



Department of Transportation
Federal Aviation Administration
Aircraft Certification Service
Washington, D.C.

TSO-C135a

Effective
Date: 07/01/09

Technical Standard Order

Subject: Transport Airplane Wheels and Wheel and Brake Assemblies

1. **PURPOSE.** This technical standard order (TSO) is for use by applicants for TSO authorization (TSOA) or letter of design approval (LODA). In it, we (the Federal Aviation Administration, or FAA) tell you what minimum performance standards (MPS) your transport category airplane wheels (without brakes), and wheel and brake assemblies with either hydraulically or electrically actuated brakes must first meet for approval and identification with the applicable TSO marking.

2. **APPLICABILITY.** This TSO affects new applications submitted after its effective date.

a. Generally we will not accept applications after the effective date of this TSO. However, we may do so up to six months after it, if we know that you were working against the earlier MPS before the new change became effective.

b. Wheels and wheel and brake assemblies approved under a previous TSOA may still be manufactured under the provisions of their original approval.

c. Major design changes to wheels and wheel and brake assemblies approved under this TSO will require a new authorization. See Title 14 of the Code of Federal Regulations (14 CFR) 21.611(b).

3. **REQUIREMENTS.**

a. New models of wheels (without brakes) and wheel and brake assemblies identified and manufactured on or after the effective date of this TSO must meet the MPS qualification and documentation requirements in appendixes 1 and/or 2 of this TSO. For hydraulically actuated brakes and wheels, only appendix 1 requirements must be met. For electrically actuated brakes, you must meet appendix 2 requirements for the brakes plus applicable requirements of appendix 1 for the wheels. Brakes and associated wheels are to be considered as an assembly for TSO authorization purposes.

b. Deviations. We have provisions for using alternate or equivalent means of compliance to the criteria in the MPS of this TSO. If you invoke these provisions, you must show that your equipment maintains an equivalent level of safety. Apply for a deviation under 14 CFR 21.609 before submitting your data package.

4. MARKING.

a. Permanently and legibly mark each wheel and brake, as applicable, per 14 CFR § 21.607(d), as follows:

- (1) Name and address of the TSO applicant. (For address use the design approval holder's city and state),
- (2) Use part number. The name, type or model designation may be deleted,
- (3) Use serial number or the date of manufacture or both,
- (4) The applicable TSO number.

b. Also, mark the following permanently and legibly:

- (1) Rim size (applies to wheels only),
- (2) Hydraulic fluid type (applies to appendix 1 brakes only), and
- (3) Electrical power rating (applies to appendix 2 brakes only-use P_{BMAX} per appendix 2, paragraph 4.1.1b).

5. APPLICATION DATA REQUIREMENTS. As a TSO applicant, you must give the FAA aircraft certification office (ACO) manager responsible for your facilities a statement of conformance, as specified in 14 CFR 21.605(a)(1) and one copy each of the following technical data to support our design and production approval. (Under 14 CFR 21.617(a)(2), LODA applicants submit the same data through their civil aviation authority)

- a.** The quality control system (QCS) description required by 14 CFR 21.143 and 21.605(a)(3), (This is not required for LODA applicants).
- b.** Applicant's TSO qualification test report.
- c.** The data requirements of paragraph 4.1 in appendixes 1 or 2, as applicable.

6. APPLICANT'S DATA REQUIREMENTS. Besides the data given directly to us, have the following technical data available for review by the responsible ACO or civil aviation authority:

- a. Functional qualification specifications for qualifying each article to ensure compliance with this TSO.
- b. Equipment calibration procedures.
- c. Prior to entry into service, a component maintenance manual (CMM), covering periodic maintenance, calibration, and repair, for the continued airworthiness of installed wheels and wheel and brake assemblies. Include recommended inspection intervals and service life.
- d. Schematic drawings, as applicable.
- e. Wiring diagrams, as applicable.
- f. Material and process specifications.
- g. List of components, by part number, that make up the wheels and wheel and brake assemblies complying with the standards prescribed under this TSO. Include vendor part number cross-references, when applicable.

7. FURNISHED DATA REQUIREMENTS. If furnishing one or more articles manufactured under this TSO to one entity (such as an operator or repair station), provide one copy of the CMM data in paragraph 6.c. of this TSO, and the following note:

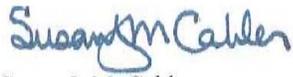
The conditions and tests for TSO approval of this article are minimum performance standards. Those installing this article, on or in a specific type or class of aircraft, must determine that the aircraft installation conditions are within the TSO standards. TSO articles must have separate approval for installation in an aircraft. The article may be installed only according to 14 CFR Part 43 or the applicable airworthiness requirements.

8. HOW TO GET REFERENCED DOCUMENTS.

a. Order SAE documents from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001. Telephone (724) 776-4970, fax (724) 776-0790. You can also order copies online at www.sae.org.

b. Order copies of 14 CFR parts from the Superintendent of Documents, Government Printing Office, P.O. Box 37154, Pittsburgh PA 15250-7954. Telephone (202) 512-1800, fax (202) 512-2250. You can also order copies online at www.access.gpo.gov. Select "Access," then "Online Bookstore." Select "Aviation," then "Code of Federal Regulations."

c. You can find a current list of technical standard orders and advisory circulars on the FAA Internet website Regulatory and Guidance Library at www.rgl.faa.gov. You will also find the TSO Index of Articles at the same site.

A handwritten signature in blue ink that reads "Susan J. M. Cabler". The signature is written in a cursive style with a large initial 'S'.

Susan J. M. Cabler
Assistant Manager, Aircraft Engineering
Division

APPENDIX 1. MPS FOR TRANSPORT AIRPLANE WHEELS AND WHEEL AND BRAKE ASSEMBLIES FOR HYDRAULICALLY ACTUATED BRAKES.

1. INTRODUCTION. This MPS was developed originally by the ARAC Braking Systems Harmonization Working Group for TSO-C135, and has been updated in this revision by the FAA and SAE A-5A Committee. It uses non U.S. governmental standard paragraph numbering, text formatting, and language from SAE publications.

1.1 PURPOSE AND SCOPE.

This MPS defines standards for wheels and wheel and brake assemblies to be used on airplanes certificated under 14 CFR part 25. Compliance with this specification is not considered approval for installation on any transport airplane.

1.2 APPLICATION.

Compliance with this minimum specification by the TSO applicant is required as a means of assuring that the equipment will have the capability to satisfactorily perform its intended function(s).

NOTE: Certain performance capabilities may be affected by airplane operational characteristics and other external influences. Consequently, anticipated airplane braking performance should be verified by airplane testing.

1.3 COMPOSITION OF EQUIPMENT.

The words “equipment” or “brake assembly” or “wheel assembly,” as used in this document, include all components that form part of the particular unit.

For example, a wheel assembly typically includes a hub or hubs, bearings, flanges, drive bars, heat shields, and fuse plugs. A brake assembly typically includes a backing plate, torque tube, cylinder assemblies, pressure plate, heat sink, and temperature sensor.

It should not be inferred from these examples that each wheel assembly and brake assembly will necessarily include either all or any of the above example components; the actual assembly will depend on the specific design chosen by the TSO applicant.

1.4 DEFINITIONS AND ABBREVIATIONS.

1.4.1 Brake Lining.

Brake lining is individual blocks of wearable material, discs that have wearable material integrally bonded to them, or discs in which the wearable material is an integral part of the disc structure.

1.4.2 $BROP_{MAX}$ - Brake Rated Maximum Operating Pressure.

$BROP_{MAX}$ is the maximum design metered pressure that is available to the brake to meet airplane stopping performance requirements.

1.4.3 BRP_{MAX} - Brake Rated Maximum Pressure.

BRP_{MAX} is the maximum pressure to which the brake is designed to be subjected (typically airplane nominal maximum system pressure).

1.4.4 BRP_{RET} - Brake Rated Retraction Pressure.

BRP_{RET} is the pressure to which the brake inlet pressure must be reduced to cause full piston retraction after a brake is sufficiently pressurized to extend all pistons.

1.4.5 $BRPP_{MAX}$ - Brake Rated Maximum Parking Pressure.

$BRPP_{MAX}$ is the maximum parking pressure available to the brake.

1.4.6 BRWL - Brake Rated Wear Limit.

BRWL is the brake maximum wear limit to ensure compliance with paragraph 3.3.3, and, if applicable, paragraph 3.3.4.

1.4.7 D - Distance Averaged Deceleration.

$D = ((\text{Initial brakes-on speed})^2 - (\text{Final brakes-on speed})^2) / (2 (\text{braked flywheel distance}))$.

D is the distance averaged deceleration to be used in all deceleration calculations.

1.4.8 D_{DL} - Rated Design Landing Deceleration.

D_{DL} is the minimum of the distance averaged decelerations demonstrated by the wheel, brake and tire assembly during the 100 KE_{DL} stops in paragraph 3.3.2.

1.4.9 D_{RT} - Rated Accelerate-Stop Deceleration.

D_{RT} is the minimum of the distance averaged decelerations demonstrated by the wheel, brake, and tire assembly during the KE_{RT} stops in paragraph 3.3.3.

1.4.10 D_{SS} - Rated Most Severe Landing Stop Deceleration.

D_{SS} is the distance averaged deceleration demonstrated by the wheel, brake and tire assembly during the KE_{SS} Stop in paragraph 3.3.4.

1.4.11 Heat Sink.

The heat sink is the mass of the brake that is primarily responsible for absorbing energy during a stop. For a typical brake, this would consist of the stationary and rotating disc assemblies.

1.4.12 KE_{DL} - Wheel/Brake Rated Design Landing Stop Energy.

KE_{DL} is the minimum energy absorbed by the wheel/brake/tire assembly during every stop of the 100 stop design landing stop test in paragraph 3.3.2.

1.4.13 KE_{RT} - Wheel/Brake Rated Accelerate-Stop Energy.

KE_{RT} is the energy absorbed by the wheel/brake/tire assembly demonstrated in accordance with the accelerate-stop test in paragraph 3.3.3.

1.4.14 KE_{SS} - Wheel/Brake Rated Most Severe Landing Stop Energy.

KE_{SS} is the energy absorbed by the wheel/brake/tire assembly demonstrated in accordance with paragraph 3.3.4.

1.4.15 L - Wheel Rated Radial Limit Load.

L is the wheel rated maximum radial limit load in paragraph 3.2.1.

1.4.16 R - Wheel Rated Tire Loaded Radius.

R is the static radius at load “S” for the wheel rated tire size at WRP. The static radius is defined as the minimum distance from the axle centerline to the tire/ground contact interface.

1.4.17 S - Wheel Rated Static Load.

S is the maximum static load (Reference 14 CFR 25.731(b)).

1.4.18 ST_R - Wheel/Brake Rated Structural Torque.

ST_R is the maximum structural torque demonstrated in paragraph 3.3.5.

1.4.19 TS_{BR} - Brake Rated Tire Type(s) and Size(s).

TS_{BR} is the tire type(s) and size(s) used to achieve the KE_{DL}, KE_{RT}, and KE_{SS} brake ratings. TS_{BR} must be a tire type and size approved for installation on the wheel (TS_{WR}).

1.4.20 TS_{WR} - Wheel Rated Tire Type(s) and Size(s).

TS_{WR} is the wheel rated tire type(s) and size(s) defined for use and approved for installation on the wheel, normally by the airplane manufacturer.

1.4.21 TT_{BT} - Suitable Tire for Brake Tests.

TT_{BT} is the rated tire type and size.

TT_{BT} is the tire type and size that has been determined as being the most critical for brake performance and/or energy absorption tests. The TT_{BT} must be a tire type and size approved for installation on the wheel (TS_{WR}), normally by the airplane manufacturer. The suitable tire may be different for different tests.

1.4.22 TT_{WT} - Suitable Tire for Wheel Test.

TT_{WT} is the wheel rated tire type and size for wheel test.

TT_{WT} is the tire type and size determined as being the most appropriate to introduce loads and/or pressure that would induce the most severe stresses in the wheel.

TT_{WT} must be a tire type and size approved for installation on the wheel (TS_{WR}), normally by the airplane manufacturer. The suitable tire may be different for different tests.

1.4.23 V_{DL} - Wheel/Brake Design Landing Stop Speed.

V_{DL} is the initial brakes-on speed for a design landing stop in paragraph 3.3.2.

1.4.24 V_R - Airplane Maximum Rotation Speed.

1.4.25 V_{RT} - Wheel/Brake Accelerate-Stop Speed.

V_{RT} is the initial brakes-on speed used to demonstrate KE_{RT} in paragraph 3.3.3.

1.4.26 V_{SS} - Wheel/Brake Most Severe Landing Stop Speed.

V_{SS} is the initial brakes-on speed used to demonstrate KE_{SS} in paragraph 3.3.4.

1.4.27 WRP - Wheel Rated Inflation Pressure.

WRP is the wheel rated inflation pressure (wheel unloaded).

2. GENERAL DESIGN SPECIFICATIONS.

2.1 AIRWORTHINESS.

The continued airworthiness of the wheels (without brakes) and wheel and brake assemblies must be considered. See paragraph 6.c on page 3 of this TSO.

2.2 FIRE PROTECTION.

Except for small parts (such as fasteners, seals, grommets, and small electrical parts) that would not contribute significantly to the propagation of a fire, all solid materials used must be self-extinguishing. See also paragraphs 2.4.5, 3.3.3.5 and 3.3.4.5.

2.3 DESIGN.

Unless shown to be unnecessary by test or analysis, the equipment must comply with the following:

2.3.1 Lubricant Retainers.

Lubricant retainers must retain the lubricant under all operating conditions, prevent the lubricant from reaching braking surfaces, and prevent foreign matter from entering the lubricated cavity.

2.3.2 Removable Flanges.

All removable flanges must be assembled onto the wheel in a manner that will prevent the removable flanges and retaining devices from leaving the wheel if a tire deflates while the wheel is rolling.

2.3.3 Adjustment.

The brake mechanism must be equipped with suitable adjustment means to maintain appropriate running clearance when subjected to BRP_{RET}.

2.3.4 Water Seal.

Wheels intended for use on amphibious aircraft must be sealed to prevent entrance of water into the wheel bearings or other portions of the wheel or brake, unless the design is such that brake action and service life will not be impaired by the presence of sea water or fresh water.

2.3.5 Burst Prevention.

Means must be provided to prevent wheel failure and tire burst that might result from overpressurization or from elevated brake temperatures. The means must take into account the pressure and the temperature gradients over the full operating range.

2.3.6 Wheel Rim and Inflation Valve.

Tire and Rim Association (see the *Aircraft Year Book*, by the Tire and Rim Association Inc.) or the European Tyre and Rim Technical Organization (reference: *Aircraft Tyre and Rim Data Book*) approval of the rim dimensions and inflation valve is encouraged.

2.3.7 Brake Piston Retention.

The brake must incorporate means to ensure that the actuation system does not allow hydraulic fluid to escape if the limits of piston travel are reached.

2.3.8 Wear Indicator.

A reliable method must be provided for determining when the heat sink is worn to its permissible limit.

2.3.9 Wheel Bearings.

Means should be incorporated to avoid mis-assembly of wheel bearings.

2.3.10 Fatigue.

The design of the wheel must incorporate techniques to improve fatigue resistance of critical areas of the wheel and minimize the effects of the expected corrosion and temperature environment. The wheel must include design provisions to minimize the probability of fatigue failures that could lead to flange separation or other wheel burst failures.

2.3.11 Dissimilar Materials.

When dissimilar materials are used in the construction and the galvanic potential between the materials indicate galvanic corrosion is likely, effective means to prevent the corrosion must be incorporated in the design. In addition, differential thermal expansion must not unduly affect the functioning, load capability, and the fatigue life of the components.

2.4 CONSTRUCTION.

The suitability and durability of the materials used for components must be established on the basis of experience or tests. In addition, the materials must conform to approved specifications that ensure the strength and other properties are those that were assumed in the design.

2.4.1 Castings.

Castings must be of high quality, clean, sound, and free from blowholes, porosity, or surface defects caused by inclusions, except that loose sand or entrapped gases may be allowed when serviceability is not impaired.

2.4.2 Forgings.

Forgings must be of uniform condition, free from blisters, fins, folds, seams, laps, cracks, segregation, and other defects. Imperfections may be removed if strength and serviceability would not be impaired as a result.

2.4.3 Bolts and Studs.

When bolts or studs are used for fastening together sections of a wheel or brake, the length of the threads must be sufficient to fully engage the nut, including its locking feature, and there must be sufficient unthreaded bearing area to carry the required load.

2.4.4 Environmental Protection.

All the components used must be suitably protected against deterioration or loss of strength in service due to any environmental cause, such as weathering, corrosion, and abrasion.

2.4.5 Magnesium Parts.

Magnesium and alloys having magnesium as a major constituent must not be used on brakes or braked wheels.

3. MINIMUM PERFORMANCE UNDER STANDARD TEST CONDITIONS.

3.1 INTRODUCTION.

The test conditions and performance criteria provide a laboratory means of demonstrating compliance with this TSO MPS. The airplane manufacturer normally defines the relevant test

parameter values, however these may also be derived from published aircraft data for applicants for supplemental type certificate (STC).

3.2 WHEEL TESTS.

To establish the ratings for a wheel, it must be substantiated that standard production wheel samples will meet the following radial load, combined load, roll load, roll-on-rim (if applicable) and overpressure test requirements.

For all tests, except the roll-on-rim test in paragraph 3.2.4, the wheel must be fitted with a suitable tire, TT_{WT} , and wheel loads must be applied through the tire. The ultimate load tests in paragraphs 3.2.1.3 and 3.2.2.3 provide for an alternative method of loading if it is not possible to conduct these tests with the tire mounted.

3.2.1 Radial Load Test.

If the radial limit load of paragraph 3.2.2 is equal to or greater than the radial limit load in this paragraph, the test specified in this paragraph may be omitted.

Test the wheel for yield and ultimate loads as follows:

3.2.1.1 Test method.

With a suitable tire, TT_{WT} , installed, mount the wheel on its axle, and position it against a flat, non-deflecting surface. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an airplane and is under the maximum radial limit load, L . Inflate the tire to the pressure recommended for the Wheel Rated Static Load, S , with gas and/or liquid.

If liquid inflation is used, liquid must be bled off to obtain the same tire deflection that would result if gas inflation were used.

Load the wheel through its axle with the load applied perpendicular to the flat, non-deflecting surface. Deflection readings must be taken at suitable points to indicate deflection and permanent set of the wheel rim at the bead seat.

3.2.1.2 Yield Load.

Apply to the wheel and tire assembly a load not less than 1.15 times the maximum radial limit load, L . Reference 14 CFR 25.471 through 25.511, as appropriate.

Determine the most critical wheel orientation with respect to the non-deflecting surface. Apply the load with the tire loaded against the non-deflecting surface, and with the wheel rotated 90 degrees with respect to the most critical orientation. Repeat the loading with the wheel 180, 270, and 0 degrees from the most critical orientation. The bearing cups, cones, and rollers used in

operation must be used for these loadings. If at a point of loading during the test bottoming of the tire occurs, then the tire pressure may be increased an amount sufficient only to prevent bottoming.

Three successive loadings at the 0 degree position must not cause permanent set increments of increasing magnitude. The permanent set increment caused by the last loading at the 0 degree position may not exceed 5 percent of the deflection caused by that loading or .005 inches (.125mm), whichever is greater. There must be no yielding of the wheel such as would result in loose bearing cups, liquid or gas leakage through the wheel or past the wheel seal.

3.2.1.3 Ultimate Load.

Apply to the wheel used in the yield test in paragraph 3.2.1.2, and the tire assembly, a load not less than 2 times the maximum radial limit load, L, for castings, and 1.5 times the maximum radial limit load, L, for forgings. Reference 14 CFR 25.471 through 25.511, as appropriate.

Apply the load with the tire and wheel against the non-deflecting surface and the wheel positioned at 0 degree orientation (paragraph 3.2.1.2). The bearing cones may be replaced with conical bushings, but the cups used in operation must be used for this loading. If, at a point of loading during the test, it is shown that the tire will not successfully maintain pressure or if bottoming of the tire occurs, the tire pressure may be increased. If bottoming of the tire continues to occur with increased pressure, then a loading block that fits between the rim flanges and simulates the load transfer of the inflated tire may be used. The arc of the wheel supported by the loading block must be no greater than 60 degrees.

The wheel must support the load without failure for at least 3 seconds. Abrupt loss of load-carrying capability or fragmentation during the test constitutes failure.

3.2.2 Combined Radial and Side Load Test.

Test the wheel for the yield and ultimate loads as follows:

3.2.2.1 Test Method.

With a suitable tire, TT_{WT} , installed, mount the wheel on its axle and position it against a flat, non-deflecting surface. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an airplane and is under the combined radial and side limit loads. Inflate the tire to the pressure recommended for the maximum static load with gas and/or liquid.

If liquid inflation is used, liquid must be bled off to obtain the same tire deflection that would result if gas inflation were used.

For the radial load component, load the wheel through its axle with load applied perpendicular to the flat non-deflecting surface. Apply the two loads simultaneously, increasing them either continuously or in increments no greater than 10 percent of the total loads to be applied.

If it is impossible to generate the side load because of friction limitations, the radial load may be increased, or a portion of the side load may be applied directly to the tire/wheel. In such circumstances it must be demonstrated that the moment resulting from the side load is no less severe than would otherwise have occurred.

Alternatively, the vector resultant of the radial and side loads may be applied to the axle.

Deflection readings must be taken at suitable points to indicate deflection and permanent set of the wheel rim at the bead seat.

3.2.2.2 Combined Yield Load.

Apply to the wheel and tire assembly radial and side loads not less than 1.15 times the respective ground limit loads. Reference 14 CFR 25.485, 25.495, 25.497, and 25.499, as appropriate. If at a point of loading during the test bottoming of the tire occurs, then the tire pressure may be increased an amount sufficient only to prevent bottoming.

Determine the most critical wheel orientation with respect to the non-deflected surface.

Apply the load with the tire loaded against the non-deflecting surface, and with the wheel rotated 90 degrees with respect to the most critical orientation. Repeat the loading with the wheel 180, 270, and 0 degrees from the most critical orientation.

The bearing cups, cones, and rollers used in operation must be used in this test.

A tube may be used in a tubeless tire only when it has been demonstrated that pressure will be lost due to the inability of a tire bead to remain properly positioned under the load. The wheel must be tested for the most critical inboard and outboard side loads.

Three successive loadings at the 0 degree position must not cause permanent set increments of increasing magnitude. The permanent set increment caused by the last loadings at the 0 degree position must not exceed 5 percent of the deflection caused by the loading, or .005 inches (.125mm), whichever is greater. There must be no yielding of the wheel such as would result in loose bearing cups, gas or liquid leakage through the wheel or past the wheel seal.

3.2.2.3 Combined Ultimate Load.

Apply to the wheel, used in the yield test of paragraph 3.2.2.2, radial and side loads not less than 2 times for castings and 1.5 times for forgings, the respective ground limit loads. Reference 14 CFR 25.485, 25.495, 25.497, and 25.499, as appropriate.

Apply these loads with a tire and wheel against the non-deflecting surface and the wheel oriented at the 0 degree position (paragraph 3.2.2.2). The bearing cones may be replaced with conical bushings, but the cups used in operation must be used for this loading.

If at any point of loading during the test it is shown that the tire will not successfully maintain pressure, or if bottoming of the tire on the non-deflecting surface occurs, the tire pressure may be increased. If bottoming of the tire continues to occur with this increased pressure, then a loading block that fits between the rim flanges and simulates the load transfer of the inflated tire may be used. The arc of wheel supported by the loading block must be no greater than 60 degrees.

The wheel must support the loads without failure for at least 3 seconds. Abrupt loss of load-carrying capability or fragmentation during the test constitutes failure.

3.2.3 Wheel Roll Test.

3.2.3.1 Test Method.

With a suitable tire, TT_{WT} , installed, mount the wheel on its axle and position it against a flat non-deflecting surface or a flywheel. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an airplane and is under the Wheel Rated Static Load, S . During the roll test, the tire pressure must not be less than 1.14 times the Wheel Rated Inflation Pressure, WRP , (0.10 to account for temperature rise and 0.04 to account for loaded tire pressure). For side load conditions, the wheel axle must be yawed to the angle that will produce a wheel side load component equal to 0.15 S while the wheel is being roll tested.

3.2.3.2 Roll Test.

The wheel must be tested under the loads and for the distances shown in Table 3-1.

Table 3-1. Load Conditions and Roll Distances for Roll Test

Load Conditions	Roll Distance Miles (km)
Wheel Rated Static Load, S	2000 (3220)
Wheel Rated Static Load, S, plus a 0.15xS side load applied in the outboard direction	100 (161)
Wheel Rated Static Load, S, plus a 0.15xS side load applied in the inboard direction	100 (161)

At the end of the test, the wheel must not be cracked, there must be no leakage through the wheel or past the wheel seal(s), and the bearing cups must not be loose.

3.2.4 Roll-on-Rim Test (not applicable to nose wheels).

The wheel assembly without a tire must be tested at a speed of no less than 10 mph (4.6 m/s) under a load equal to the Wheel Rated Static Load, S. The test roll distance (in feet) must be determined as $0.5V_R^2$ but need not exceed 15,000 feet (4572 meters). The test axle angular orientation with the load surface must represent that of the airplane axle to the runway under the static load S.

The wheel assembly must support the load for the distance defined above. During the test, no fragmentation of the wheel is permitted; cracks are allowed.

3.2.5 Overpressure Test.

The wheel assembly, with a suitable tire, TT_{WT}, installed, must be tested to demonstrate that it can withstand the application of 4.0 times the wheel rated inflation pressure, WRP. The wheel must retain the pressure for at least 3 seconds. Abrupt loss of pressure containment capability or fragmentation during the test constitutes failure. Plugs may be used in place of overpressurization protection device(s) to conduct this test. Reference 14 CFR 25.731(d).

3.2.6 Diffusion Test.

A tubeless tire and wheel assembly must hold its rated inflation pressure, WRP, for 24 hours with a pressure drop no greater than 5 percent. This test must be performed after the tire growth has stabilized.

3.3 WHEEL AND BRAKE ASSEMBLY TESTS.

3.3.1 General.

3.3.1.1 The wheel and brake assembly, with a suitable tire, TT_{BT} , installed, must be tested on a testing machine in accordance with the following, as well as paragraphs 3.3.2, 3.3.3, 3.3.5 and, if applicable, 3.3.4.

3.3.1.2 For tests detailed in paragraphs 3.3.2, 3.3.3, and 3.3.4, the test energies KE_{DL} , KE_{RT} , and KE_{SS} and brake application speeds V_{DL} , V_{RT} , and V_{SS} are as normally defined by the airplane manufacturer.

3.3.1.3 For tests detailed in paragraphs 3.3.2, 3.3.3, and 3.3.4, the initial brake application speed must be as close as practicable to, but not greater than, the speed established in accordance with paragraph 3.3.1.2, with the exception that marginal speed increases are allowed to compensate for brake pressure release permitted in paragraphs 3.3.3.4 and 3.3.4.4. An increase in the initial brake application speed is not a permissible method of accounting for a reduced (i.e., lower than ideal) dynamometer mass. This method is not permissible because, for a target test deceleration, a reduction in the energy absorption rate would result, and could produce performance different from that which would be achieved with the correct brake application speed. The energy to be absorbed during any stop must not be less than that established in accordance with paragraph 3.3.1.2. Additionally, forced air or other artificial cooling means are not permitted during these stops.

3.3.1.4 The brake assembly must be tested using the fluid (or other actuating means) specified for use with the brake on the airplane.

3.3.2 Design Landing Stop Test.

3.3.2.1 The wheel and brake assembly under test must complete 100 stops at the KE_{DL} energy, each at the mean distance averaged deceleration, D , normally defined by the airplane manufacturer, but not less than 10 ft/s^2 (3.05 m/s^2). (Reference 14 CFR 25.735(f)(1)).

3.3.2.2 During the design landing stop test, the disc support structure must not be changed if it is intended for reuse, or if the wearable material is integral to the structure of the disc. One change of individual blocks or integrally bonded wearable material is permitted. For discs using integrally bonded wearable material, one change is permitted, provided that the disc support structure is not intended for reuse. The remainder of the wheel/brake assembly parts must withstand the 100 KE_{DL} stops without failure or impairment of operation.

3.3.3 Accelerate-Stop Test.

3.3.3.1 The wheel and brake assembly under test must complete the accelerate-stop test at the mean distance averaged deceleration, D , normally defined by the airplane manufacturer, but not less than 6 ft/s^2 (1.83 m/s^2). (Reference 14 CFR 25.735(f)(2)).

This test establishes the maximum accelerate-stop energy rating, KE_{RT} , of the wheel and brake assembly using:

- a. The Brake Rated Maximum Operating Pressure, $BROP_{MAX}$; or
- b. The maximum brake pressure consistent with the airplane's braking pressure limitations (for example, tire/runway drag capability based on substantiated data).

3.3.3.2 For the accelerate-stop test, the tire, wheel, and brake assembly must be tested at KE_{RT} for both a new brake and a fully worn brake.

- a. A new brake is defined as a brake on which less than 5 percent of the usable wear range of the heat sink has been consumed.
- b. A worn brake is defined as a brake on which the usable wear range of the heat sink has already been fully consumed to BRWL.

The proportioning of wear through the brake for the various friction pairs for this test must be based on service wear experience or wear test data of an equivalent or similar brake. Either operationally worn or mechanically worn brake components may be used. If mechanically worn components are used, it must be shown that they can be expected to provide similar results to operationally worn components. The test brake must be subjected to a sufficient number and type of stops to ensure that the brake's performance is representative of in-service use; at least one of these stops, with the brake near the fully worn condition, must be a design landing stop.

3.3.3.3 At the time of brake application, the temperatures of the tire, wheel, and brake, particularly the heat sink, must, as closely as practicable, be representative of a typical in-service condition. Preheating by taxi stops is an acceptable means.

These temperatures must be based on a rational analysis of a braking cycle, taking into account a typical brake temperature at which an airplane may be dispatched from the ramp, plus a conservative estimate of heat sink temperature change during subsequent taxiing and takeoff acceleration, as appropriate.

Alternatively, in the absence of a rational analysis, the starting heat sink temperature must be that resulting from the application of 10 percent KE_{RT} to the tire, wheel and brake assembly, initially at not less than normal ambient temperature (59°F/15°C).

3.3.3.4 A full stop demonstration is not required for the accelerate-stop test. The test brake pressure may be released at a test speed of up to 23 mph (10 m/s). In this case, the initial brakes-on speed must be adjusted such that the energy absorbed by the tire, wheel and brake assembly during the test is not less than the energy absorbed if the test had commenced at the specified speed and continued to zero ground speed.

3.3.3.5 Within 20 seconds of completion of the stop, or of the brake pressure release in accordance with paragraph 3.3.3.4, the brake pressure must be adjusted to the Brake Rated

Maximum Parking Pressure, $BRPP_{MAX}$, and maintained for at least 3 minutes (reference 14 CFR 25.735(g)).

No sustained fire that extends above the level of the highest point of the tire is allowed before 5 minutes have elapsed after application of parking brake pressure; until this time has elapsed, neither fire fighting means nor coolants may be applied.

The time of initiation of tire pressure release (for example, by wheel fuse plug), if applicable, is to be recorded. The sequence of events described in paragraphs 3.3.3.4 and 3.3.3.5 is illustrated in Figure 3-1.

3.3.4 Most Severe Landing Stop Test.

3.3.4.1 The wheel and brake assembly under test must complete the most severe landing braking condition expected on the airplane as normally defined by the airplane manufacturer. This test is not required if the testing required in paragraph 3.3.3 is more severe or the condition is shown to be extremely improbable, normally by the airplane manufacturer.

This test establishes, if required, the maximum energy rating, KE_{SS} , of the wheel/brake assembly for landings under abnormal conditions using:

- a. The Brake Rated Maximum Operating Pressure, $BROP_{MAX}$; or
- b. The maximum brake pressure consistent with an airplane's braking pressure limitations (for example, tire/runway drag capability based on substantiated data).

3.3.4.2 For the most severe landing stop test, the tire, wheel and brake assembly must be capable of absorbing the test energy, KE_{SS} , with a brake on which the usable wear range of the heat sink has already been fully consumed to BRWL (reference 14 CFR 25.735(f)(3)).

The proportioning of wear through the brake for the various friction pairs for this test must be based on service wear experience or wear test data of an equivalent or similar brake. Either operationally worn or mechanically worn brake components may be used. If mechanically worn components are used, it must be shown that they can be expected to provide similar results to operationally worn components. The test brake must be subjected to a sufficient number and type of stops to ensure that the brake's performance is representative of in-service use; at least one of these stops, with the brake near the fully worn condition, must be a design landing stop.

3.3.4.3 At the time of brake application, the temperatures of the tire, wheel, and brake, particularly the heat sink, must, as closely as practicable, be representative of a typical in-service condition. Preheating by taxi stops is an acceptable means.

These temperatures must be based on a rational analysis of a braking cycle, taking into account a typical brake temperature at which the airplane may be dispatched from the ramp, plus a conservative estimate of heat sink temperature change during taxi, takeoff, and flight, as appropriate.

Alternatively, in the absence of a rational analysis, the starting heat sink temperature must be that resulting from the application of 5 percent KE_{RT} to the tire, wheel and brake assembly initially at not less than normal ambient temperature (59°F/15°C).

3.3.4.4 A full stop demonstration is not required for the most severe landing-stop test. The test brake pressure may be released at a test speed of up to 20 knots. In this case, the initial brakes-on speed must be adjusted such that the energy absorbed by the tire, wheel, and brake assembly during the test is not less than the energy absorbed if the test had commenced at the specified speed and continued to zero ground speed.

3.3.4.5 Within 20 seconds of completion of the stop, or of the brake pressure release in accordance with paragraph 3.3.4.4, the brake pressure must be adjusted to the Brake Rated Maximum Parking Pressure, $BRPP_{MAX}$, and maintained for at least 3 minutes.

No sustained fire that extends above the level of the highest point of the tire is allowed before 5 minutes have elapsed after application of parking brake pressure; until this time has elapsed, neither fire fighting means nor coolants may be applied.

The time of initiation of tire pressure release (such as by wheel fuse plug), if applicable, is to be recorded. The sequence of events described in paragraphs 3.3.4.4 and 3.3.4.5 is illustrated in Figure 3-2.

3.3.5 Structural Torque Test.

The Wheel/Brake Rated Structural Torque, ST_R , is equal to the torque demonstrated in the test defined in 3.3.5.1.

3.3.5.1 Apply to the wheel, brake and tire assembly, the radial load S and the drag load corresponding to the torque specified in paragraph 3.3.5.2 or 3.3.5.3, as applicable, for at least 3 seconds. Rotation of the wheel must be resisted by a reaction force transmitted through the brake, or brakes, by the application of at least Brake Rated Maximum Operating Pressure, $BROP_{MAX}$, or equivalent. If such pressure or its equivalent is insufficient to prevent rotation, the friction surface may be clamped, bolted, or otherwise restrained while applying the pressure. A fully worn brake configuration, $BRWL$, must be used for this test. The proportioning of wear through the brake for the various friction pairs for this test must be based on service wear experience of an equivalent or similar brake or test machine wear test data. Either operationally worn or mechanically worn brake components may be used. An actuating fluid other than that specified for use on the airplane may be used for the structural torque test.

3.3.5.2 For landing gear with one wheel per landing gear strut, the torque is 1.2 (SxR).

3.3.5.3 For landing gear with more than one wheel per landing gear strut, the torque is 1.44 (SxR).

3.3.5.4 The wheel and brake assembly must support the loads without failure for at least 3

seconds. Abrupt loss of load-carrying capability or fragmentation during the test constitutes failure.

3.3.6 Wheel to Brake Clearance

There must be no interference in any critical areas between the wheel and brake assembly (with fittings) up to limit load conditions, taking into account the axle angular orientation. Lack of interference can be established by analyses and/or tests. If chosen, testing shall be conducted per the following methods:

3.3.6.1 Radial Limit Load Wheel and Brake Clearance Test

With a suitable tire, TT_{WT} , installed, mount the wheel and brake on a suitable axle, and position it against a flat, non-deflecting surface. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an airplane and is under the maximum radial limit load, L .

Inflate the tire to the pressure recommended for the Wheel Rated Static Load, S , with gas and/or liquid. If liquid inflation is used, liquid must be bled off to obtain the same tire deflection that would result if gas inflation were used. Liquid pressure must not exceed the pressure that would develop if gas inflation were used and the tire were deflected to its maximum extent. Load the wheel through its axle with the load applied perpendicular to the flat, non-deflecting surface. Reference 14 CFR 25.471 through 25.511, as appropriate. If the radial limit load of paragraph 3.3.6.2 is equal or greater than the radial limit load specified in this paragraph, the test specified in this paragraph may be omitted.

Determine the most critical wheel orientation with respect to the non-deflecting surface. Apply the load with the tire loaded against the non-deflecting surface. If multiple critical orientations are determined, repeat the testing for each critical orientation. The bearing cups, cones, and rollers used in operation must be used for this loading. If at a point of loading during the test bottoming of the tire occurs, then the tire pressure may be increased an amount sufficient only to prevent bottoming.

3.3.6.2 Combined Limit Load Wheel and Brake Clearance Test

With a suitable tire, TT_{WT} , installed, mount the wheel and brake on a suitable axle, and position it against a flat, non-deflecting surface. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an airplane and is under the maximum radial limit load, L . Apply to the wheel and tire assembly radial and side loads not less than the respective ground limit loads. Reference 14 CFR 25.485, 25.495, 25.497, and 25.499, as appropriate. If at a point of loading during the test bottoming of the tire occurs, then the tire pressure may be increased an amount sufficient only to prevent bottoming.

Determine the most critical wheel orientation with respect to the non-deflected surface.

Apply the load with the tire loaded against the non-deflecting surface with the wheel in the most critical orientation.

The bearing cups, cones, and rollers used in operation must be used in this test.

A tube may be used in a tubeless tire only when it has been demonstrated that pressure will be lost due to the inability of a tire bead to remain properly positioned under the load. The wheel must be tested for the most critical inboard and outboard side loads. If multiple critical orientations are determined to apply, repeat the testing for each critical orientation.

3.4 BRAKE TESTS.

The brake assembly must be tested using the fluid (or other actuating means) specified for use with the brake on the airplane. It must be substantiated that standard production samples of the brake will pass the following tests:

3.4.1 Yield & Overpressure Test.

The brake must withstand a pressure equal to 1.5 times BRP_{MAX} for at least 5 minutes without permanent deformation of the structural components under test.

The brake, with actuator piston(s) extended to simulate a maximum worn condition, must, for at least 3 seconds, withstand hydraulic pressure equal to 2.0 times the Brake Rated Maximum Pressure, BRP_{MAX} , available to the brakes. If necessary, piston extension must be adjusted to prevent contact with retention devices during this test.

3.4.2 Endurance Test.

A brake assembly must be subjected to an endurance test during which structural failure or malfunction must not occur. If desired, the heat sink components may be replaced by a reasonably representative dummy mass for this test.

The test must be conducted by subjecting the brake assembly to 100,000 cycles of an application of the average of the peak brake pressures needed in the design landing stop test (paragraph 3.3.2) and release to a pressure not exceeding the Brake Rated Retraction Pressure, BRP_{RET} . The pistons must be adjusted so that 25,000 cycles are performed at each of the four positions where the pistons would be at rest when adjusted to nominally 25, 50, 75, and 100 percent of the wear limit, BRWL. The brake must then be subjected to 5000 cycles of application of pressure to BRP_{MAX} and release to BRP_{RET} at the 100 percent wear limit.

Hydraulic brakes must not exceed a total leakage of 5 cc during the test.

3.4.3 Piston Retention.

The hydraulic pistons must be positively retained without leakage at 1.5 times BRP_{MAX} for at least 10 seconds with the heat sink removed.

3.4.4 Extreme Temperature Soak Test.

Hydraulic brakes must not exceed a total leakage of 5 cc during the following tests.

Subject the brake to at least a 24-hour hot soak at the maximum piston housing fluid temperature experienced during a design landing stop test (paragraph 3.3.2), conducted without forced air cooling. While at the hot soak temperature, the brake must be subjected to the application of the average of the peak brake pressures required during the 100 design landing stops and release to a pressure not exceeding BRP_{RET} for 1000 cycles, followed by 25 cycles of $BROP_{MAX}$ and release to a pressure not exceeding BRP_{RET} .

The brake must then be cooled from the hot soak temperature to a cold soak temperature of $-40^{\circ}F$ ($-40^{\circ}C$) and maintained at this temperature for at least 24 hours. While at the cold soak temperature, the brake must be subjected to the application of the average of the peak brake pressures required during the KE_{DL} stops and release to a pressure not exceeding BRP_{RET} , for 25 cycles, followed by 5 cycles of $BROP_{MAX}$ and release to a pressure not exceeding BRP_{RET} .

3.4.5 Leakage Tests (Hydraulic Brakes).

3.4.5.1 Static Leakage Test.

The brake must be subjected to a pressure equal to 1.5 times BRP_{MAX} for at least 5 minutes. The brake pressure must then be adjusted to an operating pressure of 5 psig (35 kPa) for at least 5 minutes. There must be no measurable leakage (less than one drop) during this test.

3.4.5.2 Dynamic Leakage Test.

The brake must be subjected to 25 applications of BRP_{MAX} , each followed by the release to a pressure not exceeding BRP_{RET} . Leakage at static seals must not exceed a trace. Leakage at moving seals must not exceed one drop of fluid per each 3 inches (76mm) of peripheral seal length.

4. DATA REQUIREMENTS.

4.1 The TSO applicant must provide the following data with any application for approval of equipment.

4.1.1 The following wheel and brake assembly ratings:

a. Wheel Ratings.

Wheel Rated Static Load, S,
Wheel Rated Inflation Pressure, WRP,
Wheel Rated Tire Loaded Radius, R.

Wheel Rated Maximum Limit Load, L as applicable,
Wheel Rated Tire Size, TS_{WR} .

b. Wheel/Brake and Brake Ratings.

Wheel/Brake Rated Design Landing Energy, KE_{DL} , and associated brakes-on-speed, V_{DL} ,
Wheel/Brake Rated Accelerate-Stop Energy, KE_{RT} , and associated brakes-on-speed, V_{RT} ,
Wheel/Brake Rated Most Severe Landing Stop Energy, KE_{SS} , and associated brakes-on-speed,
 V_{SS} (if applicable),
Brake Rated Maximum Operating Pressure, $BROP_{MAX}$,
Brake Rated Maximum Pressure, BRP_{MAX} ,
Brake Rated Retraction Pressure, BRP_{RET} ,
Wheel/Brake Rated Structural Torque, ST_R ,
Rated Design Landing Deceleration, D_{DL} ,
Rated Accelerate-Stop Deceleration, D_{RT} ,
Rated Most Severe Landing Stop Deceleration, D_{SS} (if applicable),
Brake Rated Tire Size, TS_{BR} ,
Brake Rated Wear Limit, $BRWL$.

4.1.2 The weight of the wheel or brake, as applicable.

4.1.3 Specification of hydraulic fluid used, as applicable.

4.1.4 One copy of the test report showing compliance with the test requirements.

NOTE: When test results are being recorded for incorporation in the compliance test report, it is not sufficient to note merely that the specified performance was achieved. The actual numerical values obtained for each of the parameters tested must be recorded, except where tests are pass/fail in character.

Figure 3-1. Taxi, Accelerate-Stop, Park Test Sequence

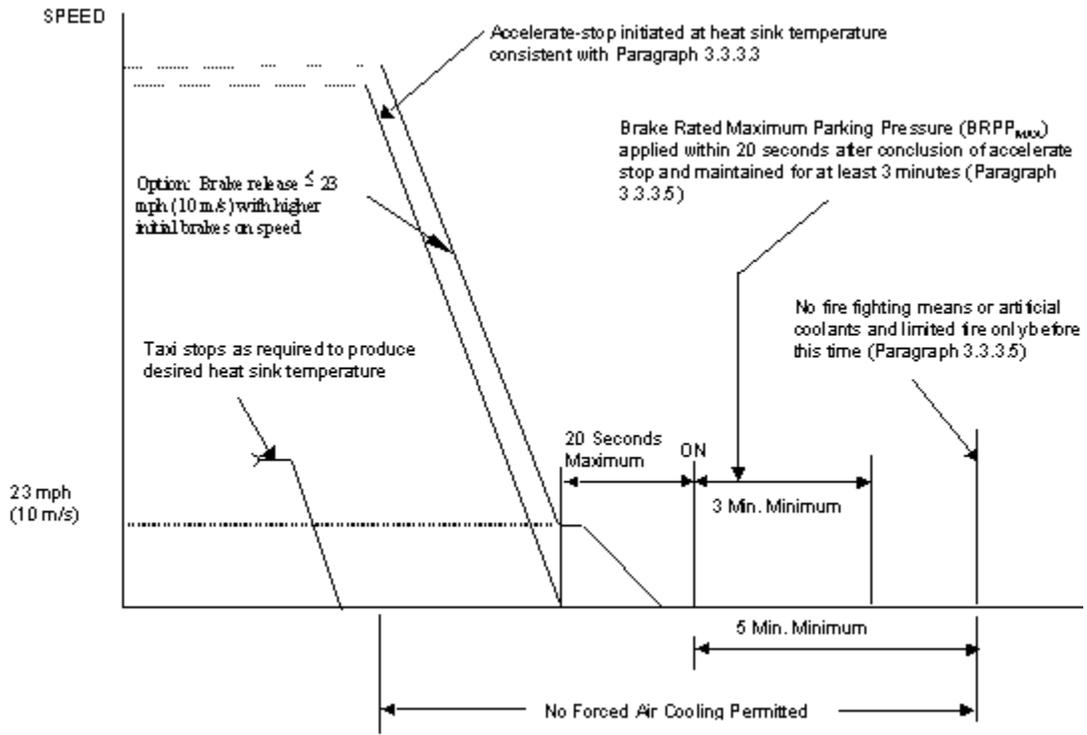
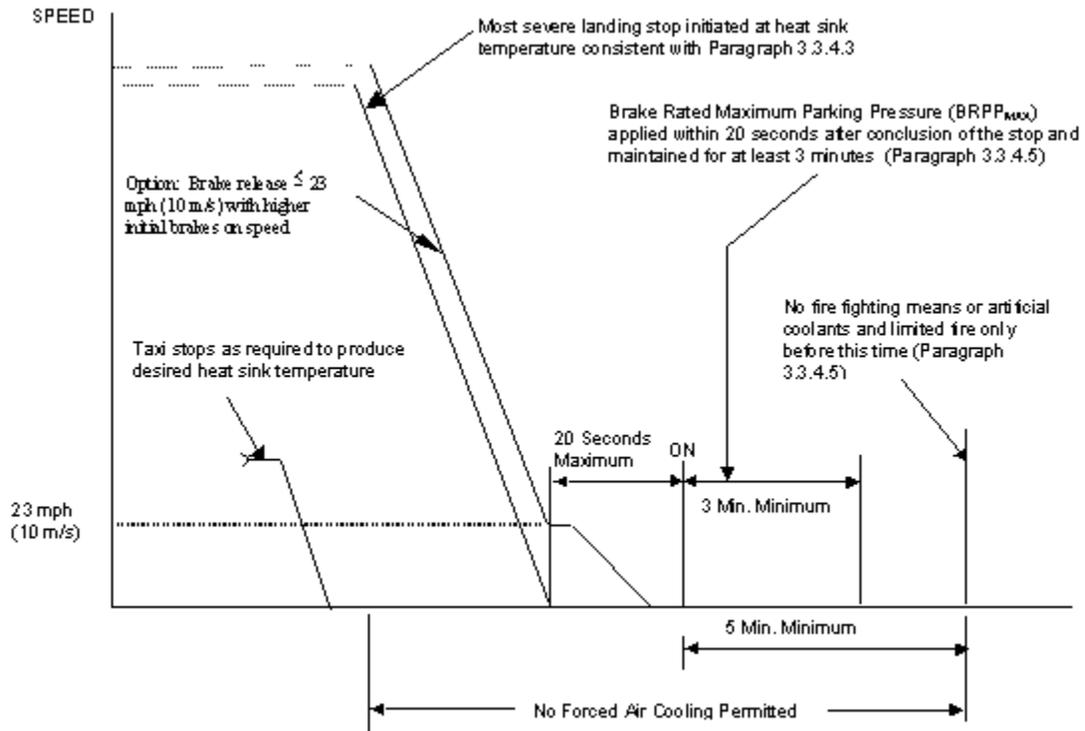


Figure 3-2. Most Severe Landing-Stop, Park Test Sequence



APPENDIX 2. MPS FOR TRANSPORT AIRPLANE WHEEL AND BRAKE ASSEMBLIES FOR ELECTRICALLY ACTUATED BRAKES

1. INTRODUCTION. This MPS was developed by the SAE A-5A Committee, as defined in SAE Aerospace Standard (AS) 5663, *Minimum Performance Requirements for Transport Airplane Wheel and Brake Assemblies Using Electric Power Actuation*, dated January 2007, modified by the SAE A-5A panel and recommended to FAA for this revision. It uses non-U.S. governmental standard paragraph numbering, text formatting, and language derived from SAE publications.

1.1 PURPOSE AND SCOPE.

This MPS defines the standards for wheel and brake assemblies to be used on airplanes certificated under 14 CFR part 25. Compliance with this specification is not considered approval for installation on any transport airplane.

1.2 APPLICATION.

Compliance with this minimum specification by the TSO applicant is required as a means of assuring that the equipment will have the capability to satisfactorily perform its intended function(s).

NOTE: Certain performance capabilities may be affected by airplane Operational characteristics and other external influences. Consequently, anticipated airplane braking performance should be verified by airplane testing.

1.3 COMPOSITION OF EQUIPMENT.

The words “equipment” or “brake assembly” or “wheel assembly,” as used in this document, include all components that form part of the particular unit.

For example, a wheel assembly typically includes a hub or hubs, bearings, flanges, drive bars, heat shields, and fuse plugs. A brake assembly typically includes a backing plate, torque tube, electro-mechanical actuators, pressure plate, heat sink, temperature sensor, and other axle mounted components integral to the braking activity.

For the purpose of this specification, the interface boundaries of the equipment are the wheel and brake attachments to the landing gear and the electrical connectors to the aircraft brake control system.

It should not be inferred from these examples that each wheel assembly and brake assembly will necessarily include either all or any of the above example components; the actual assembly will depend on the specific design chosen by the TSO applicant.

1.4 DEFINITIONS AND ABBREVIATIONS.

1.4.1 Brake Lining.

Brake lining is individual blocks of wearable material, discs that have wearable material integrally bonded to them, or discs in which the wearable material is an integral part of the disc structure.

1.4.2 BOP – Brake Off Position

BOP is a retracted EMA position that permits free rotation of the wheel and brake assembly after a brake application and release cycle.

1.4.3 BRWL - Brake Rated Wear Limit.

BRWL is the brake maximum wear limit to ensure compliance with paragraph 3.3.3, and, if applicable, paragraph 3.3.4.

1.4.4 D - Distance Averaged Deceleration.

$D = (\text{Initial brakes-on speed})^2 - (\text{Final brakes-on speed})^2 / (2 (\text{braked flywheel distance}))$.

D is the distance averaged deceleration to be used in all deceleration calculations.

1.4.5 D_{DL} - Rated Design Landing Deceleration.

D_{DL} is the minimum of the distance averaged decelerations demonstrated by the wheel, brake and tire assembly during the 100 KE_{DL} stops in paragraph 3.3.2.

1.4.6 D_{RT} - Rated Accelerate-Stop Deceleration.

D_{RT} is the minimum of the distance averaged decelerations demonstrated by the wheel, brake, and tire assembly during the KE_{RT} stops in paragraph 3.3.3.

1.4.7 D_{SS} - Rated Most Severe Landing Stop Deceleration.

D_{SS} is the distance averaged deceleration demonstrated by the wheel, brake and tire assembly during the KE_{SS} Stop in paragraph 3.3.4.

1.4.8 EMA – Electro-Mechanical Actuator

The EMA is the brake subassembly, typically comprised of but not limited to, the ball screw or roller screw, electric motor, and gear train that converts electrical power to brake clamping force.

1.4.9 Heat Sink.

The heat sink is the mass of the brake that is primarily responsible for absorbing energy during a stop. For a typical brake, this would consist of the stationary and rotating disc assemblies.

1.4.10 I_{BMAX} - Maximum Brake Current

I_{BMAX} is the maximum current drawn by the brake in the most critical of the dynamic tests of paragraph 3.3.3 or 3.3.4 as determined by test or analysis of test results.

1.4.11 I_{SMAX} - Maximum Brake System Current

I_{SMAX} is the maximum current the aircraft brake control system can deliver to the brake assembly in normal operation.

1.4.12 KE_{DL} - Wheel/Brake Rated Design Landing Stop Energy.

KE_{DL} is the minimum energy absorbed by the wheel/brake/tire assembly during every stop of the 100 stop design landing stop test in paragraph 3.3.2.

1.4.13 KE_{RT} - Wheel/Brake Rated Accelerate-Stop Energy.

KE_{RT} is the energy absorbed by the wheel/brake/tire assembly demonstrated in accordance with the accelerate-stop test in paragraph 3.3.3.

1.4.14 KE_{SS} - Wheel/Brake Rated Most Severe Landing Stop Energy.

KE_{SS} is the energy absorbed by the wheel/brake/tire assembly demonstrated in accordance with paragraph 3.3.4.

1.4.15 L_{BMAX} - Maximum Brake Load

L_{BMAX} is the nominal maximum clamping load the brake is designed to generate with maximum brake control system command under normal conditions established by analysis or test.

1.4.16 L_{DL} - Brake Design Landing Load

L_{DL} is the average of the 100 peak clamping loads generated in the brake assembly during the KE_{DL} stop test of paragraph 3.3.2 as determined by test or analysis of test results.

1.4.17 L_{LMT} - Brake Limit Load

L_{LMT} is the maximum clamping load the brake structure may be subjected to in its operation which would not result in permanent deformation that would prevent it from performing its intended function.

1.4.18 P_{BMAX} - Maximum EMA Brake Power

P_{BMAX} is the maximum power supplied to the brake during the most critical of the dynamic tests of Section 3 as determined by test or analysis of test results.

1.4.19 P_{SMAX} - Maximum Brake System Power

P_{SMAX} is the maximum power that is available to the brake assembly from the aircraft brake control system.

1.4.20 PBC – Parking Brake Command

PBC is the configuration to which the EMAs are commanded following a high energy stop as normally defined by the airplane manufacturer associated with the parking brake applications in paragraphs 3.3.3.5 and 3.3.4.5.

1.4.21 R - Wheel Rated Tire Loaded Radius.

R is the static radius at load “S” for the wheel rated tire size at WRP. The static radius is defined as the minimum distance from the axle centerline to the tire/ground contact interface.

1.4.22 S -Wheel Rated Static Load.

S is the maximum static load (Reference 25.731(b)).

1.4.23 ST_R - Wheel/Brake Rated Structural Torque.

ST_R is the maximum structural torque demonstrated in paragraph 3.3.5.

1.4.24 TS_{BR} - Brake Rated Tire Type(s) and Size(s).

TS_{BR} is the tire type(s) and size(s) used to achieve the KE_{DL} , KE_{RT} , and KE_{SS} brake ratings. TS_{BR} must be a tire type and size approved for installation on the wheel (TS_{WR}).

1.4.25 TS_{WR} - Wheel Rated Tire Type(s) and Size(s).

TS_{WR} is the wheel rated tire type(s) and Size(s) defined for use and approved for installation on the wheel (TS_{WR}), normally by the airplane manufacturer.

1.4.26 TT_{BT} - Suitable Tire for Brake Tests.

TT_{BT} is the rated tire type and size.

TT_{BT} is the tire type and size that has been determined as being the most critical for brake performance and/or energy absorption tests. The TT_{BT} must be a tire type and size approved for installation on the wheel (TS_{WR}), normally by the airplane manufacturer. The suitable tire may be different for different tests.

1.4.27 V_{BMAX} - Maximum EMA Brake Voltage

V_{BMAX} is the maximum voltage applied to the brake assembly during the most critical of the dynamic tests of Section 3 as determined by test or analysis of test results.

1.4.28 V_{SMAX} - Maximum Brake System Voltage

V_{SMAX} is the maximum voltage that is available to the brake assembly from the aircraft brake control system.

1.4.29 V_{DL} - Wheel/Brake Design Landing Stop Speed

V_{DL} is the initial brakes-on speed for a design-landing stop in paragraph 3.3.2.

1.4.30 V_{RT} - wheel/brake accelerate-stop speed

V_{RT} is the initial brakes-on speed used to demonstrate KE_{RT} in paragraph 3.3.3

1.4.31 V_{SS} - wheel/brake most severe landing stop speed

V_{SS} is the initial brakes-on speed used to demonstrate KE_{SS} in paragraph 3.3.4.

2. GENERAL DESIGN SPECIFICATIONS

2.1 AIRWORTHINESS

The continued airworthiness of the airplane on which the wheels (without brakes) and wheel and brake assemblies are installed must be considered. See paragraph 6.c on page 3 of this TSO.

2.2 FIRE PROTECTION

Except for small parts such as fasteners, seals, grommets, and small electrical parts that would not contribute significantly to the propagation of a fire, all solid materials used must be self-extinguishing. See also paragraphs 2.4.5, 3.3.3.5 and 3.3.4.5.

2.3 DESIGN

Unless shown to be unnecessary by test or analysis, the equipment must comply with the following:

2.3.1 Lubricant Retainers

Lubricant retainers must retain the lubricant under all operating conditions, prevent the lubricant from reaching braking surfaces, and prevent foreign matter from entering the lubricated cavity.

2.3.2 Brake Release And Wear Adjustment

The brake assembly and its control system must provide a suitable means to maintain an appropriate running clearance throughout the entire heat sink wear and thermal range when no braking is commanded.

2.3.3 Wear Indicator

A reliable method must be provided for determining when the heat sink is worn to its permissible limit.

2.3.4 Dissimilar Materials

When dissimilar materials are used in the construction and the galvanic potential between the materials indicate galvanic corrosion is likely, effective means to prevent the corrosion must be incorporated in the design. In addition, differential thermal expansion must not unduly affect the functioning, load capability, and the fatigue life of the components.

2.3.5 Insulation Resistance

The equipment shall have an adequate insulation resistance level to ensure the design is robust to leakage current paths in accordance with established industry standards.

2.3.6 Dielectric Strength

The equipment shall have a suitable dielectric withstanding capability for the voltages and voltage surges to which it will be subjected in accordance with established industry standards.

2.3.7 Bonding, Grounding

The equipment shall employ suitable electrical bonding and grounding techniques in its design to protect ground personnel, and the equipment, from fault currents, and from the potentially high voltages that may be present, in accordance with established industry standards.

2.4 CONSTRUCTION

The suitability and durability of the materials used for components must be established on the basis of experience or tests. In addition, the materials must conform to approved specifications that ensure the strength and other properties are those that were assumed in the design.

2.4.1 Castings

Castings must be of high quality, clean, sound, and free from blowholes, porosity, or surface defects caused by inclusions, except that loose sand or entrapped gases may be allowed when serviceability is not impaired.

2.4.2 Forgings

Forgings must be of uniform condition, free from blisters, fins, folds, seams, laps, cracks, segregation, and other defects. Imperfections may be removed if strength and serviceability would not be impaired as a result.

2.4.3 Bolts and Studs

When bolts or studs are used for fastening together sections of a wheel or brake, the length of the threads must be sufficient to fully engage the nut, including its locking feature, and there must be sufficient unthreaded bearing area to carry the required load.

2.4.4 Environmental Protection

All the components used must be suitably protected against deterioration or loss of strength in service due to any environmental cause, such as weathering, corrosion, and abrasion.

2.4.5 Magnesium Parts

Magnesium and alloys having magnesium, as a major constituent, must not be used on brakes or braked wheels.

3. MINIMUM PERFORMANCE UNDER STANDARD TEST CONDITIONS

3.1 INTRODUCTION The test conditions and performance criteria provide a laboratory means of demonstrating compliance with this TSO MPS. The airplane manufacturer normally defines the relevant test parameter values, however these parameters may be derived from published aircraft data for supplemental type certificate (STC).

3.2 WHEEL TESTS

The wheel should be tested, results documented, and reported per appendix 1, paragraphs 3.2, 4.1.1(a) and 4.1.4.

3.3 WHEEL AND BRAKE ASSEMBLY TESTS.

3.3.1 General

3.3.1.1 The wheel and brake assembly, with a suitable tire, TT_{BT} , installed, must be tested on a testing machine in accordance with the following, as well as paragraphs 3.3.2, 3.3.3, 3.3.5 and, if applicable, 3.3.4.

3.3.1.2 For tests detailed in paragraphs 3.3.2, 3.3.3, and 3.3.4, the test energies KE_{DL} , KE_{RT} , and KE_{SS} and brake application speeds V_{DL} , V_{RT} , and V_{SS} are as normally defined by the airplane manufacturer.

3.3.1.3 For tests detailed in paragraphs 3.3.2, 3.3.3, and 3.3.4, the initial brake application speed must be as close as practicable to, but not greater than, the speed established in accordance with paragraph 3.3.1.2, with the exception that marginal speed increases are allowed to compensate for brake clamping force release permitted in paragraphs 3.3.3.4 and 3.3.4.4. An increase in the initial brake application speed is not a permissible method of accounting for a reduced (that is, lower than ideal) dynamometer mass. This method is not permissible because, for a target test deceleration, a reduction in the energy absorption rate would result, and could produce performance different from that which would be achieved with the correct brake application speed. The energy to be absorbed during any stop must not be less than that established in accordance with paragraph 3.3.1.2. Additionally, forced air or other artificial cooling means are not permitted during these stops.

3.3.1.4 For brake stopping performance tests, the brake assembly must be tested using a control system and electrical power source providing representative characteristics of the actuating means to the EMAs, including limitations, specified for the aircraft braking system. I_{BMAX} , V_{BMAX} and P_{BMAX} shall not exceed the capabilities of the aircraft brake control system, I_{SMAX} , V_{SMAX} and P_{SMAX} , for which the equipment is intended.

3.3.1.5 For brake structural tests, the brake assembly may be tested with an alternate control system to that required for the brake stopping performance tests. The control system must be capable of structurally loading the EMA load path and brake structure to the static values required by the test conditions.

3.3.2 Design Landing Stop Test

3.3.2.1 The wheel and brake assembly under test must complete 100 stops at the KE_{DL} energy, each at the mean distance averaged deceleration, D , normally defined by the airplane manufacturer, but not less than 10 ft/s^2 (3.05 m/s^2). (Reference 14 CFR 25.735(f)(1)).

3.3.2.2 During the design landing stop test, the disc support structure must not be changed if it is intended for reuse, or if the wearable material is integral to the structure of the disc. One change of individual blocks or integrally bonded wearable material is permitted. For discs using integrally bonded wearable material, one change is permitted, provided that the disc support structure is not intended for reuse. The remainder of the wheel/brake assembly parts must withstand the 100 KE_{DL} stops without failure or impairment of operation.

3.3.3 Accelerate-Stop Test

3.3.3.1 The wheel and brake assembly under test must complete the accelerate-stop test at the mean distance averaged deceleration, D, normally defined by the airplane manufacturer, but not less than 6 ft/s² (1.83 m/s²). (Reference 14 CFR 25.735(f)(2)).

This test establishes the maximum accelerate-stop energy rating, KE_{RT}, of the wheel and brake assembly using:

- a. I_{SMAX}, V_{SMAX} and P_{SMAX}; or
 - b. The maximum brake current, voltage and power inputs consistent with the airplane's braking force limitations (tire/runway drag capability based on substantiated data).
- 3.3.3.2 For the accelerate-stop test, the tire, wheel, and brake assembly must be tested at KE_{RT} for both a new brake and a fully worn brake.
- a. A new brake is defined as a brake on which less than 5 percent of the usable wear range of the heat sink has been consumed.
 - b. A worn brake is defined as a brake on which the usable wear range of the heat sink has already been fully consumed to BRWL.

The proportioning of wear through the brake for the various friction pairs for this test must be based on service wear experience or wear test data of an equivalent or similar brake. Either operationally worn or mechanically worn brake components may be used. If mechanically worn components are used, it must be shown that they can be expected to provide similar results to operationally worn components. The test brake must be subjected to a sufficient number and type of stops to ensure that the brake's performance is representative of in-service use; at least one of these stops, with the brake near the fully worn condition, must be a design landing stop.

3.3.3.3 At the time of brake application, the temperatures of the tire, wheel, and brake assembly, particularly the heat sink and EMAs, must, as closely as practicable, be representative of a typical in-service condition. Preheating by taxi stops is an acceptable means.

These temperatures must be based on a rational analysis of a braking cycle, taking into account a typical brake temperature at which an airplane may be dispatched from the ramp, plus a conservative estimate of heat sink temperature change during subsequent taxiing and takeoff acceleration, as appropriate.

Alternatively, in the absence of a rational analysis, the starting heat sink and EMA temperatures must be that resulting from the application of 10 percent KE_{RT} to the tire, wheel and brake assembly, initially at not less than normal ambient temperature (59°F/15°C).

- 3.3.3.4 A full stop demonstration is not required for the accelerate-stop test. The test brake clamping force may be released at a test speed of up to 23 mph (10 m/s). In this case, the initial brakes-on speed must be adjusted such that the energy absorbed by the tire, wheel and brake assembly during the test is not less than the energy absorbed if the test had commenced at the specified speed and continued to zero ground speed.
- 3.3.3.5 Within 20 seconds of completion of the stop, or of the brake clamping force release in accordance with paragraph 3.3.3.4, apply the Parking Brake Command (PBC) and maintain for at least 3 minutes (reference 14 CFR 25.735(g)).

No sustained fire that extends above the level of the highest point of the tire is allowed before 5 minutes have elapsed after application of brake clamping force; until this time has elapsed, neither fire fighting means nor coolants may be applied.

The time of initiation of tire pressure release (for example, by wheel fuse plug), if applicable, is to be recorded. The sequence of events described in paragraphs 3.3.3.4 and 3.3.3.5 is illustrated in Figure 3-1.

3.3.4 Most Severe Landing Stop Test

- 3.3.4.1 The wheel and brake assembly under test must complete the most severe landing braking condition expected on the airplane as normally defined by the airplane manufacturer. This test is not required if the testing required in paragraph 3.3.3 is more severe or the condition is shown to be extremely improbable, normally by the airplane manufacturer.

This test establishes, if required, the maximum energy rating, KE_{SS} , of the wheel/brake assembly for landings under abnormal conditions using:

- a. I_{SMAX} , V_{SMAX} and P_{SMAX} ; or
 - b. The maximum brake current, voltage and power inputs consistent with the airplane's braking force limitations (for example, tire/runway drag capability based on substantiated data).
- 3.3.4.2 For the most severe landing stop test, the tire, wheel, and brake assembly must be capable of absorbing the test energy, KE_{SS} , with a brake on which the usable wear range of the heat sink has already been fully consumed to BRWL (reference 14 CFR 25.735(f)(3)).

The proportioning of wear through the brake for the various friction pairs for this test must be based on service wear experience or wear test data of an equivalent or similar brake. Either operationally worn or mechanically worn brake components may be used. If mechanically worn components are used, it must be shown that they can be expected to provide similar results to operationally worn components. The test brake must be subjected to a sufficient number and type of stops to ensure that the brake's performance is representative of in-service use; at least one of these stops, with the brake near the fully worn condition, must be a design landing stop.

- 3.3.4.3 At the time of brake application, the temperatures of the tire, wheel, and brake, particularly the heat sink and EMA, must, as closely as practicable, be representative of a typical in service condition. Preheating by taxi stops is an acceptable means.

These temperatures must be based on a rational analysis of a braking cycle, taking into account a typical brake temperature at which the airplane may be dispatched from the ramp, plus a conservative estimate of heat sink temperature change during taxi, takeoff, and flight, as appropriate.

Alternatively, in the absence of a rational analysis, the starting heat sink and EMA temperatures must be that resulting from the application of 5 percent KE_{RT} to the tire, wheel and brake assembly initially at not less than normal ambient temperature (59°F/15°C).

- 3.3.4.4 A full stop demonstration is not required for the most severe landing-stop test. The test brake clamping force may be released at a test speed of up to 23 mph (10 m/s). In this case, the initial brakes-on speed must be adjusted such that the energy absorbed by the tire, wheel, and brake assembly during the test is not less than the energy absorbed if the test had commenced at the specified speed and continued to zero ground speed.
- 3.3.4.5 Within 20 seconds of completion of the stop, or of the brake clamping force release in accordance with paragraph 3.3.4.4, apply the Parking Brake Command (PBC) and maintain for at least 3 minutes (reference 14 CFR 25.735(g)).

No sustained fire that extends above the level of the highest point of the tire is allowed before 5 minutes have elapsed after application of brake clamping force; until this time has elapsed, neither fire fighting means nor coolants may be applied.

The time of initiation of tire pressure release (for example by wheel fuse plug), if applicable, is to be recorded. The sequence of events described in paragraphs 3.3.4.4 and 3.3.4.5 is illustrated in Figure 3-2.

3.3.5 Structural Torque Test

The Wheel/Brake Rated Structural Torque, ST_R , is equal to the torque demonstrated in the test defined in paragraph 3.3.5.1.

3.3.5.1 Apply to the wheel, brake and tire assembly, the radial load S and the drag load corresponding to the torque specified in paragraphs 3.3.5.2 or 3.3.5.3, as applicable, for at least 3 seconds. Rotation of the wheel must be resisted by a reaction force transmitted through the brake, or brakes, by the application of at least L_{BMAX} , or equivalent. If such clamping force or its equivalent is insufficient to prevent rotation, the friction surface may be clamped, bolted, or otherwise restrained while applying the clamping force. A fully worn brake configuration, BRWL, must be used for this test. The proportioning of wear through the brake for the various friction pairs for this test must be based on service wear experience of an equivalent or similar brake or test machine wear test data. Either operationally worn or mechanically worn brake components may be used. The EMA may be cooled and/or restrained at the source of electromotive force generation after initial application of L_{BMAX} in lieu of maintaining application of electrical current throughout the test.

3.3.5.2 For landing gear with one wheel per landing gear strut, the torque is $1.2 (SxR)$.

3.3.5.3 For landing gear with more than one wheel per landing gear strut, the torque is $1.44 (SxR)$.

3.3.5.4 The wheel and brake assembly must support the loads without failure for at least 3 seconds. Abrupt loss of load-carrying capability or fragmentation during the test constitutes failure.

3.3.6 Wheel to Brake Clearance

There must be no interference in any critical areas between the wheel and brake assembly (with fittings) up to limit load conditions, taking into account the axle angular orientation. Lack of interference can be established by analyses and/or tests. If chosen, testing shall be conducted per the following methods:

3.3.6.1 Radial Limit Load Wheel and Brake Clearance Test

With a suitable tire, TT_{WT} , installed, mount the wheel and brake on a suitable axle, and position it against a flat, non-deflecting surface. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an airplane and is under the maximum radial limit load, L .

Inflate the tire to the pressure recommended for the Wheel Rated Static Load, S , with gas and/or liquid. If liquid inflation is used, liquid must be bled off to obtain the same tire deflection that would result if gas inflation were used. Liquid pressure must not exceed the pressure that would develop if gas inflation were used and the tire was deflected to its maximum extent. Load the wheel through its axle with the load applied perpendicular to the flat, non-deflecting surface. Reference 14 CFR 25.471 through 25.511, as appropriate. If the

radial limit load of paragraph 3.3.6.2 is equal or greater than the radial limit load specified in this paragraph, the test specified in this paragraph may be omitted.

Determine the most critical wheel orientation with respect to the non-deflecting surface. Apply the load with the tire loaded against the non-deflecting surface. If multiple critical orientations are determined, repeat the testing for each critical orientation. The bearing cups, cones, and rollers used in operation must be used for this loading. If at a point of loading during the test bottoming of the tire occurs, then the tire pressure may be increased an amount sufficient only to prevent bottoming.

3.3.6.2 Combined Limit Load Wheel and Brake Clearance Test

With a suitable tire, TT_{WT} , installed, mount the wheel and brake on a suitable axle, and position it against a flat, non-deflecting surface. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an airplane and is under the maximum radial limit load, L . Apply to the wheel and tire assembly radial and side loads not less than the respective ground limit loads. Reference 14 CFR 25.485, 25.495, 25.497, and 25.499, as appropriate. If at a point of loading during the test bottoming of the tire occurs, then the tire pressure may be increased an amount sufficient only to prevent bottoming.

Determine the most critical wheel orientation with respect to the non-deflected surface.

Apply the load with the tire loaded against the non-deflecting surface with the wheel in the most critical orientation.

The bearing cups, cones, and rollers used in operation must be used in this test.

A tube may be used in a tubeless tire only when it has been demonstrated that pressure will be lost due to the inability of a tire bead to remain properly positioned under the load. The wheel must be tested for the most critical inboard and outboard side loads. If multiple critical orientations are determined to apply, repeat the testing for each critical orientation.

3.4 **BRAKE TESTS**

It must be substantiated that standard production samples of the brake will pass the following tests:

3.4.1 Limit and Ultimate Load Test

Alternative control systems and artificial cooling of the electromotive devices may be used for the following tests if needed to generate and maintain the required clamping forces.

Limit Load: The brake must withstand for at least 5 seconds a force equal to the Brake Limit Load (L_{LMT}) without permanent deformation that would prevent it from performing its intended function after the test.

Ultimate Load: The brake, with EMAs extended to simulate a maximum worn condition, must for at least 3 seconds withstand a force equal to 1.5 times L_{LMT} . If necessary, EMA extension may be adjusted to prevent interaction with any retention means during this test.

3.4.2 Endurance Test

A brake assembly must be subjected to an endurance test during which structural failure or malfunction must not occur. If desired, the heat sink components may be replaced by a reasonably representative dummy mass for this test.

The test must be conducted by subjecting the brake assembly to 100,000 cycles of an application of the Brake Design Landing Load (L_{DL}) in the design landing stop test (paragraph 3.3.2) and release to the Brake Off Position (BOP). The EMAs must be adjusted so that the cycles are equally divided among at least five or more equally incremented wear positions, including the new and fully worn positions, BRWL.

The brake must then be subjected to 5000 cycles of application of force to the Maximum Brake Load (L_{BMAX}) and release to BOP. The EMAs must be adjusted so that the cycles are equally divided between at least five or more equally incremented, wear positions including the new and fully worn positions, BRWL.

The brake assembly must meet the integrity requirements of paragraph 3.4.4 at the completion of this test.

3.4.3 Extreme Temperature Soak Test

Subject the brake to at least a 24-hour hot soak at the maximum actuator housing temperature experienced during a design landing stop test (paragraph 3.3.2), conducted without forced air cooling. While at the hot soak temperature, the brake must be subjected to the application of the Brake Design Landing Load (L_{DL}) required during the 100 design landing stops and release to BOP for 1000 cycles, followed by 25 cycles of Maximum Brake Load (L_{BMAX}) and release to BOP.

The brake must then be cooled from the hot soak temperature to a cold soak temperature of -40°F (-40°C) and maintained at this temperature for at least 24 hours. While at the cold soak temperature, the brake must be subjected to the application of the Brake Design Landing Load (L_{DL}) required during the KE_{DL} stops and release to BOP, for 25 cycles, followed by 5 cycles of Maximum Brake Load (L_{BMAX}) and release to BOP.

The brake assembly must meet the integrity requirements of paragraph 3.4.4 at the completion of this test.

3.4.4 Brake Assembly Integrity

The brake assembly shall meet the functional test requirements (acceptance tests) established to assure continued airworthiness as prescribed by paragraph 6.c. page 3 of this TSO.

4. DATA REQUIREMENTS

4.1 The TSO applicant must provide the following data with any application for approval of equipment:

4.1.1 The following wheel and brake assembly ratings:

a. Wheel Ratings

See TSO-C135a, Appendix 1, paragraph 4.1.1a.

b. Wheel/Brake and Brake Ratings

Wheel/Brake Rated Design Landing Energy, KE_{DL} , and associated brakes-on-speed, V_{DL}

Wheel/Brake Rated Accelerate-Stop Energy, KE_{RT} , and associated brakes-on-speed, V_{RT}

Wheel/Brake Rated Most Severe Landing Stop Energy, KE_{SS} , and associated brakes-on-speed, V_{SS} (if applicable)

Maximum Brake Load, L_{BMAX}

Brake Limit Load, L_{LMT}

Wheel/Brake Rated Structural Torque, ST_{R}

Rated Design Landing Deceleration, D_{DL}

Rated Accelerate-Stop Deceleration, D_{RT}

Rated Most Severe Landing Stop Deceleration, D_{SS} (if applicable)

Brake Rated Tire Size, TS_{BR}

Brake Rated Wear Limit, BRWL

Maximum EMA Brake Voltage, V_{BMAX}

Maximum EMA Brake Current, I_{BMAX}

Maximum EMA Brake Power, P_{BMAX}

Maximum System Voltage, V_{SMAX}

Maximum System Current, I_{SMAX}

Maximum System Power, P_{SMAX}

- 4.1.2 The weight of the wheel and brake assemblies, as applicable.
- 4.1.3 Specification of the voltage and current supply limitations used during the tests.
- 4.1.4 Analysis and/or data substantiating I_{BMAX} , L_{BMAX} , L_{DL} , L_{LMT} , P_{BMAX} and V_{BMAX} , as appropriate.
- 4.1.5 One copy of the test report showing compliance with the test requirements.

NOTE: When test results are being recorded for incorporation in the compliance test report, it is not sufficient to note merely that the specified performance was achieved. The actual numerical values obtained for each of the parameters tested must be recorded, except where tests are pass/fail in character.

Figure 3-1 - Taxi, Accelerate-Stop, Park Test Sequence

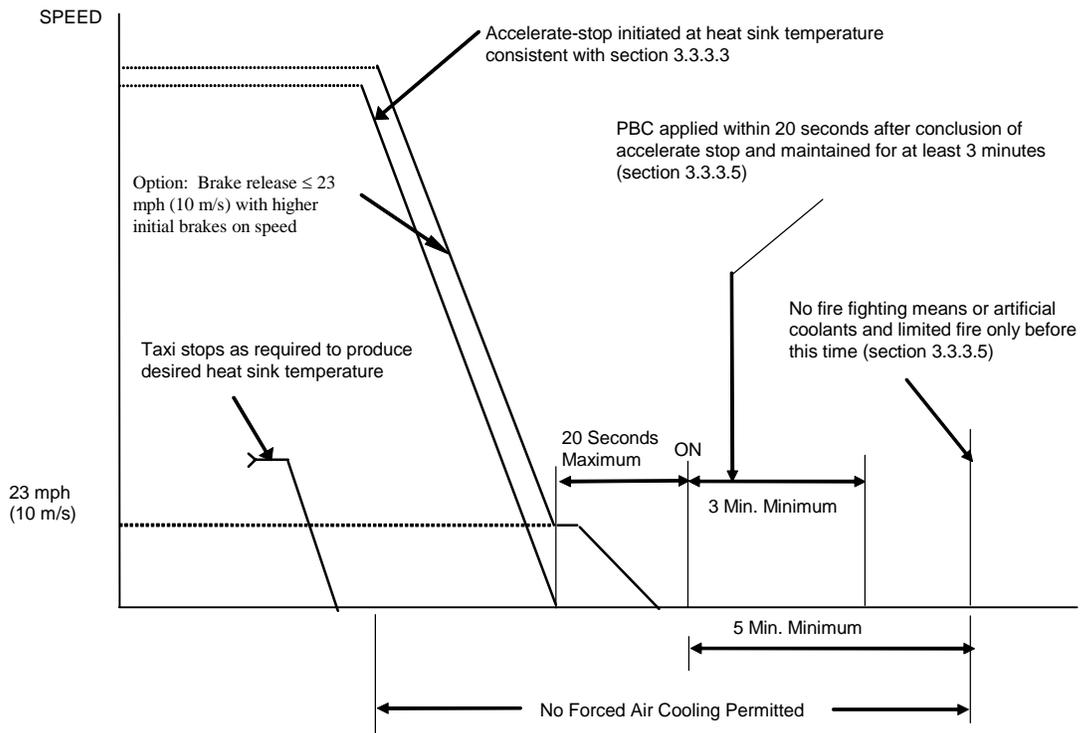


Figure 3-2 - Most Severe Landing-Stop, Park Test Sequence

