INTERNATIONAL

AEROSPACE RECOMMENDED PRACTICE

ARP1493	REV. C
Issued 1979-07 Reaffirmed 2007-07 Revised 2008-06 Stabilized 2013-11 Superseding ARP1493B	

Wheel and Hydraulically Actuated Brake Design and Test Requirements for Military Aircraft

RATIONALE

Due to current U.S. government rules effecting sharing of information regarding military technology and services (i.e. ITAR, EAR, etc.) further updates to this document will no longer be possible.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE A-5A Wheels, Brakes and Skid Controls Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical/standards/ARP1493C

TABLE OF CONTENTS

1. SCOPE

This document covers military aircraft wheel and hydraulically actuated brake equipment.

1.1 Purpose

This document provides recommended practices for designing and testing wheels and hydraulically actuated brakes for use on new designs of military aircraft. Intended users are airframe and military personnel who prepare detail design and performance specifications. It is not intended to be a procurement document. This document provides updated information to MIL-W-5013 which has been classified inactive for new design.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

ARP597 Wheels and Brakes, Supplementary Criteria for Design Endurance Civil Transport Aircraft

AS707 Thermal Sensitive Inflation Pressure Release Devices for Tubeless Aircraft Wheels

ARP813 Maintainability Recommendations for Aircraft Wheels and Brake Design

ARP1619 Replacement and Modified Brakes and Wheels

ARP5146 Assessment of Aircraft Wheel Sealing Systems

AS5202 Port or Fitting End, Internal, Straight Thread, Design Standard

AS5440 Hydraulic Systems, Aircraft, Design and Installation Requirements for

AIR5451 A Guide to Landing Gear System Integration

ARP5481 Recommended Wheel Tie Bolt Preload Procedure

ARP5600 Disposition of Damaged Wheels Involved in Accidents/Incidents

AS8860 Landing Gear Structural Requirements as Listed in the MIL-886X Series of Specifications

AS25427 Coupling Assembly, Hydraulic, Self-Sealing, Quick Disconnect

AS28775 Packing, Preformed, Hydraulic, +275°F (O-Ring)

AMS2175 Castings, Classification and Inspection of

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E 1417 Standard Practice for Liquid Penetrant Testing

ASTM E 1444 Standard Practice for Magnetic Particle Testing

2.1.3 U.S. Government Publications

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, http://assist.daps.dla.mil/quicksearch/.

JSSG-226 Aircraft Structures, General Specification

MIL-A-8625 Anodic Coatings for Aluminum and Aluminum Alloys

MIL-HDBK-275 Lubricants Fluids and Compounds for use in Flight Vehicles and Components, Selection Guide

MIL-HDBK-838 Lubrication of Military Equipment

MIL-P-83461 Packing, Preformed, Petroleum Hydraulic Fluid Resistant Improved Performance at 275°F (135° C) for use in Boss Fittings, Sizes and Tolerances

MIL-PRF-23377 Primer Coatings; Epoxy, High-Solids

MIL-PRF-85285 Coating, Polyurethane, Aircraft and Support Equipment

MIL-W-5013 Wheel and Brake Assemblies, Aircraft, General Specification (for Reference Only - Inactive for New Design)

MS27436 Cable Configuration, Grounding Aircraft

MS27611 Valve, Hydraulic Bleeder, Aircraft Wheel Brake

2.2 Definitions

2.2.1 Design Drawings

The terms “specification control drawing” or “applicable design drawing” used in this document mean the design drawing prepared by and available from the procuring activity.

2.2.2 Normal Operating Pressure

The term “normal operating pressure” means the brake hydraulic pressure required to produce an aircraft deceleration in accordance with the procurement document, as determined by the average of the distance averaged pressure measurements in landplane landing design gross weight tests specified in 4.2.7.

2.2.3 Normal Parking Pressure

The term “normal parking pressure” means the brake hydraulic pressure required to lock the wheel at the rated static load specified for the wheel.

2.2.4 Maximum Operating Pressure

The term “maximum operating pressure(s)” means the maximum brake hydraulic pressure(s) supplied at the brake under design conditions.

2.2.5 Weights and Speeds

The weight conditions specified in Table 3 and related speeds should be used to establish design values. When the procurement document specifies more severe conditions these should be used instead. For speeds the values in Table 1 should be used:

TABLE 1- WEIGHT AND SPEED CONDITIONS

Condition	Brakes on Speed	Aircraft Weight
Normal Landing	0.9 V_a	LPLGW
Maximum Landing	0.9 V_a	MLGW
Rejected Takeoff (RTO)	1.0 MWLO	MTOGW
Worn Brake RTO	1.0 MWLO	MTOGW
Rapid Turnaround (if required)		
Landing	0.9 V_a	LPLGW
Taxi-In	*	LPLGW
Taxi-Out	*	MTOGW
RTO	1.0 MWLO	MTOGW

where:

V_a - Standard day approach speed for related weight

LPLGW = Landplane landing gross weight

MLGW = Maximum landing gross weight

MWLO = Rational main wheel lift off speed at sea level standard day or a specified by the procuring activity

MTOGW - Maximum takeoff gross weight

* = Brake energy is the total amount of braking required to oppose the idle thrust over the taxi distance and the number of anticipated stops during the taxi phase

2.2.6 Loads

For the purpose of load testing, the following definitions will apply:

a. Limit Load: The maximum load anticipated during all normal conditions of operation as determined by the procurement activity. It should be not less than the load determined by using AS8860 specification, JSSG-2006, or as defined in the aircraft detail specification.

b. Yield Load: 1.15 times the limit load.

c. Design Ultimate Load: 1.5 times the limit load.

d. Design landing loads will be as determined by the procurement activity in accordance with the load conditions of AS8860.

3. REQUIREMENTS

The wheel and brake should fulfill all the regulatory and/or any airframe manufacturer's design requirements that are considered applicable to the aircraft being designed.

3.1 Drawings

3.1.1 Design Proposal Drawings

Design proposal drawings prepared by the wheel and brake manufacturer should include the following:

a. Reference to the applicable specification.

b. End-view and cross-sectional drawing including definition of the rim flange, brake and wheel mounting, hydraulic interface data, and envelope definition.

c. Material, principal manufacturing process, and finish definition for all major components.

d. Wheel static and dynamic loading conditions, brake energy definitions, separate and combined maximum weights for the wheel and brake assemblies.

e. Brake design parameters, including:

    1. Heat sink mass and definition of heat sink components, new and fully-worn

    2. Swept area

    3. Mean radius

    4. Piston area

f. Brake performance predictions, including:

    1. Pressure-volume curve defining the pressure to begin brake piston movement

    2. Pressure to cause disk contact

    3. Brake release pressure (brake rotors are free to rotate)

    4. Maximum system pressure as prescribed by the procuring activity to provide full flow to allow for rudder, spoilers, speed brakes, etc.

g. Other technical information required communicating the design

3.1.2 Interface Drawings

Interface drawings should be developed and approved by the procuring activity that define the applicable interfaces with tolerances for the wheels and brakes. This should include but not limited to all interfaces with the axle, landing gear, hydraulic system, hub cap, brake temperature or tire pressure monitoring system as applicable. Component or assembly interface drawings suitable for alternate source procurement should be the subject of separate contract by specific request.

3.2 Materials

Unless otherwise specified in the procurement specification, the following materials are commonly used for the major components:

a. Aluminum components: Forged aluminum alloys of 2040-T6, 7050-T74, 2014-T6 or 2014-T61 are suitable alloys for wheel halves and brake housings

3.3 Protective Treatment

Unless otherwise specified in the procurement specification, aluminum alloy should be anodized in accordance with MIL-A-8625, Type II or III, all over after cold working.

In addition, all exterior surfaces should be painted with one coat of MIL-PRF-23377 primer and two coats of MIL-PRF-85285 urethane topcoat.

3.4 Detail Design Requirements

3.4.1 Wheel Design Requirements

Wheel design should meet the specified requirements with all tire part numbers specified by the procuring agency.

3.4.1.1 Tie Bolts

Wheel tie bolts, where used, should be of the through-type with nuts: no inserts should be permitted. If chamfered washers are used, they should be chamfered on both sides. Appropriate MS head form bolts should be used. Appropriate thread lubricant and tie bolt torque procedure (reference ARP5481) should be specified with appropriate substantiation per 3.4.3.5.1.

3.4.1.2 Demountable Flange

Demountable flange wheel configuration should be designed in a manner that prevents the flange and its retaining device from leaving the wheel if a flat tire occurs while the wheel is rolling up to take off speeds. Design consideration should be given to protection against corrosion and fretting.

3.4.1.3 Wheel Fatigue

It is recommended that a system for tracking accumulated wheel usage in service be established. Accordingly, wheels should incorporate removal due date and/or tire change counters or an alternative concept that is consistent with the aircraft maintenance philosophy.

3.4.1.4 Lubricant and Lubricant Retainers

Suitable retainers should be provided to prevent lubricant from reaching the braking surface and to prevent foreign material from entering the bearings. The retainers should be removable to allow for cleaning and lubrication of the bearings. Where possible, the wheel bearings should be sealed on a stationary surface. Wheel bearing seals should be designed to not rub on the stationary or permanent portion of the brake housing or strut. Rubbing surfaces should be contained to nonstructural parts that are removed from the aircraft during a typical tire change. Applicable requirements of MIL-HDBK-838 and MIL-HDBK-275 should be observed. A suitable lubricant should be specified.

3.4.1.5 Lubrication Fittings

Wheels should not be fitted with pressure type lubrication fittings except for amphibian and beaching gear applications.

3.4.1.6 Wheel Valve and Boss

Tubeless tire valves should conform to MS27436. The boss that accommodates the valve should be in accordance with AS5202.

3.4.1.7 Overinflation Protection Devices

Overinflation protection devices should be provided unless deleted by the procurement specification. Valve boss should be in accordance with AS5202.

3.4.1.8 Tire Pressure Gages

If used, Integral tire pressure gauges should conform to MIL-G-83016. The gauge boss should be in accordance with AS5202.

3.4.1.9 Wheel Mating Seals and Grooves

Seals and sealing cavities should be in accordance with proven design. If the design has not been proven by service experience of a similar configuration in a comparable application, the sealing system should be verified per ARP5146. Standard MIL-P-83461 seal compounds should be used unless other compounds are shown to be preferred for performance, operational, environmental, reliability, maintainability or cost considerations

3.4.1.10 Static Balance

Wheel halves should be statically balanced with asymmetrical or nonsymmetrical components installed within the limits specified in Figure 1 to the nearest whole ounce-inch. Assembly of the two wheel halves of a split-type wheel assembly in alternative position or assembly of halves of different wheels should not result in imbalance beyond the specified limits.

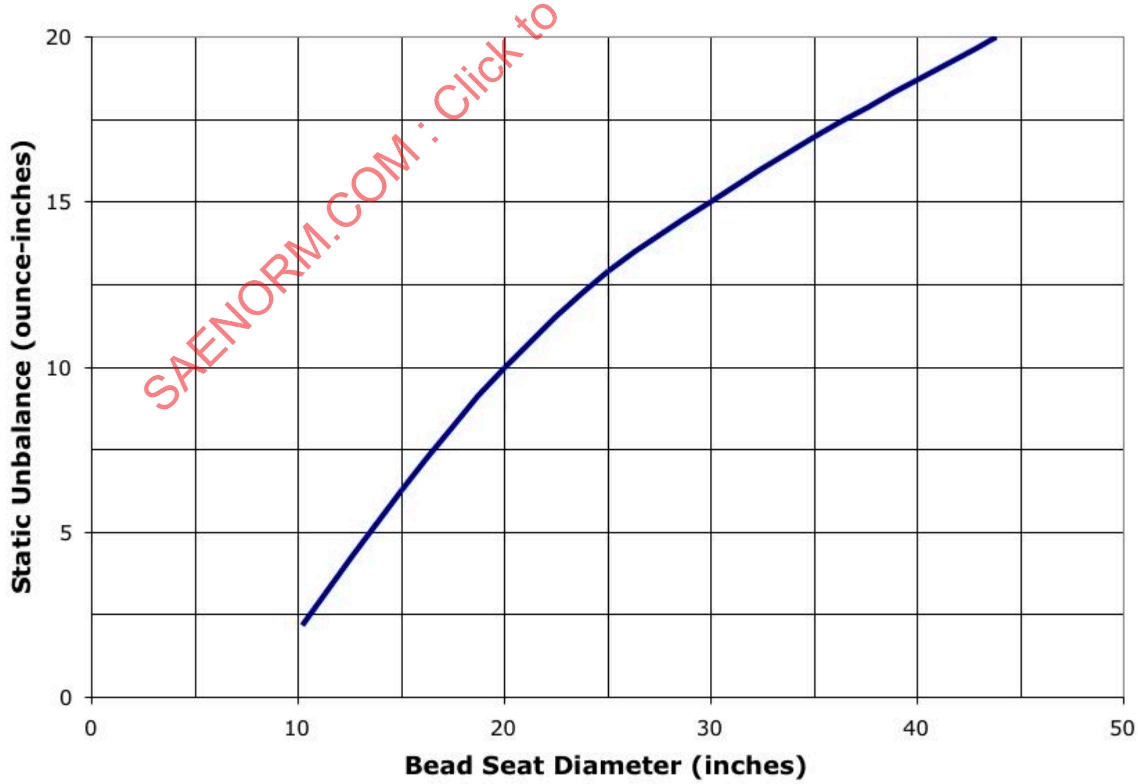

FIGURE 1 - ALLOWABLE STATIC IMBALANCE

3.4.1.11 Braked Wheel Thermal Sensitive Pressure Release Devises (Fuse Plugs)

Braked Wheel Thermal Sensitive Pressure Release Devices (Fuse Plugs): A minimum of three fuse plugs should be provided and located in the wheel tubewell area approximately equally spaced about the wheel. They should be designed so that tire pressure will be released prior to tire or wheel failure resulting from temperature induced structural degradation. The wheel bead ledge temperature should not be permitted to exceed 400 °F (204 °C) without fuse plug release. The fuse plugs should not release during tests at maximum landing weight (Table 3) (Reference AS707).

3.4.1.12 Wheel Burst Factor

The following wheel burst load factors apply to wheel tests:

TABLE 2 - WHEEL BURST FACTORS

Type of Aircraft	Factor Times Rated Inflation Pressure
Land Based Aircraft	3.5
Carrier Based Aircraft	4.5
Helicopter	3.0

3.4.2 Brake Design Requirements

3.4.2.1 Seals and Glands

Piston cylinder design sealing cavities should be in accordance with proven design. AS28775 seals should be used unless the performance, operational, environmental, reliability, maintainability or cost requirement compliance justifies an alternative seal geometry or compound selection. Other configurations of seals may be used with prior approval.

3.4.2.2 Wear Indicators

The brake assembly should have wear indicators that are visible during a walk around inspection. The indicators should show “go-no go” status without the need for measuring tools.

3.4.2.3 Automatic Adjusters

Automatic adjusters should be provided to compensate for brake lining wear where needed. Brake assemblies should be designed for the most practical protection of the brake adjusters.

3.4.2.4 Cylinder Liners

Brakes should be designed with replaceable cylinder liners. If aluminum pistons or cylinder liners are used, the surface wiped by dynamic seals should be anodized in accordance with MIL-A-8625, Type III or other protective coating approved by the procuring activity. Helicopters are frequently waived of this requirement.

3.4.2.5 Inlet and Bleeder Fittings

Brake inlet fittings, threads, and bosses should be in accordance with AS5440. Brake bleeder valves should conform dimensionally to MS27611 and be installed in a boss, inlet fitting, or attaching bolt machined in accordance with AS5202. A threaded steel insert should be provided for inlet bosses in nonferrous brake housings. All fittings should be safetied or suitably locked. Self-sealing couplings, if required by the procurement specification, should conform to AS25427. As an option, self-sealing, quick-disconnect assemblies may be provided to enable brake assemblies to be bled in the shop rather than on the aircraft, if appropriate to the aircraft maintenance philosophy.

3.4.2.6 Brake Operating Pressure and Release

The brake should be compatible with the full range of operating pressures provided by the aircraft. The brake return mechanism should fully release to the design travel at a pressure not less than 110% of the maximum steady state backpressure imposed on the brake.

3.4.2.7 Operating Media

The brakes should be compatible with the operating media as defined in the procurement specification for the applicable aircraft.

3.4.2.8 Piston Stops

Piston stops that limit piston travel should be provided to prevent venting of hydraulic fluid upon heat sink failure or operation beyond the normal removal condition. The piston stops should allow sufficient piston travel to permit a maximum design gross weight rejected takeoff at the 100% worn brake condition with the maximum operating hydraulic pressure applied. The stops should be designed for 1.5 times the maximum operating pressure without the brake discs installed.

3.4.3 Detail Design Requirements - General

The configuration should be compatible with the total aircraft performance, maintenance, and operational environment. Wheel-brake assemblies should be designed to tolerate external loads and braking action that may be associated with proper performance during brake application while the aircraft is steered through a turn. Wheel and brake assemblies should be capable of use on any mounting position on the aircraft. Brake heat sink removal should not be required for wheel removal. Standard fasteners should be used where practical on wheel and brake assemblies.

3.4.3.1 Assembly and Installation

Wheels and brakes should be designed so that they cannot be improperly assembled or improperly installed on the aircraft.

3.4.3.2 Rework

Sufficient rework material should be provided to allow rework and repair of the base material in areas such as bearing bores, wheel tie bolt bosses, and brake attachment bushings that have been historically troublesome.

3.4.3.3 Special Tools

Special or unusual tools and equipment should not be required for installation, removal, or normal maintenance and inspection of the wheels and brakes unless authorized by the procurement activity.

3.4.3.4 Maintainability

ARP813 should be used as a design guide.

3.4.3.5 Identification of Product

All markings should be legible. Where procurement activity requirements exist for unique identification, the product should be marked accordingly.

3.4.3.5.1 Wheel Marking

Wheels should be marked with the following information using integral lettering. Nameplates should be used only when specifically approved.

a. Size

b. Serial number on both wheel halves, on demountable flange and wheel body, or, in the case of other designs, on similar major wheel parts

c. Manufacturer's name and/or code and part number

d. Date of manufacture (month and year, which may be combined with the serial number)

e. All wheels should carry a warning note to require deflation of the tire before loosening of the tie bolts or removing the lock ring retention devices.

f. Tie-bolt type wheels should carry a suitable note to clearly describe the lubrication method and to torque tie bolts per applicable maintenance manual (reference ARP5481).

3.4.3.5.2 Brake Marking

Brakes should be marked with the following information. Stamping or integral lettering is preferred. If nameplates are required, details should be submitted with the drawings of 3.1.1.

a. Manufacturer's name and part number

b. Date of manufacture (month and year, which may be combined with the serial number)

c. Serial number

d. Fluid type

3.4.3.5.3 Location of Marking

The part number should be located to be readable after assembly of the part in the complete unit.

3.4.3.5.4 Part and Subassembly Marking

Each part and subassembly, except the following, should be marked with the appropriate part or subassembly part numbers:

a. Components that are permanently assembled by welding, brazing, soldering, or riveting should carry the subassembly part number.

b. Components that do not have suitable or sufficient surface for the part number.

c. Components where marking would impair the function or structural integrity.

3.4.3.5.5 Type of Marking

Marking should be such that they will not be obliterated or defaced as a result of service usage.

3.4.4 Interface Definition for Wheel and Brake Detail Design

The wheel and brake detail specification provided by the procurement activity should define the following interface information together with a statement of the basis for the information, whether analytical, test, or estimated.

3.4.4.1 Tires

The following tire data should be provided:

a. Size designation

b. Tire construction (Bias or Radial)

c. Ply rating

d. Speed rating

e. Load rating

f. Dynamic load

g. Rated inflation pressure

h. Load deflection curves (rated deflection)

I. Weight (nominal and maximum)

j. Minimum and Maximum Tire dimensions:

    1. Grown Section Width

    2. Grown Outside Diameter

    3. Grown Shoulder Width

    4. Grown Shoulder Diameter

k. Static loaded radius.

L. Flat tire radius

m. Aspect ratio

n. Polar moment of inertia

o. Vertical, lateral, and fore and aft spring rates over the full range of operations.

p. Approximate bottoming load

q. Tread skid depth

r. Wheel dimensions:

    1. Bead ledge width (minimum)

    2. Wheel rim size

    3. Width between flanges

    4. Bead ledge diameter

    5. Flange height

3.4.4.2 Shock Strut- Axle

The following related shock strut-axle information should be provided in a format that will support compatible wheel and brake design:

a. Dimensions

b. Material

c. Finish

d. Load distribution into the axle attachment

e. Deflection with load

f. Fore and aft spring rates

g. Damping

h. Temperature limitations

I. Axle centerline attitude relative to ground line

j. Strength limits

k. Torsional spring rate

3.4.4.3 Hydraulics

The aircraft hydraulic information should be provided as follows:

a. Hydraulic fluid description and temperature limitations

b. Normal and maximum steady state back pressure

c. Hydraulic fitting callout

d. Definition of requirements for braking at gear retraction, if used

e. Maximum fluid displacement

f. Maximum pressure rate of application

g. Spike surge definition

h. Parking brake pressure (maximum and minimum)

3.4.4.4 Skid Control System

The following information should be provided, when available:

a. Wheel speed transducer interface dimensions

b. Envelope and mounting information

c. Temperature limitations

d. Dynamic pressure ramp rates

e. Concentricity of drive mechanism

f. Wheel speed transducer drive interface requirements

3.4.4.5 Aircraft General

The following general information should be provided:

a. Wheel well temperature profile

b. Orientation on aircraft gear up and gear down

c. Critical g loads during all phases of the operational environment

d. Maximum allowable dimensional envelope

3.5 Capability Requirements

3.5.1 Performance

The wheels and brakes should satisfy the test requirements specified in Section 4.

3.5.2 Reliability

Satisfactory completion of all applicable tests in Section 4 should constitute demonstration of compliance.

3.5.3 Maintainability

ARP813 should be used as a design guide. The requirements should be consistent with the system program requirements. Quantitative task allotments should be identified.

3.5.4 Braking Capacity

The brake energy absorption capacity of the installed wheel and brake assembly should be defined in the detailed specification and should consider all aspects of the aircraft detail specification and anticipated realistic operational requirements. It is recommended that the design service life and the design usage be based on the mission requirements with due consideration of the following factors:

a. Total number of flights

b. Total number and type of landings

c. Total service years

d. Mission mix or number of flights of each mission

e. Any other special requirements, such as functional check flights, ground maintenance operational checks, etc.

f. Special operations, such as quick turnaround

Unless otherwise specified, the brake should be designed to provide the number of dynamometer stops defined in Tables 3 and 4. Separate heat sinks are used for Table 3 and Table 4 testing.

Testing to Table 3 is intended to cover capacity requirements, principally for sizing and performance limits, including safety of flight. Table 4 is intended to represent durability requirements under realistic average operating conditions in actual service.

3.5.4.1 Landing and Takeoff Brake Capacity Analysis

The design brake energy should be the result of a rational aircraft and aircraft operational analysis and should be approved by the procurement activity. For the analysis, the following criteria should apply unless stated otherwise: On the landplane landing, maximum landing and rejected takeoff conditions, the brakes should be applied to a torque level associated with the effectively available dry concrete tire-friction level. The ground velocity of brake application should be as defined in paragraph 2.3.5. The service energy condition should be defined from the average service landing weight, landing rollout, and braking techniques anticipated for the aircraft. The landplane landing, maximum landing, and maximum takeoff weights should be as defined in AS8860 or JSSG-2006.

3.5.4.2 Operational Energy Analysis

An aircraft operational energy analysis that considers the total operational environment of the aircraft should be performed. The results of the analysis should be approved by the procurement activity and reflected in the brake test program.

3.5.4.2.1 Turnaround Capacity

If a mission turnaround requirement is placed upon the total aircraft system, a special brake dynamic torque test sequence demonstrating the required capability should be conducted. The test sequence should be subject to the approval of the government procurement activity.

TABLE 3 - WHEEL BRAKE CAPACITY REQUIREMENTS

Type of Aircraft	No. of Dynamometer Stops	Average Rate of Deceleration [A] ft/s^2 (m/s^2)	Aircraft Weight Condition	Energy Credit [B] Reversed Propeller or Engine Thrust	Energy Credit [B] Drag Parachute
1. Rotary Wing	20	6 (1.8)	Basic Design Gross	Not Applicable	Not Applicable
	1	8.8 (2.7)	Maximum Landing Gross	No	No
2. Research and Other Types Not Listed	As Specified By The Procurement Activity	As Specified By The Procurement Activity	As Specified By The Procurement Activity	As Specified By The Procurement Activity	As Specified By The Procurement Activity
3. Land and Carrier Based:					
Fixed Wing (Including USAF Safety of Flight)	30 [C]	10 (3.0)	Landplane Landing Design Gross	Yes [D]	Yes [D]
	3 [C]	10 (3.0)	Maximum Landing Gross	No	Yes [D]
	1 [F]	10 (3.0)	Maximum Landing Gross [E]	No	No
	1 [F]	10 (3.0)	Maximum Takeoff Gross [E]	No	No
Fixed Wing (USAF)	100	10 (3.0) [G]	Landing Design Gross	No	Yes
	5	10 (3.0) [G]	Maximum Landing Gross	No	Yes
	1 (new Brake)	10 (3.0) [G]	Maximum Takeoff Gross	No	No
	1 (Fully Worn Brake)	10 (3.0) [G]	Maximum Takeoff Gross	No	No
Navy Tactical (Navy)	45	10 (3.0) [G]	Landing Design Gross	No	Yes
	5	10 (3.0) [G]	Maximum Landing Gross	No	Yes
	1 (new Brake)	10 (3.0) [G]	Maximum Takeoff Gross	No	No
	1 (Worn Brake)	10 (3.0) [G]	Maximum Takeoff Gross	No	No

Flag Notes:

A Aircraft deceleration and dynamometer deceleration should be consistent with the approved brake energy analysis.

B The amount of energy credit should be approved by the procurement activity in each instance.

C The 30-3 dynamic torque sequence should be conducted with 3 sequences of 10 landplane landing design gross weight (normal energy) stops followed by one maximum landing gross weight (overload energy) stop.

D If used in standard landing procedure.

E Whichever condition (Maximum Landing Gross or Maximum Takeoff Gross) is the more critical should be tested. Fire if present during and following the RTO should not exceed the height of the tire.

F A new heat sink should be used for the RTO stop. For steel and carbon brake designs, the brake may be conditioned prior to the RTO demonstration by three 50% landplane landing design energy break-in stops (30 stop).

G Stop distance or lower deceleration may be used in accordance with aircraft performance requirements and as approved by procurement agency.

General Notes:

1. The calculations for Table 3 capacity requirements should represent the worst situation as they affect overall sizing of the brakes.
2. Maximum operating pressure should be applied to the brake assembly and released prior to each of the 30-3-1 and 45-5-1/100-5-1 stop demonstrations.
3. Success criteria:
   a. 30-3 and 45-5/100-5 Sequence:
      (1) KE absorption
      (2) Torque pressure relationship met
      (3) No failed parts permitted
      (4) No malfunctions
      (5) No lining fusing
      (6) Fuse plugs must not release
      (7) Thermal limits met
      (8) Deceleration achieved
   b. RTO Test:
      (1) KE absorption
      (2) Stop distance
      (3) Brake torque pressure relationship met
      (4) No malfunctioning
      (5) Fuse plug release, if temperature limits are exceeded
      (6) Thermal limits met as applicable

TABLE 4 - WHEEL BRAKE FIELD SERVICE LIFE SPECTRUM

Applicable to all land and carrier based type aircraft listed on Line 3 of Table 3. All conditions should represent the average expected operational aircraft in service.

Brake Stop Description	Typical Field Service Landing	Short Field Landing	Overweight Landing [C]	Aborted Mission
Kinetic Energy- ft-lb (J)				
Deceleration- ft/s^2 (m/s^2)				
Tire Load - lb (N)				
Brake-On Velocity (kts)				
Flywheel Inertia Equivalent - lb (N)				
Taxi Distance at 30 knots – ft (m)	16 000 (5000) before and after stop	6000 (1829) before and after stop	16 000 (5000) before and after stop	6000 (1829) before stop
Number of 30 knot stops during taxi (one of which is to be at maximum effort)	2 before and after stop	2 before and after stop	2 before and after stop	2 before stop
Number of stops and sequences of stops at each condition (read left to right and top to bottom)	5 5 20 60 5 [A] 5	- 1 1 - - -	1 - - 3 1 -	- - - - - 1 [B]
TOTAL	100	2	5	1

Flag Notes:

A The wear data obtained should be used to support a calculation of the safe removal point in aircraft service. The stack of heat sink members and/or linings should be machined to their respective fully worn thickness for the final 12-stop demonstration.

B The worn brake RTO stop is conducted to determine the aborted mission energy capacity and stopping distance of a worn brake and to demonstrate the ability of the brake to complete an aborted mission stop to reasonable conditions. See General Note 1 below.

C Maximum energy landing.

General Notes:

1. For Table 4 the analysis should be based on the realistic average conditions that are expected during service use of the aircraft. Testing may be accomplished using a shaft dynamometer for all sequences.
2. The brake energy absorbed during taxi should be consistent with the operational environment defined for the specific aircraft. Cooling air of 30 knots may be used during all taxis. Taxi snubs during rolling may be specified if applicable to the aircraft system.
3. Wear data achieved, as testing proceeds should be extrapolated to judge the conformity of performance to the design goal.
4. Maximum operating pressure should be applied to the brake assembly and released prior to each of the 108 stop demonstrations
5. Success criteria:
   a Wear within limits
   b. No detrimental brake drag
   c. No detrimental component distortion
   d. Torque pressure relationship met
   e. Thermal limits met as applicable
   f. No failed parts
   g. No binding
   h. No malfunctioning
   i. Stop distance achieved

3.5.4.3 Additional Testing

During the development program, consideration should be given to conducting special tests to characterize performance to the following operating limits:

a. Hot brake parking - kinetic energy limit, if any, below Table 3 overload energy at which parking pressure is applied following the stop for a period of 1-hour without seal leakage or other degradation that would limit the brake from continued use.

b. Structural functional integrity or metal creep after heat exposure and parking

c. Fuse plug release and energy limits

d. Dynamic compatibility with support structure

e. Dynamic compatibility with antiskid control system

3.5.5 Wheel Capacity

The load capacity of each landing wheel on an aircraft should be equal to or greater than the maximum load that the wheel will be subjected to the maximum towing or taxiing design gross weight of the aircraft. Nose wheels should carry a dynamic rating equivalent to the actual maximum dynamic load for the condition of load shifting onto the nose gear during braking. In cases where auxiliary wheels do not normally support structural loads (as in wingtip protection wheels), the wheel capacity should be determined by the procurement activity, based on appropriate dynamic loading calculations. The procurement activity should provide loading spectrum for the main and auxiliary wheels based upon static and dynamic conditions.

3.5.6 Compatibility Requirements

Wheel and brake assemblies should be subjected to laboratory tests for the purpose of proving compatibility of the wheel and brake assembly with the airplane brake system. Dynamometer stops should be performed at normal braking energy levels with the brakes actuated by a system that simulates a pilot's commands through the airplane's braking system, including any skid control provisions if they are available for testing and only if demanded by the procuring activity. A torque requirement analysis that considers wet and dry brake static and dynamic torque requirements of the brake assembly during the expected operational aircraft environment should be performed. The results of the analysis should produce the brake pressure torque requirements definition in the procurement specification and should be demonstrated during qualification testing.

These compatibility tests should be designed to accumulate evidence that:

a. The overall brake system has characteristics that permit the pilot to safely control the airplane's velocity during ground operations.

b. The individual system components function as required to achieve overall system performance.

c. The durability or structural integrity on any individual brake system component is not impaired by operating under simulated braking conditions and that the system components, including laboratory test axles that simulate the structural deflection characteristics of the aircraft axle, fit together and function as required.

3.5.7 Environment

The wheel and brake equipment should be compatible with the intended air vehicle environmental requirements.

4. QUALITY ASSURANCE PROVISIONS

4.1 Product Verification

Product verification of design and performance requirements may be made by analysis, demonstration, similarity, or by tests.

4.1.1 Stress Analysis

The manufacturer should prepare a stress analysis covering the wheel and brake assembly. All static and fatigue loads should be analyzed and margins of safety noted for critical parts.

4.2 Test Methods

4.2.1 Radial Load Test

This test should be performed by applying the radial load to the wheel through a tire of proper size and fit inflated to an initial pressure equal to the rated inflation pressure (or as specified in the procurement document for shipboard operations). Either air or water inflation may be used. If the tire is filled with water, the water should be bled off during loading to approximate the same tire deflection that would result if air inflation were used, and the inflation pressure should not exceed the pressure at maximum tire deflection. The load should be applied to the wheel and perpendicular to the axle centerline by means of an axle passing through the hub. The tire should be loaded directly against a flat, nondeflecting surface. Deflection and permanent set readings should be taken at suitable points on the wheel to indicate deflections of the wheel rim at the bead seat, and other critical areas identified by structural analysis. Wheels intended for tubeless tire mounting should be tested with these mountings unless otherwise specified. If the radial load component of the combined load test exceeds the radial load test requirement, then the radial load test may be omitted. The required radial load tests are specified below.

4.2.1.1 Yield Radial Load Test

The wheel should support the yield radial load for 10 seconds when applied consecutively at 90 degrees, 180 degrees, and 270 degrees, followed by three more load applications at the 0 degree position with brake assembly or a suitable simulation installed. The 0 degree position should be the most critical load contact point. The 90 degree increments may be altered when structural conditions indicate. The successive loadings at the 0 degree position should not cause radial permanent set increments of increasing magnitude. The permanent set increment caused by the last loading (at the 0 degree position) should not exceed 5% (or 0.005 inch (0.127 mm) whichever is greater) of the total deflection caused by the last loading. There should be no yielding of the wheel that could result in loose bearing cups, air leakage, or interference in any critical clearance areas (as defined by the procuring activity) resulting in damage or impaired performance of the wheel and brake assembly. The main wheel shall be tested with the brake installed and it shall be determined that no interference exists. The bearing cups, cones, and rollers should be used for this test.

4.2.1.2 Ultimate Radial Load Test

The ultimate load should be applied at the 0 degree position of the same wheel on which the yield radial loads were applied. The wheel should support the ultimate load for 10 seconds after which there should be no cracks in any areas. The bearing cones may be replaced with conical bushings, but the cups should be used. If desired, a tubeless tire may be replaced with tire and tube.

4.2.2 Design Landing Radial Load Test

The load should be applied in the same manner as described in 4.2.1. The load should be supported for not less than 10 seconds, and the resulting permanent set should not produce loose bearing cups, air leakage, interference in critical running areas (as defined by the procuring activity) resulting in damage or impaired performance of the wheel and brake assembly. The main wheel shall be tested with the brake installed and it shall be determined that no interference exists. The tire inflation pressure should be the maximum design operating pressure for the condition being simulated. For Navy aircraft intended for shipboard use, the wheel should be loaded for this test condition through a 1-5/8 in (41 mm) diameter cable or steel bar that simulates statically the wheel design landing load plus the load imposed by rolling over or landing on a 1-5/8 in (41 mm) diameter cable. If a cable is used, the specimen should be at least 3 ft (0.914 m) long with ends secured to prevent looseness. Unless otherwise specified by the procurement activity, the wheel should be loaded perpendicular to the axle centerline.

4.2.3 Combined Load Test

The combined load test should be performed by applying the load to the wheel through a tire inflated to an initial pressure equal to the rated inflation pressure or the carrier design operating pressure. Air or water inflation pressure may be used. If the tire is filled with water, the water should be bled off during loading to approximate the same tire deflection that would result if air inflation were-used, and inflation should not exceed the pressure at maximum tire deflection. Yield loads should be applied in both inboard and outboard directions on the same wheel and at the ground angle and magnitude determined by the procurement activity in accordance with applicable specifications. The wheel and tire assembly should be mounted on an axle passing through the hub. The tire should be loaded directly against a flat, nondeflecting surface so that the combined load is as ascertained above. The loads should be applied simultaneously, either continuously or in increments of approximately 10% of the specified values. Readings should be taken at suitable points on the wheel to indicate deflections and permanent sets. The required combined load tests are specified below.

For the yield and ultimate combined load tests, it is permissible to limit the tire deflection to the deflection achieved under the limit load conditions of vertical and lateral loads by the use of load transfer blocks (saddle type) that bear directly on the wheel rim structure. An alternative, where justifiable, is the use of tire inflation exceeding the aforementioned values.

4.2.3.1 Yield Combined Load Test

The wheel should support the components of the yield combined load applied consecutively at 90 degrees, 180 degrees, and 270 degrees, followed by three more load applications at the 0 degrees position with brake assembly or a suitable simulation installed. Each load application should be sustained for a minimum of 10 seconds. The 0 degree position should be the most critical load contact point. The 90 degree increments may be altered when structural conditions dictate. The successive loadings at the 0 degree position should not cause permanent set increments of increasing magnitude. There should be no yielding of the wheel that could result in loose bearing cups, air leakage through the wheel or past the wheel seal, or interference in any critical clearance areas (as defined by the procuring activity) resulting in damage or impaired performance of the wheel and brake assembly. The main wheel shall be tested with the brake installed and it shall be determined that no interference exists. The bearing cups, cones, and rollers should be used for this test. A conventional tire and tube may be used when testing a tubeless wheel only when it has been demonstrated that pressure will be lost due to the inability of the tire bead to remain properly positioned when under load.

4.2.3.2 Wheel-Brake Interference

For wheel assemblies used in conjunction with brakes, the yield load test of 4.2.1.1, 4.2.2, and 4.2.3.1 should be run as indicated with the brake assembly or a suitable simulation installed, and it should be determined that no interference exists during the tests by visual confirmation and/or following the tests using an interference marking media.

4.2.3.3 Ultimate Combined Load Test

The ultimate combined load should be applied at the 0 degree position of the same wheel on which the respective yield combined load tests were performed. The ultimate load should be sustained for a minimum of 10 seconds after which there should be no cracks in any area. The wheel should be loaded in the most critical direction. The bearing cones may be replaced with conical bushings, but the cups should be used. Tubeless tire mountings may be replaced with a tire and tube.

4.2.4 Burst Test

The burst test load should be applied to the wheel by means of hydrostatic pressure in the tire. A tire and tube may be used when testing a tubeless tire wheel by adding the necessary valve hole to the test article. Wheels should be tested to a burst pressure equivalent to the rated tire pressure multiplied by the wheel burst factor specified in Table 2 of this document. If the burst pressure of the tire is less than the calculated wheel burst pressure, then test to the burst pressure of the tire. Over-inflation devices may be removed or isolated for the purpose of accomplishing the test.

4.2.5 Roll Test

The roll test should consist of a series of landings or a continuous roll of the wheel assembly against a rotating road wheel. Roll tests should be performed with tires having the same size and ply rating and construction (bias or radial) as will be installed for aircraft usage. Tubeless tires should be used when testing tubeless wheels. Roll test tire inflation pressure should be the flat-surface inflation applicable to the loading condition imposed by the procurement activity. For each loading condition, the roll test tire inflation pressure should be constant. All tire test pressures, road wheel sizes, and mileage should be reported in the qualification test report. Roll tests should be performed in accordance with the following procedures and conditions and should not result in cracks or other evidence of failure. Final inspection should be made with all hardware removed from the structural components.

a. Thermal Conditioning: Prior to roll testing, all wheels that have been shot peened, roll burnished, or subjected to any other cold-working processes should have been subjected to thermal conditioning equivalent to the cumulative temperature-time history resulting from brake heat dissipation experienced during the dynamic torque tests of 4.2.7 except for the rejected takeoff condition. Thermal conditioning may be accomplished by performing dynamic torque testing, by simulation of the thermal distribution in the wheel using a simulated brake heat sink to produce the same temperatures encountered during the dynamic torque testing, or by a suitable oven heat soak.

b. Stress Measurement: The stresses in the bead seat or other areas affected by the tire should be measured for each loading condition and for each test inflation pressure used. The stress measurements should be reported in the qualification test report. Any change in the tire supplier construction or ply rating should require retest of the wheel or the generation of a suitable comparative stress analysis.

c. Minimum Roll Distance: The applied loading conditions and roll distances should be supplied by the procurement activity. The minimum requirement should be 3000 miles (4800 km) [2000 miles (3219 km) for helicopter wheels] at loads encountered on the aircraft at maximum taxi gross weight.

   1. A suitable portion of the roll test should be conducted at the static rated capacity. A minimum combined load roll of 75 miles (121 km) in each direction should be conducted with combined radial and side loads provided by the procuring activity; normally corresponding to those produced by a 0.25 g turn or 25% of the radial load at maximum design gross weight.

   2. Helicopter wheels are not subject to the loading conditions in (1) above unless specified in the detail specification. Instead, helicopter wheels should be rolled 2000 miles (3219 km) minimum with an applied radial load not less than the static wheel reaction based on helicopter maximum taxi gross weight.

   3. Wheels for carrier-based aircraft should be subjected to a roll test that simulates catapult takeoff loads. The conditions for this test should be approved by the procurement activity.

   4. Five percent of the straight roll portion of the roll test for carrier-based aircraft wheels should be conducted with the tire inflated to the pressure required for shipboard operation.

   5. As part of the roll test, a 50-mile straight roll test at rated load with 90% recommended tie-bolt torque (or 90% preload if the angle torque method applies) should be performed as applicable.

d. Extended Roll Test: Upon completion of the minimum roll requirement, the roll test conditions should be repeated until wheel failure occurs. After the minimum portion of the test has been completed, tie bolt or bearing failure should not be construed as wheel failure. The roll to failure portion of this test may be concluded prior to failure provided a total roll test distance of 6000 miles (9656 km) has been obtained on the test wheel. The qualification test report should be amended to include these data.

e. Alternative Tests: When specified by the procurement document, alternative test arrangements that represent combined loads or spectrum tests may be required.

4.2.6 Tubeless Wheel Pressure Test

4.2.6.1 Dynamic Pressure Test

The tubeless tire, whose growth has stabilized, and the wheel assembly should be rolled under the load specified by the straight roll test (4.2.5) for 25 miles (40 km) with no pressure drop greater than 5%. Mileage accumulated during this test may be used in computing the total mileage in the roll test

4.2.7 Dynamic Torque Test

The dynamic torque tests should be in accordance with the conditions outlined on the applicable specification drawing or in the procurement specification. Unless otherwise specified, the number of stops should be as specified in Section 3. The wheel and brake should successfully complete the test sequence defined in Tables 3 and 4. Table 3 testing is fundamentally for the purpose of establishing braking capacity and performance capability. Table 4 testing is a demonstration of field service life. Success criteria listed on Tables 3 and 4 apply.

Brake wear data from each of the landing test conditions should be extrapolated and a curve should be plotted that relates brake life for the various landing conditions represented. Tubeless tires should be used where applicable.

During these tests, the brake assembly may be disassembled to enhance learning during development-qualification testing. Parts should not be changed or removed except as noted at the beginning of taxiing per Table 4. The brake may have the lining dust removed by the use of an air hose or equivalent with the wheel removed. When the wheel assembly is reinstalled, the brake-rotating disk should be placed in the same position and in relationship with the other disks and wheel disk drive keys, as it was when the wheel was removed. After completion of the test, all parts should be cleaned and inspected for defects. No parts should have cracked during these tests to the extent of compromising the structural integrity during the 20, 30-3, or 100-5 stop condition of Table 3, or the first 107 stop conditions of Table 4. If cracks or defects are present, an analysis should be performed to determine the origin and cause of the defect and the potential effect of continued service. Tubeless tires should be used when testing tubeless wheels. The tire should be the same size and ply rating and construction type, as the aircraft installed tire. The dynamic torque tests should be in accordance with the following procedure:

a. Test to design requirements as furnished by the procurement activity.

b. A flywheel weight and/or electric inertia should be selected that provides an inertia equivalent approximately equal to, but not less than: the effective mass of aircraft per brake based on the rational analysis of 3.5.4.1. Energy and drag forces caused by auxiliary braking means such as aerodynamic drag, reversed thrust, and drag chutes may be accommodated by adjusting the inertia downward from the actual aircraft mass. In any cases where residual engine thrust exceeds these auxiliary-braking forces, added inertia should be used. For testing in accordance with Table 3, the energy credit is disallowed in certain cases. The inertia adjustments mentioned above do not apply in such cases.

c. The flywheel speed at application of the brake should be determined as the peripheral speed that, under the chosen flywheel weight, will give the required kinetic energy. Brake application speed should be the actual speed when using electrical simulation dynamometer.

d. The following should be accomplished in the order stated: The flywheel should be brought to the proper velocity, the test wheel should be landed, the prescribed load should be applied, brake pressure should be applied, and the test unit should be brought to a complete stop. The design specification should identify the required deceleration. The average deceleration for any five consecutive landplane landing weight stops should be equal to the correct deceleration for the test condition. All stops that fail to meet the minimum required performance must be compensated by a comparable increase in deceleration within the next five stops, alternatively, added testing, which satisfactorily demonstrates the capability of the brake to produce the deceleration required, may be accomplished.

e. During the dynamic torque test, the brake pressures required to develop static torque suitable to comply with the torque compatibility analysis (3.5.6) should be determined under the following conditions:

1. With the brake at room temperature, approximately 70 °F (21 °C)

2. With the brake heated by a landplane landing design gross weight energy stop and with the static torque test applied as soon as possible after completion of that stop consistent with the safety precautions that must be taken

3. At less than 10%, at 50% approximately, and again after 90% of the number of stops required by Table 4, or as otherwise specified by the procurement activity. (This test may be conducted by applying a tangential force at the static radius of the tire.)

4. If carbon composite or other water absorbing material is used as brake lining material and the aircraft is designated for shipboard operation, the following additional test should be performed:

0.5 gal (1892 ml) of water should be sprayed into heat sink cavity of the brake. The brake should be able to produce a static torque equivalent to parking a maximum gross weight airplane in any orientation on a 10 degrees slope without movement. The hydraulic pressure for this test should contribute to establishing the emergency braking pressure for the airplane.

f. During the dynamic torque test, the following data should be recorded:

1. Weight and description of wheel, brake, and tire used

2. Flywheel diameter, inertia equivalent, speeds, and kinetic energies

3. The test facility should obtain time-temperature relationships of the following components for the conditions noted and present the data in the formal qualification test report:

(a) Hydraulic fluid

(b) Wheel adjacent to the fuse plug (if incorporated)

(c) Bead ledge above each brake

(d) Other critical components

(e) Axle

(f) Brake heat sink