Department of Transportation
Federal Aviation Administration
Aircraft Certification Service
Washington, DC

TSO-C135

Proposed
Technical Standard Order

Subject: **Transport Airplane Wheels and Wheel and Brake Assemblies**

1. PURPOSE. This Technical Standard Order (TSO) prescribes the minimum performance standards (MPS) that transport category airplane wheels, and wheel and brake assemblies must meet to be identified with the applicable TSO marking.

2. APPLICABILITY.

a. This TSO is effective for new applications submitted after the effective date of this TSO.

b. Previously Approved Equipment. Wheels and wheel-brake assemblies approved prior to the effective date of this TSO may continue to be manufactured under the provisions of their original approval.

3. REQUIREMENTS. Wheels, and wheel and brake assemblies, that are to be so identified and that are manufactured on or after the effective date of this TSO must meet the MPS qualification and documentation requirements set forth in appendix 1 of this TSO titled "Minimum Performance Specification for Transport Airplane Wheels, Brakes, and Wheel and Brake Assemblies." Brakes and associated wheels are to be considered as an assembly for TSO authorization purposes.

4. MARKING.

a. In addition to the marking specified in 14 CFR 21.607(d), the following information shall be legibly and permanently marked on the major equipment components:

(1) Size (this marking applies to wheels only)

(2) Hydraulic fluid type (this marking applies to brakes only)

(3) Serial Number

b. The manufacturer's address required by § 21.607(d)(1) may be omitted from the markings. All stamped, etched, or embossed markings must be located in non-critical areas.

5. DATA REQUIREMENTS.

a. Application Data. In addition to the data specified in § 21.605, the manufacturer must furnish one copy each of the following to the Manager of the FAA Aircraft Certification Office (ACO) having geographical purview of the manufacturer's facilities:

(1) The applicable limitations pertaining to installation of wheels or wheel and brake assemblies on airplane(s), including the data requirements of paragraph 4.1 of appendix 1 of this TSO.

(2) The manufacturer's TSO qualification test report.

b. Data to be Furnished with Manufactured Articles.

(1) Prior to entry into service use, the manufacturer must make available the applicable maintenance instructions and data necessary for continued airworthiness to the ACO specified in paragraph (c) above.

(2) The manufacturer must provide the applicable maintenance instructions and data necessary for continued airworthiness to each organization or person receiving one or more articles manufactured under this TSO. In addition, a note with the following statement must be included:

> The existence of TSO approval of the article displaying required marking does not automatically constitute the authority to install and use the article on an airplane. The conditions and tests required for TSO approval of this article are minimum performance standards. It is the responsibility of those desiring to install this article either on or within a specific type or class of airplane to determine that the airplane operating conditions are within the TSO standards. The article may be installed only if further evaluation by the user/installer documents an acceptable installation and the installation is approved by the Administrator.
>
> Additional requirements may be imposed based on airplane specifications, wheel and brake design, and quality control specifications. In-service maintenance, modifications, and use of replacement components must be in compliance with the performance standards of this TSO, as well as any additional specific airplane requirements.

6. AVAILABILITY OF REFERENCED DOCUMENTS.

a. Part 21 of Title 14 CFR may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402-9325.

b. Advisory Circular No. 20-110, " Index of Aviation Technical Standard Orders," and this TSO, which includes the "Minimum Performance Specification for Transport Airplane Wheel and Wheel and Brake Assemblies" may 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.

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APPENDIX 1:MINIMUM PERFORMANCE SPECIFICATION FOR TRANSPORT AIRPLANE WHEELS, BRAKES, AND WHEEL AND BRAKE ASSEMBLIES

CHAPTER 1
INTRODUCTION

1.1 PURPOSE AND SCOPE

This Minimum Performance Specification defines the minimum performance standards for wheels, brakes, and wheel and brake assemblies to be used on airplanes certified under 14 Code of Federal Regulations (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 manufacturers, installers and users 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 manufacturer.

1.4 DEFINITIONS AND ABBREVIATIONS

1.4.1 Wheel Rated Static Load (S)

S = Maximum Static Load (Reference § 25.731(b)).

1.4.2 Wheel Rated Inflation Pressure (WRP)

WRP = Wheel Rated Inflation Pressure (wheel unloaded).

1.4.3 Wheel Rated Tire Loaded Radius (R)

R = 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.

1.4.4 Wheel Rated Radial Limit Load (L)

L = Radial Limit Load. L is the Wheel Rated Maximum Radial Limit Load (paragraph 3.2.1).

1.4.5 Wheel Rated Tire Type(s) and Size(s) (TS_{WR})

TS_{WR} = Wheel Rated Tire Type(s) and Size(s) defined for use and approved by the airplane manufacturer for installation on the wheel.

1.4.6 Suitable Tire for Wheel Test (TT_{WT})

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

1.4.7 Wheel/Brake Rated Structural Torque (ST_R)

ST_R = Wheel/Brake Rated Structural Torque.

ST_R is the maximum structural torque demonstrated (paragraph 3.3.5).

1.4.8 Wheel/Brake Rated Design Landing Stop Energy (KE_{DL})

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

KE_{DL} is the minimum energy absorbed by the wheel/brake/tire assembly during each stop of the 100 stop Design Landing Stop Test. (paragraph 3.3.2).

1.4.9 Wheel/Brake Design Landing Stop Speed (V_{DL})

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

V_{DL} is the initial brakes-on speed for a Design Landing Stop (paragraph 3.3.2).

1.4.10 Wheel/Brake Rated Accelerate-Stop Energy (KE_{RT})

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.

1.4.11 Wheel/Brake Accelerate-Stop Speed (V_{RT})

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

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

1.4.12 Wheel/Brake Rated Most Severe Landing Stop Energy (KE_{SS})

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.

1.4.13 Wheel/Brake Most Severe Landing Stop Speed (V_{SS}).

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

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

1.4.14 Brake Rated Wear Limit (BRWL)

BRWL = Brake maximum wear limit to ensure compliance with paragraph 3.3.3, and, if applicable, paragraph 3.3.4.

1.4.15 Airplane Maximum Rotation Speed (V_R).

V_R = Airplane Maximum Rotation Speed.

1.4.16 Brake Rated Maximum Operating Pressure ($BROP_{MAX}$)

$BROP_{MAX}$ = Brake Rated Maximum Operating Pressure.

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

1.4.17 Brake Rated Maximum Pressure (BRP_{MAX})

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).

1.4.18 Brake Rated Maximum Parking Pressure ($BRPP_{MAX}$).

$BRPP_{MAX}$ = Brake Rated Maximum Parking Pressure.

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

1.4.19 Brake Rated Retraction Pressure (BRP_{RET})

BRP_{RET} = Brake Rated Retraction Pressure.

BRP_{RET} is the highest pressure at which piston retraction to the unpressurized position is assured.

1.4.20 Distance Averaged Deceleration (D)

D = ((Initial brakes-on speed)^2 - (Final brakes-on speed)^2)/(2 (braked flywheel distance))

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

1.4.21 Rated Design Landing Deceleration (D_{DL}).

D_{DL} = Rated Design Landing Deceleration.

D_{DL} is the minimum of the distance averaged deceleration values demonstrated during the 100 KE_{DL} stops of paragraph 3.3.2.

1.4.22 Rated Accelerate-Stop Deceleration (D_{RT}).

D_{RT} = Rated Accelerate -Stop Deceleration.

D_{RT} is the distance averaged deceleration which the wheel/brake/tire assembly will produce when absorbing KE_{RT}.

1.4.23 Rated Most Severe Landing Stop Deceleration (D_{SS}).

D_{SS} = Rated Most Severe Landing Stop Deceleration.

D_{SS} is the distance averaged deceleration which the wheel/brake /tire assembly will produce when absorbing KE_{SS}.

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

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.

1.4.25 Suitable Tire for Brake Tests (TT_{BT}).

TT_{BT} = 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, and must be a tire type and size approved for installation on the wheel. The suitable tire may be different for different tests.

1.4.26 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.

1.4.27 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.

CHAPTER 2
GENERAL DESIGN SPECIFICATION

2.1 AIRWORTHINESS.

The airworthiness of the airplane on which the equipment is to be installed must be considered. (See the paragraph titled "Data to be Furnished with Manufactured Articles.")

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 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 Wheel Bearing Lubricant Retainers.

Wheel bearing lubricant retainers must retain the lubricant under all operating conditions, prevent the lubricant from reaching braking surfaces, and prevent foreign matter from entering the bearings.

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 devices 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 otherwise 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 (Reference: Aircraft Year Book-Tire and Rim Association Inc.) or, alternatively, 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 misassembly 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 Metals.

Adequate protection must be provided to prevent electrolytic action when dissimilar metals are used. In addition, differential thermal expansion must not unduly affect the load capability and fatigue life.

2.4 CONSTRUCTION.

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 Corrosion Protection.

Corrosion protection means, where used, must be compatible with the expected environment. This protection must include protection for all holes and passages exposed to potentially corrosive environments.

2.4.5 Magnesium Parts.

Magnesium parts must not be used on brakes or braked wheels.

2.4.6 Bearing and Braking Surface.

Surface and protective finishes must not be applied to bearings and braking surfaces..

CHAPTER 3
MINIMUM PERFORMANCE UNDER STANDARD TEST CONDITIONS

3.1 INTRODUCTION.

The test conditions and performance criteria described in this Chapter provide a laboratory means of demonstrating compliance with this TSO minimum performance standard. The airplane manufacturer must define all relevant test parameter values.

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 of 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 of 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 of this paragraph, the test specified in this paragraph may be omitted.

Test the wheel for yield and ultimate loads as follow:

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.

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. 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, as determined under 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.

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. There must be no interference in any critical areas between the wheel and brake assembly, or between the most critical deflected tire and brake (with fittings) up to limit load conditions, taking into account the axle flexibility. Lack of interference can be established by analyses and/or tests.

3.2.1.3 Ultimate Load.

Apply to the wheel used in the yield test of 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, as determined under 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, 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.

Liquid pressure must not exceed the pressure that would develop if gas inflation were used and the tire were deflected to its maximum extent. 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, as determined under 14 CFR 25.485, 25.495, 25.497, and 25.499 as appropriate.

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. There must be no interference in any critical areas between the wheel and brake assembly, or between the most critical deflected tire and brake (with fittings) up to limit load conditions, taking into account the axle flexibility. Lack of interference can be established by analyses and/or tests.

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 as determined under 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; however, 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, 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 0.15 S side load applied in the outboard direction	100 (161)
Wheel Rated Static Load, S plus 0.15 S 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 9 knots 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.

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 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 under 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 deceleration, D, defined by the airplane manufacturer, but not less than 10 ft/s^2 (3.05 m/s^2).

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 deceleration, D, defined by the airplane manufacturer, but not less than 6 ft/s^2 (1.83 m/s^2).

This test establishes the maximum takeoff 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 (e.g., 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 capable of absorbing the test energy, KE_{RT}, using a brake on which the usable wear range of the heat sink BRWL has already been fully consumed.

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 a taxi stop(s) 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 worn brake accelerate-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.

3.3.3.5 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 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 (e.g., 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 defined by the airplane manufacturer. This test is not required if the testing required by paragraph 3.3.3 is more severe or the condition is shown to be extremely improbable 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 (e.g., 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 BRWL has already been fully consumed.

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 a taxi stop(s) 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 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 (e.g., 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

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. The wheel/brake rated structural torque (ST_R) is equal to the torque demonstrated in the test defined in 3.3.5.1.

3.3.5.2 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.

3.4 BRAKE TESTS.

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 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 two 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 return 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 meet the leakage requirements of paragraph 3.4.5 at the completion of the test.

3.4.3 Piston Retention.

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

3.4.4 Extreme Temperature Soak Test

The brake actuation system must comply with the dynamic leakage limits of paragraph 3.4.5.2 for the following tests.

Subject the brake to a 24-hour hot soak at the maximum piston housing fluid temperature experienced during the 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°F (-40°C) and maintained at this temperature for 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 5 minutes. The brake pressure must then be adjusted to an operating pressure of 5 psig (35 kPa) for 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.

CHAPTER 4

DATA REQUIREMENTS.

4.1 The manufacturer 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
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 Type 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.

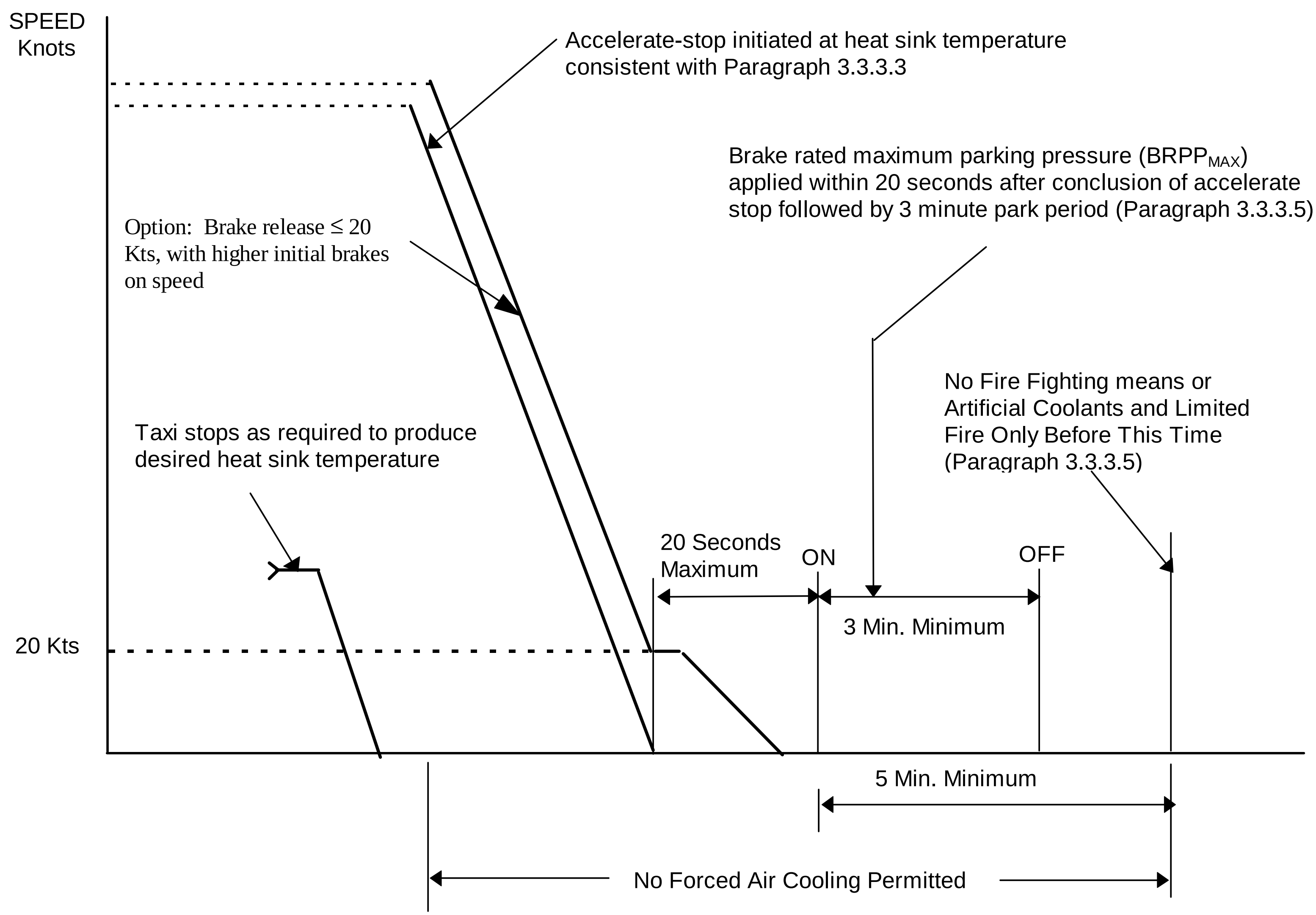

Figure 3-1. Taxi, Accelerate-Stop, Park Test Sequence

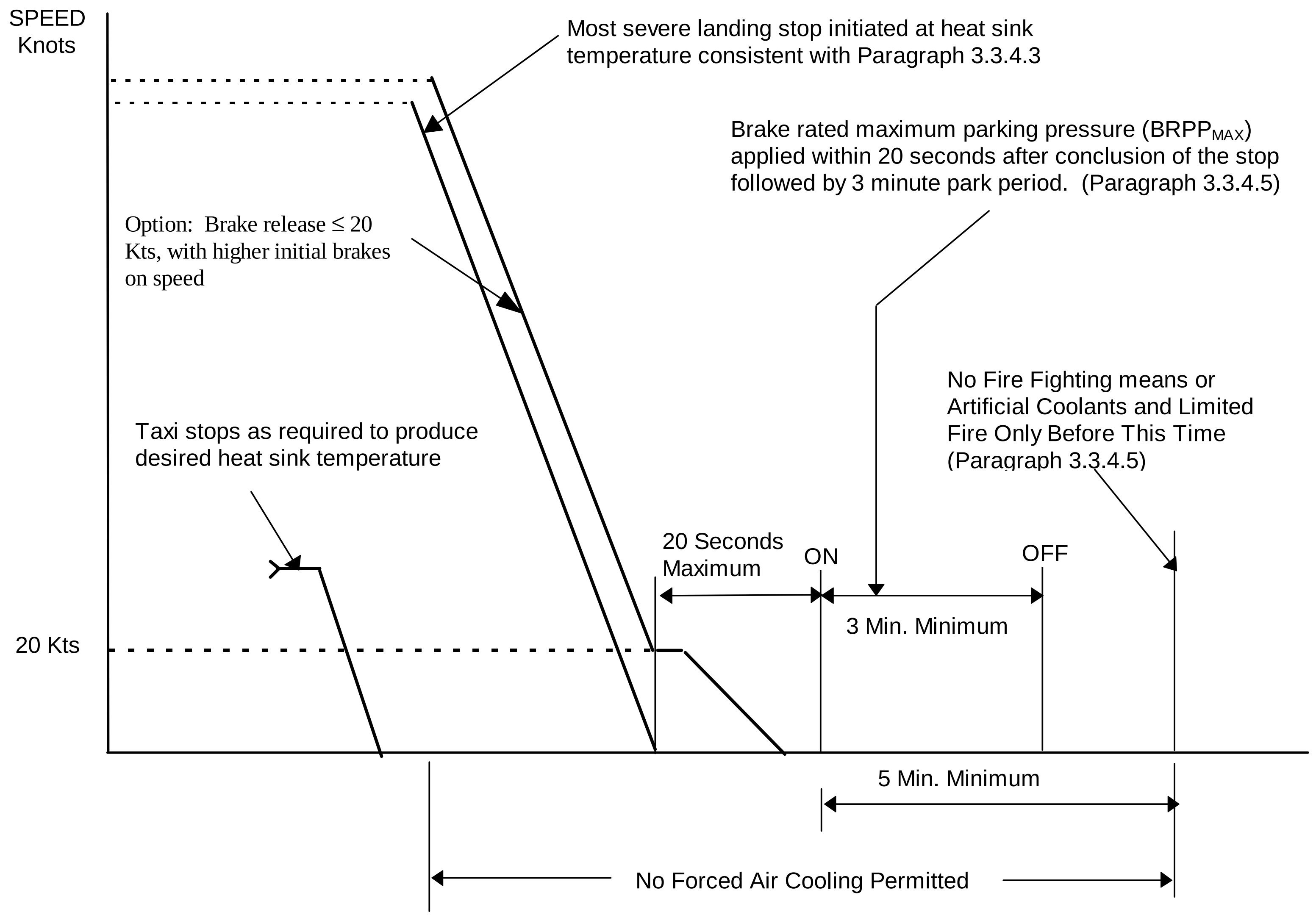

Figure 3-2. Most Severe Landing-Stop, Park Test Sequence