U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject	**BRAKES AND BRAKING SYSTEMS CERTIFICATION TESTS AND ANALYSIS**	**Date:**	**4/10/02**	**AC No.:**	**25.735-1**
		Initiated by:	**ANM-100**	**Change**	

1. PURPOSE. This Advisory Circular (AC) provides guidance material for use as an acceptable means, although not the only means, of demonstrating compliance with the braking system requirements of Title 14, Code of Federal Regulations (14 CFR) part 25 for transport category airplanes. Like all AC material, this AC is not, in itself, mandatory and does not constitute a regulation. Terms used in this AC, such as "shall" or "must," are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance described herein is used. While these guidelines are not mandatory, they are derived from extensive Federal Aviation Administration (FAA) and industry experience in determining compliance with the pertinent CFR. This AC does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.

2. RELATED DOCUMENTS.

a. Related Federal Aviation Regulations. Sections 25.731 and 25.735 of 14 CFR, as amended through Amendment 25-107, and other sections relating to brakes and braking system installations. Sections that prescribe requirements for the design, substantiation, and certification of braking systems include:

§ 21.303 Replacement and modification parts
§ 25.101 General
§ 25.109 Accelerate-stop distance
§ 25.125 Landing

§ 25.301 Loads
§ 25.303 Factor of safety
§ 25.729 Retracting mechanism
§ 25.733 Tires
§ 25.1301 Function and installation.
§ 25.1309 Equipment, systems and installations.
§ 25.1322 Warning, caution and advisory lights.
§ 25.1501 General: Systems and equipment limitations (JAR25x1524)
§ 25.1541 Markings and Placards
14 CFR part 21, Subpart O

b. 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 braking systems include, but are not limited to:

§ 21.101 Designation of applicable regulations
§ 25.863 Flammable fluid fire protection
§ 25.943 Negative acceleration (JAR 25x1315)
§ 25.1001 Fuel jettisoning system
§ 25.1183 Flammable fluid-carrying components
§ 25.1185 Flammable fluids

c. Advisory Circulars (AC's).

AC 25.1309-1A System Design and Analysis
AC 25-7A Flight Test Guide for Certification of Transport Category Airplanes
AC 91-6A Water, Slush, and Snow on the Runway (AMJ 25x1591 Supplementary Performance Information for Takeoff from Wet Runways and for Operation on Runways Contaminated by Standing Water, Slush, Loose Snow, Compacted Snow, or Ice)

d. Technical Standard Orders (TSO's).

TSO-C26c Aircraft Wheels and Wheel-Brake Assemblies with Addendum I
TSO-C135 Transport Airplane Wheel and Wheel and Brake Assemblies
TSO-C62d Tires
TSO-C75 Hydraulic Hose Assemblies

e. Federal Aviation Administration Orders.

Order 8110.4A Type Certification Process
Order 8110.8 Engineering Flight Test Guide For Transport Category Airplanes

f. Advisory Circulars, TSO's, and FAA Orders 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, or an electronic copy may be downloaded using the Internet at the following address: http://www.faa.gov/certification/aircraft/air_index.htm

g. Society of Automotive Engineers (SAE) Documents.

ARP 597C Wheels and Brakes, Supplementary Criteria for Design Endurance-– Civil Transport Aircraft
ARP 813A Maintainability Recommendations for Aircraft Wheels and Brakes
AIR 1064B Brake Dynamics
ARP 1070B Design and Testing of Antiskid Brake Control Systems for Total Aircraft Compatibility
AS 1145A Aircraft Brake Temperature Monitor System (BTMS)
ARP 1619 Replacement and Modified Brakes and Wheels
AIR 1739 Information on Antiskid Systems
ARP 1907 Automatic Braking System Requirements
AIR 1934 Use of Carbon Heat Sink Brakes on Aircraft
ARP 4102/2 Automatic Braking System (ABS)
ISO 7137 Environmental Conditions and Test Procedures for Airborne Equipment (not an SAE document but is available from the SAE)

h. These documents can be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096.

i. RTCA Documents.

RTCA/DO-160D Conditions and Test Procedures for Airborne equipment, Issued July 12, 1996.

RTCA/DO-178B Software Considerations in Airborne Systems and Equipment Certification, Issued December 1, 1992

j. Copies of RTCA documents may be purchased from the RTCA Inc., 1140 Connecticut Avenue NW, Suite 1020, Washington, D.C. 20036.

k. Military Documents.

MIL-STD-810 Environmental Test Methods and Engineering Guidelines

l. This document can be obtained from the Department of Defense, DODSSP, Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.

3. BACKGROUND.

a. Effective February 1, 1965, part 25 was added to 14 CFR to replace part 4b of the Civil Air Regulations (CAR). For wheels, CAR 4b.335(a) and (b), became §§ 25.731(a) and (b) respectively, of 14 CFR. For brakes/braking systems, CAR 4b.337 (a)(1), 4b.337(a)(2) and (a)(3), 4b.337(b), 4b.337(c), 4b.337(d), 4b.335(c), and 4b.335(d), became §§ 25.735(a), 25.735(b), 25.735(c), 25.735(d), 25.735(e), 25.735(f), and 25.735(g) respectively, of 14 CFR. Since then, § 25.735 has been revised by Amendment 25-23 (1970), Amendment 25-48 (1979), Amendment 25-52 (1980), Amendment 25-72 (1990), Amendment 25-92, Improved Standards for Determining Rejected Takeoff and Landing Performance (1998), and Amendment 25-107, Revision of Braking Systems Airworthiness Standards to Harmonize with European Airworthiness Standards for Transport Category Airplanes. These amendments were adopted to make the regulations more comprehensive and to delete redundancies.

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

(2) Amendment 25-48 revised the technical standard order TSO-C26b for aircraft wheels and wheel-brake assemblies and related type certification requirements for airplane brakes (§ 25.735). The revised standard TSO-C26c incorporated updated and improved minimum performance standards for the design and construction of aircraft wheels and brakes. The amendment also changed § 25.735 as follows:

(a) Under § 25.735(b), the incorrect reference to § 25.75 was replaced by a correct reference to § 25.125.

(b) 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.

(c) 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 definition.

(d) Under § 25.735(g), the term V_{SO} was replaced by V to be consistent with terminology used under § 25.735(f)(2).

(3) Under Amendment 25-52, § 37.172, Aircraft wheels and brakes, TSO-C26c was removed from the regulations, previously published as Subpart B of 14 CFR part 37, and made available to the public. The TSO-C26c is available through the FAA Office of Airworthiness, Aircraft Engineering Division, Systems Branch (AWS-130) at FAA Headquarters in Washington, D.C., and at all regional Flight Standards Engineering and Manufacturing Offices. Subpart A of 14 CFR part 37 was included in Subpart O of 14 CFR part 21. Part 37 of 14 CFR was revoked.

(4) Under Amendment 25-72, the text of the last sentence in existing § 25.735(b) was changed to clarify the intent. In addition, § 25.731 was amended to become compatible with § 25.25, which had been amended to provide for weights that are in excess of takeoff weight, such as ramp weights, provided that compliance with the applicable structural requirements, including wheel strength, is demonstrated at the higher weights.

(5) Under Amendment 25-92, the regulations were updated to add the brake wear limits determination requirements. On May 21, 1988, an American Airlines DC-10 experienced an 86 percent 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 in the early portion of 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. The FAA issued a series of airplane specific airworthiness directives between 1989 and 1994 to establish brake wear limits using the new criteria.

(6) Although part 25 and JAR-25 are very similar, they are not identical. Differences between part 25 and the JAR can result in substantial additional costs when airplanes are type certificated to both standards. Starting In 1992, the harmonization effort for various systems-related airworthiness requirements was undertaken by the Aviation Rulemaking Advisory Committee (ARAC). A working group of industry and government braking systems specialists from Europe, the United States, and Canada was chartered by notice in the Federal Register (59 FR 30080, June 10, 1994). The working group was tasked to develop harmonized standards and any collateral documents, such as advisory circulars, concerning new or revised requirements for braking systems, and the associated test conditions for braking systems, installed in transport category airplanes (§§ 25.731 and 25.735). The advisory material contained in this AC was developed by the Braking Systems Harmonization Working Group to ensure consistent application of the standards revised under Amendment 25-107, Revision of Braking Systems Airworthiness Standards to Harmonize with European Airworthiness Standards for Transport Category Airplanes, and the corresponding new TSO-C135.

4. DISCUSSION.

a. Approval.

(1) Section § 25.735(a) states that each assembly consisting of a wheel(s) and brake(s) must be approved. Each wheel and brake assembly fitted with each designated and approved tire type and size, where appropriate, should be shown to be capable of meeting the minimum standards and capabilities detailed in the applicable TSO, in combination with the type certification procedures for the airplane, or by any other means approved by the Administrator. This applies equally to replacement, modified, and

refurbished wheel and brake assemblies or components, whether the changes are made by the Original Equipment Manufacturer (OEM) or others. Additionally, the components of the wheels, brakes, and braking systems should be designed to:

(a) Withstand all pressures and loads, applied separately and in conjunction, to which they may be subjected in all operating conditions for which the airplane is certificated.

(b) Withstand simultaneous applications of normal and emergency braking functions, unless adequate design measures have been taken to prevent such a contingency.

(c) Meet the energy absorption requirements without auxiliary cooling devices (such as cooling fans).

(d) Not induce unacceptable vibrations at any likely ground speed and condition or any operating condition (such as retraction or extension).

(e) Protect against the ingress or effects of foreign bodies or materials (water, mud, oil, and other products) that may adversely affect their satisfactory performance. Following initial airplane certification, any additional wheel and brake assemblies should meet the applicable airworthiness requirements specified in §§ 21.101(a) and (b) to eliminate situations that may have adverse consequences on airplane braking control and performance. This includes the possibility of the use of modified brakes either alone (i.e., as a shipset) or alongside the OEM's brakes and the mixing of separately approved assemblies.

(2) Refurbished and Overhauled Equipment. Refurbished and overhauled equipment is equipment overhauled and maintained by the applicable OEM or its designee in accordance with the OEM's Component Maintenance Manual (CMM) and associated documents. It is necessary to demonstrate compliance of all refurbished configurations with the applicable TSO and airplane manufacturer's specifications. It is also necessary to verify that performances are compatible for any combination of mixed brake configurations, including refurbished/overhauled and new brakes. It is essential to assure that Airplane Flight Manual braking performance and landing gear and airplane structural integrity are not adversely altered.

(3) Replacement and Modified Equipment. Replacement and modified equipment includes changes to any approved wheel and brake assemblies not addressed under paragraph 4a(2) of this AC. Consultation with the airplane manufacturer on the extent of testing is recommended. Particular attention should be paid to potential differences in the primary brake system parameters (e.g., brake torque, energy capacity, vibration, brake sensitivity, dynamic response, structural strength, and wear state). If comparisons are made to previously approved equipment, the test articles (other than the proposed parts to be changed) and conditions should be comparable, as well as the test procedures and equipment on which comparative tests are to be conducted. For wheel

and brake assembly tests, the tire size, manufacturer, and ply rating used for the test should be the same and the tire condition should be comparable. For changes of any heat sink component parts, structural parts (including the wheel), and friction elements, it is necessary for the applicant to provide evidence of acceptable performance and compatibility with the airplane and its systems.

(a) Minor Changes. Changes to a brake might be considered as a minor change, as long as the changes are not to the friction elements. The proposed change cannot affect the airplane stopping performance, brake energy absorption characteristics, and/or continued airworthiness of the airplane or wheel and brake assembly (e.g., vibration and/or thermal control, and brake retraction integrity). It is incumbent on the applicant to provide technical evidence justifying a minor change.

(b) Major Changes. Changes to a wheel assembly outside the limits allowed by the OEM’s CMM should be considered a major change due to potential airworthiness issues.

(c) Past history with friction elements has indicated the necessity of on-going monitoring (by dynamometer test) of frictional and energy absorption capabilities to assure that they are maintained over the life of the airplane program. These monitoring plans have complemented the detection and correction of unacceptable deviations. The applicant should submit a monitoring plan to the cognizant FAA Aircraft Certification Office to ensure continued airworthiness of the product.

(d) Intermixing of wheel and brake assemblies from different suppliers is generally not acceptable due to complexities experienced with different friction elements, specific brake control tuning, and other factors.

b. Brake System Capability.

(1) The system should be designed so that no single failure of the system degrades the airplane stopping performance beyond doubling the braked roll stopping distance (refer to § 25.735(b)(1)). Failures are considered to be fracture, leakage, or jamming of a component in the system, or loss of an energy source. Components of the system include all parts that contribute to transmitting the pilot's braking command to the actual generation of braking force. Multiple failures resulting from a single cause should be considered a single failure (e.g., fracture of two or more hydraulic lines as a result of a single tire failure). Sub-components within the brake assembly, such as brake discs and actuators (or their equivalents), should 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 sub-components within the brake assembly would not reduce the braking effectiveness below that specified in § 25.735(b)(1).

(a) In order to meet the stopping distance requirements of § 25.735(b)(1) in the event of failure of the normal brake system, it is common practice to provide an alternate brake system. The normal and alternate braking systems should be independent, being supplied by separate power sources. Following a failure of the normal system, the changeover to a second system (whether manually or by automatic means) and the functioning of a secondary power source should be effected rapidly and safely. The changeover should not involve risk of wheel locking, whether the brakes are applied or not at the time of changeover.

(b) The brake systems and components should be separated or appropriately shielded so that complete failure of the braking system(s) as a result of a single cause is minimized.

(2) Compliance with § 25.735(b)(2) may be achieved by:

(a) Showing that fluid released would not impinge on the brake, or any part of the assembly that might cause the fluid to ignite;

(b) Showing that the fluid will not ignite; or

(c) Showing that the maximum amount of fluid released is not sufficient to sustain a fire.

(3) Additionally, in the case of a fire, the applicant may show that the fire is not hazardous, taking into consideration such factors as landing gear geometry, location of fire sensitive (susceptibility) equipment and installations, system status, flight mode, etc. If more than one fluid is allowed for the hydraulic system, compliance should be addressed for all fluids.

c. <u>Brake Controls</u>.

(1) The braking force should increase or decrease progressively as the force or movement applied to the brake control is increased or decreased (refer to § 25.735(c)(1)). The braking force should respond to the control as quickly as is necessary for safe and satisfactory operation. A brake control intended only for parking need not operate progressively. There should be no requirement to select the parking brake “off” in order to achieve a higher braking force with manual braking.

(2) When an automatic braking system is installed (refer to § 25.735(c)(2)) such that various levels of braking (e.g., low, medium, high) may be preselected to occur automatically following a touchdown, the pilot(s) should be provided with a means that is separate from other brake controls to arm and/or disarm the system prior to the touchdown.

(3) The automatic braking system design should be evaluated for integrity and non-hazard, including the probability and consequence of insidious failure of critical components, and noninterference with the non-automatic braking system. Single failures in the automatic braking system should not compromise non-automatic braking of the airplane. Automatic braking systems that are to be approved for use in the event of a

rejected takeoff should have a single selector position, set prior to takeoff, enabling this operating mode.

d. Parking Brake. It should be demonstrated that the parking brake has sufficient capability in all allowable operating conditions (Master Minimum Equipment List (MMEL) to be able to prevent the rotation of braked wheels. This demonstration is to be accomplished with the stated engine power settings, and with the airplane configuration (i.e., ground weight, c.g., position and nosewheel (or tailwheel) angle) least likely to result in skidding on a dry, level runway surface (refer to § 25.735(d)). Use of ground idle thrust on the “other” engine is not mandatory, higher thrust levels may be used to prevent airplane motion due to the asymmetric engine thrust. Where reliable test data are available, substantiation by means other than airplane testing may be acceptable.

(1) For compliance with the requirement for indication that the parking brake is not fully released, the indication means should be associated, as closely as is practical, with actual application of the brake rather than the selector (control). The intent is to minimize the possibility of false indication due to failures between the brake and the point at which the parking brake state is sensed. This requirement is separate from, and in addition, to the parking brake requirements associated with JAR 25.703(a)(3), Take-off warning systems.

(2) The parking brake control, whether or not it is independent of the emergency brake control, should be marked with the words "Parking Brake" and should be constructed in such a way that, once operated, it can remain in the selected position without further flightcrew attention. It should be located where inadvertent operation is unlikely, or be protected by suitable means against inadvertent operation.

e. Antiskid System.

(1) If an antiskid system is installed (refer to § 25.735(e)), then no single failure in the antiskid system should result in the brakes being applied, unless braking is being commanded by the pilot. In the event of an antiskid system failure, means should be available to allow continued braking without antiskid. These means may be automatic, pilot controlled, or both.

(2) Compliance with §§ 25.735(e)(1) and (e)(2)) may be achieved by:

(a) Failures that render the system ineffective should not prevent manual braking control by the pilot(s) and should normally be indicated. Failure of wheels, brakes, or tires should not inhibit the function of the antiskid system for unaffected wheel, brake, and tire assemblies.

(b) The antiskid system should be capable of giving a satisfactory braking performance over the full range of tire to runway friction coefficients and surface conditions, without the need for pre-flight or pre-landing adjustments or selections. The range of friction coefficients should encompass those appropriate to dry, wet, and contaminated surfaces and for both grooved and ungrooved runways.

(c) The use of the phrase “without external adjustment” is intended to imply that once the antiskid system has been optimized for operation over the full range of expected conditions for which the airplane is to be type certificated, pre-flight or pre-landing adjustments made to the equipment to enable the expected capabilities to be achieved are not acceptable. For example, a specific pre-landing selection for a landing on a contaminated, low μ (friction level) runway, following a takeoff from a dry, high μ runway, should not be necessary for satisfactory braking performance to be achieved.

(d) It should be shown that the brake cycling frequency imposed by the antiskid installation will not result in excessive loads on the landing gear. Antiskid installations should not cause surge pressures in the brake hydraulic system that would be detrimental to either the normal or emergency brake system and components.

(e) The system should be compatible with all tire sizes and type combinations permitted and for all allowable wear states of the brakes and tires. Where brakes of different types or manufacture are permitted, compatibility should be demonstrated or appropriate means should be employed to ensure that undesirable combinations are precluded.

(f) The antiskid function must be able to reduce braking for a wheel/tire that is going into a skid, whether the braking level is commanded by the pilot or an autobrake system if installed.

f. Kinetic Energy Capacity. The kinetic energy capacity of each tire, wheel, and brake assembly should be at least equal to that part of the total airplane energy that the assembly will absorb during a stop, with the heat sink at a defined condition at the commencement of the stop (Refer to § 25.735(f)).

(1) Calculation of Stop Kinetic Energy.

(a) The design landing stop, the maximum kinetic energy accelerate-stop, and the most severe landing stop brake kinetic energy absorption requirements of each wheel and brake assembly should be determined using either of the following methods:

(1) A conservative rational analysis of the sequence of events expected during the braking maneuver; or

(2) A direct calculation based on the airplane kinetic energy at the commencement of the braking maneuver.

(b) When determining the tire, wheel, and brake assembly kinetic energy absorption requirement using the rational analysis method, the analysis should use conservative values of the airplane speed at which the brakes are first applied, the range of the expected coefficient of friction between the tires and runway, aerodynamic and propeller drag, powerplant forward thrust, and, if more critical, the most adverse single engine or propeller malfunction.

(c) When determining the tire, wheel, and brake assembly energy absorption requirement using the direct calculation method, the following formula, which needs to be modified in cases of designed unequal braking distribution, should be used:

$$KE = 0.0443\, WV^2/N \text{ (ft-lb.)}$$

where KE = Kinetic Energy per wheel (ft-lb.)
N = Number of main wheels with brakes
W = Airplane Weight (lb.)
V = Airplane Speed (knots)

or if SI (Metric) units are used:

$$KE = 1/2\, mV^2/N \text{ (Joule)}$$

where KE = Kinetic Energy per wheel (J)
N = Number of main wheels with brakes
m = Airplane Mass (kg.)
V = Airplane Speed (m/s)

(d) For all cases, V is the ground speed and takes into account the prevailing operational conditions. All approved landing flap conditions should be considered when determining the design landing stop energy.

(e) These calculations should account for cases of designed unequal braking distributions. “Designed unequal braking distribution” refers to unequal braking loads between wheels that result directly from the design of the airplane. An example would be the use of both mainwheel and nosewheel brakes, or the use of brakes on a centerline landing gear supporting lower vertical loads per braked wheel than the main landing gear braked wheels. It is intended that this term should account for effects such as runway crown. Crosswind effects need not be considered.

(f) For the design landing case, the airplane speed should not be less than $V_{REF}/1.3$, where V_{REF} is the airplane steady landing approach speed at the maximum design landing weight and in the landing configuration at sea level. Alternatively, the airplane speed should not be less than V_{SO}, the poweroff stall speed of the airplane at sea level, at the design landing weight, and in the landing configuration.

(g) For the most severe landing case, the applicant should address effects and consequences of typical single and multiple failure conditions that are foreseeable events and can necessitate landings at abnormal speeds and weights. The critical landing weight for this condition is the maximum takeoff weight, less fuel burned and jettisoned during a return to the departure airfield. A 30-minute flight should be assumed, with 15 minutes of active fuel jettisoning if equipped with a fuel jettisoning system.

(2) Heat Sink Condition at Commencement of the Stop.

(a) For the maximum kinetic energy accelerate-stop case, the calculation should account for

(b) The brake temperature following a previous typical landing,

(c) The effects of braking during taxi-in, the temperature change while parked,

(d) The effects of braking during taxi-out, and

(e) The additional temperature change during the takeoff acceleration phase, up to the time of brake application.

(f) The analysis may not take account of auxiliary cooling devices. Assessment of ambient conditions within the operational limits established by the applicant and the typical time the airplane will be on the ground should be used.

(g) For the most severe landing stop case, the same temperature conditions and changes used for the maximum kinetic energy accelerate-stop case should be assumed, except that further temperature change during the additional flight phase may be considered.

(h) The brake temperature at the commencement of the braking maneuver should be determined using the rational analysis method. However, in the absence of such analysis, an arbitrary heat sink temperature should be used equal to the normal ambient temperature, increased by the amount that would result from a 10 percent maximum kinetic energy accelerate-stop for the accelerate-stop case and from a 5 percent maximum kinetic energy accelerate-stop for landing cases.

(3) Substantiation.

(a) Substantiation is required to show that the wheel and brake assembly is capable of absorbing the determined levels of kinetic energy at all permitted wear states up to and including the declared fully worn limits. The term “wear state" is used to clarify that consideration should be given to possible inconsistencies or irregularities in brake wear in some circumstances, such as greater wear at one end of the heat sink than the other end. Qualification related to equally distributed heat sink wear may not be considered adequate. If in-service wear distribution is significantly different from wear distribution used during qualification testing, additional substantiation and/or corrective action may be necessary.

(b) The minimum initial brakes-on speed used in the dynamometer tests should not be more than the velocity (V) used in the determination of the kinetic energy requirements of § 25.735(f). This assumes that the test procedure involved a specific rate of deceleration and, therefore, for the same amount of kinetic energy, a higher initial brakes-on speed would result in a lower rate of energy absorption. Such a situation is recognized and is similarly stated in TSO-C135, which provides an acceptable means for brake approval under § 25.735(a).

(c) For certification purposes, a brake having a higher initial brakes-on speed is acceptable if the dynamometer test showed that both the energy absorbed and the energy absorption rates required by § 25.735(f) had been achieved.

(d) Brake qualification tests are not intended as a means of determining expected airplane stopping performance, but may be used as an indicator for the most critical brake wear state for airplane braking performance measurements.

g. Brake condition after high kinetic energy dynamometer stop(s). (Reference § 25.735(g)).

(1) Following the high kinetic energy stop(s), the parking brake should be capable of restraining further movement of the airplane and should maintain this capability for the period during which the need for an evacuation of the airplane can be determined and then fully accomplished. It should be demonstrated that, with a parking brake application within a period not exceeding 20 seconds of achieving a full stop, or within 20 seconds from the time that the speed is retarded to 20 knots (or lower), in the event that the brakes are released prior to achieving a full stop (as permitted by TSO-C135), the parking brake can be applied normally and that it remains functional for at least 3 minutes.

(2) Practical difficulties associated with dynamometer design may preclude directly demonstrating the effectiveness of the parking brake in the period immediately following the high energy dynamometer stop(s). Where such difficulties prevail, it should be shown that, for the 3-minute period, no structural failure or other condition of the brake components occurs that would significantly impair the parking brake function.

(3) Regarding the initiation of a fire, it should be demonstrated that no continuous or sustained fire, extending above the level of the highest point of the tire, occurs before the 5-minute period has elapsed. Neither should any other condition arise during this same period or during the stop, either separately or in conjunction with a fire, that could be reasonably judged to prejudice the safe and complete airplane evacuation. Fire of a limited extent and of a temporary nature (e.g., those involving wheel bearing lubricant or minor oil spillage) is acceptable. For this demonstration, neither firefighting means nor coolants may be applied.

h. Stored energy systems.

(1) Stored energy systems use a self-contained source of power, such as a pressurized hydraulic accumulator or a charged battery (refer to § 25.735(h)). This requirement is not applicable for those airplanes that provide a number of independent

braking systems, including a stored energy system, but are not "reliant" on the stored energy system for the demonstration of compliance with § 25.735(b).

(2) The indication of usable stored energy should show:

(a) The minimum energy level necessary to meet the requirements of §§ 25.735 (b)(1) and (h) (i.e., the acceptable level for dispatch of the airplane);

(b) The remaining energy level; and

(c) The energy level below which further brake application may not be possible.

(3) If a gas pressurized hydraulic accumulator is to be used as the energy storage means, indication of accumulator pressure alone is not considered adequate means to indicate available stored energy, unless verification can be made of the correct precharge pressure with the hydraulic system pressure off and the correct fluid volume with the hydraulic system pressure on. Furthermore, additional safeguards may be necessary to ensure that sufficient energy will be available at the end of the flight. Similar considerations should be made if other stored energy systems are used.

(4) A full brake application cycle is defined as an application from brakes fully released to brakes fully applied, and back to fully released.

i. <u>Brake wear indicators</u>. The indication means should be located such that no special tool or illumination (except in darkness) is required. Expert interpretation of the indication should not be necessary (refer to § 25.735(i)).

j. <u>Overtemperature and overpressure burst prevention</u>. Generally, two separate types of protection should be provided: one specifically to release the tire pressure should the wheel temperature increase to an unacceptable level, and the other to release the tire pressure should the pressure become unacceptably high, particularly during the inflation process. The temperature sensitive devices are required in braked wheels only, but the pressure sensitive devices are required in all wheels (refer to §§ 25.735(j) and 25.731(d)).

(1) The temperature sensitive devices (e.g., fuse or fusible plugs) should be sufficient in number and appropriately located to reduce the tire pressure to a safe level before any part of the wheel becomes unacceptably hot, irrespective of the wheel orientation. The devices should be designed and installed so that once operated (or triggered) their continued operation is not impaired by the releasing gas. The effectiveness of these devices in preventing hazardous tire blowout or wheel failure should be demonstrated. It should also be demonstrated that the devices will not release the tire pressure prematurely during takeoff and landing, including during “quick turnaround” types of operation.

(2) It should be shown that the overpressurization devices, or the devices in conjunction with the tire inflation means permanently installed in the wheel, would not permit the tire pressure to reach an unsafe level regardless of the capacity of the inflation source.

(3) Both types of devices should normally be located within the structure of the wheel in positions that minimize the risk of damage or tampering during normal maintenance.

k. Compatibility. Compliance with § 25.735(k) may be achieved by the following:

(1) As part of the overall substantiation of safe and anomaly free operation, it is necessary to show that no unsafe conditions arise from incompatibilities between the brakes and brake system with other airplane systems and structures. Areas that should be explored include antiskid tuning, landing gear dynamics, tire type and size, brake combinations, brake characteristics, brake and landing gear vibrations, etc. Similarly, wheel and tire compatibility should be addressed. These issues should be readdressed when the equipment is modified.

(2) During brake qualification testing, sufficient dynamometer testing over the ranges of permissible brake wear states, energy levels, brake pressures, brake temperatures, and speeds should be undertaken to provide information necessary for systems integration.

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