGGAGE COMPARTMENT SMOKE OR FIRE DETECTION SYSTEMS.

a. Rule Text.

If certification with cargo or baggage compartment smoke or fire detection provisions is requested, the following must be met for each cargo or baggage compartment with those provisions:
(a) The detection system must provide a visual indication to the flight crew within one minute after the start of a fire.
(b) The system must be capable of detecting a fire at a temperature significantly below that at which the structural integrity of the airplane is substantially decreased.
(c) There must be means to allow the crew to check in flight, the functioning of each fire detector circuit.
(d) The effectiveness of the detection system must be shown for all approved operating configurations and conditions.
[Amdt. 25-54, 45 FR 60173, Sep. 11, 1980; Amdt. 25-93 63 FR 8032, Feb. 17, 1998]

b. Intent of Rule. This rule provides minimum design and certification requirements for cargo or baggage compartment fire or smoke detection systems. This rule is intended to provide a standard that a fire be detected and indicated to the crew in less than one minute after inception.

c. Background. This section was added to part 25 of the Code of Federal Regulations (14 CFR) with Amendment 25-54. Prior to Amendment 25-54, a detection limit of no more than five minutes was established by policy since there was no regulatory reference to detection time. Section 25.858(d) requires detection testing in any configuration proposed by the applicant, including depressurized flight. The cognizant ACO may certify minor changes by analysis of similarities to previously certified configurations, laboratory test, or ground test.

(1) Amendment 25-93 (February 17, 1998) revised the section heading and introductory paragraph to add reference to baggage compartments and smoke detection systems.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Smoke Detection Certification Testing. The following policy is extracted from an FAA memorandum dated June 18, 1997, which was developed in response to inquiries regarding smoke quantities to certify smoke detection systems in cargo compartments. The memo was used to distribute video guidance to help clarify smoke quantities specified in Advisory Circular (AC) 25-9A.

(a) Section 25.858(a) requires that a cargo compartment fire detection system provide a visual indication to the flightcrew within one minute after the start of a fire. AC 25-9A, section 10, provides guidelines for the conduct of certification tests related to smoke detection. The AC states that systems which provide a warning within one minute from the start of smoke generation are considered to be in compliance with the requirements of § 25.858 for cargo compartments. Paragraph 10.b. states that the objective of the smoke detection test is "to demonstrate that the smoke detection system installation will detect a smoldering fire producing a small amount of smoke."

(b) In February 1997, FAA/Industry meetings were held to discuss how manufacturers and operators intended to support the part 25 and 121 rule changes requiring fire detection and suppression systems to be installed in existing Class D cargo compartments. During the meeting, Industry expressed concern that a large number of conversions were going to be made and several Aircraft Certification Offices (ACO's) would be impacted. Industry was concerned that the smoke detection standards used by the ACO's varied and requested the FAA's effort to standardize the test criteria used to satisfy § 25.858.

(c) In response to this request, the FAA held a standardization workshop at the FAA Technical Center in Atlantic City, NJ, during April 1997. ACO personnel and designated engineering representatives (DER's) attended to discuss smoke generation and quantities, and other certification requirements relevant to cargo compartments requiring both detection and suppression systems.

(d) During the standardization workshop, the Technical Center provided a demonstration of a typical smoke quantity from a smoldering fire by igniting rags inside a suitcase. There was a consensus agreement among the ACO members present that this suitcase demonstration generated an appropriate quantity of smoke for a one minute detection system. It was agreed that a video of the burning suitcase should be distributed to the ACO's as an aid to visually demonstrate the amount of smoke that is representative of smoke from a smoldering fire as is mentioned in AC 25-9A. This video is considered visual guidance demonstrating a typical amount of smoke from a smoldering fire. The amount of smoke demonstrated in this video helps to clarify the objective of paragraph 10.b. in AC 25-9A.

(e) Copies of the video mentioned above are available through the FAA William J. Hughes Technical Center. Refer to the Appendix of this AC for the mailing address.

(f) Additional items of discussion at the workshop included the following:

1 The tests conducted at the FAA Technical Center have shown that some materials that are routinely carried in cargo compartments burn very quickly with open flames

and little smoke. It was shown that a fire internal to a suitcase can rupture an aerosol can (containing butane, propane, or isobutane) contained therein and cause the liner to be breached. Once the liner is breached, ventilation control and ability to maintain adequate Halon concentration will be lost. It is inappropriate to rely on detection systems that depend on copious quantities of smoke prior to detection. A fire does not know what volume compartment it is in. A smoldering fire will generate the same levels of smoke regardless of the compartment size and should be detected within the required time to detection (one minute or five minutes as applicable) in any compartment. The solution to larger compartments may be an increased number of detectors, increased sensitivity of detectors, different type of detectors (fanned or ionic), or infrared detectors.

2 All of the current smoke detection limits and guidance have been subjective and based on previous certification practices. The FAA Technical Center's planned test program includes defining fire hazards, the amount of heat generated, and the typical quantity (in more objective terms) of smoke generated, associated with typical cargo fire hazards. The suitcase video is intended to provide clearer guidance until the Technical Center test program is complete. It is a continuing step toward standardizing the approach to smoke detection testing until the FAA determines usable, objective criteria.

(2) Certification Testing for Smoke Detection. The following policy is extracted from an FAA memorandum dated February 11, 1993, in response to an inquiry regarding certification of smoke detection systems in the cargo compartments of transport category airplanes, and provides guidance for determining detection times for these systems.

(a) Advisory Circular (AC) 25-9 and AC 25-17, differ in the guidance provided for time to detection for certification testing. AC 25-9 states in paragraph 7.e.(3) that "smoke detection should occur within one minute after the start of smoke generation." AC 25-17 states in paragraph 671.b.(6) that "An acceptable detection time for smoke detectors is 5 minutes. Use the smoke quantity and location criteria of AC 25-9, 'Smoke Detection, Penetration, and Evacuation Tests, and Related Flight Manual Emergency Procedures,' for showing that the smoke detection system detects a fire in satisfactory time. The time for fire detection systems was changed to one minute by Amendment 25-54 in § 25.858."

(b) The guidance contained in AC 25-9 reflects the detection times required in Amendment 25-54, which added § 25.858. This section established a higher standard of safety than previously existed for transport category airplanes, and applies to airplanes which have Amendment 25-54 in their certification basis. When an applicant applies for an amended or supplemental type certificate to convert a passenger configuration to a cargo configuration on an older airplane whose certification basis predates Amendment 25-54, the allowable maximum detection time is not specifically stated in 14 CFR. The five minute detection time, which is not mentioned in AC 25-9, was established in an FAA letter in 1965, and has been the accepted maximum detection time requirement until § 25.858 became effective on September 11, 1980.

(c) If an applicant applies for an amended or supplemental type certificate and the certification basis for the airplane predates Amendment 25-54, there is no regulatory basis for requiring a detection time of one minute. The applicant should be encouraged to meet the later amendment, or to make detection within one minute a design goal, but it would be inappropriate to require that the applicant comply with § 25.858.

(d) Two additional points should be made regarding wording in regulations that address fire detection systems. When the terms "fire detector" or "fire detection system" are used, this also encompasses smoke detectors and smoke detection systems. A review of the preamble to Amendment 25-54 reveals that the rule is intended to address systems which detect fires, and smoke detection systems were included. Also, questions are frequently asked regarding the expression that detection must occur "within one minute after the start of a fire." As noted in AC 25-9, time to detection is measured "after the start of smoke generation." Therefore, detection time is defined as the elapsed time from when the smoke generator is activated (switched to the mode which actively generates smoke) to when detection occurs (annunciation of smoke detection to the flight crew).

(3) Smoke Detection Certification Testing. The following policy is extracted from two FAA letters dated December 3 and December 15, 1992. The letters were in response to a request for approval of five items discussed in a meeting between the FAA and an applicant on November 6, 1992, all related to "Smoke Detection Testing Methodology/Procedures For Compliance To § 25.858."

(a) The five items below were discussed individually. It was noted prior to responding that the positions provided in the letter related to demonstration of compliance with the provisions of § 25.858, as promulgated by Amendment 25-54, and were not intended to provide guidance as to methods to be used for certification of an airplane which does not have Amendment 25-54 in its certification basis. In addition, the responses provided were not intended to be all inclusive. Other methods of demonstrating compliance could also be acceptable.

(b) The first proposal related to a specific fuel load (using tobacco as the fuel), tamping, and lighting procedure to be used for generating smoke to show compliance with the FAA requirements. The procedure and the tobacco weights were proposed to meet the requirements in a large compartment such as in a large transport category all cargo airplane. There were two charges (basket sizes) proposed. These two charges should be acceptable for all large transport category airplane cargo compartments. The FAA reserves the option to stipulate smaller fuel loads when finding compliance in small compartments.

(c) The second proposal discussed the use of a smoke deflector hat, which is required to provide a more realistic smoke propagation pattern than a direct smoke exhaust directed toward the crown of the compartment. The FAA had seen no evidence that a direct smoke stack exhaust provided a representative smoke pattern. It was stated that the deflector hat would continue to be required in future tests using a tobacco generator.

(d) The third proposal requested approval of continuous smoke generation until detection, and allowed "averaging" the detection times to give a one minute overall average for all positions tested, with maximum time not to exceed 110 seconds at any location. Section 25.858 states that detection must occur within one minute after the start of a fire. When § 25.858 was proposed, several commenters stated that the one minute detection time was too stringent, especially in light of the existing policy (5 minutes to detection). It was the opinion of the commenters that the technology was not available to enable the airplane manufacturers to meet the one minute requirement. The preamble to the final rule, issued as part of Amendment 25-54, noted that the technology was available or would be available when new airplanes affected by the rule were certificated. Subsequently, a number of airplanes have shown compliance with the one minute rule, indicating that the promulgators of the rule were correct in their assessment. The technology is available, and the FAA could not arbitrarily change that requirement to allow a fire to go undetected for 110 seconds in some locations in the cargo compartment. Such a finding would not be in accordance with the rule as issued. A rule change to allow longer detection times in special cases, such as for very large cargo compartments on all-cargo airplanes, would be required.

(e) The fourth proposal dealt with a means to reduce the number of locations at which smoke would be generated within the compartment to diminish the costs associated with flight testing new cargo compartment configurations. The proposal stated that smoke detection locations would be representative of high, low, and normal detection locations as documented in the applicant's tests. The certification locations were to be randomly selected from a population of representative locations. The number of representative test locations must be at least twice the number of required certification test locations and they must be available for FAA review. Typically, laboratory and ground testing determine the worst locations in each part of the compartment. The random selection of flight test locations should be acceptable provided the whole population of ground test times is already compliant with the rule. The FAA determined that this approach was acceptable for demonstrating compliance with § 25.858, and also for testing on the applicant's airplane.

(f) The fifth proposal discussed the "Statistical Procedure and Methodology" for demonstrating compliance with § 25.858. The proposal to use an average detection time for all locations, with no tested location having a detection time exceeding 110 seconds, was not acceptable to the FAA. However, it was recognized that smoke testing is not a perfectly repeatable process, and testing at any one location may yield varying detection times with multiple tests. Previous certification tests have proceeded as follows: If the first test at a given location results in a detection time of greater than 60 seconds, the applicant must repeat the test two more times; if the resulting average of the three tests at the given location is 60 seconds or less, the given location is a “Pass;” if the resulting average of the three tests at the given location is greater than 60 seconds, the given location and the fire detection system are both “Failed” and require a redesign of the system.

(g) Two additional points were raised by the applicant. In the FAA response to the second proposal, paragraph (c) above, regarding the use of a smoke deflector hat on the smoke generator, the FAA noted that "...we will continue to require the deflector hat on future tests." The applicant was concerned that this statement could lead to a misunderstanding regarding the use of the deflector hat on previous tests. The FAA had commented in previous correspondence that the smoke generator tends to direct smoke toward the top of the compartment, which could result in earlier detection times than would be the case if a cargo fire actually occurred (the objective of the generated smoke is to simulate natural bouyancy, not necessarily the upward velocity). It was noted that there had been no certification tests conducted using the applicant's smoke generator with a deflector hat in place. However, a deflector hat was informally tested during a certification flight test, and the FAA decided to require the use of a smoke deflector for the tobacco generator for any future certification flight tests that involved demonstrating compliance with the provisions of § 25.858.

(h) The FAA noted in our response to the third proposal, paragraph (d) above, regarding approval of continuous smoke generation until detection and allowing "averaging" the detection times to give a one minute overall average for all positions tested, that " Such a finding would not be in accordance with the rule as issued." The applicant expressed the opinion that the § 25.858 wording "...within one minute after the start of a fire" was not adequately defined in the rule. Demonstration of compliance for smoke detection systems, whether the requirement is the previous 5 minute standard per policy or the 1 minute provision in § 25.858, has always been accomplished by measuring the time from smoke generator "ON" until detection. We did not anticipate any change in this policy. If this were not the case, the period of time during which the tobacco charge is being ignited with a torch would be included in the time for detection. For the tobacco generator, the "ON" time is when the tobacco basket is placed in the generator and the fan turned on. For a theatrical smoke generator, the "ON" time is when the switch is turned on. It is recognized that a theatrical smoke generator may have a built in time delay (by design) between the "switch on" event and when the smoke begins to exit; the cognizant ACO engineer needs to make that determination. Such a time differential may be negligible or not measurable.

(4) William J. Hughes Technical Center Research and Development. The FAA Technical Center is currently conducting a research and development (R&D) program to help standardize fire detection certification methods. When this R&D effort is complete, it is intended to revise AC 25-9A to provide more objective criteria for smoke/fire detection certification. The above Policy/Compliance Methods will be subject to change and/or incorporation into the revision to AC 25-9A in the future.

e. References. The addresses for ordering the latest revision of advisory circulars and other referenced documents listed below can be found in the Appendix to this AC.

AC 25-9A - Smoke Detection, Penetration, and Evacuation tests and related flight manual Emergency Procedures.
AC 25-17 - Transport Airplane Cabin Interiors Crashworthiness Handbook
FAA Video, Smoke Quantities to Certify Smoke Detection Systems in Cargo Areas.

40. SECTION 25.863 - FLAMMABLE FLUID FIRE PROTECTION.

a. Rule Text.

(a) In each area where flammable fluids or vapors might escape by leakage of a fluid system, there must be means to minimize the probability of ignition of the fluids and vapors, and the resultant hazards if ignition does occur.
(b) Compliance with paragraph (a) of this section must be shown by analysis or tests, and the following factors must be considered:
(1) Possible sources and paths of fluid leakage, and means of detecting leakage.
(2) Flammability characteristics of fluids, including effects of any combustible or absorbing materials.
(3) Possible ignition sources, including electrical faults, overheating of equipment, and malfunctioning of protective devices.
(4) Means available for controlling or extinguishing a fire, such as stopping flow of fluids, shutting down equipment, fireproof containment, or use of extinguishing agents.
(5) Ability of airplane components that are critical to safety of flight to withstand fire and heat.
(c) If action by the flight crew is required to prevent or counteract a fluid fire (e.g., equipment shutdown or actuation of a fire extinguisher) quick acting means must be provided to alert the crew.
(d) Each area where flammable fluids or vapors might escape by leakage of a fluid system must be identified and defined.
[Amdt. 25-23, 35 FR 5676, Apr. 8, 1970, as amended by Amdt. 25-46, 43 FR 50597, Oct. 30, 1978]

b. Intent of Rule. The intent of this rule is to minimize the probability of ignition of flammable fluid or vapor leakage in any area where they may exist and, in case of ignition, to minimize the resultant hazard to the aircraft. The definition in 14 CFR 1.1 says "Flammable, with respect to a fluid or gas, means susceptible to igniting readily or to exploding. Examples are aviation jet fuel, hydraulic fluid, and oxygen. Hydraulic equipment, e.g., pumps are qualified per airplane and engine manufacturers' specifications, (SAE) industry standards and/or military standards addressing issues of bonding and grounding, flame and arc resistance, explosion proofing, dielectric strength and case drain temperature limits.

c. Background. For guidance on compliance with this requirement, refer to Advisory Circular (AC) 25-XX, Propulsion Systems Handbook, chapter 3, section 1.

d. Policy/Compliance Methods. For guidance with this requirement, refer to Advisory Circular (AC) 25-XX, Propulsion Systems Handbook, chapter 3, section 1. Section 25.1435(c), Hydraulic systems-fire protection, requires compliance with § 25.863.

e. Reference. The address for ordering the latest revision of the advisory circular listed below can be found in the Appendix to this AC.

AC 25-XX, Propulsion Systems Handbook.

41. SECTION 25.869 - FIRE PROTECTION SYSTEMS.

a. Rule Text.

(a) Electrical system components:
(1) Components of the electrical system must meet the applicable fire and smoke protection requirements of 25.831(c) and 25.863.
(2) Electrical cables, terminals, and equipment in designated fire zones, that are used during emergency procedures, must be at least fire resistant.
(3) Main power cables (including generator cables) in the fuselage must be designed to allow a reasonable degree of deformation and stretching without failure and must be-
(i) Isolated from flammable fluid lines; or
(ii) Shrouded by means of electrically insulated, flexible conduit, or equivalent, which is in addition to the normal cable insulation.
(4) Insulation on electrical wire and electrical cable installed in any area of the fuselage must be self-extinguishing when tested in accordance with the applicable portions of Part I, appendix F of this Part.
(b) Each vacuum air system line and fitting on the discharge side of the pump that might contain flammable vapors or fluids must meet the requirements 25.1183 if the line or fitting is in a designated fire zone. Other vacuum air systems components in designated fire zones must be at least fire resistant.
(c) Oxygen equipment and lines must-
(1) Not be located in any designated fire zone,
(2) Be protected from heat that may be generated in, or escape from, any designated fire zone, and

(3) Be installed so that escaping oxygen cannot cause ignition of grease, fluid, or vapor accumulations that are present in normal operation or as a result of failure or malfunction of any system.
[Amdt. 25-72, 55 FR 29784, Jul. 20, 1990]

b. Intent of Rule. The intent of this rule is to minimize the probability of fire damage and to assure critical components of the electrical system, vacuum air system, and oxygen equipment and lines maintain the capability needed to complete safe flight and landing following a fire.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Section 4b.626 of the CAR became § 25.1359 of 14 CFR for electrical system fire and smoke protection; section 4b.658 of the CAR became §§ 25.1433(b) and 25.1433(c) of 14 CFR for vacuum air system line and fittings fire protection; and § 4b.651(f) of the CAR became § 25.1451 of 14 CFR for oxygen equipment and lines fire protection..

(1) Amendment 25-72 (July 20, 1990) consolidated all fire protection requirements for electrical, vacuum, and oxygen systems and transferred to § 25.869 “Fire protection: systems.” Section 25.1359 became § 25.869(a) except for test acceptance criteria which was transferred to Appendix F. Sections 25.1433(b) and (c) were combined as §§ 25.869(b) and 25.1451 became § 25.869(c). Minor editorial changes were also made as necessary.

d. Policy/Compliance Methods: For guidance on compliance with this requirement, refer to the preamble of this rule and the following information. For policy and guidance on § 25.869(a), electrical system components, refer to Advisory Circular (AC) 25-16, AC 25-17 (section 25.1359, paragraph 781), and Appendix F to part 25. For policy and guidance on § 25.869(b), vacuum air systems, refer to the Propulsion Systems Handbook, section 25.1183. For policy and guidance on § 25.869(c), oxygen equipment and lines, see paragraph 115. d.(3)(e) of this document and AC 25-17, section 25.1451, par 1011.

e. References. The address for ordering the latest revision of the advisory circulars listed below can be found in the Appendix to this AC.

AC 25-16, Electrical Fault and Fire Prevention and Protection.
AC 25-17, Transport Airplane Cabin Interiors Crashworthiness Handbook.

Chapter 2. - POWERPLANT

Section 1. GENERAL

42. SECTION 25.943 - NEGATIVE ACCELERATION.

a. Rule Text.

No hazardous malfunction of an engine, an auxiliary power unit approved for use in flight, or any component or system associated with the powerplant or auxiliary power unit may occur when the airplane is operated at the negative accelerations within the flight envelopes prescribed in 25.333. This must be shown for the greatest duration expected for the acceleration.
[Amdt. 25-40, 42 FR 15043, Mar. 17, 1977]

NOTE: This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group will be tasked to recommend revisions to § 25.943, paragraphs 25.943 and 25X1315 of the JAR, as well as develop any advisory information if neccessary.

NOTE: For policy and guidance on compliance with this requirement, see Advisory Circular (AC) 25-XX, Propulsion Systems Handbook, chapter 4. This regulation applies to hydraulic and pneumatic system components as well. See AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes, paragraph 101, for flight test procedures. Also see paragraph 25X1315 of the JAR and ACJ 25X1315 for additional information.

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Section 2. FUEL SYSTEM COMPONENTS

43. <u>SECTION 25.1001 - FUEL JETTISONING SYSTEM.</u>

a. <u>Rule Text.</u>

(a) A fuel jettisoning system must be installed on each airplane unless it is shown that the airplane meets the climb requirements of §§ 25.119 and 25.121(d) at maximum takeoff weight, less the actual or computed weight of fuel necessary for a 15-minute flight comprised of a takeoff, go-around, and landing at the airport of departure with the airplane configuration, speed, power, and thrust the same as that used in meeting the applicable takeoff, approach, and landing climb performance requirements of this part.
(b) If a fuel jettisoning system is required it must be capable of jettisoning enough fuel within 15 minutes, starting with the weight given in paragraph (a) of this section, to enable the airplane to meet the climb requirements of §§ 25.119 and 25.121(d), assuming that the fuel is jettisoned under the conditions, except weight, found least favorable during the flight tests prescribed in paragraph (c) of this section.
(c) Fuel jettisoning must be demonstrated beginning at maximum takeoff weight with flaps and landing gear up and in-
(1) A power-off glide at 1.4 Vs_1;
(2) A climb at the one-engine inoperative best rate-of-climb speed, with the critical engine inoperative and the remaining engines at maximum continuous power; and
(3) Level flight at 1.4 Vs_1 ; if the results of the tests in the conditions specified in paragraphs (c) (1) and (2) of this section show that this condition could be critical.
(d) During the flight tests prescribed in paragraph (c) of this section, it must be shown that-
(1) The fuel jettisoning system and its operation are free from fire hazard;
(2) The fuel discharges clear of any part of the airplane;
(3) Fuel or fumes do not enter any parts of the airplane; and
(4) The jettisoning operation does not adversely affect the controllability of the airplane.
(e) For reciprocating engine powered airplanes, means must be provided to prevent jettisoning the fuel in the tanks used for takeoff and landing below the level allowing 45 minutes flight at 75 percent maximum continuous power. However, if there is an auxiliary control independent of the main jettisoning control, the system may be designed to jettison the remaining fuel by means of the auxiliary jettisoning control.
(f) For turbine engine powered airplanes, means must be provided to prevent jettisoning the fuel in the tanks used for takeoff and landing below the level

allowing climb from sea level to 10,000 feet and thereafter allowing 45 minutes cruise at a speed for maximum range. However, if there is an auxiliary control independent of the main jettisoning control, the system may be designed to jettison the remaining fuel by means of the auxiliary jettisoning control.
(g) The fuel jettisoning valve must be designed to allow flight personnel to close the valve during any part of the jettisoning operation.
(h) Unless it is shown that using any means (including flaps, slots, and slats) for changing the airflow across or around the wings does not adversely affect fuel jettisoning, there must be a placard, adjacent to the jettisoning control, to warn flight crewmembers against jettisoning fuel while the means that change the airflow are being used.
(i) The fuel jettisoning system must be designed so that any reasonably probable single malfunction in the system will not result in a hazardous condition due to unsymmetrical jettisoning of, or inability to jettison, fuel.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-18, 33 FR 12226, Aug. 30, 1968; Amdt. 25-57, 49 FR 6848, Feb. 23, 1984]

NOTE: This regulation will be the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group may recommend revisions to the regulation and any associated advisory material.

NOTE: For policy and guidance on compliance with this requirement, see Advisory Circular (AC) 25-XX, Propulsion Systems Handbook. This regulation may require special consideration for certain equipment where the airplane is not capable of a return landing without exceeding equipment ratings/capabilities such as brakes and tires. Brake maximum kinetic energy rating(s) and tire maximum speed ratings may be exceeded for an immediate return/turnback, or a flapless landing, especially for large two engine airplanes.

Section 3. POWERPLANT FIRE PROTECTION

44. SECTION 25.1183 - FLAMMABLE FLUID-CARRYING COMPONENTS.

a. Rule Text.

(a) Except as provided in paragraph (b) of this section, each line, fitting, and other component carrying flammable fluid in any area subject to engine fire conditions, and each component which conveys or contains flammable fluid in a designated fire zone must be fire resistant, except that flammable fluid tanks and supports in a designated fire zone must be fireproof or be enclosed by a fireproof shield unless damage by fire to any non-fireproof part will not cause leakage or spillage of flammable fluid. Components must be shielded or located to safeguard against the ignition of leaking flammable fluid. An integral oil sump of less than 25-quart capacity on a reciprocating engine need not be fireproof nor be enclosed by a fireproof shield.
(b) Paragraph (a) of this section does not apply to-
(1) Lines, fittings, and components which are already approved as part of a type certificated engine; and
(2) Vent and drain lines, and their fittings, whose failure will not result in, or add to, a fire hazard.
(Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-11, 32 FR 6913, May 5, 1967; Amdt. 25-36, 39 FR 35461, Oct. 1, 1974; Amdt. 25-57, 49 FR 6849, Feb. 23, 1984)

NOTE: For policy and guidance on compliance with this requirement, see Advisory Circular (AC) 25-XX, Propulsion Systems Handbook, chapter 4, section 9. Section 25.1435(c) - Hydraulic systems - Fire protection, requires compliance with § 25.1183.

NOTE: Under planned harmonization effort, paragraph 25.1183(c) of the JAR will be adopted by FAA as § 25.1183(c); the text is as follows:

"(c) All components, including ducts, within a designated fire zone must be fireproof if, when exposed to or damaged by fire, they could -

(1) Result in fire spreading to other regions of the airplane, or

(2) Cause unintentional operation of, or inability to operate, essential services or equipment."

45. SECTION 25.1185 - FLAMMABLE FLUIDS.

a. Rule Text.

(a) Except for the integral oil sumps specified in 25.1013 (a), no tank or reservoir that is a part of a system containing flammable fluids or gases may be in a designated fire zone unless the fluid contained, the design of the system, the materials used in the tank, the shut-off means, and all connections, lines, and control provide a degree of safety equal to that which would exist if the tank or reservoir were outside such a zone.
(b) There must be at least one-half inch of clear airspace between each tank or reservoir and each firewall or shroud isolating a designated fire zone.
(c) Absorbent materials close to flammable fluid system components that might leak must be covered or treated to prevent the absorption of hazardous quantities of fluids.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964 as amended by Amdt. 25-19, 33 FR15410, Oct. 17, 1968]

NOTE: For policy and guidance on compliance with this requirement, see Advisory Circular (AC) 25-XX, Propulsion Systems Handbook, chapter 4, section 9. Section 25.1435(c) - Hydraulic systems - Fire protection, requires compliance with § 25.1185.

46. SECTION 25.1189 - SHUTOFF MEANS.

a. Rule Text.

(a) Each engine installation and each fire zone specified in § 25.1181(a) (4) and (5) must have a means to shut off or otherwise prevent hazardous quantities of fuel, oil, deicer, and other flammable fluids, from flowing into, within, or through any designated fire zone, except that shutoff means are not required for-
(1) Lines, fittings, and components forming an integral part of an engine; and
(2) Oil systems for turbine engine installations in which all components of the system in a designated fire zone, including oil tanks, are fireproof or located in areas not subject to engine fire conditions.
(b) The closing of any fuel shutoff valve for any engine may not make fuel unavailable to the remaining engines.
(c) Operation of any shutoff may not interfere with the later emergency operation of other equipment, such as the means for feathering the propeller.
(d) Each flammable fluid shutoff means and control must be fireproof or must be located and protected so that any fire in a fire zone will not affect its operation.
(e) No hazardous quantity of flammable fluid may drain into any designated fire zone after shutoff.

(f) There must be means to guard against inadvertent operation of the shutoff means and to make it possible for the crew to reopen the shutoff means in flight after it has been closed.
(g) Each tank-to-engine shutoff valve must be located so that the operation of the valve will not be affected by powerplant or engine mount structural failure.
(h) Each shutoff valve must have a means to relieve excessive pressure accumulation unless a means for pressure relief is otherwise provided in the system.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-23, 35FR 5677, Apr. 8, 1970; Amdt. 25-57, 49 FR 6849, Feb. 23, 1984]

NOTE: This regulation is the subject of a Federal Aviation Regulations/Joint Aivation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group is planning to recommend criteria for compliance as advisory material.

NOTE: For policy and guidance on compliance with this requirement, see Advisory Circular (AC) 25-XX, Propulsion Systems Handbook, chapter 4, section 9. Section 25.1435(c) - Hydraulic systems - Fire protection, requires compliance with § 25.1189.

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Chapter 3. EQUIPMENT

Section 1. GENERAL

47. SECTION 25.1301 - FUNCTION AND INSTALLATION.

a. Rule Text.

Each item of installed equipment must-
(a) Be of a kind and design appropriate to its intended function;
(b) Be labeled as to its identification, function, or operating limitations, or any applicable combination of these factors;
(c) Be installed according to limitations specified for that equipment; and
(d) Function properly when installed.

b. Intent of Rule. The intent of this requirement is to define general conditions for certification of all installed equipment regardless if it's covered under another requirement. This requirement applies to all equipment/systems whether required as minimum equipment for installation on airplanes or non-required/non-essential equipment (e.g., advisory systems, pilot aids, or passenger comfort related amenities).

c. Background. This requirement originated under § 4b.682 of the Civil Air Regulations (CAR), October 1, 1949, with reference to items of equipment for which type certification was required outlined in part 15 of the CAR. Effective July 20, 1950, it was recodified as § 4b.601 by deleting reference to part 15 per Amendment 04b-2 (effective February 6, 1950), and allowing approval of materials, parts, and appliances per § 04b.05 and the new TSO system. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the CAR. Section 4b.601 of the CAR became § 25.1301 of 14 CFR.

(1) Harmonization. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group is recommending revisions to §§ 25.1301, 25.1309, a new 25.1310, and a revised Advisory Circular AC 25.1309-1B. Section 25.1301(d) will be deleted as being redundant with the proposed § 25.1309(a).

d. Policy/Compliance Methods. Information regarding installation limitations and proper functioning is normally available from the equipment manufacturers in their installation and operations manuals. For example, TSO Rating Limits apply under § 25.1309(c). Under § 25.1301(d), TSO is not an installation approval. The user/installer is responsible for form, fit, and function.

(1) Joint Aviation Requirements (JAR) ACJ 25.1301(b). The following guidance is extracted from JAR ACJ 25.1301(b):

(a) An adequate means of identification should be provided for all cables, connectors, and terminals. The means employed should be such as to ensure that the identification does not deteriorate under service conditions.

(b) When pipelines (hydraulic/pneumatic, etc.) are marked for the purpose of distinguishing their functions, the markings should be such that the risk of confusion by maintenance or servicing personnel will be minimized. Distinction by means of color markings alone is not acceptable. The use of alphabetic or numerical symbols will be acceptable if recognition depends upon reference to a master key and any relation between symbol and function is carefully avoided. Specification ISO.12 gives acceptable graphical markings.

e. Reference. None.

48. SECTION 25.1309 - EQUIPMENT, SYSTEMS, AND INSTALLATION.

a. Rule Text.

(a) The equipment, systems, and installations whose functioning is required by this subchapter, must be designed to ensure that they perform their intended functions under any foreseeable operating condition.
(b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that-
(1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and
(2) The occurrence of any other failure conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable.
(c) Warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards.
(d) Compliance with the requirements of paragraph (b) of this section must be shown by analysis, and where necessary, by appropriate ground, flight, or simulator tests. The analysis must consider-
(1) Possible modes of failure, including malfunctions and damage from external sources.
(2) The probability of multiple failures and undetected failures.
(3) The resulting effects on the airplane and occupants, considering the stage of flight and operating conditions, and
(4) The crew warning cues, corrective action required, and the capability of detecting faults.

(e) Each installation whose functioning is required by this subchapter, and that requires a power supply, is an "essential load" on the power supply. The power sources and the system must be able to supply the following power loads in probable operating combinations and for probable durations:
(1) Loads connected to the system with the system functioning normally.
(2) Essential loads, after failure of any one prime mover, power converter, or energy storage device.
(3) Essential loads after failure of-
(i) Any one engine on two-engine airplanes; and
(ii) Any two engines on three-or-more-engine airplanes.
(4) Essential loads for which an alternate source of power is required by this chapter, after any failure or malfunction in any one power supply system, distribution system, or other utilization system.
(f) In determining compliance with paragraphs (e) (2) and (3) of this section, the power loads may be assumed to be reduced under a monitoring procedure consistent with safety in the kinds of operation authorized. Loads not required in controlled flight need not be considered for the two-engine-inoperative condition on airplanes with three or more engines.
(g) In showing compliance with paragraphs (a) and (b) of this section with regard to the electrical system and equipment design and installation, critical environmental conditions must be considered. For electrical generation, distribution, and utilization equipment required by or used in complying with this chapter, except equipment covered by Technical Standard Orders containing environmental test procedures, the ability to provide continuous, safe service under foreseeable environmental conditions may be shown by environmental tests, design analysis, or reference to previous comparable service experience on other aircraft.
[Amdt. 25-23, 35 FR 5679, Apr. 8, 1970, as amended by Amdt. 25-38, 41 FR 55467, Dec. 20, 1976; Amdt. 25-41, 42 FR 36970, Jul. 18, 1977]

b. Intent of Rule. This regulation covers, but is not limited to, mechanical, electrical, pneumatic, and hydraulic power sources, associated distribution, and corresponding utilization systems.

c. Background. This regulation originated under Amendment 4b-6 of the Civil Air Regulations (CAR), effective March 5, 1952, as § 4b.606 and was codified on December 31, 1953. It was amended under Amendment 4b-1, effective May 18, 1954, by clarifying the allowed assumptions in the determination of probable operating combinations of essential loads for the power failure conditions. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the CAR. Section 4b.606 of the CAR became § 25.1309 of 14 CFR.

(1) Amendment 25-23 (April 8, 1970) added these requirements:

(i) Where the consequences of complete loss of system function would be catastrophic, combinations of failures and multiple failures due to common causes must be considered, and sufficient reliability, redundancy and isolation provided to make catastrophic systems failure extremely improbable.

(ii) Occurrence of failures that result in serious degradation of flight characteristics, a large increase in crew work-load, or difficult emergency procedures be improbable.

(iii) Warning information must be provided to alert the crew to unsafe system operating conditions and to enable them to take corrective action.

(iv) Compliance to (i), (ii), and (iii) be shown by analysis and ground/flight/simulator tests.

(2) Amendment 25-38 (February 1, 1977) amended the title by inserting a comma between the words "equipment" and "Systems" and between the words "Systems" and "and." The change was strictly editorial.

(3) Amendment 25-41 (September 1, 1977(revised §§ 25.1309(b)(2), (c), lead-in of (d), (e)(3), and (f). The reference to occupant injury in (b)(2) was deleted because the matter of preventing injuries to occupants is covered elsewhere in the regulations; deleted reference to (c) in (d) because it could have been unreasonably burdensome for compliance; added provisions in (c) to minimize crew errors; revised (e)(3) and (f) related to electrical systems.

(4) Harmonization. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group is recommending revisions to §§ 25.1301, 25.1309, a new 25.1310, and a revised AC 25.1309-1B. Section 25.1301(d) will be deleted as being redundant with the proposed § 25.1309(a).

d. Policy/Compliance Methods. The term "subchapter" in § 25.1309(a) is intended to cover not only subchapter "C," but also the equipment, systems, and installations not specifically required by subchapter "C" but installed in airplanes in order to engage in operations covered by other subchapters. Dependence for safety of flight might be placed on installations not otherwise mentioned in the rules.

(1) Probability of a Fire. The following is extracted from an FAA memorandum, dated March 9, 1995. This is in response to a request for guidance regarding the use of the probability of a fire in a failure analysis when showing compliance with § 25.1309. The focus of the request was directed at the three issues addressed below:

(a) The first issue concerns whether the occurrence of a cargo compartment fire should be considered to have a probability of one, or something less than one. Advisory Circular (AC) 25.1309-1A, paragraph 8e, "Operational and Environmental Conditions," allows that random conditions may be considered to have a probability of occurrence less than one, and may usually be included in a safety analysis. The AC indicates that a random condition is a condition for which the airplane is not designed, and in which the airplane is not normally approved to operate. It also indicates that a random condition may be used in the analysis even when the system under analysis is designed to protect against the occurrence of the random condition. The AC provides, as an example, that it would be reasonable and rational to use a probability of less than one of encountering hazardous turbulence or gust levels after the failure of a structural load alleviation system. A probability less than one of fire occurring after a failure of the fire protection system is similar to this example, and may be used in the analysis. Advisory Circular 25.1309-1A also provides counter-examples for conditions which should not be considered random, and for which a probability of one should be used. These are conditions for which the airplane is designed. The examples provided, instrument meteorological conditions and Category III weather operations, are conditions in which the airplane would be expected to operate as a matter of course, and for which operational approval would be granted.

(b) The second issue concerns what value less than one should be assigned to the probability of the occurrence of a fire. Advisory Circular 25.1309-1A, paragraph 8e, provides guidance that the statistically-derived probability used in the analysis should be based on an applicable supporting database and a valid statistical distribution. When requesting approval for the use of the probability of a random condition in a safety analysis, it is incumbent on the applicant to supply the data, show the applicability of the database from which the data is supplied, and derive a valid statistical conclusion. The ACO should then evaluate the applicant's statistical information and determine if the value used in the analysis is supported by the data presented. This value must be reassessed for subsequent programs, as service experience gained in the future may require the probability of the occurrence to be re-evaluated.

(c) The third issue is whether the required safety level reached through the use of the Maintenance Steering Group, Revision 3 (MSG-3) procedures is higher than that reached using a § 25.1309 related analysis. We contend that this is not so, and that a like-comparison of the two sets of procedures is not valid. The § 25.1309 analysis process is directed at assessing the contributions of failures to given failure conditions, and to directing the airplane or system design appropriately. The MSG-3 process is directed at determining appropriate maintenance actions given the contribution of a failure to a reduction in safety. Findings from the § 25.1309 analysis process are used as starting points for certain MSG-3 processes to determine maintenance activities and intervals, or whether the maintenance process can adequately minimize the risk elements assigned to it. The MSG-3 procedures must assume the combination of a system failure with the occurrence of the condition, which the system was designed to protect against, in order to account for hidden failures when determining maintenance actions. Expected or allowable probabilities related to system failures are not derived through the MSG-3 process. In applying the above guidance, note that § 25.1309 is a rule of general applicability, and should not be used to replace a more specific and stringent requirement. Cargo compartments, and compartment fire detection and protection systems must meet requirements specified in §§ 25.855, 25.857, and 25.858, regardless of probabilities as determined in a § 25.1309 related analysis.

(2) Examples. For an example of compliance with § 25.1309(c), see paragraph d(1) under § 25.1441, Oxygen equipment and supply, of this AC. Another example of compliance is included under paragraph d(2), § 25.855, Cargo or baggage compartments, of this AC.

(3) Safe and Reliable. The following is extracted from an FAA memorandum dated October 26, 1990, and addresses an inquiry regarding (i) The meaning of "safe and reliable" used in §§ 25.109(b) and 25.125(b)(3) in terms of AC 25.1309-1A probability, and (ii) The acceptable failure probability for deceleration devices like anti-skid and ground spoilers that have relatively large and small effects on landing distance. The FAA response follows:

(a) Safe and reliable is generally used to mean that a failure condition is improbable. In terms of AC 25.1309-1A quantitative probability terms, improbable failure conditions are those having a probability on the order of 1×10^{-5} or less.

(b) Each deceleration device, such as anti-skid and ground spoilers, would be expected to have a failure condition that is at least improbable (i.e. 1×10^{-5} or less) regardless of its effect on stopping distance.

e. References. For policy and guidance on compliance with this requirement, see AC 25.1309-1A, System Design Analysis, issued June 21, 1988, or latest revision, and AC 25-19, Certification Maintenance Requirements, issued November 28, 1994, or latest revision.

49 - 51. [RESERVED]

Section 2. INSTRUMENTS: INSTALLATION

52. SECTION 25.1325 - STATIC PRESSURE SYSTEMS.

a. Rule Text.

(a) Each instrument with static air case connections must be vented to the outside atmosphere through an appropriate piping system.
(b) Each static port must be designed and located in such manner that the static pressure system performance is least affected by airflow variation, or by moisture or other foreign matter, and that the correlation between air pressure in the static pressure system and true ambient atmospheric static pressure is not changed when the airplane is exposed to the continuous and intermittent maximum icing conditions defined in Appendix C of this Part.
(c) The design and installation of the static pressure system must be such that-
(1) Positive drainage of moisture is provided; chafing of the tubing and excessive distortion or restriction at bends in the tubing is avoided; and the materials used are durable, suitable for the purpose intended, and protected against corrosion; and
(2) It is airtight except for the port into the atmosphere. A proof test must be conducted to demonstrate the integrity of the static pressure system in the following manner:
(i) Unpressurized airplanes. Evacuate the static pressure system to a pressure differential of approximately 1 inch of mercury or to a reading on the altimeter, 1,000 feet above the airplane elevation at the time of the test. Without additional pumping for a period of 1 minute, the loss of indicated altitude must not exceed 100 feet on the altimeter.
(ii) Pressurized airplanes. Evacuate the static pressure system until a pressure differential equivalent to the maximum cabin pressure differential for which the airplane is type certificated is achieved. Without additional pumping for a period of 1 minute, the loss of indicated altitude must not exceed 2 percent of the equivalent altitude of the maximum cabin differential pressure or 100 feet, whichever is greater.
(d) Each pressure altimeter must be approved and must be calibrated to indicate pressure altitude in a standard atmosphere, with a minimum practicable calibration error when the corresponding static pressures are applied.
(e) Each system must be designed and installed so that the error in indicated pressure altitude, at sea level, with a standard atmosphere, excluding instrument calibration error, does not result in an error of more than +/- 30 feet per 100 knots speed for the appropriate configuration in the speed range between 1.3 V_{SO} *with flaps extended and 1.8* V_{S1} *with flaps retracted. However, the error need not be less than +/- 30 feet.*

(f) If an altimeter system is fitted with a device that provides corrections to the altimeter indication, the device must be designed and installed in such manner that it can be bypassed when it malfunctions, unless an alternate altimeter system is provided. Each correction device must be fitted with a means for indicating the occurrence of reasonably probable malfunctions, including power failure, to the flight crew. The indicating means must be effective for any cockpit lighting condition likely to occur.
(g) Except as provided in paragraph (h) of this section, if the static pressure system incorporates both a primary and an alternate static pressure source, the means for selecting one or the other source must be designed so that-
(1) When either source is selected, the other is blocked off; and
(2) Both sources cannot be blocked off simultaneously.
(h) For unpressurized airplanes, paragraph (g)(1) of this section does not apply if it can be demonstrated that the static pressure system calibration, when either static pressure source is selected, is not changed by the other static pressure source being open or blocked.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-5, 30 FR 8261, Jun. 29, 1965; Amdt. 25-12, 32 FR 7587, May 24, 1967; Amdt. 25-41, 42 FR 36970, Jul. 18, 1977]

b. Intent of Rule. This rule provides minimum design and certification requirements for static pressure systems to ensure proper static system operation in varying operating conditions.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Many of the requirements in § 4b.612(b) of the CAR were carried over essentially unchanged to § 25.1325 of 14 CFR.

(1) Amendment 25-5 (June 29, 1965) added requirements for (1) operation in icing conditions and (2) devices that provide corrections to the altimeter indication.

(2) Amendment 25-12 (May 24, 1967) added requirements for static system proof testing for pressurized and unpressurized airplanes.

(3) Amendment 25-41 (July 18, 1977) added standards for static pressure systems, which incorporate the ability to select one or the other of primary and alternate static systems.

d. Policy/Compliance Methods. For policy and guidance on compliance with this requirement, refer to Advisory Circular (AC) 25-XX, Electrical Systems Handbook.

e. References. None.

Section 3. SAFETY EQUIPMENT

53. SECTION 25.1419 ICE PROTECTION.

a. Rule Text.

If certification with ice protection provisions is desired, the airplane must be able to safely operate in the continuous maximum and intermittent maximum icing conditions of appendix C. To establish that the airplane can operate within the continuous maximum and intermittent maximum conditions of appendix C:
(a) An analysis must be performed to establish that the ice protection for the various components of the airplane is adequate, taking into account the various airplane operational configurations; and
(b) To verify the ice protection analysis, to check for icing anomalies, and to demonstrate that the ice protection system and components are effective, the airplane or its components must be flight tested in the various operational configurations, in measured natural atmospheric icing conditions and, as found necessary, by one or more of the following means:
(1) Laboratory dry air or simulated icing tests, or a combination of both, of the components or models of the components.
(2) Flight dry air tests of the ice protection system as a whole, or of its individual components.
(3) Flight tests of the airplane or its components in measured simulated icing conditions.
(c) Caution information, such as an amber caution light or equivalent, must be provided to alert the flightcrew when the anti-ice or de-ice system is not functioning normally.
(d) For turbine engine powered airplanes, the ice protection provisions of this section are considered to be applicable primarily to the airframe. For the powerplant installation, certain additional provisions of Subpart E of this Part may be found applicable.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-23, 35 FR 5680, Apr. 8, 1970; Amdt. 25-72, 55 FR 29785, Jul. 20, 1990]

b. Intent of Rule. This rule provides standards for certification of an airplane with ice protection provisions. Certification for flight in icing conditions is optional at the discretion of the applicant. If the airplane is not certificated for flight in icing condition, appropriate limitations shall be placed in the type certificate data sheet and the airplane flight manual.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Many of the provisions in section 4b.640 of the CAR were carried over with minor word changes to § 25.1419 of 14 CFR. However, the intent of the CAR 4b.640 was unchanged.

Amendment 25-23 revised paragraph (c) to require flight tests in measured natural atmospheric icing conditions. Prior to Amendment 25-23 flight tests in measured natural atmospheric icing conditions were optional.

(1) Amendment 25-23 (April 8, 1970) added the requirements for flight testing in natural icing conditions contained in § 25.1419(c).

(2) Amendment 25-72 (July 20, 1990) rearranged the sub-paragraphs and inserted a new paragraph (c), which requires caution information when the anti-ice or de-ice system is not functioning normally. Prior to this amendment, a means to determine that a pneumatic de-icing boot system was working normally was required by § 25.1416. Section 25.1416 was removed to allow for the concept of the "dark cockpit." (The term "dark cockpit" is descriptive language that refers to the absence of annunciation lights in the cockpit unless a system is operating abnormally.)

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and AC 20-73 and AC 25.1419-1.

e. References. The addresses for ordering the latest revision of advisory circulars, and other referenced documents listed below can be found in the Appendix to this AC.

AC 20-73, Aircraft Ice Protection.
AC 23.1419-2, Certification of Part 23 Airplanes for Flight in Icing Conditions.
AC 25.1419-1, Certification of Transport Category Airplanes for Flight in Icing Conditions.
Report No. DOT/FAA/CT-88/8-1 - Aircraft Icing Handbook (three volumes)
FAA Technical Report ADS-4 - Engineering summary of Airframe Icing Technical Data, December 1963. (Although most of the information contained in this report is still valid, some is outdated, and more usable information is now available through recent research and experience and is included in the Aircraft Icing Handbook.)

54 - 58. [RESERVED]

Section 4. MISCELLANEOUS EQUIPMENT

59. SECTION 25.1433 - VACUUM SYSTEMS.

a. Rule Text.

There must be means, in addition to the normal pressure relief, to automatically relieve the pressure in the discharge lines from the vacuum air pump when the delivery temperature of the air becomes unsafe.
[Amdt. 25-72, 55 FR 29785, Jul. 20, 1990]

b. Intent of Rule. This rule provides minimum design and certification requirements for vacuum systems, specifically to require automatic pressure relief in the presence of high delivery air temperatures.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The requirements in section 4b.658 of the CAR were carried over essentially unchanged to § 25.1433 of 14 CFR.

(1) Amendment 25-72 (July 20, 1990) moved §§ 25.1433(b) and 25.1443(c), which dealt with fire protection for vacuum air systems, to § 25.869, Fire protection: Systems.

d. Policy/Compliance Methods. There is no existing written policy or guidance related to this subject in our files.

e. References. None.

60. SECTION 25.1435 - HYDRAULIC SYSTEMS.

a. Rule Text.

(a) Design.
(1) Each element of the hydraulic system must be designed to withstand, without deformation that would prevent it from performing its intended function, the design operating pressure loads in combination with limit structural loads which may be imposed.
(2) Each element of the hydraulic system must be able to withstand, without rupture, the design operating pressure loads multiplied by a factor of 1.5 in combination with ultimate structural loads that can reasonably occur simultaneously. Design operating pressure is maximum normal operating pressure, excluding transient pressure.

(b) Tests and analysis.
(1) A complete hydraulic system must be static tested to show that it can withstand 1.5 times the design operating pressure without a deformation of any part of the system that would prevent it from performing its intended function. Clearance between structural members and hydraulic system elements must be adequate and there must be no permanent detrimental deformation. For the purpose of this test, the pressure relief valve may be made inoperable to permit application of the required pressure.
(2) Compliance with 25.1309 for hydraulic systems must be shown by functional tests, endurance tests, and analyses. The entire system, or appropriate subsystems, must be tested in an airplane or in a mockup installation to determine proper performance and proper relation to other aircraft systems. The functional tests must include simulation of hydraulic system failure conditions. Endurance tests must simulate the repeated complete flights that could be expected to occur in service. Elements which fail during the tests must be modified in order to have the design deficiency corrected and, where necessary, must be sufficiently retested. Simulation of operating and environmental conditions must be completed on elements and appropriate portions of the hydraulic system to the extent necessary to evaluate the environmental effects. Compliance with 25.1309 must take into account the following:
(i) Static and dynamic loads including flight, ground, pilot, hydrostatic, inertial and thermally induced loads, and combinations thereof.
(ii) Motion, vibration, pressure transients, and fatigue.
(iii) Abrasion, corrosion, and erosion.
(iv) Fluid and material compatibility.
(v) Leakage and wear.
(c) Fire protection. Each hydraulic system using flammable hydraulic fluid must meet the applicable requirements of 25.863, 25.1183, 25.1185, and 25.1189.
[Amdt. 25-13, 32 FR 9154, Jun. 28, 1967, as amended by Amdt. 25-41, 42 FR 36971, Jul. 18, 1977; Amdt. 25-72, 55 FR 29786, Jul. 20, 1990]

b. Intent of Rule. The intent of this rule is to provide minimum design, performance, and safety requirements for transport category airplane hydraulic systems addressing the following aspects of component design and qualification, subsystem/system design, and system integration:

(1) Design operating loads in combination with limit and ultimate structural loads.

(2) Pressure transients and cyclic pressures.

(3) Environmental conditions.

(4) Fatigue and endurance life.

(5) Single and multiple failure modes.

(6) Indication and warning.

(7) Installation and support.

(8) Pump/engine interface.

(9) Fire protection.

(10) Continued safe flight and landing .

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Sections 4b.653, 4b.654, and 4b.655 respectively became §§ 25.1435(a), 25.1435(b), and 25.1435(c) of 14 CFR for hydraulic systems. Since then, § 25.1435 has been revised under Amendment 25-13, Amendment 25-41, and Amendment 25-72 to make the regulations more comprehensive and to delete redundancies.

(1) Amendment 25-13 (June 28, 1967) prescribed more comprehensive design and test requirements by requiring (1) cockpit indication of system fluid quantity, (2) a means to prevent harmful or hazardous concentrations of the fluid or vapors in the crew or passenger compartments during flight due to hydraulic fluid leakage/release, and (3) compliance with § 25.1309 by functional tests, endurance tests, and analysis of the entire system or appropriate subsystems tested in an airplane or in a mockup installation to determine proper performance and proper relation to other aircraft systems.

(a) Regarding compliance with § 25.1435(b)(2), the preamble to the final rule states in part that, "the FAA agrees that the proposed environmental testing of the assembled system is not necessary in order to achieve a reasonable and effective testing program for improving hydraulic system reliability." The final rule was changed to allow applicants to meet endurance test requirements by performing endurance testing on components as long as the test program was representative of the airplane installation and environment.

(b) Applicants have shown compliance to the endurance testing requirements of § 25.1435 by conducting endurance tests on components or subassemblies using fixtures that represent the airplane installation and environmental conditions. The FAA normally accepts endurance test programs that vary hydraulic fluid temperature during endurance testing. The other environmental conditions are usually tested independent of the endurance test program.

The regulation does not specify the number of repeated cycles to meet endurance test requirements. As a minimum, the applicant must show that the reliability of components will meet the airplane system reliability requirements of § 25.1309.

(2) Amendment 25-23 (April 8, 1970) expanded § 25.1435(a)(4) to require means to ensure that no pressure will exceed a safe limit above design operating pressure by specifying pressure variation tolerances of +/- 10% on the pump discharge pressures and an upper limit of 125% of the design operating pressure for transients. These tolerances were based on in-service experience with such systems.

(3) Amendment 25-41 (July 18, 1977) clarified under § 25.1435(a)(2) that the pressure and quantity indication requirement was applicable to systems performing a function that is essential for continued safe flight and landing, or requiring corrective crew action when a system malfunction has occurred. It also recognized that means other than gages (e.g., warning lights) were an acceptable means of compliance. Sections 25.1435(a)(7) and 25.1435(a)(8) were added to allow certain transient pressures to exceed prescribed limits under (a)(4)(ii), provided the resulting fatigue strength was accounted for, and to require pump design such that loss of fluid condition could not create a hazard preventing continued safe flight and landing.

(4) Amendment 25-72 (July 20, 1990). Prior to this amendment, § 25.1435(b) was labeled "Tests," and contained references to a hydraulic system proof test, which was needed in order to comply with § 25.1309. Under Amendment 25-72, the general requirements of the old §§ 25.1435(a)(2) through 25.1435(a)(8), relative to indication, system pressures, transients, volumetric changes, pump discharge pressure limits, ripple damping devices, vibration, abrasion, corrosion, mechanical damage, inertia loads, hazardous vapors, relative motion, differential vibration, transient pressures, fatigue strength and loss of fluid to the pumps, were consolidated under a general listing as "Tests and Analyses" in the new § 25.1435(b)(2).

(5) Exemptions. In October 1993, pursuant to the authority contained in §§ 313(a) and 601(c) of the Federal Aviation Act of 1958, an applicant was granted an exemption (refer to exemption 5758A) from § 25.1435(b)(1) of Title 14, Code of Federal Regulations (14 CFR) to the extent necessary to permit type certification of a new airplane by testing of the complete hydraulic system at the system relief pressure, but not less than 3400 psig, in lieu of 1.5 times the design operating pressure (4500 psig). Additional similar exemptions have been granted (Refer to Exemptions 6086, 6504, and 6577).

(6) Harmonization. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group has recommended revisions to § 25.1435 and a new Advisory Circular (AC) 25.1435-1. The harmonized rule will reflect the exemptions granted, see (5) above. The notice of proposed rulemaking (NPRM 96-6) and accompanying proposed AC 25.1435-1, were published in the Federal Register on July 3, 1996 (61 FR 35056) and public comments were invited. The final rule is at the FAA headquarters for a regulatory evaluation. The final rule and AC are expected to be adopted in 2000.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Hydraulic Fluid Contamination. The following was extracted from an FAA letter to the National Transportation Safety Board (NTSB), dated June 29, 1998, and related correspondence. The NTSB accepted the FAA-Industry (Society of Automotive Engineers Committee A-6) task force resolution concerning the NTSB safety recommendation, A-96-116.

(a) Background. Following the crash of the USAir flight 427, a Boeing 737-300, on September 8, 1994, an NTSB investigation team found hydraulic fluid with a high particulate count in the main rudder power control unit (PCU). While the effect of contaminated hydraulic fluid on the different aircraft systems was not known at that time, it was examined as a potential factor. In October 1996, the NTSB made safety recommendation, A-96-116, which recommended that the FAA define and implement standards for in-service hydraulic fluid cleanliness and sampling intervals for all transport-category aircraft.

(b) Discussion. An April 1995, FAA study concluded that the existing standard, NAS 1638, was adequate for classifying the particulate contamination levels for aircraft hydraulic fluid. At the FAA's request, an industry task force formed by the Society of Automotive Engineers (SAE) Committee A-6 studied the fluid contamination issues. The industry task force concluded that (i) flight control servoactuators had demonstrated operation at contamination levels up to NAS 1638 class 17 and higher and, (ii) an in-service limit of NAS 1638 class 9 prescribed by the majority of current airframe manufacturers was conservative, adequate, and the maximum recommended limit. The task force also studied chemical contamination effects and provided in-service limits for fluid properties such as specific gravity, moisture content, viscosity, and chlorine content.

(c) Chemical Sensitivity. Actuation systems are insensitive to chemical contamination within normal in-service operational limits (see tabulation below). Gross contamination with other fluids is prohibited.

Chemical Quality Recommendations for In-Service Hydraulic Fluid

Analysis	**Limit**	**Reason**
Appearance	No cloudiness or phase separation or precipitation	Particulate and/or chemical contamination
Moisture	1.0 percent maximum	Corrosion, fluid stability (acidity), low temperature pumpability
Neutralization number	1.5 mg KOH/gm maximum	Corrosion, deposit formation
Kinematic viscosity @ 100ºF/38ºC	6.0 - 12.5cs	Lubricity
Chlorine contamination*	200 ppm maximum	Fluid purity, erosion

* This limitation is in addition to the amount already contained in the base stock.

(d) Sensitivity Methods. The task force recognized that the inconsistencies in the existing hydraulic fluid sampling procedures gave wide variations in the measured levels of particulate contamination. As a result, an Aerospace Recommended Practice ARP-5376, "Methods, Locations and Criteria for System Sampling and Measuring the Solid Particle Contamination of Hydraulic Fluids," was developed and published in September 1998.

(e) Sampling. The fluid sampling interval requirement for particulate contamination check is the same as the current one for checking chemical contamination. Typical fluid sampling intervals used by airlines are on-condition, C-check, and 2C-check. In addition, manufacturers recommend fluid sampling when a suspected hydraulic contamination may exist (for example, due to or indicated by excessive component wear or deterioration).

(f) In summary. The FAA has identified an existing industry standard, NAS 1638, that defines fluid cleanliness levels as Classes 00 to 12; has defined NAS 1638 class 9, as the in-service limit, verified that the manufacturers already recommend these limits in their maintenance manuals including a sampling interval, and helped develop an SAE ARP document for sampling and testing techniques. The intent of the safety recommendation has been met and no regulatory corrective action is deemed necessary.

(2) <u>Certification of Hydraulic Lines for Temporary Repairs.</u> The following was extracted from an FAA letter dated April 23, 1992, which addresses certification of hydraulic lines for use as temporary repairs.

(a) It is not clear from the applicant's letter whether the hydraulic tubing assemblies being discussed are rigid or flexible, but it is assumed that the discussion involves various lengths of flexible hydraulic hose assemblies which can be joined together to replace rigid or flexible hydraulic lines that have become unserviceable. There is an FAA Technical Standard Order (TSO) which provides minimum airworthiness requirements for hydraulic hose assemblies intended for use on transport category airplanes. Technical Standard Order TSO-C75, Hydraulic Hose Assemblies, and the accompanying Federal Aviation Standard should be considered. It should be noted that while the TSO provides an authorization for manufacturing a part that meets certain standards, it does not automatically approve the part for a specific installation.

(b) Section 43.13(a) requires that repairs must be accomplished in accordance with the manufacturers' maintenance manuals. However, air carriers are supposed to follow their Air Carrier Manual approved under part 121.

(c) The only mechanism available for certification of these repair systems by a manufacturer other than the type certificate holder would be a Supplemental Type Certificate (STC). An STC, issued for each installation on every model of airplane on which the applicant desired approval, would be a daunting task. Major airframe manufacturers, because they have all the pertinent data regarding design parameters for the hydraulic systems on their airplanes, can issue appropriate instructions in their maintenance manuals for installation of temporary repairs. Airlines should use the manufacturer's manuals per § 43.13(a).

(d) One of the ways a manufacturer, other than the type certificate holder who wishes to manufacture parts for a certificated airplane, can apply for a Parts Manufacturing Authorization (PMA) is to show that the parts it makes are identical to those produced by the original manufacturer. Unless the applicant has original drawings complete with all necessary standards and specifications, it is difficult to show identicality. The cognizant FAA Manufacturing Inspection District Office can provide insight into the appropriate PMA application procedures, reference Order 8110.42A.

(3) <u>Use of Hydraulic Lines for Temporary Repairs.</u> The following was extracted from an FAA memorandum dated January 25, 1988, which addresses the use of flexible hydraulic hoses as temporary repairs for unserviceable hydraulic tubing.

(a) The use of flexible hydraulic hoses as temporary repairs for unserviceable hydraulic tubing has been commonplace on transport category airplanes for a number of years. The lack of adverse service history indicates that this practice can be a viable method of repair, when used with the proper cautions. Strictly speaking, such substitution of hoses for rigid tubing would cause the airplane to be not in compliance with its type design; however, the provisions of Part 43 allow repairs and alterations to be made, provided the work is done in accordance with the methods, techniques, and practices in the current manufacturer's maintenance manual. With respect to multiple repairs, the FAA has concluded that they would be acceptable, provided that each one is individually performed in accordance with an approved procedure, and, collectively, the repairs will not interfere with each other or with any structure, or with the operation or performance of any system on the airplane.

(b) The key issue is the length of time that these temporary repairs may be allowed to exist on the airplane. Only by limiting the exposure can the repair be considered to be a safe alternative to the original design, much in the same manner that the Minimum Equipment List allows operation of the airplane for a short time with certain items of equipment inoperative. Since a temporary repair would not have been evaluated and certificated in the same manner as the original system, it would not be proper to allow the repair to become, in any way, a permanent part of the type design. It has been suggested by one manufacturer that these repairs be replaced at the next "C" check, which in some cases may be a year in the future. The FAA has concluded that this much time is unwarranted, and may seriously compromise the safety of the repair. An interval of 300 to 350 hours would, in most cases, allow for the ordering and delivery of any needed parts and the scheduling of the airplane for restoration of the system to the original configuration. Also, limiting the time in this manner will reduce the problem of multiple repairs on the system. Any time limit would be largely arbitrary, but this figure, which represents approximately a month of operations, appears to be a good compromise between the economic interests of the operators, and the need for a short exposure to the temporary repair.

(4) Hydraulic System Certification Philosophy. The following was extracted from an FAA letter dated March 5, 1982, which addresses guidance concerning compliance with § 25.1435(b)(2), 14 CFR.

(a) The FAA has not been requested to accept endurance and reliability data based solely on flight test. This is because it is impractical, within a given certification time frame, to conduct the number of test cycles required to comply with § 25.1435(b)(2). The FAA would have no objection to using flight test data in addition to simulated functional endurance and reliability data, provided the manufacturer establishes that the flights are representative of expected service cycles.

(b) It is normal practice, for certification purposes, to comply with the requirements of § 25.1435(b)(2) by the use of simulators such as an "iron bird." The simulators are intended to be representative of the aircraft systems. Mounting brackets, hydraulic and electrical system flight controls, and control surfaces are all the same as the actual airplane. For practical purposes, simulation may be broken into functional subsystems, i.e., wing, rudder, gear, etc. Deviations from actual simulation have been allowed where the deviation will not interfere with the intent of establishing endurance and reliability. Deviation cases have to be ruled on in a case by case basis.

(c) The FAA would not accept compliance with § 25.1435(b)(2) based on only vendor component tests and flight tests. Functional tests and endurance tests, either using an airplane or mock-up (iron bird, simulator) at the system or subsystem level, are required. Functional tests are required prior to first flight test.

(d) The manufacturer will develop load data through analysis, wind tunnel data, flight test experience, and/or any combination of these (spoilers and slots require flight test data, § 25.459). This load data is submitted to the FAA in the form of a loads document. The loads document is usually approved by FAA designated engineering representatives (DER) and submitted to the FAA for a spot check review when and where it is considered necessary. Flight test load verification is not required when the methods used in determining those loading conditions are shown to be reliable (§ 25.301(b)). Most manufacturers go beyond FAA requirements and check the loads with strain gauges during flight tests.

(e) The airframe manufacturer (type design applicant) identifies the loading spectrum (amplitude and cycles) for the hydraulic systems based on the loads document and expected service. The FAA will be involved only indirectly in most cases, through the loads DER's.

(f) The manufacturer subjects components and systems or the aircraft to the selected load/cycle spectrum in demonstrating compliance with the endurance requirements of § 25.1435(b)(2). Normally, vendor testing will be used for verification of the components for endurance as well as other requirements, such as environmental qualifications, fatigue, etc. The airframe manufacturer's simulator (iron bird) or simulators will be used for endurance tests and functional tests. The qualification reports documenting these tests are reviewed by FAA DER's and approved or submitted to the FAA with a recommendation for approval. This option is designated by the FAA.

(5) Interpretation of § 25.1435(a)(4) of 14 CFR. The following was extracted from an FAA memorandum dated September 14, 1978, which addresses interpretation of § 25.1435(a)(4), Amendment 25-41.

(a) Section 25.1435(a)(4)(i) states: "There must be a means to keep hydraulic system pressures within +/- 10 percent of the pressure at the discharge of the pump outlet or the transient pressure dampening device, if provided."

(b) This rule was originally established to cover pump ripple pressure variations. It can be seen that, under extreme system loading (high flow) conditions, the pump average discharge pressure can decrease as much as 25 percent. Apparently, the system pressure tolerance of +/- 10 percent mentioned above would then apply to this reduced pump average discharge pressure, decreased due to high flow conditions.

(c) Section 25.1435(a)(4)(ii) states: "Except as provided in Paragraph (a)(7) of this section, system pressures will not exceed 125 percent of the design operating pressure, excluding pressure at the pump outlet or dampening device. Design operating pressure is defined as the maximum steady operating pressure."

(d) The FAA has determined that Paragraph (4)(i) covers pressure variations due to pump ripple and high flow conditions while Paragraph (4)(ii) covers variations due to pressure transients. Note the use of "pump average discharge pressure" in (4)(i) and "design operating pressure" in (4)(ii).

e. References. The addresses for ordering the latest revision of advisory circulars, technical standard orders, and other referenced documents listed below can be found in the Appendix to this AC.

AC 25.1309-1A - System Design and Analysis.
AC 120-42A - Extended Range Operation with Two Engine Airplanes.
AC 20-128 - Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failures.
TSO-C47 - Pressure Instruments-Fuel, Oil, and Hydraulic.
TSO-C75 - Hydraulic Hose Assemblies.
SAE AS-595B - Civil Type Aircraft and Variable Delivery Hydraulic Pump.
SAE ARP-763 - Accumulators, Ground, Hydropneumatic Pressure.
SAE AIR-4150 - Inspection of In-Service Airborne Accumulators.
SAE AIR-1047C - A Guide for Selection of Quick Disconnect Couplings for Aerospace Fluid Systems.
SAE ARP-1709 - Coupling Assembly, Hydraulic Self Sealing, Quick Disconnect.
SAE AIR-786A - Elastomer Compatibility Considerations Relative to O-Ring and Sealant Selection.
SAE AS-1241B - Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft.
SAE AIR-1116 - Fluid Properties.
SAE ARP-1084 - Hydraulic External Leakage for In-service Components.
SAE AIR-1362 - Physical Properties of Hydraulic Fluids.
SAE ARP-1832 - Color Identification for O-Ring Seals.
SAE AIR-737E - Hydraulic and Pneumatic Specifications and Standards.
SAE ARP-994 - Design of Tubing Installations for Aerospace Fluid Power Systems.
SAE AIR-4003 - Turbine Engine Containment.
SAE AIR-1083B - Airborne Hydraulic and Control System Survivability for Military Aircraft.
SAE AIR-1899 - Aircraft Hydraulic System Characteristics.
SAE AIR-1918 - Comparison of Hydraulic System Cleanliness Procedures and Requirements for Ten Aerospace Companies.
SAE ARP-24B - Determination of Hydraulic Pressure Drop.
SAE ARP-490E - Electro-Hydraulic Servovalves.
SAE ARP-1280A - Aerospace Application Guide for Hydraulic Power Transfer Units.
SAE ARP-1281B - Actuators: Aircraft Flight Controls, Power Operated, Hydraulic, General Specification.
SAE ARP-4379 - Accumulator, Hydraulic, Cylindrical Aircraft.
SAE ARP-4752 - Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems.
FAA Order 8000.40D - Maintenance of Pressure Cylinders in Use as Aircraft Equipment.

61. SECTION 25.1438 PRESSURIZATION AND PNEUMATIC SYSTEMS.

a. Rule Text.

(a) Pressurization system elements must be burst pressure tested to 2.0 times, and proof pressure tested to 1.5 times, the maximum normal operating pressure.
(b) Pneumatic system elements must be burst pressure tested to 3.0 times, and proof pressure tested to 1.5 times, the maximum normal operating pressure.
(c) An analysis, or a combination of analysis and test, may be substituted for any test required by paragraph (a) or (b) of this section if the Administrator finds it equivalent to the required test.
[Amdt. 25-41, 42 FR 36971, Jul. 18, 1977]

b. Intent of Rule. This rule provides standards for the tests that must be conducted to demonstrate that pneumatic and pressurization ducting and components will not fail in normal operation. The rule was originated to address the pneumatic system, from the engine bleed port(s) to the pressure regulating and/or shut-off valve, and the pressurization system, which comprises all ducting and components of the air distribution system downstream of the above-mentioned valve.

c. Background. This subject was not addressed in either part 4b of the Civil Air Regulations (CAR) or part 25 of Title 14, Code of Federal Regulations (14 CFR) when it was originally codified. The reason for proposing the new standards was: "Components (such as ducts and couplings) of pressurization and pneumatic systems have failed at an unacceptable rate in service. The proposed standards for these components have been effective in preventing design deficiencies in the past."

(1) Harmonization. This regulation is the subject of a Federal Aviation Regulations/Joint Aviation Requirements (FAR/JAR) harmonization effort under the Aviation Rulemaking Advisory Committee (ARAC). The ARAC working group may recommend a revised § 25.1438/JAR 25.1438 and JAR 25X1436, and may develop an accompanying new advisory circular.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Pneumatic Versus Pressurization System Identification: The following policy was extracted from an FAA letter dated October 19, 1993, in response to questions regarding § 24.1438 and the difference between pressurization system elements and pneumatic system elements.

(a) Section 25.1438(a) states: "Pressurization system elements must be burst pressure tested to 2.0 times, and proof pressure tested to 1.5 times, the maximum normal operating pressure," and § 25.1438(b) states: "Pneumatic system elements must be burst pressure tested to 3.0 times, and proof pressure tested to 1.5 times, the maximum normal operating pressure."

(b) The FAA considers the pneumatic system to include all air supply elements from the bleed port on the engine to the pressure regulating and shutoff valve. Pressurization system elements are all other elements in the air distribution system.

(c) The burst pressure test requirement for pneumatic and pressure system elements has been used to demonstrate that high pressure air will be contained within the system or element. The element is not required to function during or after the burst pressure test, but pressurized air must be contained within the element or system. The proof pressure test is used to demonstrate that pneumatic and pressure system elements can function after a higher than normal pressure (1.5 times the maximum normal operating pressure) is introduced into the element or system.

(d) Section 25.1438(c) allows the applicant to use an analysis as a method of showing compliance to the burst and proof pressure test requirement in §§ 25.1438(a) & (b).

e. References. None.

62. SECTION 25.1439 PROTECTIVE BREATHING EQUIPMENT.

a. Rule Text.

(a) If there is a class A, B, or E cargo compartment, protective breathing equipment must be installed for the use of appropriate crewmembers. In addition, protective breathing equipment must be installed in each isolated separate compartment in the airplane, including upper and lower lobe galleys, in which crewmember occupancy is permitted during flight for the maximum number of crewmembers expected to be in the area during any operation.
(b) For protective breathing equipment required by paragraph (a) of this section or by any operating rule of this chapter, the following apply:
(1) The equipment must be designed to protect the flight crew from smoke, carbon dioxide, and other harmful gases while on flight deck duty and while combating fires in cargo compartments.
(2) The equipment must include-
(i) Masks covering the eyes, nose, and mouth; or
(ii) Masks covering the nose and mouth, plus accessory equipment to cover the eyes.
(3) The equipment, while in use, must allow the flight crew to use the radio equipment and to communicate with each other, while at their assigned duty stations.
(4) The part of the equipment protecting the eyes may not cause any appreciable adverse effect on vision and must allow corrective glasses to be worn.
(5) The equipment must supply protective oxygen of 15 minutes duration per crewmember at a pressure altitude of 8,000 feet with a respiratory minute volume of 30 liters per minute BTPD. If a demand oxygen system is used, a supply of 300

liters of free oxygen at 70° F. and 760 mm. Hg. pressure is considered to be of 15-minute duration at the prescribed altitude and minute volume. If a continuous flow protective breathing system is used (including a mask with a standard rebreather bag) a flow rate of 60 liters per minute at 8,000 feet (45 liters per minute at sea level) and a supply of 600 liters of free oxygen at 70° F. and 760 mm. Hg. pressure is considered to be of 15-minute duration at the prescribed altitude and minute volume. BTPD refers to body temperature conditions (that is, 37° C., at ambient pressure, dry).
(6) The equipment must meet the requirements of paragraphs (b) and (c) of § 25.1441.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-38, 41 FR 55468, Dec. 20, 1976]

b. Intent of Rule. The intent of this rule is for the protective breathing equipment (PBE) provisions to protect crewmembers from the effects of hazardous gasses and smoke, either while on flight deck duty or combating a fire, if there is a class A, B, or E cargo compartment or an isolated compartment in which crewmembers are permitted access during flight. This rule does not address passenger protective breathing equipment. Section 25.1439(b) contains wording that requires PBE if required "by any operating rule of this chapter. . . " There are two technical standard orders (TSO) providing standards for approval of PBE. Technical Standard Order, TSO-C99, provides standards for use by flight crewmembers while on flight deck duty. Per the TSO, the PBE must provide eye protection in addition to preventing inspiration of smoke/fumes. The flightcrew supplemental oxygen system can provide this via a full face mask with a setting that provides a positive pressure differential between the mask and ambient pressure in the cockpit to prevent smoke/fumes from entering the mask. If the crew supplemental oxygen system is equipped with an oro-nasal type mask (covers nose and mouth only) rather than a full mask, the eye protection can be achieved via a pair of goggles located within easy reach. This type of equipment is intended for use by flight crewmembers at their stations for a prolonged length of time. It would not generally be acceptable for firefighting since the crewmember's ability to reach the fire would be limited by the amount of extra oxygen tubing provided by the stationary system. TSO-C116 provides standards for PBE to be used by crewmembers while locating and fighting a fire. Per the TSO, it also provides head and shoulder protection from "drippings," and typically provides protective oxygen for 15 minutes. This type of PBE would not be suitable for use by the flightcrew at their stations.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Many of the requirements in section 4b.651 of the CAR were carried over essentially unchanged to § 25.1439 of 14 CFR. Part 25 standards state that PBE must be installed “if there is a class A, B, or E cargo compartment.”

(1) Amendment 25-38 (December 20, 1976) added the requirement that PBE be installed in each isolated separate compartment, including upper and lower lobe galleys, in which crewmember occupancy is permitted during flight for the maximum number of crewmembers expected to be in the area.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Protective Breathing Equipment Usage When Approved Under TSO-C99 and TSO-C116. The following policy, extracted from an FAA letter dated May 13, 1993, clarifies compliance with the requirements of § 25.1439 using equipment of the "smoke hood" variety approved under TSO-C116.

(a) The FAA letter clarified whether smoke hood type PBE would be acceptable for meeting the requirements of § 25.1439. The FAA is not aware of any smoke hood type PBE being approved as meeting the requirements of § 25.1439(b)(3), which relates to the use of radio equipment by the flight crew. The FAA would consider a smoke hood type PBE if compliance with § 25.1439(b)(3) is demonstrated.

(b) The FAA letter also clarified that a finding of equivalent safety would be required if an applicant wishes to use a “breathable gas,” in lieu of providing oxygen as specified in § 25.1439(b)(5).

(c) The FAA letter also addressed § 25.1439(b)(6), which specifies that there must be a means provided to allow the crew to readily determine the quantity of oxygen available. PBE approved in accordance with TSO-C116 may or may not have such features. The FAA does not grant exemptions for the cases where the PBE is used by the flight crewmembers while on flight deck duty. When the PBE is intended for use in locating and combating a fire, the FAA will approve equipment which, when the container is intact, is considered to have a full charge of oxygen or, for chemical oxygen generation, the canister has not been activated. The container is "tamper evident" and the crewmember can readily determine that the equipment is fully charged and ready for use. This PBE would not be suitable for approval in meeting the flight crewmember requirements addressed by § 25.1439.

(d) The letter provided an FAA position on PBE requirements for the first and second observers. The FAA treats the first observer and second observer differently. The first observer must have the same protection, i.e., the same equipment, as the flight crewmembers. The second observer may be supplied with oxygen equipment suitable for passengers. Again, the first observer must have the same protection (including the ability to communicate on the crewmember interphone) that is provided for the flight crewmembers; the second observer may be provided with passenger-type oxygen equipment.

(2) Protective Breathing Equipment Serviceability. The following policy was extracted from an FAA memorandum dated March 9, 1990, to provide guidance regarding the approval of PBE which met the requirements of § 121.337 and FAA Action Notice 8150.2.

(a) Section 121.337 was revised in 1987 and, in part, incorporated the intent of § 25.1439 and expanded on those requirements. This revision resulted in a new type of PBE for use by any crewmember while combating fires on board an airplane. The approval basis was contained in Action Notice A8150.2, dated September 1, 1987, in advance of TSO-C116.

(b) Section 121.337 clearly intends that any crewmember PBE be immediately ready to perform its intended function during an emergency. In fact, the rule requires that each certificate holder's operations manual designate at least one crewmember to check that <u>each</u> PBE unit is properly stowed and serviceable prior to the first-flight of the day.

(c) The approval basis (TSO-C116) for crewmember PBE requires that the equipment has a means to indicate the serviceability of the unit in its stowed condition. Some manufacturers of the crewmember PBE designs approved by the FAA have elected to use a vacuum sealed envelope as a means of protecting the PBE, and the loss of vacuum has been accepted as an indicator that the PBE is not serviceable.

(d) One manufacturer recommended that when the vacuum is lost the PBE need not be replaced immediately, since ambient moisture will not deactivate the potassium superoxide in the atmosphere regenerating system for a number of days. This may well be correct, but it is only one consideration. Since the cause of the loss of vacuum will most likely not be known to the crewmember making the inspection, and the extent of damage to the PBE itself may not be evident, the PBE should be considered not serviceable. Another consideration is that a design, which includes a protective envelope material that can readily be damaged, may not perform its intended function.

(e) Based on the above information, ACO's should ensure that the manufacturer submits operating, installation, and maintenance instructions with limitations, warnings, or cautions for FAA approval. The information being provided the end user should be in accord with the safety intent of § 121.337.

(3) <u>Protective Breathing Equipment on the Flight Deck.</u> The following policy was extracted from an FAA memorandum dated December 19, 1988, and provided additional guidance on protective breathing equipment for use on the flight deck.

(a) Section 121.337 specifies provisions for protective breathing equipment with the airplane both pressurized and unpressurized. Section 25.1439 makes no such distinction. The part 25 rule specifies that protective breathing equipment must be installed as part of the type design if certain types of cargo compartments or isolated, occupied compartments are installed. If these specified compartments are not installed on the airplane, then protective breathing equipment is not required as part of the type design.

(b) For an unpressurized part 25 airplane certified without these specified compartments and operated under Part 121, however, the decision to require protective breathing equipment should be based on an evaluation of the hazard. Section 25.831(d) states that if accumulation of hazardous quantities of smoke in the cockpit area is reasonably probable, smoke evacuation must be readily accomplished, starting with full pressurization and without depressurizing beyond safe limits. This capability must be demonstrated for certification under any normal operating condition, including unpressurized flight; and smoke clearance must be accomplished within three minutes (Advisory Circular 25-9A, or latest revision, explains a test procedure in detail). Section 25.831 also specifies limits for carbon dioxide and carbon monoxide, but does not define unsafe levels of any other gas, vapor, or fume. Since the toxicity of smoke or fumes generated by a fire is unknown, the FAA has required that there be essentially no penetration of smoke into an occupied compartment. Since it is likely that smoke of unknown composition would be generated within the cockpit, and may be present for up to three minutes prior to its removal, installation of protective breathing equipment would be appropriate, unless the applicant can show that it is not necessary.

(4) Definition of Terms Used in § 25.1439. The following policy was extracted from an FAA memorandum dated February 26, 1985, that responded to a request for the meaning of the words "isolated separate compartment," as used in § 25.1439.

(a) The preamble to the Notice 75-10, item 2-91, read: "The proposal would require protective breathing equipment for crewmembers expected in isolated areas." Item 2-91 was based on the First Biennial Airworthiness Review of 1974-1975, proposal No. 812 that read: "(a) Protective breathing equipment must be installed for each required crewmember in isolated separate compartments, such as upper or lower lobe galleys, in which occupancy is permitted during flight."

(b) Based on the intent of the background quoted above, the FAA concluded that the crew rest area, not being part of the main cabin, is similar in location to a lower lobe galley and, therefore, is an isolated separate compartment. However, as crewmembers are not required in the crew rest area except to fight a fire, only sufficient protective breathing equipment need be provided in the crew rest area for that function. It is also noted that, as long as the lavatory is located next to the flight deck door, there is little chance that a crewmember may be isolated there by a fire. The crew lavatory need not be considered isolated.

e. References. The address for ordering the latest revision of the technical standard orders listed below can be found in the Appendix to this AC.

TSO-C99, Protective Breathing Equipment.
TSO-C116, Crewmember Protective Breathing Equipment.

63. SECTION 25.1441 - OXYGEN EQUIPMENT AND SUPPLY.

a. Rule Text.

(a) If certification with supplemental oxygen equipment is requested, the equipment must meet the requirements of this section and 25.1443 through 25.1453.
(b) The oxygen system must be free from hazards in itself, in its method of operation, and in its effect upon other components.
(c) There must be a means to allow the crew to readily determine, during flight, the quantity of oxygen available in each source of supply.
(d) The oxygen flow rate and the oxygen equipment for airplanes for which certification for operation above 40,000 feet is requested must be approved.

b. Intent of Rule. This rule is intended to ensure that, if supplemental oxygen equipment is to be included in the type design of an airplane, the oxygen dispensing equipment will protect passengers and crewmembers from the effects of hypoxia. Many of the oxygen system requirements are addressed in §§ 25.1443 through 25.1453, which are incorporated by reference.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The requirements in section 4b.651(a) of the CAR for oxygen systems were carried over essentially unchanged to § 25.1441 of 14 CFR.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Compliance with §§ 25.1309(c) and 25.1441(c). The following policy was extracted from an FAA memorandum dated February 23, 1994, and provides an FAA position on the requirements of § 25.1309(c) as related to a Passenger Gaseous Oxygen System that could erroneously indicate oxygen is available.

(a) Section 25.1309(c) states: "Warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards." Section 25.1441(c) states: "There must be a means to allow the crew to readily determine, during flight, the quantity of oxygen available in each source of supply." An applicant proposed a passenger oxygen system where the means is provided through an indication available to the flight crew of the oxygen pressure in the oxygen system plumbing between the oxygen bottles and the flow control valves. There are several bottles, each with its own shut-off valve, manifolded together. If, during maintenance, the valves on all the bottles are turned off and left in that position, but the tubing between the bottles and the flow control valve is not disturbed, the pressure in the lines will continue to read the same value that would be measured if the bottle valves were open. Therefore, the reading in the cockpit will erroneously indicate that oxygen is available. A concern arises because the flightcrew will dispatch believing that passenger oxygen is available. If a depressurization event occurs, the passengers will not have supplemental oxygen available as required by the regulations. Passengers will be at risk during the emergency descent due to lack of available oxygen.

(b) The non-availability of passenger supplemental oxygen presents a hazard if a depressurization occurs. In most cases of depressurization, the flightcrew executes an emergency descent and the cabin altitude does not exceed safe limits. This is not, of course, always the case; loss of consciousness or more serious injury, and even death, could occur for some passengers if oxygen is not available after depressurization. There is usually no risk to the airplane itself because the flightcrew has a separate oxygen system and, assuming they act properly, the airplane will quickly descend to a safe altitude and proceed to the nearest airport. For these reasons, passenger supplemental oxygen being unavailable is not an immediate threat to continued safe flight and landing. However, one of the design principles suggested in Advisory Circular (AC) 25.1309-1A for ensuring fail-safe design concepts is <u>error tolerance</u> to allow for possible adverse effects of foreseeable errors during the airplane's design, test, manufacture, operation, and maintenance. This system does not appear to adhere to that principle. In addition, the AC also notes that a warning is required for a failure which makes it necessary for the flightcrew to make an unscheduled landing to reduce exposure to a more hazardous failure condition that would result from subsequent failures or operational conditions, or if the failure must be corrected before a subsequent flight. In conclusion, a warning to the flightcrew for non-availability of passenger oxygen is the type of warning addressed in the first sentence of § 25.1309(c).

(c) The system installed to provide the crew with an indication of the amount of oxygen available does not appear to meet the requirement contained in the second sentence of § 25.1309(c). The false indication of oxygen pressure resulting from the oxygen trapped between the shut off valves and the flow control valves will continue indefinitely, leading to dispatch after dispatch with no means to detect the problem until either a depressurization occurs or some maintenance action leads to the discovery that the oxygen bottle valves are closed. If the crew were aware of the situation, they would not dispatch or, if the problem were discovered in flight, they would immediately divert to an alternate airport. Clearly, the indication system is not designed to minimize crew errors that could create additional hazards.

(d) It is not acceptable to use probability of the <u>event</u> (depressurization) to demonstrate the probability of the <u>unsafe condition</u> (decompression combined with passenger oxygen being unavailable). In this case, the unsafe condition is not catastrophic so it is not necessary to show that it is extremely improbable. As noted in the earlier advisory material regarding System Design Analysis (AC 25.1309-1), "If a quantitative analysis is used to help show compliance with Federal Aviation Regulations for equipment which is installed and required only for a specific operating condition for which the airplane is thereby approved, credit may not be taken for the fact that the operating condition does not always exist." While this note does not appear in AC 25.1309-1A, the basic philosophy has not changed.

(2) Guidance, Availability of Flightcrew Oxygen. The following policy was extracted from an FAA memorandum dated May 11, 1992, in response to an FAA Safety Recommendation regarding annunciation that oxygen is available for use by the flightcrew when in actuality there is no oxygen available.

(a) On a recent twin-engine transport airplane flight, the crew elected to divert after the first officer donned his oxygen mask and discovered he had no oxygen available. After landing, the crew oxygen bottle valve was found turned to the closed position. Prior to the flight, maintenance had started to replace the bottle due to low pressure, and the valve located at the bottle was turned off. When the bottle pressure was found to be acceptable, the bottle was reinstalled but the valve was left turned off and safety wired in that position. The maintenance crew checked the bottle pressure on the airplane Engine Indication and Crew Alerting System (EICAS) status page and because the EICAS displays the pressure in the line downstream of the valve, the residual pressure in the line resulted in a displayed pressure that was within limits.

(b) The existing system on this airplane measures the oxygen pressure in the line to the flightcrew regulator. If the shutoff valve at the pressure bottle is shut off, there is sufficient pressure remaining in the line to indicate a pressure high enough for dispatch. Even when the crew checks the masks, only a small amount of oxygen is allowed to escape, and there are currently no means to determine that the valve is off. Further, the oxygen pressure, and therefore the quantity, is observable on EICAS only when the crew selects the status page.

(c) The FAA determined that this is unacceptable for the following reasons:

1. Section 25.1441(c) requires that the crew be able to determine the quantity of oxygen available. When the valve is in the "OFF" position, the oxygen is not available, but the indication on EICAS (the residual pressure in the line) is that oxygen is available if needed. The pressure measurement gives information about quantity only when the valve is open. If the valve is inadvertently left closed, the information provided is misleading.

2. Section 25.1309(c) states: “Warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards.” It is clear that the existing design gives misleading information to the flightcrew, which could lead them into an unsafe operation. If depressurization takes place at a significant altitude, and oxygen is not available to the crew, an unsafe condition exists.

3. Further, § 121.333(c)(4) states: "Before the takeoff of a flight, each flight crewmember shall personally preflight his oxygen equipment to insure that the oxygen mask is functioning, fitted properly, and connected to appropriate supply terminals, and that the oxygen supply and pressure are adequate for use." In theory, adherence to this rule should ensure that the oxygen supply is available.

(d) In order for the scenario discussed above to be a hazard, four separate events would have to occur:

1 There would have to be maintenance performed on the airplane oxygen system that required the valve, located on the oxygen bottle, to be turned off for some reason. The airplane maintenance manual contains both visual and operational checks to ensure that the oxygen valve is open and the pressure is adequate. These procedures were not followed in the case of interest because the bottle was never removed.

2 The flightcrew check of their oxygen equipment would have to fail to indicate that oxygen is not available. This is possible with the present preflight procedure, but the procedure is being changed.

3 A decompression would have to occur that required the use of oxygen by the flightcrew.

4 Event 3 would have to occur before the flightcrew had attempted to use supplemental oxygen (which would demonstrate no oxygen available) or checked the EICAS Status Page, which would indicate low oxygen pressure. In either case, airline procedures and Federal Aviation Regulations require that the crew divert to fix the problem.

(e) The manufacturer of the airplane involved in the incident which prompted this memorandum is changing their operational procedures, which are used by the airlines for their Operations Manuals, to describe an acceptable procedure to verify that adequate oxygen is available at the pilots mask. This procedure involves two separate flow tests (Normal and 100 percent), followed by a pressure check on EICAS. As all flightcrew masks must be tested (at least two on any transport category airplane), there will be ample tests and pressure checks to identify a problem prior to dispatch. Based on the above considerations, the FAA has determined an adequate level of safety is achieved through the existing and proposed procedures with the certificated design. However, this mechanization is not considered to meet the requirements of § 25.1309(c).

(f) Flightcrew oxygen systems should be reviewed to ensure that on future certification programs, a system design that can lead to misinformation is not allowed.

(3) Oxygen Installation for Medical Use. The following policy was extracted from an FAA facsimile message dated January 3, 1991, that was written in response to a request for policy relative to the installation of shutoff valves, pressure relief devices and overboard vent lines installed on oxygen bottles for medical use.

(a) There is no current written FAA policy relative to the installation of manifolded oxygen systems other than Civil Aeronautics Manual (CAM) 4b.651-1. CAM 4b.651-1 recommends that low pressure oxygen systems have a pressure relief device to prevent over pressurization during the filling operation.

(b) Department of Transportation (DOT) regulation (49 CFR, § 173.34(d)) requires that all pressure cylinders be provided with a safety device (a rupture disc) to prevent explosion of the bottle if the bottle is subjected to over-pressure or excessive heat. The pressure relief device may be installed on the bottle or on the valve of the bottle (on the pressure side of the valve).

(c) To meet the requirements of § 25.1441(b) and § 1451(c) (note: Amendment 25-72 deleted § 25.1451 and moved the requirements to § 25.869(c)), aircraft manufacturers have been installing oxygen systems that have a pressure relief that vents through a vent line, normally stainless steel, to the outside of the aircraft. A colored blowout plug is installed at the end of the vent line on the surface of the aircraft to indicate if the rupture disc has blown.

(d) The inquiring FAA office indicated that they may have approved single high pressure bottle (air ambulance) installations that do not have the overboard drain line. Further, these single bottle installations are filled off the airplane. There may be other installations without a vent line because there doesn't appear to be a written policy on this subject.

(e) To determine if a vent line is needed to comply with §§ 25.1441(b) and § 25.869(c)(3) (formerly 25.1451(c)), the consequences of the pressure relief device venting the total contents of the bottle or bottles (if manifolded together) into the compartment should be considered, i.e., overpressurizing the compartment; exposure to grease, flammable fluids and ignition sources.

(f) All the installations, which the FAA is aware of, have a high pressure shutoff valve located on the bottle to isolate the bottle from the oxygen system. On a manifolded system, these valves normally are lockwired in the open position. However, the bottle shutoff valve is downstream of the pressure relief device in order that the pressure relief device will protect the bottle from exploding if the bottle is isolated (valve shut) from the system and is exposed to heat or over- pressurization.

(g) The FAA is not aware of any objection to having a common high pressure manifold without the bottle shutoff valves as long as there is a manifold system shutoff valve and a pressure relief device between the bottles and the shutoff valve.

(h) One objection might be exposing the airplane and maintenance personnel to the hazards of a fully pressurized vented bottle or bottles if someone tries to remove a bottle from the system. The total system has to be depressurized before the bottle can be removed as opposed to the manifold system where each bottle shutoff valve can be closed, and an individual bottle with its valve can be removed.

(i) In general, industry practice has been to separate and isolate the oxygen system from sources of ignition. Ignition sources include pumps, motors, and electrical equipment associated with the medical installations as well as the aircraft equipment. Further, the manufacturers normally install a pressure relief device with an overboard vent line.

e. Reference. The address for ordering the document listed below can be found in the Appendix to this AC.

The Society of Automotive Engineers (SAE) has aerospace committees that prepare documents reflecting industry standards and practices. The SAE A-10 Committee, Aircraft Oxygen Equipment, has prepared a handbook, "1992 SAE Aircraft Oxygen Equipment Handbook," containing all Aerospace Standards, Aerospace Recommended Practices, and Aerospace Information Reports related to oxygen equipment published by SAE. While not regulatory in nature, this handbook contains information that may be of interest to an applicant.

64. SECTION 25.1443 - MINIMUM MASS FLOW OF SUPPLEMENTAL OXYGEN.

a. Rule Text.

(a) If continuous flow equipment is installed for use by flight crewmembers, the minimum mass flow of supplemental oxygen required for each crewmember may not be less than the flow required to maintain, during inspiration, a mean tracheal oxygen partial pressure of 149 mm. Hg. when breathing 15 liters per minute, BTPS, and with a maximum tidal volume of 700 cc. with a constant time interval between respirations.

(b) If demand equipment is installed for use by flight crewmembers, the minimum mass flow of supplemental oxygen required for each crewmember may not be less than the flow required to maintain, during inspiration, a mean tracheal oxygen partial pressure of 122 mm. Hg., up to and including a cabin pressure altitude of 35,000 feet, and 95 percent oxygen between cabin pressure altitudes of 35,000 and 40,000 feet, when breathing 20 liters per minute BTPS. In addition, there must be means to allow the crew to use undiluted oxygen at their discretion.

(c) For passengers and cabin attendants, the minimum mass flow of supplemental oxygen required for each person at various cabin pressure altitudes may not be less than the flow required to maintain, during inspiration and while using the oxygen equipment (including masks) provided, the following mean tracheal oxygen partial pressures:

(1) At cabin pressure altitudes above 10,000 feet up to and including 18,500 feet, a mean tracheal oxygen partial pressure of 100 mm. Hg. when breathing 15 liters per minute, BTPS, and with a tidal volume of 700 cc. with a constant time interval between respirations.

(2) At cabin pressure altitudes above 18,500 feet up to and including 40,000 feet, a mean tracheal oxygen partial pressure of 83.8 mm. Hg. when breathing 30 liters

per minute, BTPS, and with a tidal volume of 1,100 cc. with a constant time interval between respirations.
(d) If first-aid oxygen equipment is installed, the minimum mass flow of oxygen to each user may not be less than four liters per minute, STPD. However, there may be a means to decrease this flow to not less than two liters per minute, STPD, at any cabin altitude. The quantity of oxygen required is based upon an average flow rate of three liters per minute per person for whom first-aid oxygen is required.
(e) If portable oxygen equipment is installed for use by crewmembers, the minimum mass flow of supplemental oxygen is the same as specified in paragraph (a) or (b) of this section, whichever is applicable.

b. Intent of Rule. The requirements of this rule provide standards to ensure that oxygen dispensing equipment will protect passengers and crewmembers from the effects of hypoxia. The requirements for flight crewmembers are provided in terms of mean tracheal partial pressure of oxygen, which is not easily measured in certification testing. Dispensing equipment is, however, designed to provide the required oxygen flow. This equipment is, in most cases, approved through the technical standard order system. Requirements for passenger and cabin crewmember equipment are expressed in terms of oxygen flow rates.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The requirements in § 4b.651(b) of the CAR were carried over essentially unchanged to § 25.1443 of 14 CFR.

d. Policy/Compliance Methods. There is no written policy or guidance in our files.

e. Reference. The address for ordering the document listed below can be found in the Appendix to this AC.

The Society of Automotive Engineers (SAE) has aerospace committees that prepare documents reflecting industry standards and practices. The SAE A-10 Committee, Aircraft Oxygen Equipment, has prepared a handbook containing all Aerospace Standards, Aerospace Recommended Practices, and Aerospace Information Reports related to oxygen equipment published by SAE. While not regulatory in nature, this handbook contains valuable information that may be of interest to an applicant.

65. SECTION 25.1445 - EQUIPMENT STANDARDS FOR THE OXYGEN DISTRIBUTING SYSTEM.

a. Rule Text.

(a) When oxygen is supplied to both crew and passengers, the distribution system must be designed for either-
(1) A source of supply for the flight crew on duty and a separate source for the passengers and other crewmembers; or
(2) A common source of supply with means to separately reserve the minimum supply required by the flight crew on duty.
(b) Portable walk-around oxygen units of the continuous flow, diluter-demand, and straight demand kinds may be used to meet the crew or passenger breathing requirements.

b. Intent of Rule. This rule addresses the oxygen distribution system and does not address oxygen dispensing equipment (masks), the standards for which are addressed in § 25.1447.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The requirements in § 4b.651(c) of the CAR were carried over essentially unchanged to § 25.1445 of 14 CFR, except for the standards on potable walk-around units that are found in § 25.1445(b).

d. Policy/Compliance Methods. There is no written policy or guidance in our files.

e. Reference. The address for ordering the document listed below can be found in the Appendix to this AC.

The Society of Automotive Engineers (SAE) has aerospace committees that prepare documents reflecting industry standards and practices. The SAE A-10 Committee, Aircraft Oxygen Equipment, has prepared a handbook, "1992 SAE Aircraft Oxygen Equipment Handbook," containing all Aerospace Standards, Aerospace Recommended Practices, and Aerospace Information Reports related to oxygen equipment published by SAE. While not regulatory in nature, this handbook contains information that may be of interest to an applicant.

66. SECTION 25.1447 - EQUIPMENT STANDARDS FOR OXYGEN DISPENSING UNITS.

a. Rule Text.

If oxygen dispensing units are installed, the following apply:
(a) There must be an individual dispensing unit for each occupant for whom supplemental oxygen is to be supplied. Units must be designed to cover the nose and mouth and must be equipped with a suitable means to retain the unit in

position on the face. Flight crew masks for supplemental oxygen must have provisions for the use of communication equipment.
(b) If certification for operation up to and including 25,000 feet is requested, an oxygen supply terminal and unit of oxygen dispensing equipment for the immediate use of oxygen by each crewmember must be within easy reach of that crewmember. For any other occupants, the supply terminals and dispensing equipment must be located to allow the use of oxygen as required by the operating rules in this chapter.
(c) If certification for operation above 25,000 feet is requested, there must be oxygen dispensing equipment meeting the following requirements:
(1) There must be an oxygen dispensing unit connected to oxygen supply terminals immediately available to each occupant, wherever seated, and at least two oxygen dispensing units connected to oxygen terminals in each lavatory. The total number of dispensing units and outlets in the cabin must exceed the number of seats by at least 10 percent. The extra units must be as uniformly distributed throughout the cabin as practicable. If certification for operation above 30,000 feet is requested, the dispensing units providing the required oxygen flow must be automatically presented to the occupants before the cabin pressure altitude exceeds 15,000 feet. The crew must be provided with a manual means of making the dispensing units immediately available in the event of failure of the automatic system.
(2) Each flight crewmember on flight deck duty must be provided with a quick-donning type oxygen dispensing unit connected to an oxygen supply terminal. This dispensing unit must be immediately available to the flight crewmember when seated at his station, and installed so that it:
(i) Can be placed on the face from its ready position, properly secured, sealed, and supplying oxygen upon demand, with one hand, within five seconds and without disturbing eyeglasses or causing delay in proceeding with emergency duties; and
(ii) Allows, while in place, the performance of normal communication functions.
(3) The oxygen dispensing equipment for the flight crewmembers must be:
(i) The diluter demand or pressure demand (pressure demand mask with a diluter demand pressure breathing regulator) type, or other approved oxygen equipment shown to provide the same degree of protection, for airplanes to be operated above 25,000 feet.
(ii) The pressure demand (pressure demand mask with a diluter demand pressure breathing regulator) type with mask-mounted regulator, or other approved oxygen equipment shown to provide the same degree of protection, for airplanes operated at altitudes where decompressions that are not extremely improbable may expose the flightcrew to cabin pressure altitudes in excess of 34,000 feet.
(4) Portable oxygen equipment must be immediately available for each cabin attendant.
[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-41, 42 FR 36971, Jul. 18, 1977; Amdt. 25-87, 61 FR 28696, Jun. 5, 1996]

b. Intent of Rule. This rule addresses the oxygen dispensing units, including oxygen masks and regulators, and do not address oxygen distributing systems, the standards for which are addressed in § 25.1445.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). Many of the requirements in § 4b.651(d) of the CAR for oxygen dispensing units were carried over essentially unchanged to § 25.1447 of 14 CFR.

(1) Amendment 25-41 (July 18, 1977) added requirements for a manual means for the crew to make the dispensing units available in the event of a failure of the automatic means, and that the masks for use by the flight crewmembers be of the quick donning type.

(2) Amendment 25-87 (June 5, 1996) added flightcrew oxygen equipment requirements for a pressure demand type with mask-mounted regulator, or other approved equipment, for airplanes operated at altitudes where decompressions that are not extremely improbable may expose the flightcrew to cabin pressure altitudes in excess of 34,000 feet.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Oxygen Equipment for Forward Observer's Position. The following policy was extracted from an FAA memorandum dated February 1, 1988, that was written to provide guidance for certification of forward observer's oxygen equipment.

(a) The requirements for a forward observer's seat are contained in § 25.785(k), § 121.581(a), § 125.317(b), and § 135.75(b). In parts 121, 125, and 135 of 14 CFR, there is no specific list of required equipment for the first observer's seat, but rather a general statement that the required equipment would be "determined by the Administrator." The FAA considers a representative of the Administrator, occupying the first observer's seat and performing official duties, to be a required crewmember. This designation also applies to a company check airman, or other person performing official duties relating to the performance of the crew or operation of the airplane. This person would be expected to interact with the captain and other flight crewmembers, in addition to his or her normal duties relating to enroute inspection and surveillance. For these reasons, it is important that the occupant of the observer seat be provided with the equipment necessary to perform his or her function, e.g., oxygen, protective breathing equipment, and communication via a radio and interphone panel which is the same type equipment provided to the flightcrew.

(b) Section 25.785(l) does not specify what type of equipment must be provided at the observer seat as part of the type design. The rule states, "Each forward observer's seat required by the operating rules must be shown to be suitable for use in conducting the necessary enroute inspection." Section 25.785(l) has been interpreted to allow the use of passenger-type oxygen equipment, provided that the airplane in question is not to be used in Part 121, 125, or 135 operation. If the airplane is to be so used, the oxygen, communication, and protective breathing requirements stated above must be provided. If the airplane is not to be used in parts 121, 125, or 135 operation (i.e., in Part 91 operation), installation of either type of oxygen equipment at the first observer's seat is adequate to show compliance with the requirements of § 25.1441, Oxygen Equipment and Supply, and installation of communication equipment and protective breathing equipment would be optional.

(c) The duration of oxygen supply should be commensurate with the crew supply, since protection may be necessary due to a delayed descent following decompression, protective breathing requirements, or other extended usage.

e. References. The addresses for ordering the latest revision of technical standard orders and other referenced documents listed below can be found in the Appendix to this AC.

TSO-C64a, Oxygen Mask Assembly Continuous Flow, Passenger (For Air Carrier Aircraft).
TSO-C78, Crewmember Demand Oxygen Masks.
TSO-C89, Oxygen Regulators, Demand.
TSO-C99, Protective Breathing Equipment.
TSO-C116, Crewmember Protective Breathing Equipment.

The Society of Automotive Engineers (SAE) has aerospace committees which prepare documents reflecting industry standards and practices. The SAE A-10 Committee, Aircraft Oxygen Equipment, has prepared a handbook, "1992 SAE Aircraft Oxygen Equipment Handbook," containing all Aerospace Standards, Aerospace Recommended Practices, and Aerospace Information Reports related to oxygen equipment published by SAE. While not regulatory in nature, this handbook contains information that may be of interest to an applicant.

67. SECTION 25.1449 - MEANS FOR DETERMINING USE OF OXYGEN.

a. Rule Text.

There must be a means to allow the crew to determine whether oxygen is being delivered to the dispensing equipment.

b. Intent of Rule. The standards in this section ensure that the flightcrew is able to determine that oxygen is being dispensed properly.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The requirement in § 4b.651(e) of the CAR that there be a means for the crew to determine that oxygen is being delivered to the dispensing equipment (masks) were carried over essentially unchanged to § 25.1449 of 14 CFR.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information. Compliance with this section is usually accomplished by the use of flow indicators in the oxygen regulators (for flight crewmembers) and in the oxygen tubes leading to the masks (for passenger equipment).

(1) Oxygen Equipment for Observer Position. The following policy was extracted from an FAA letter dated April 19, 1996, in response to an inquiry concerning the requirement for supplemental oxygen flow indication at the observers' stations.

(a) An applicant proposed installing mask-mounted regulators without flow indication at the observers' stations. This configuration has been certified for previous versions of the same airplane model. It was the applicant's position that the FAA exempts mask-mounted regulators from the § 25.1449 flow indication requirement. They cited FAA Technical Standard Order (TSO) C-89, which exempts mask-mounted regulators from the TSO requirement to provide a means to indicate oxygen flow from the regulator outlet. Although the TSO allows omission of flow indicators for mask-mounted regulators, it is not an authorization to install such items on transport airplanes. However, the FAA reviewed the original certification data for the airplane model in question, and the background of § 25.1449. Based on this review, the FAA determined that installation of the mask-mounted regulators without flow indicators at the observers' stations meets the intent of § 25.1449.

(b) The background for § 25.1449 is found in the FAA Civil Aeronautics Manual (CAM) 4b. Section 25.1449 states: "There must be a means to allow the crew to determine whether oxygen is being delivered to the dispensing equipment." Similarly, § 4b.651 of the Civil Air Regulation (CAR) states: "Means shall be provided to enable the crew to determine whether oxygen is being delivered to the dispensing units." Although flow indicators for each individual passenger or flight crew station represent one method of compliance, policy guidance provided in § 4b.651-10 of the CAR (for crew systems) and § 4b.651-11 of the CAR (for passenger systems) allows operators to establish procedures for checking the oxygen flow to individual oxygen users. For passenger diluter-demand systems, § 4b.651-11 of the CAR states that the procedure may be "checking of the oxygen flow by a trained crewmember by momentarily moving the regulator lever to Automix 'OFF' (100% OXYGEN) while the mask is being worn." Lack of oxygen flow would be "immediately evidenced by the user's inability to inhale while wearing his mask."

(c) The FAA is satisfied that § 25.1449 does not specifically require flow indicators at each mask. Although these indicators are generally provided, other methods of flow indication are not precluded. Therefore, the FAA is satisfied that flow indicators are not required at the observers' stations for certification, provided that the applicant incorporates suitable design features and procedures to ascertain flow at the observers' stations. On the model in question, supplemental oxygen for the flightcrew and the observers' stations is provided by a common source. Flow of oxygen from the source is split between the flight crew and observers' stations by a "T" fitting. Under normal operations, all cockpit masks are set for "100% OXYGEN." At this setting, lack of flow would be immediately detected by the user. The FAA is requiring incorporation of a preflight check of the observers' masks in the airplane flight manual (AFM). In addition, a positive indication of flow at the flightcrew stations by the flow indicators installed at those stations would indicate that oxygen is also flowing to the observers' stations. The FAA is satisfied that the system design, the preflight inspection procedure, and flow indicators at the flightcrew stations are adequate to meet the intent of § 25.1449.

(2) Determination of Passenger Oxygen Supply. The following policy was extracted from an FAA memorandum dated January 8, 1996, which addresses compliance with § 25.1449 for a design that will determine, from the flightdeck, that oxygen is flowing to the passenger supplemental oxygen masks. It is noted that 14 CFR does not require a means for the flightcrew to make this determination while on flight deck duty. A number of airplanes have gaseous supplemental oxygen systems which do not have a specific indication of oxygen flow on the flight deck. Compliance with 14 CFR requirements is usually shown through use of a flow indicating device in the oxygen mask tubing. Technical Standard Order TSO-C64a, and the associated Society of Automotive Engineers Aerospace Standard SAE-AS 8025, require a means for the crew to determine that oxygen is flowing. This is usually accomplished with a small device that provides a green indication when the flow rate exceeds 0.5 liters per minute. A cabin crewmember verifies from the indicator whether or not oxygen is flowing. If there are no cabin crewmembers, this would require a flight crewmember to leave their station and check. The FAA has determined that this would not be a viable option during an emergency such as a decompression.

e. References. None.

68. SECTION 25.1450 - CHEMICAL OXYGEN GENERATORS.

a. Rule Text.

(a) For the purpose of this section, a chemical oxygen generator is defined as a device which produces oxygen by chemical reaction.
(b) Each chemical oxygen generator must be designed and installed in accordance with the following requirements:
(1) Surface temperature developed by the generator during operation may not create a hazard to the airplane or to its occupants.
(2) Means must be provided to relieve any internal pressure that may be hazardous.
(c) In addition to meeting the requirements in paragraph (b) of this section, each portable chemical oxygen generator that is capable of sustained operation by successive replacement of a generator element must be placarded to show-
(1) The rate of oxygen flow, in liters per minute;
(2) The duration of oxygen flow, in minutes, for the replaceable generator element; and
(3) A warning that the replaceable generator element may be hot, unless the element construction is such that the surface temperature cannot exceed 100 degrees F.
[Amdt. 25-41, 42 FR 36971, Jul. 18, 1977]

b. Intent of Rule. The standards in this rule ensure that chemical oxygen generators safely provide oxygen.

c. Background. The standards in this section address chemical oxygen generators. This subject was not addressed in either part 4b of the CAR or part 25 when it was originally codified. This section was added at Amendment 25-41, July 18, 1977.

d. Policy/Compliance Methods. There is no written policy or guidance in our files.

e. Reference. The address for ordering the latest revision of the document listed below can be found in the Appendix to this AC.

The Society of Automotive Engineers (SAE) has aerospace committees that prepare documents reflecting industry standards and practices. The SAE A-10 Committee, Aircraft Oxygen Equipment, has prepared a handbook, "1992 SAE Aircraft Oxygen Equipment Handbook," containing all Aerospace Standards, Aerospace Recommended Practices, and Aerospace Information Reports related to oxygen equipment published by SAE. While not regulatory in nature, this handbook contains information that may be of interest to an applicant.

69. SECTION 25.1453 PROTECTION OF OXYGEN EQUIPMENT FROM RUPTURE.

a. Rule Text.

Oxygen pressure tanks, and lines between tanks and the shutoff means, must be-
(a) Protected from unsafe temperatures; and
(b) Located where the probability and hazards of rupture in a crash landing are minimized.

b. Intent of Rule. This rule ensures that the oxygen equipment is not exposed to unsafe temperatures and minimizes the possibility of rupture in the event of a crash landing.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The requirements in § 4b.651(g) of the CAR were carried over essentially unchanged to § 25.1453 of 14 CFR.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the following information.

(1) Flexible Plastic Oxygen Lines. The following policy was extracted from an FAA memorandum dated December 27, 1983, to provide guidance regarding the use of flexible plastic tubing for oxygen distribution lines. While this guidance was generated for Part 23 airplanes, it is equally applicable for part 25 airplanes.

(a) The FAA has determined that the use of plastic lines for an oxygen distribution system that is operating under continuous pressure is not acceptable for certification in Part 23 airplanes.

(b) Lines constructed of combustible materials, including nylon, polyvinylchloride (PVC) and Teflon, may be used in oxygen lines which are pressurized only when cabin depressurization occurs. The following precautions should be taken when using such lines in the oxygen system:

1 Swaged metal type end fittings should be used to prevent leakage from cold flow.

2 Lines should be protected from abrasion by use of a reinforcing sleeving of fabric braid.

3 Precautions should be taken to route such lines away from areas where they might be subjected to elevated temperatures, electrical arcing (relays and switches) and flammable fluids.

4 Refer to Advisory Circular (AC) 43.13-2A, Chapter 6, for additional guidance material.

(2) Use of Plastic Oxygen Lines. The following policy was extracted from an FAA memorandum dated October 28, 1983, and addresses the use of plastic or nylon tubing as oxygen lines.

(a) Tubing in the fuselage for high or low pressure oxygen systems that are located behind liners or in the walls of the fuselage are typically made of rigid stainless steel (for high pressure) or aluminum (for low pressure). Synthetic flexible lines connecting the oxygen mask to the oxygen distribution system have been accepted. Swaged metal end fitted PVC tubing, covered with a synthetic braid (for abrasion resistance and strength), should be used between the aluminum low pressure distribution line and the passenger service unit manifold of many large transports. These tubes and aluminum line do not contain oxygen until a depressurization occurs. Then, the pressure is low and for a short duration. These hoses meet the interior burn requirements.

(b) Synthetic lines such as plastic or nylon cannot be recommended for oxygen high or low pressure lines that will be exposed to a continuous pressure (i.e., as opposed to pressurized when needed). These materials can cold flow. Care must be taken in the selection of the fitting design for exposures of even short duration.

(c) In addition to cold flow, polyethylene and nylon will lose strength with increasing temperature. These materials are much more susceptible to combustion in the presence of oxygen than either stainless steel or aluminum. For these reasons, the FAA considers polyethylene or nylon tubing inappropriate and unsafe for oxygen lines that are subjected to continuous oxygen pressure.

e. Reference. The address for ordering the document listed below can be found in the Appendix to this AC.

The Society of Automotive Engineers (SAE) has aerospace committees that prepare documents reflecting industry standards and practices. The SAE A-10 Committee, Aircraft Oxygen Equipment, has prepared a handbook, "1992 SAE Aircraft Oxygen Equipment Handbook," containing all Aerospace Standards, Aerospace Recommended Practices, and Aerospace Information Reports related to oxygen equipment published by SAE. While not regulatory in nature, this handbook contains information that may be of interest to an applicant.

70. SECTION 25.1455 - DRAINING OF FLUIDS SUBJECT TO FREEZING.

a. Rule Text.

If fluids subject to freezing may be drained overboard in flight or during ground operation, the drains must be designed and located to prevent the formation of hazardous quantities of ice on the airplane as a result of the drainage.
[Amdt. 25-23, 35 FR 5680, Apr. 8, 1970]

b. Intent of Rule. This rule addresses fluids subject to freezing that normally drain from the airplane either in flight or during ground operation. The intent is to prevent damage to the airplane when the ice disengages and falls free. This section addresses "gray" water from the sinks and drains in galleys and lavatories. Section 25.1455 does not apply to lavatory drain systems that are normally drained when the airplane is parked, rather than being in "ground operation." This requirement is usually met by designing the drain masts (usually heated to prevent the fluid from freezing) so that the fluid does not impact the airframe or engines when it is draining.

c. Background. Effective February 1, 1965, part 25 was added to Title 14, Code of Federal Regulations (14 CFR) to replace part 4b of the Civil Air Regulations (CAR). The requirements in section 4b.660 of the CAR were carried over to § 25.1455 of 14 CFR.

(1) Amendment 25-23 (April 8, 1970) changed the intent of the rule from preventing the formation of ice to preventing the formation of hazardous quantities of ice on the airplane as a result of drainage.

d. Policy/Compliance Methods. There is no written policy or guidance in our files.

e. Reference. The address for ordering the latest revision of the advisory circular listed below can be found in the Appendix to this AC.

AC 25.1455-1, Waste Water/Potable Water Drain System Certification Testing.

71. SECTION 25.1461 - EQUIPMENT CONTAINING HIGH ENERGY ROTORS.

a. Rule Text.

(a) Equipment containing high energy rotors must meet paragraph (b), (c), or (d) of this section.
(b) High energy rotors contained in equipment must be able to withstand damage caused by malfunctions, vibration, abnormal speeds, and abnormal temperatures. In addition-
(1) Auxiliary rotor cases must be able to contain damage caused by the failure of high energy rotor blades; and
(2) Equipment control devices, systems, and instrumentation must reasonably ensure that no operating limitations affecting the integrity of high energy rotors will be exceeded in service.
(c) It must be shown by test that equipment containing high energy rotors can contain any failure of a high energy rotor that occurs at the highest speed obtainable with the normal speed control devices inoperative.
(d) Equipment containing high energy rotors must be located where rotor failure will neither endanger the occupants nor adversely affect continued safe flight.
[Amdt. 25-41, 42 FR 36971, Jul. 18, 1977]

b. Intent of Rule. This rule ensures that failures of high energy rotating equipment will not adversely affect systems, structure, or occupants in the event that the rotating components fail at high speeds. Some of the equipment that contains high energy rotors are turbine engine starters, air cycle machines, air driven hydraulic pumps, cooling fans for galley equipment and electronic bays, cabin ventilation recirculation fans, and high speed electrically driven hydraulic pumps. This section does not pertain to equipment covered by Subpart E, Propulsion, such as engines and auxiliary power units, which are covered by the provisions of § 25.903(d).

c. Background.

(1) Amendment 4b-8 of the Civil Air Regulations (CAR). This subject was first addressed in part 4b of the CAR under Amendment 4b-8, effective May 17, 1958. A new § 4b.659 was included which required appropriate protection of the airplane against failure of high energy rotors when such rotors were incorporated in any equipment on the airplanes. Section 4b.659 read "Equipment incorporating high energy rotors shall be demonstrated as capable of containing a failed rotor or shall be so located that failure will not affect the ability of the airplane to continue safe flight."

(2) Amendment 4b-12 of the Civil Aeronautics Manual (CAM). Amendment 4b-12, effective May 13, 1962, deleted § 4b.659 because it was surmised that its substance was covered by the provisions of § 4b.606 (which later became § 25.1309) which is concerned with the reliability of all equipment, systems, and installations.

(3) Amendment 25-41. Amendment 25-41 added § 25.1461 as a result of an Airworthiness Review Program conducted in 1975. This new section added requirements for protection against the failure of equipment containing high energy rotors. Experience had demonstrated that failures which release the energy stored in these rotors may result in engine or structural damage, fires, or injury to occupants.

d. Policy/Compliance Methods. Compliance to §25.1461(c) is accomplished if it can be shown by test that equipment containing high-energy rotors can contain any failure of the rotor that occurs at the highest speed obtainable with normal speed control devices inoperative. In general, three phase induction motor driven fans do not have speed control devices. Fan speed is a function of the input power frequency supplied to the device.

(1) Because of the absence of speed controls, these fans can be treated as an extension of the aircraft power generating system. To comply with § 25.1461(c), the minimum test speed would be at the highest speed obtainable with power generating system speed control devices inoperative (speed control device is the mechanical system that governs generator shaft speed). In the event of such a failure, generating system controls will limit frequency. Exceeding those limits would require further multiple failures. These higher order failures do not have to be considered to comply with § 25.1461(c).

(2) For external ground power operation, the same frequency limits are applicable. The cart (or other) providing power must fail, the cart protective overfrequency protection must fail, and the airplane protective systems must fail to trip the external power contactor. In addition, an uncontained fan rotor burst on the ground is classified differently as it is not a safety of flight issue.

e. References. None.

Chapter 4. OPERATING LIMITATIONS AND INFORMATION

Section 1. OPERATING LIMITATIONS

72. SECTION 25.1529 - INSTRUCTIONS FOR CONTINUED AIRWORTHINESS.

a. Rule Text.

The applicant must prepare instructions for Continued Airworthiness in accordance with Appendix H to this Part that are acceptable to the Administrator. The instructions may be incomplete at type certification if a program exists to [Amdt. 25-54, 45 FR 60173, Sep. 11, 1980] ensure their completion prior to delivery of the first airplane for issuance of a standard certificate of airworthiness, whichever occurs later.

H25.4 Airworthiness Limitations section.
The Instructions for Continued Airworthiness must contain a section titled Airworthiness Limitations that is segregated and clearly distinguishable from the rest of the document. This section must set forth each mandatory replacement time, structural inspection interval, and related structural inspection procedures approved under § 25.571. If the Instructions for Continued Airworthiness consist of multiple documents, the section required by this paragraph must be included in the principal manual. This section must contain a legible statement in a prominent location that reads: "The Airworthiness Limitations section is FAA approved and specifies maintenance required under §§ 43.16 and 91.403 of the Federal Aviation Regulations unless an alternative program has been FAA approved."
[Amdt. 25-54, 45 FR 60173, Sep. 11, 1980; Amdt. 25-68, 54 FR 34329, Aug. 18, 1989]

b. Intent of Rule. The purpose of this rule is to ensure continued airworthiness of the airplane by requiring that inspections, checks, and replacement of parts are performed in accordance with the requirements established for type certification.

c. Background. This subject was not addressed in either section 4b of the Civil Air Regulations (CAR) or part 25 of Title 14, Code of Federal Regulations (14 CFR). This rule was added, along with Appendix H, by Amendment 25-54.

d. Policy/Compliance Methods. For guidance on compliance with this requirement, refer to the preamble of this rule and the airworthiness limitations document.

e. Reference. The address for ordering the latest revision of the advisory circular listed below can be found in the Appendix to this AC.

Advisory Circular 25-19, Certification Maintenance Requirements.

APPENDIX 1, CROSS REFERENCE FOR SELECTED SECTIONS OF PART 25, CAR 4b/CAM 4b

DISTRIBUTION TABLE

Revised Section	Former Section		Revised Section	Former Section
25.671	4b.320 (less (b))		25.869(b)	25.1443(b) & (c) [4b.658]
25.672	not applicable		25.869(c)	25.1451 [4b.651(f)]
25.699	4b.323(e) & (f)		25.1001	4b.437 (less (e) (last sent.))
25.701	4b.324		25.1183	4b.333, 4b.483
25.703	not applicable		25.1185	4b.481
25.729	4b.334, -2		25.1189	4b.382
25.731	4b.335(a) & (b)		25.1301	4b.600, 4b.601
25.733	4b.336		25.1309	4b.606
25.735	4b.335 less (a), (b)		25.1416	not applicable
	4b.337, -4 (1st sent.)		25.1419	4b.640 (less intro, 3rd sent.
25.771	4b.350		25.1431	4b.650
25.773	4b.351		25.1433	4b.658
25.775	4b.352		25.1435	4b.653, 4b.654, 4b.655
25.777	4b.353		25.1438	not applicable
25.783	4b.356, -1(last sent)		25.1439	4b.651 (less (a)-(g)
	4b.356-2(a)/1st sent		25.1441	4b.651(a)
25.831	4b.371, 4b.371-1		25.1443	4b.651(b)
25.832	not applicable		25.1445	4b.651(c), 4b.651-5a
25.833	4b.372		25.1147	4b.651(d)
25.841	4b.374, 4b.375, -1		25.1449	4b.651(e)
25.843	4b.376		25.1450	not applicable
25.851	4b.380 (less (c)), 4b.383 (2nd sent. of (a) & (b)(3)		25.1453	4b.651(g)
25.854	not applicable		25.1455	4b.660
25.855	4b.382, 4b.384		25.1461	not applicable
25.857	not applicable			
25.858	not applicable			
25.863	4b.385			

APPENDIX 2, GLOSSARY OF ACRONYMS

AC	Advisory Circular
ACO	Aircraft Certification Office
AD	Airworthiness Directive
AFM	Airplane Flight Manual
AIA	Aerospace Industries Association
AIR	Aircraft Certification Service
ARAC	Aviation Rulemaking Advisory Committee
ARP	Aerospace Recommended Practice (SAE)
BTMS	Aircraft Brake Temperature Monitor System
CAA	Civil Aeronautics Administration (US)
CAR	Civil Air Regulations
CAM	Civil Aeronautics Manual
CFR	Code of Federal Regulations
DER	Designated Engineering Representative
ECS	Environmental Control System
EICAS	Engine Indication and Crew Alerting System
FAR	Federal Aviation Regulations
IIDSS	Inflight Ice Detection Sensing Systems
JAA	Joint Aviation Authorities
JAR	Joint Airworthiness Requirements
KE	Kinetic Energy
NOE	Non-original Equipment
NTSB	National Transportation Safety Board
OAT	Outside Air Temperature
OBOGS	On-Board Oxygen Generating System
OEM	Original Equipment Manufacturer
PBE	Protective Breathing Equipment
PMA	Parts Manufacturer Approval
PPM	Parts Per Million
PPMV	Parts Per Million by Volume
QTR	Qualification Test Report
R&D	Research & Development
RTO	Rejected Take-off
SAE	Society of Automotive Engineers
SLD	Supercooled Large Droplets
SLE	Sea Level Equivalent
STC	Supplemental Type Certificate
TAD	Transport Airplane Directorate
TAT	Total Air Temperature
TC	Type Certificate
TSO	Technical Standard Order
TWA	Time-Weighted-Average

APPENDIX 3, INDEX OF ADVISORY CIRCULAR REFERENCES

The advisory circulars listed below contain information relevant to the approval of mechanical systems on transport category airplanes. They can be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, USA.

AC No.	Title	Section Reference
20-32B	Carbon Monoxide (CO) Contamination in Aircraft-Detection and Prevention, November 24, 1972, or latest revision, ACE-110	25.831
20-33B	Technical Information Regarding Civil Aeronautics Manuals 1, 3, 4a, 4b, 5, 6, 7, 8, 9, 13 and 14, May 1, 1975, or latest revision, AIR-200	All sections
20-34D	Prevention of Retractable Landing Gear Failures, August 8, 1980, or latest revision, AFS-340	25.729
20-36S	Index of Articles (Materials, Parts, Processes and Appliances) Certified Under the Technical Standard Order System, September 1, 1993, or latest revision, AFS-613	All sections
20-41A	Substitute Technical Standard Order (TSO) Aircraft Equipment, April 5, 1977, or latest revision, AIR-120	All sections
20-42C	Hand Fire Extinguishers for use in Aircraft, March 7, 1984, or latest revision, ACE-110	25.851
20-62D	Eligibility, Quality, and Identification of Approved Aeronautical Replacement Parts, May 24, 1996, or latest revision, AFS-340	All sections
20-73	Aircraft Ice Protection, April 21, 1971, or latest revision, AIR-120	25.1419
20-97A	High-Speed Tire Maintenance and Operational Practices, May 13, 1987, or latest revision, AFS-340	25.733

20-99	Antiskid and Associated Systems, May 27, 1977, or latest revision, ANM-100	25.735
20-110J	Index of Aviation Technical Standard Orders, May 30, 1997, or latest revision, AIR-120	All sections
20-117	Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing, December 17, 1982; Chg. 1, April 15, 1983, or latest revision, AFS-200	25.1419
20-128A	Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failures, March 25, 1997, or latest revision, ANM-114	25.1435
21-16C	Radio Technical Commission for Aeronautics (now called RTCA Inc.) Document DO-160C, February 14, 1990, or latest revision, AIR-120	All sections
21-23	Airworthiness Certification of Civil Aircraft Engine, Propellers, and Related Products, July 7, 1987, or latest revision, AIR-4	25.735
23.729-1	Landing Gear Doors and Retraction Mechanism, March 26, 1984, or latest revision, ACE-110. For information only.	23.729
23-1419-2	Certification of Part 23 Airplanes for Flight in Icing Conditions, January 3, 1992, or latest revision, ACE-100	23.1419
25-7A	Flight Test Guide for Certification of Transport Category Airplanes, March 31, 1998, or latest revision, ANM-110	25.729, 25.731 25.733, 25.735 25.773
25-9A	Smoke Detection, Penetrating, and Evacuation Tests and Related Flight Manual Emergency Procedures, January 6, 1994, or latest revision, ANM-110	25.831, 25.854 25.855, 25.858
25-14	High Lift and Drag Devices, May 4, 1988, or latest revision, ANM-112	25.699, 25.703 25.671, 25.672
25-16	Electrical Fault and Fire Prevention and Protection, April 5, 1991, or latest revision, ANM-111	25.869
25-17	Transport Airplane Cabin Interiors Crashworthiness Handbook, July 15, 1991, or latest revision, ANM-114	25.773, 25.857 25.858, 25.869

25-18	Transport Category Airplanes Modified for Cargo Service, January 6, 1994, or latest revision, ANM-114	25.857
25-19	Certification Maintenance Requirements, November 28, 1994, or latest revision, ANM-113	25.1309
25-20	Pressurization, Ventilation, and Oxygen Systems Assessment for Subsonic Flight Including High Altitude Operation, September 10, 1996, or latest revision, ANM-111	25.831, 25.841
25-21	Certification of Transport Airplane Structure, September 1, 1999, ANM-110	25.671, 25.672 25.701
25.672-1	Active Flight Controls, November 15, 1983, or latest revision, ANM-110B	25.672
25.703-1	Takeoff Configuration Warning Systems, March 17, 1993, or latest revision, ANM-111	25.703
25.773-1	Pilot Compartment View for Transport Category Airplanes, January 8, 1993, or latest revision, ANM-111	25.773
25.783-1	Fuselage Doors, Hatches, and Exits, December 10, 1986, or latest revision, ANM-110	25.783
25.963--1	Fuel Tank Access Covers, July 29, 1992, or latest revision, ANM-112	25.729
25.1309-1A	System Design Analysis, June 21, 1988, or latest revision, ANM-112	25.1309, 25.1435
25.1419-1	Certification of Transport Category Airplanes for Flight in Icing Conditions, August 18, 1999, or latest revision, ANM-112	25.1419
25.1455-1	Waste Water/Potable Water Drain System Certification Testing, March 11, 1985, or latest revision, ANM-112	25.1455
27-1A	Certification of Normal Category Rotorcraft, dated July 30, 1997, or latest revision, ASW-111	25.731

29-2B	Certification of Transport Category Rotorcraft, July 30, 1997, or latest revision, ASW-111	25.731
43.13-1A	Acceptable Methods, Techniques and Practices Aircraft Inspection and Repair (with Errata Sheet), dated April 17, 1972, or latest revision, AFS-600	25.729, 25.731, 25.733, 25.735
43.13-2A	Acceptable Methods, Techniques, and Practices Aircraft Alterations, includes Chg. 1, dated June 9, 1977; Chg. 2, dated Oct. 30, 1989, or latest revision, AFS 340	All sections
91-6A	Water, Slush, and Snow on the Runway, May 24, 1978, or latest revision, AFS-430	25.109, 25.735
91-13C	Cold Weather Operation of Aircraft, July 24, 1979, or latest revision, AFS-806	25.109, 25.735
91-51A	Effect of Icing on Aircraft Control and Airplane De-ice and Anti-Ice Systems, July 19, 1996, or latest revision, AFS-820	25.1419
120-38	Transport Category Airplanes Cabin Ozone Concentrations, October 10, 1980, or latest revision, AFS-260	25.832
120-39	Hazards of Waste Water Ice Accumulation Separating From Aircraft in Flight, October 31, 1980, or latest revision, AFS-331	25.1455
120-42A	Extended Range Operation with Two Engine Airplanes (ETOPS), December 30, 1988, or latest revision, AFS-400	25.1435
120-58	Pilot Guide for Large Aircraft Ground Deicing, September 30, 1992, or latest revision, AFS-420	25.1419
121.195-1A	Operational Landing Distances for Wet Runways: Transport Category Airplanes, June 19, 1990, or latest revision, AFS-430	25.109, 25.735
145-4	Inspection, Retread, Repair and Alterations of Aircraft Tires, September 27, 1982, or latest revision, AFS-340	25.733

*25-XX	Cargo Compartment Fire Extinguishing or Suppression Systems, date TBD	25.857
*25-XX	Class B and F Cargo Compartments, date TBD	25.857
*25-XX	Propulsion Systems Handbook (Mega AC) date TBD	25.863, 25.943, 25.1001, 25.1183, 25.1185, 25.1189
*25-XX	Electrical Systems Handbook (Mega AC) date TBD	25.1301, 25.1309, 25.1325

*NOTE: The designation "25-XX" means that a draft AC exists for the subject. Upon approval, the "XX" will be replaced with a numerical reference identification code.

APPENDIX 4, INDEX OF INCORPORATED GUIDANCE MATERIAL AND REFERENCES

1. FAA Memorandums and Letters Referenced in this AC:

Copies of the memorandums and letters are available from the FAA Transport Airplane Directorate, 1601 Lind Ave. SW, Renton, WA 98055, USA.

Section	Subject	Date
25.729	Protection of Equipment in Wheel Wells, § 25.729(f)(1)	Dec. 4, 1997
25.729	Landing Gear Position Indication System - "Backup Requirement" - Section 25.729(e)	July 12, 1988
25.729	Flap System/Landing Gear Warning System Tie-In	Dec. 19, 1983
25.729	Landing Gear Position Indication System	June 3, 1983
25.729	Landing Gear Slush Tests	April 22, 1983
25.733	Approval of Retreaded Tires by Similarity	March 1, 1995
25.733	Approval of Nonretreadable Tires - Qualification Testing	August 18, 1988
25.733	Approval Method for Substitute Tires	April 14, 1988
25.733	Replacement of Bias Ply Tires with Radial Ply Tires	Feb. 7, 1984
25.733	Certification Program for Replacing Bias Tires with Radial Tires, Part 25 Transports; All Weight Categories	Jan. 12, 1984
25.733	Certification of Radial Tire Installation	March 28, 1984
25.733	Critical Conditions & Maximum Ramp Weight Definitions	Jan. 26, 1981
25.735	Carbon Brake Refurbishment (redensification)	April 11, 1996
25.735	Parts Manufacturer Approval for a Non-U.S. Location: § 21.303(g)	April 9, 1996
25.735	Certification of Replacement Brakes: Non-U.S. Location	May 19, 1992
25.735	Parking Brake Testing	March 20, 1992,
25.735	Worn Brake Requirements for Non-Original-Equipment Parts (letter)	Feb. 18, 1992
25.735	Determination of Allowable Worn Brake Limits	Feb. 23, 1990, Mar. 2, 1990
25.735	Credit for Reverse Thrust in Worn Brake Testing	April 28, 1989

25.735	Certification of Brake Replacement Components - Performance	Mar. 16, 1989, Dec. 27, 1988, and March 16, 1988
25.735	Ground Equipment-Brake Cooling Unit	Dec. 27, 1988
25.735	Certification Requirements for Asbestos-Free Brake Linings	Dec. 16, 1987
25.735	Determination of Certification Requirements for Brake Components - Performance	Oct. 26, 1987
25.735	Approval of Brake Components Utilizing New Brake Friction Material	July 27, 1987
25.735	Maximum Quick Turnaround Times	August 19, 1983
25.735	Dynamometer Test Guidelines to Establish Brake Wear Limits (letter)	March 2, 1990
25.831	Ventilation During Takeoff with the Environmental Control System Turned Off	May 20, 1983
25.831	Fresh Air and Normal Operating Conditions	Sept. 10, 1997
25.831	Cabin Altitude Limit; § 25.841(a)	Jan. 12, 1994
25.832	Use of Operational Limitations	March 31, 1997
25.832	Meaning of the Term Time-Weighted Average in § 25.832 of the FAR	Oct. 26, 1987
25.833	Standards for Certification of Combustion Heaters	March 14, 1948
25.841	Rapid Equalization of Pressure	June 21, 1982
25.841	Access to a Pressurized Cargo Compartment in the Engine Burst Zone During High Altitude Operation	June 25, 1986
25.841	Cabin Altitude Limit; § 25.841(a)	Jan. 12, 1994
25.843	Pressure Tests for Compliance with 25.843(a)	Feb. 21, 1990
25.854	Approval of Lavatory Smoke Detectors	Oct. 28, 1991
25.854	Approval of Lavatory Fire Extinguishers Containing Agents Other Than Halon	March 31, 1997
25.857	Main Deck Cargo Compartment Fire Protection Certification Procedures	June 6, 1997
25.857	Cargo Compartments	Sept. 13, 1988
25.857	Class A Cargo Compartments	February 8, 1996
25.857	Class E Cargo Compartments	March 21, 1991
25.857	Class E Cargo Compartments	July 3, 1990
25.858	Smoke Detection Certification Testing	June 18, 1997
25.858	Smoke Detection Certification Testing	Feb. 11, 1993
25.858	Smoke Detection Certification Testing	Dec. 3, 1992, Dec. 15, 1992
25.1419	Inflight Ice Detection Systems	Jan. 13, 1998
25.1419	Aircraft Mounted Ground Ice Detection Systems	Oct. 10, 1996
25.1419	Roll Control in Supercooled Large Droplets	July 23, 1997
25.1435	Hydraulic Fuel Contamination	April 20, 1995

25.1435	Certification of Hydraulic Lines for Temporary Repairs	April 23, 1992
25.1435	Use of Hydraulic Lines for Temporary Repairs	Jan. 25, 1988
25.1435	Hydraulic System Certification Philosophy	March 5, 1982
25.1435	Interpretation of 25.1425(a)(4) of the FAR	Sept. 14, 1978
25.1438	Pneumatic Versus Pressurization System Identification	Oct. 19, 1993
25.1439	Protective Breathing Equipment Usage When Approved Under TSO-C99 and TSO-C116	May 13, 1993
25.1439	Protective Breathing Equipment Serviceability	March 9, 1990
25.1439	Protective Breathing Equipment on the Flight Deck	Dec. 19, 1988
25.1439	Definition of Terms Used in § 25.1439	Feb. 26, 1985
25.1441	Certification of On-Board Oxygen Generation Systems	Jan. 31, 1996
25.1441	Compliance with §§ 25.1309(c) and 25.1441(c)	Feb. 23, 1994
25.1441	Guidance Availability of Flightcrew Oxygen	May 11, 1992
25.1441	Oxygen Installation for Medical Use	Jan. 3, 1991
25.1445	Isolation of Flight Crewmember Oxygen Supply	Jan. 8, 1996
25.1447	Oxygen Equipment for Forward Observer’s Position	Feb. 1, 1988
25.1447	Oxygen Equipment for Observer Position	Jan. 24, 1983
25.1449	Oxygen Equipment for Observer Position	April 19, 1996
25.1450	Life Limit on Solid State Oxygen	Aug. 15, 1983
25.1453	Use of Plastic Oxygen Lines	Dec. 27, 1983
25.1453	Use of Plastic Oxygen Lines	Oct. 28, 1983

APPENDIX 4

2. FAA Technical Standard Orders (TSO) Referenced in this AC.

The Technical Standard Orders listed below contain information relevant to mechanical system components installed on transport category airplanes. They can be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, USA.

TSO	Date	Title	Section Reference
TSO-C1c	July 10, 1987	Cargo and Baggage Compartment Smoke Detection Instruments	25.854
TSO-C19b		Portable Water-Solution Type Fire Extinguishers	25.851
TSO-C20		Combustion Heaters	25.833
TSO-C26	Mar. 15, 1952		25.731
TSO-C26a	June 1, 1961		25.731
TSO C26b	1962	Aircraft Tires	25.733
TSO-C26b	Jan. 21, 1971		25.731
TSO-C26c	Dec. 31, 1979	Aircraft Tires	25.731
TSO-C26c	May 18, 1984	Aircraft Wheels and Wheel-Brake Assemblies, with Addendum I	25.731, 25.735
TSO-C45a	Feb. 28, 1995	Manifold Pressure Indicating Instruments	25.869
TSO-C47		Pressure Instruments - Fuel, Oil, and Hydraulic	25.1435
TSO-C48		Carbon Monoxide Detector Instruments	25.831
TSO C62c	Dec. 31, 1979	Aircraft Tires	25.733
TSO-C62c	Sept. 12, 1984	Aircraft Tires, with Addendum 1	25.733
TSO-C62d	Sept. 7, 1990	Aircraft Tires	25.733
TSO-C64a	Aug. 25, 1989	Oxygen Mask Assembly Continuous Flow, Passenger (for air carrier aircraft)	25.1445, 25.1447
TSO-C75		Hydraulic Hose Assemblies	25.1435
TSO-C78		Crewmember Demand Oxygen Masks	25.1447
TSO-C89		Oxygen Regulators, Demand	25.1447, 25.1449
TSO-C99	June 27, 1983	Protective Breathing Equipment	25.1439
TSO-116	March 1, 1990	Crewmember Protective Breathing Equipment	25.1439, 25.1447

APPENDIX 4

3. FAA Orders Referenced in this AC.

The FAA Orders listed below contain information relevant to mechanical system components installed on transport category airplanes. They can be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, USA.

Number	Title	Section Reference
8000.40D	Maintenance of Pressure Cylinders In Use As Aircraft Equipment, Dec. 26, 1995, AFS-350	25.857, 25.1435
8000.54	Process Specifications for Retreading Tires and Inspection Procedures Manuals for Tire Retreaders, Nov. 2, 1982, AFS-350	25.733
8000.64	Qualification of Aircraft Radial Tires for Use on Aircraft and for Retreading, Dec. 4, 1986, AFS-350	25.733
8110.4A	Type Certification Process, March 2, 1995, AIR-110	21.11 to 21.53
8110.8	Engineering Flight Test Guide for Transport Category Airplanes, Chg. 5, July 17, 1986. This order was canceled by AC 25-7A, March 31, 1998, ANM-100	25.729, 25.735
8150.1A	Technical Standard Order Procedures, Sept. 21, 1987, AIR-120	21.60 to 21.621

4. FAA Videos Referenced in this AC:

These videos are available from the William J. Hughes (FAA) Technical Center, Atlantic City International Airport, Atlantic City, NJ 08405, USA.

Title	Section Reference
FAA's Tire Approval Process Video, MTS 422/422.1, 42:15 minutes, September, 1994	25.733
FAA's Wheels & Brakes Approval Process Videos, Parts 1 & 2, September, 1994	25.735
FAA's Smoke Quantities to Certify Smoke Detection Systems in Cargo Areas, June, 1997	25.858

APPENDIX 4

5. SAE Documents Referenced in this AC.

The Society of Automotive Engineers (SAE) has aerospace committees that prepare documents reflecting industry standards and practices. While not regulatory in nature, this handbook contains information that may be of interest to an applicant. These documents provide additional information, guidance, and/or standards, and are available from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA.

Number	Title	Section Reference
SAE AIR-737E	Hydraulic and Pneumatic Specifications and Standards, May 1995	25.1435
SAE AIR-786A	Elastomer Compatibility Considerations Relative to O-Ring and Sealant Selection, July 1992	25.1435
SAE AIR-811B	Disposition of Wheels which have been Overheated, April 1, 1996	25.731
SAE AIR-1047C	A Guide for Selection of Quick Disconnect Couplings for Aerospace Fluid Systems, April 1994	25.1435
SAE AIR-1064C	Brake Dynamics, March 1, 1993	25.735
SAE AIR-1083B	Airborne Hydraulic and Control System Survivability for Military Aircraft, June 1994	25.1435
SAE AIR-1116	Fluid Properties, July 1992	25.1435
SAE AIR-1362	Physical Properties of Hydraulic Fluids, Nov. 1991	25.1435
SAE AIR-1739	Information on Antiskid Systems, March 1, 1993	25.735
SAE AIR-1899	Aircraft Hydraulic System Characteristics, Nov. 1991	25.1435
SAE AIR-1904	Tire Spray Suppression-Airplane, Design Consideration and Testing, Jan. 1, 1997	25.733
SAE AIR-1918	Comparison of Hydraulic System Cleanliness Procedures and Requirements for Ten Aerospace Companies, Nov. 1991	25.1435
SAE AIR-1934A	Use of Carbon Heat Sink Brakes on Aircraft, March 1, 1995	25.735
SAE AIR-4003	Turbine Engine Containment, Jan. 1991	25.1435
SAE AIR-4150	Inspection of In-Service Airborne Accumulators, Feb. 1993	25.1435
SAE AIR-4566	Crashworthiness Landing Gear Design, July 1992	25.729
SAE ARP-24B	Determination of Hydraulic Pressure Drop, Nov. 1991	25.1435
SAE ARP-219	Procedure and Method for Conducting Test of Hydraulic Components in Contamination Controlled System	25.1435
SAE ARP-490E	Electro-Hydraulic Servovalves, Sept. 1993	25.1435
SAE ARP 507C	Wheels and Brakes, Supplementary Criteria for Design Endurance-Civil Transport Aircraft	25.735
SAE ARP-597C	Wheels and Brakes, Supplementary Criteria for Design Endurance, Civil Transport Aircraft, April 1, 1996	25.735
SAE ARP-598B	The Determination of Particulate Contamination in Liquids	25.1435

	by the Particle Count Method	
SAE ARP-763	Accumulators, Ground, Hydropneumatic Pressure, Oct. 15, 1962	25.1435
SAE ARP-785	Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure	25.1435
SAE ARP 813A	Maintainability Recommendations for Aircraft Wheels and Brakes	25.735
SAE ARP-813B	Maintainability Recommendations for Aircraft Wheels and Brakes, April 1, 1993	25.735
SAE ARP-862A	Skid Control Performance, April 1, 1996	25.735
SAE ARP-994	Design of Tubing Installations for Aerospace Fluid Power Systems, Nov. 1991	25.1435
SAE ARP 1064B	Brake Dynamics	25.735
SAE ARP-1070B	Design and Testing of Antiskid Brake Control, April 1, 1996	25.735
SAE ARP-1084	Hydraulic External Leakage for In-Service Components, November 1991	25.1435
SAE ARP-1280A	Aerospace Application Guide for Hydraulic Power Transfer Units, July 1994	25.1435
SAE ARP-1281B	Actuators: Aircraft Flight Controls, Power Operated, Hydraulic, General Specification, May, 1993	25.1435
SAE ARP-1311A	Landing Gear - Aircraft, January 1995	25.729
SAE-ARP 1322	Overpressurization Release Devices, March 1, 1992	25.731, 25.733
SAE ARP-1619	Replacement and Modified Brakes and Wheels, April 1, 1993	25.735
SAE APR-1709	Coupling Assembly, Hydraulic Self Sealing, Quick Disconnect, April 1994	25.1435
SAE ARP-1786	Wheel Roll on Rim Criteria for Aircraft Application, July 1, 1994	25.731
SAE ARP-1832	Color Identification for O-Ring Seals, Dec. 1992	25.1435
SAE-ARP-1907	Automatic Braking Systems Requirements, April 1, 1993	25.735
SAE ARP-4379	Accumulator, Hydraulic, Cylindrical Aircraft, June 1991	25.1435
SAE ARP-4752	Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems, Sept. 1994	25.1435
SAE-ARP-4834	Recommended Practice for Retreaded Aircraft Tires-Radial and Bias, Nov. 1, 1995	25.733
SAE AS-483A	Skid Control Equipment, March 1, 1992	25.735
SAE AS 595B	Civil Type Aircraft and Variable Delivery Hydraulic Pump, March 1995	25.1435
SAE AS-707B	Thermal Sensitive Inflation Pressure Release Devices for Tubeless Aircraft Wheels, March 1, 1992	25.731, 25.733

SAE AS-1145A	Aircraft Brake Temperature Monitor System (BTMS), March 1, 1992	25.735
SAE-AS-1188	Aircraft Tire Inflation-Deflation Equipment, April 1, 1993	25.733
SAE AS-1241B	Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft, Feb. 18, 1992	25.1435
SAE AS-4059	Cleanliness Classification for Hydraulic Fluids	25.1435
SAE-AS-4833	Aircraft New Tire Standard-Bias and Radial, June 1, 1995	25.733

SAE A-6 Committee has prepared the Aerospace Fluid Power Actuation & Control Technologies documents, related to methods for testing and measurement of fluid contamination.	25.1435
SAE A-10 Committee has prepared the Aircraft Oxygen Equipment Handbook, 1992, or latest revision, containing all Aerospace Standards, Aerospace Recommended Practices, and Aerospace Information Reports related to oxygen equipment published by SAE	25.1441, 25.1443, 25.1445, 25.1447, 25.1453
SAE publication “Aircraft Flight Control Actuation System Design,” by E. T. Raymond and C. C. Chenoweth	25.1435

APPENDIX 4

6. Miscellaneous References in this AC:

These documents provide additional information, guidance, and/or standards, and are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, USA.

Number	Title	Section Reference
DOT/FAA/AR-96/122	Development of a Minimum Performance Standard for Lavatory Trash Receptacle Automatic Fire Extinguishers, February 1997	25.854
DOT/FAA/CT-88/8-1	Aircraft Icing Handbook (three volumes)	25.1419
DOT/FAA/CT/83/1	FAA Technical Center Report, Analysis of Dissipation of Gaseous Extinguisher Agents in Ventilated Compartments, May 1983	25.857
CAA Technical Development Report No. 146, Appendix I	Evaluation of Flight Fire Protection Means for Inaccessible Aircraft Baggage Compartments, June 1951	25.857
FAA Technical Report ADS-4	Engineering Summary of Airframe Icing Technical Data, Dec. 10, 1963	25.1419
FAA Report FAA-AEQ-77-13	Ozone Concentration By Latitude, Altitude, and Month, Near 80° West, August 1977	25.832
FAA Report FAA-AM-79-20	Effects of Ozone on Exercising and Sedentary Adult Men and Women Representative of the Flight Attendant Population, October 1979	25.832
Generic Issue Paper	PCARGOE.DOC, Protection of Critical Systems & Equipment within Class E Cargo Compartments	25.855

NPRM 89-31	Minimum Air Flow, Requirements, Fresh Air	25.831
NPRM 93-8	Determination of Allowable Worn Brake Limits	25.735
AD-93-07-15	Class B Fire Extinguishing Methods	25.857

The Tire and Rim Association, Inc. prepares a yearbook which lists aircraft tire and rim sizes and ratings. The address is: Tire and Rim Association, Inc. 175 Montrose West Ave., Suite 150 Copley, OH 44321, USA.	25.731 25.735

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APPENDIX 4

7. Cross Reference for Other Handbooks.

While not regulatory in nature, these handbooks contain information that may be of interest to an applicant. These documents provide additional information, guidance, and/or standards. Copies of the handbooks are available from the FAA Transport Airplane Directorate, 1601 Lind Ave. SW, Renton, WA 98055, USA.

Part 25 Airworthiness Standards: Transport Category Airplanes Mechanical Systems

Subpart B - Performance								
Section	Subject	Order 8110.8	AC 25-7A	AC Draft Propulsion Handbook	AC 25-21	AC Draft Crashworthiness Handbook	AC Draft Electrical Systems Handbook	AC Draft Mechanical Systems Handbook
25.109	Accelerate-stop distance	x	x					x
25.125	Landing	x	x					x
Subpart C - Structures								

Section	Subject	Order 8110.8	AC 25-7A	AC Draft Propulsion Handbook	AC 25-21	AC Draft Crashworthiness Handbook	AC Draft Electrical Systems Handbook	AC Draft Mechanical Systems Handbook
25.581	Lightning protection			x				x

Subpart D - Design and Construction

Section	Subject	Order 8110.8	AC 25-7A	AC Draft Propulsion Handbook	AC 25-21	AC Draft Crashworthiness Handbook	AC Draft Electrical Systems Handbook	AC Draft Mechanical Systems Handbook
Control Systems								
25.671	General	x	x					x
25.672	Stability augmentation				x			x
25.677	Trim systems				x			
25.699	Lift and drag device ind.							x
25.701	Flap interconnection	x	x		x			x
25.703	Takeoff warning system							x
Landing Gear								
25.729	Retracting mechanism	x	x		x			x
25.731	Wheels		x		x			x
25.733	Tires				x			x
25.735	Brakes	x	x		x			x

Personnel/Cargo Accommodation								
25.773	Pilot compartment view		x		x			x
25.783	Doors				x	x		x
Ventilation and Heating								
25.831	Ventilation	x	x					
25.832	Cabin ozone concentration							x
25.833	Combustion heating systems							x
Pressurization								
25.841	Pressurized cabins		x					x
25.843	Tests for pressurized cabins		x					x
Section	Subject	Order 8110.8	AC 25-7A	AC Draft Propulsion Handbook	AC 25-21	AC Draft Crashworthiness Handbook	AC Draft Electrical Systems Handbook	AC Draft Mechanical Systems Handbook
Fire Protection								
25.851	Fire extinguishers					x		x
25.854	Lavatory fire protection							x
25.855	Cargo or baggage compartments					x		x
25.857	Cargo compartment classification					x		x
25.858	Cargo Compartment							

	fire detection systems							x
25.863	Flammable fluid fire protection			x				x
25.865	Fire protection of flight controls			x	x			
25.869	Fire protection: systems				x		x	x
Subpart E - Powerplant								
Section	Subject	Order 8110.8	AC 25-7A	AC Draft Propulsion Handbook	AC 25-21	AC Draft Crashworthiness Handbook	AC Draft Electrical Systems Handbook	AC Draft Mechanical Systems Handbook
General								
25.943	Negative acceleration		x	x				x
Fuel System Components								
25.1001	Fuel jettisoning system	x	x	x				x

Section	Subject	Order 8110.8	AC 25-7A	AC Draft Propulsion Handbook	AC 25-21	AC Draft Crashworthiness Handbook	AC Draft Electrical Systems Handbook	AC Draft Mechanical Systems Handbook
Powerplant Fire Protection								
25.1183	Flammable fluid-carrying components			x				x
25.1185	Flammable fluids			x				x
25.1189	Shutoff means			x				x
Subpart F - Equipment								
Section	Subject	Order 8110.8	AC 25-7A	AC Draft Propulsion Handbook	AC 25-21	AC Draft Crash-worthiness Handbook	AC Draft Electrical Systems Handbook	AC Draft Mechanical Systems Handbook
General								
25.1301	Function and installation	x	x	x			x	x
25.1309	Equipment, system, & installation	x	x	x			x	x
25.1316	System lightning protection						x	x
25.1322	Warning, caution, & advisory						x	x
25.1351	System lightning protection						x	x

25.1359	Electrical system fire & smoke protection (now 25.869)						x	x
Safety Equipment								
25.1419	Ice protection			x				x
Section	Subject	Order 8110.8	AC 25-7A	AC Draft Propulsion Handbook	AC 25-21	AC Draft Crashworthiness Handbook	AC Draft Electrical Systems Handbook	AC Draft Mechanical Systems Handbook
Miscellaneous Equipment								
25.1431	Electronic equipment	x	x				x	x
25.1433	Vacuum systems							x
25.1435	Hydraulic systems							x
25.1438	Pressurization & pneumatic systems							x
25.1439	Protective breathing equipment							x
25.1441	Oxygen equipment and supply							x
25.1443	Minimum mass flow of supplemental oxygen							x
25.1445	Equipment standards for oxygen distributing system							x
25.1447	Equipment standards for oxygen dispensing units							x
25.1449	Means for							

	determining use of oxygen							x
25.1450	Chemical oxygen generators							x
25.1451	Fire protection: oxygen equipment (now 25.869)							x
25.1453	Protection of oxygen equipment from rupture							x
25.1455	Draining of fluids subject to freezing							x
25.1461	Equipment containing high energy rotors							x

Subpart G- Operating Limitations								
Section	Subject	Order 8110.8	AC 25-7A	AC Draft Propulsion Handbook	AC 25-21	AC Draft Crashworthiness Handbook	AC Draft Electrical Systems Handbook	AC Draft Mechanical Systems Handbook
General								
25.1529	Instructions for continued airworthiness							x
25.1541	Markings and placards							x
25.1557	Miscellaneous markings and placards							x
25.1581	Airplane flight manual							x

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