(2) Minor changes in tyre characteristics.

(3) Minor changes in unsprung mass (e.g. brakes).

(4) Local strengthening or minor sizing changes to the landing gear.

To allow justification by analysis for the reserve energy requirement, neither the shock strut nor the tyres should bottom during the reserve energy analysis or the tests upon which the analysis is correlated.

4. LIMIT FREE DROP TESTS.

a. Compliance with CS 25.723(a) may be shown by free drop tests, provided they are made on the complete aeroplane, or on units consisting of a wheel, tyre, and shock absorber, in their proper positions, from free drop heights not less than--

(1) 475 mm (18.7 inches) for the design landing weight conditions; and

(2) 170 mm (6.7 inches) for the design takeoff weight conditions.

b. If aeroplane lift is simulated by air cylinders or by other mechanical means, the weight used for the drop must be equal to W. If the effect of aeroplane lift is represented in free drop tests by a reduced weight, the landing gear must be dropped with an effective weight equal to

$$W_e = W\left[\frac{h + (1 - L)d}{h + d}\right]$$

where:

W_e = the effective weight to be used in the drop test (kg);

h = specified free drop height (mm);

d = deflection under impact of the tyre (at the approved inflation pressure) plus the vertical component of the axle travel relative to the drop weight (mm);

W = W_M for main gear units (kg), equal to the static weight on that unit with the aeroplane in the level attitude (with the nose wheel clear in the case of nose wheel type aeroplanes);

W = W_T for tail gear units (kg), equal to the static weight on the tail unit with the aeroplane in the tail-down attitude;

W = W_N for nose wheel units (kg), equal to the vertical component of the static reaction that would exist at the nose wheel, assuming that the mass of the aeroplane acts at the centre of gravity and exerts a force of 1.0 *g* downward and 0.25 *g* forward; and

L = ratio of the assumed aeroplane lift to the aeroplane weight, but not more than 1.0.

c. The drop test attitude of the landing gear unit and the application of appropriate drag loads during the test must simulate the aeroplane landing conditions in a manner consistent with the development of rational or conservative limit loads.

d. The value of *d* used in the computation of W*e* in paragraph 4.(b) of this AMC may not exceed the value actually obtained in the drop test.

5. RESERVE ENERGY FREE DROP TESTS.

a. Compliance with the reserve energy absorption condition specified in CS 25.723(b) may be shown by free drop tests provided the drop height is not less than 69 cm (27 inches).

b. If aeroplane lift is simulated by air cylinders or by other mechanical means, the weight used for the drop must be equal to W. If the effect of aeroplane lift is represented in free drop tests by an equivalent reduced weight, the landing gear must be dropped with an effective weight:

$$W_e = \left[\frac{Wh}{h+d}\right]$$

where the symbols and other details are the same as in paragraph 4 above.

[Amdt 25/2]

CS 25.729 Extending and retracting mechanisms

ED Decision 2016/010/R

(See AMC 25.729)

(a) *General*. For aeroplanes with retractable landing gear, the following apply:

(1) The landing gear extending and retracting mechanisms, wheel well doors, and supporting structure, must be designed for –:

(i) the loads occurring in the flight conditions when the gear is in the retracted position;

(ii) the combination of friction loads, inertia loads, brake torque loads, air loads, and gyroscopic loads resulting from the wheels rotating at a peripheral speed equal to 1·23 V_{SR} (with the flaps in takeoff position at design take-off weight), occurring during retraction and extension at any airspeed up to 1·5 V_{SR1} with the wing-flaps in the approach position at design landing weight, and

(iii) any load factor up to those specified in CS 25.345(a) for the wing-flaps extended condition.

(2) Unless there are other means to decelerate the aeroplane in flight at this speed, the landing gear, the extending and retracting mechanisms, and the aeroplane structure (including wheel well doors) must be designed to withstand the flight loads occurring with the landing gear in the extended position at any speed up to 0·67 V_C.

(3) Landing gear doors, their operating mechanism, and their supporting structures must be designed for the yawing manoeuvres prescribed for the aeroplane in addition to the conditions of airspeed and load factor prescribed in sub-paragraphs (a)(1) and (2) of this paragraph.

(b) *Landing gear lock*. There must be positive means to keep the landing gear extended in flight and on the ground. There must be positive means to keep the landing gear and doors in the correct retracted position in flight, unless it can be shown that lowering of the landing gear or doors, or flight with the landing gear or doors extended, at any speed, is not hazardous.

(c) *Emergency operation*. There must be an emergency means for extending the landing gear in the event of –

(1) any reasonably probable failure in the normal extension and retraction systems; or

(2) the failure of any single source of hydraulic, electric, or equivalent energy supply.

(d) *Operation test.* The proper functioning of the extending and retracting mechanisms must be shown by operation tests.

(e) *Position indicator and warning device.* If a retractable landing gear is used, there must be a landing gear position indicator easily visible to the pilot or to the appropriate crew members (as well as necessary devices to actuate the indicator) to indicate without ambiguity that the retractable units and their associated doors are secured in the extended (or retracted) position. The means must be designed as follows:

(1) If switches are used, they must be located and coupled to the landing gear mechanical systems in a manner that prevents an erroneous indication of 'down and locked' if the landing gear is not in a fully extended position, or of 'up and locked' if the landing gear is not in the fully retracted position. The switches may be located where they are operated by the actual landing gear locking latch or device.

(2) The flight crew must be given an aural warning that functions continuously, or is periodically repeated, if a landing is attempted when the landing gear is not locked down.

(3) The warning must be given in sufficient time to allow the landing gear to be locked down or a go-around to be made.

(4) There must not be a manual shut-off means readily available to the flight crew for the warning required by sub-paragraph (e)(2) of this paragraph such that it could be operated instinctively, inadvertently or by habitual reflexive action.

(5) The system used to generate the aural warning must be designed to minimise false or inappropriate alerts.

(6) Failures of systems used to inhibit the landing gear aural warning, that would prevent the warning system from operating, must be improbable.

(7) A clear indication or warning must be provided whenever the landing gear position is not consistent with the landing gear selector lever position.

[Amdt 25/4]
[Amdt 25/14]
[Amdt 25/18]

AMC 25.729 Extending retracting mechanisms

ED Decision 2016/010/R

1. PURPOSE. This Acceptable Means of Compliance (AMC) provides guidance material for use as an acceptable means of demonstrating compliance with the landing gear retracting mechanism requirements of the Certification Specification (CS) for large aeroplanes.

2. RELATED DOCUMENTS.

a. Related Certification Specifications. CS 25.729 and other paragraphs relating to landing gear extending and retracting mechanisms installations together with their applicable AMCs, if any. Paragraphs which prescribe requirements for the design, substantiation, and certification of landing gear extending and retracting mechanisms include:

CS 25.111 Take-off path

CS 25.301 Loads

CS25.303 Factor of safety

CS 25.305 Strength and deformation

CS 25.307 Proof of structure

CS 25.333 Flight envelope

CS 25.471 General [Ground loads]

CS 25.561 General [Emergency Landing Conditions]

CS 25.601 General [Design and Construction]

CS 25.603 Materials

CS 25.605 Fabrication methods

CS 25.607 Fasteners

CS 25.609 Protection of structure

CS 25.613 Material strength properties

CS 25.619 Special factors

CS 25.621 Casting factors

CS 25.623 Bearing factors

CS 25.625 Fitting factors

CS 25.729 Extending and retracting mechanisms

CS 25.777 Cockpit controls

CS 25.779 Motion and effect of cockpit controls

CS 25.781 Cockpit control knob shape

CS 25.863 Flammable fluid fire protection

CS 25.869 Fire protection: systems

CS 25.899 Electrical bonding, etc.

CS 25.1301 Function and installation

CS 25.1309 Equipment, systems and installations

CS 25.1315 Negative acceleration

CS 25.1316 System lightning protection

CS 25.1322 Warning, caution and advisory lights

CS 25.1353 Electrical equipment and installations

CS 25.1357 Circuit protective devices

CS 25.1360 Precautions against injury

CS 25.1435 Hydraulic systems

CS 25.1515 Landing gear speeds

CS 25.1555 Control markings

CS 25.1583 Operating limitations

CS 25.1585 Operating procedures

b. FAA Advisory Circulars (AC's).

AC 20-34D	Prevention of Retractable Landing Gear Failures
AC 23-17B	Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships
AC 25.1309-1A	System Design and Analysis
AC 25-7C	Flight Test Guide for Certification of Transport Category Airplanes
AC 25-22	Certification of Transport Airplane Mechanical Systems
AC 43.13-1B	Acceptable Methods, Techniques and Practices - Aircraft Inspection and Repair.

c. Federal Aviation Administration Orders.

Order 8110.4C Type Certification Process

Advisory Circulars and FAA Orders can be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785.

d. Society of Automotive Engineers (SAE) Documents.

SAE AIR-4566	Crashworthiness Landing Gear Design
SAE ARP-1311A	Landing Gear - Aircraft
ISO 7137	Environmental Conditions and Test Procedures for Airborne Equipment (not an SAE document but is available from the SAE)

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

e. Industry Documents.

(1) EUROCAE ED-14G/RTCA, Inc., Document No. DO-160G,

Environmental Conditions and Test Procedures for Airborne Equipment.

(2) AMC 20-115, Software Considerations in Airborne Systems and Equipment Certification.

These documents can be obtained from EUROCAE, 17 rue Hamelin, 75783 Paris Cedex 15, France

f. Military Documents.

MIL-STD-810 Environmental Test Methods and Engineering Guidelines

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

4. DISCUSSION.

a. Intent of rule. (Reference CS 25.729 Extending and retracting mechanisms)

This rule provides minimum design and certification requirements for landing gear actuation systems to address:

(1) Structural integrity for the nose and main landing gear, extending and retracting mechanism(s), doors, gear supporting structure for loads imposed during flight;

(2) Positive locking of the kinematic mechanisms;

(3) Redundant means of extending the landing gear;

(4) Demonstration of proper operation by test;

(5) Gear up-and-locked and down-and-locked position indications and aural warning;

(6) Equipment damage from tyre burst, loose tread, and wheel brake temperatures.

b. Demonstration of extending and retracting mechanisms proper functioning. (Reference CS 25.729(d) Operation test)

Guidance addressing flight testing used to demonstrate compliance with this paragraph may be found in FAA Advisory Circular (AC) 25-7C, Flight Test Guide for Transport Category Aeroplanes, Chapter 4, Section 4, paragraph 52, dated 16 October 2012.

c. Extending and retracting mechanisms indication. (Reference CS 25.729(e) Position indicator and warning device)

(1) When light indicators are used, they should be arranged so that-

(i) A green light for each unit is illuminated only when the unit is secured in the correct landing position.

(ii) A warning light consistent with CS 25.1322 is illuminated at all times except when the landing gear and its doors are secured in the landing or retracted position.

(2) The warning required by CS 25.729(e)(2) should preferably operate whatever the position of wing leading- or trailing-edge devices or the number of engines operating.

(3) The design should be such that nuisance activation of the warning is minimised, for example-

(i) When the landing gear is retracted after a take-off following an engine failure, or during a take-off when a common flap setting is used for take-off and landing;

(ii) When the throttles are closed in a normal descent; or

(iii) When flying at low altitude in clean or low speed configuration (special operation).

(4) Inhibition of the warning above a safe altitude out of final approach phase either automatically or by some other means to prevent these situations is acceptable, but it should automatically reset for a further approach.

(5) Means to de-activate the warning required by CS 25.729(e) may be installed for use in abnormal or emergency conditions provided that it is not readily available to the flight crew, i.e. the control device is protected against inadvertent actuation by the flight crew and its de-activated state is obvious to the flight crew.

d. Definitions. For definitions of V_{SR} and V_C, see CS-Definitions Chapter 2, entitled 'Abbreviations and symbols'.

[Amdt 25/4]
[Amdt 25/12]
[Amdt 25/14]
[Amdt 25/18]

CS 25.731 Wheels

ED Decision 2003/2/RM

(a) Each main and nose wheel must be approved.

(b) The maximum static load rating of each wheel may not be less than the corresponding static ground reaction with –

(1) Design maximum weight; and

(2) Critical centre of gravity.

(c) The maximum limit load rating of each wheel must equal or exceed the maximum radial limit load determined under the applicable ground load requirements of this CS-25.

(d) *Overpressure burst prevention.* Means must be provided in each wheel to prevent wheel failure and tyre burst that may result from excessive pressurisation of the wheel and tyre assembly.

(e) *Braked wheels*. Each braked wheel must meet the applicable requirements of CS 25.735.

CS 25.733 Tyres

ED Decision 2020/024/R

(a) When a landing gear axle is fitted with a single wheel and tyre assembly, the wheel must be fitted with a suitable tyre of proper fit with a speed rating approved by the Agency that is not exceeded under critical conditions, and with a load rating approved by the Agency that is not exceeded under –

(1) The loads on the main wheel tyre, corresponding to the most critical combination of aeroplane weight (up to the maximum weight) and centre of gravity position; and

(2) The loads corresponding to the ground reactions in sub-paragraph (b) of this paragraph, on the nose-wheel tyre, except as provided in sub-paragraphs (b)(2) and (b)(3) of this paragraph.

(b) The applicable ground reactions for nosewheel tyres are as follows:

(1) The static ground reaction for the tyre corresponding to the most critical combination of aeroplane weight (up to maximum ramp weight) and centre of gravity position with a force of 1·0 g acting downward at the centre of gravity. This load may not exceed the load rating of the tyre.

(2) The ground reaction of the tyre corresponding to the most critical combination of aeroplane weight (up to maximum landing weight) and centre of gravity position combined with forces of 1·0 g downward and 0·31 g forward acting at the centre of

gravity. The reactions in this case must be distributed to the nose and main wheels by the principles of static's with a drag reaction equal to 0·31 times the vertical load at each wheel with brakes capable of producing this ground reaction. This nose tyre load may not exceed 1·5 times the load rating of the tyre.

(3) The ground reaction of the tyre corresponding to the most critical combination of aeroplane weight (up to maximum ramp weight) and centre of gravity position combined with forces of 1·0 g downward and 0·20 g forward acting at the centre of gravity. The reactions in this case must be distributed to the nose and main wheels by the principles of static's with a drag reaction equal to 0·20 times the vertical load at each wheel with brakes capable of producing this ground reaction. This nose tyre load may not exceed 1·5 times the load rating of the tyre.

(c) When a landing gear axle is fitted with more than one wheel and tyre assembly, such as dual or dual-tandem, each wheel must be fitted with a suitable tyre of proper fit with a speed rating approved by the Agency that is not exceeded under critical conditions, and with a load rating approved by the Agency that is not exceeded by –

(1) The loads on each main wheel tyre, corresponding to the most critical combination of aeroplane weight (up to maximum weight) and centre of gravity position, when multiplied by a factor of 1·07; and

(2) Loads specified in sub-paragraphs (a)(2), (b)(1), (b)(2) and (b)(3) of this paragraph on each nose-wheel tyre.

(d) Each tyre installed on a retractable landing gear system must, at the maximum size of the tyre type expected in service, have a clearance to surrounding structure and systems that is adequate to prevent unintended contact between the tyre and any part of the structure or systems.

(e) For an aeroplane with a maximum certificated take-off weight of more than 34019 kg (75 000 pounds), tyres mounted on braked wheels must be inflated with dry nitrogen or other gases shown to be inert so that the gas mixture in the tyre does not contain oxygen in excess of 5% by volume, unless it can be shown that the tyre liner material will not produce a volatile gas when heated, or that means are provided to prevent tyre temperatures from reaching unsafe levels.

(f) A means shall be provided to minimise the risk that a tyre is below its minimum serviceable inflation pressure during operation. (See AMC 25.733(f))

[Amdt 25/26]

AMC 25.733(f) Tyre inflation pressure check

ED Decision 2020/024/R

1. General

'Minimum serviceable inflation pressure' means a tyre inflation pressure specified by the aeroplane type certificate holder below which damage to the tyre, potentially leading to a tyre failure, may occur.

In order to demonstrate compliance with CS 25.733(f), the applicant should use one, or a combination, of the following means:

(a) Provide a task in the Instructions for Continued Airworthiness (ICA) that requires tyres inflation pressure checks to be performed at a suitable time interval,

(b) Install a system that monitors the tyres inflation pressures and:

(1) provides an alert to the flight crew, in compliance with CS 25.1322, whenever a tyre inflation pressure is below the minimum serviceable inflation pressure, or

(2) allows the tyres inflation pressures to be checked prior to the dispatch of the aeroplane, and a tyre inflation pressure check task is included in the Aeroplane Flight Manual (AFM) pre-flight procedures.

2. ICA Tyre inflation pressure check

A 'suitable time interval' is the maximum time interval between two consecutive tyre inflation pressure checks.

Checks should be conducted daily in order to ensure that the elapsed clock time between two consecutive tyre inflation pressure checks does not exceed 48 hours.

Time intervals longer than 48 hours may be used if they are substantiated and agreed by EASA. This substantiation should at least include an analysis of the expected loss of tyre pressure during operation, taking into account the environmental and operational factors, including the potential for pressure loss at a rate that exceeds the normal diffusion resulting from damage to or degradation of the tyre/wheel assembly. If available, statistical data related to pressure losses gathered from the service experience of aeroplanes equipped with equivalent wheel designs should also be used. The substantiation should be made in cooperation with the tyre manufacturer(s). In addition, the applicant may take credit from an installed system monitoring the tyre inflation pressures.

3. Tyre inflation pressure monitoring systems

If a system is installed, its development assurance level should be commensurate with the potential consequences of an alert not being provided, as well as with the consequences of false alerts. If the system includes the indication of tyre pressure levels, the consequence of a false indication should also be taken into account. The assessment of these consequences should include the effects of the failure of one or more tyres (including simultaneous tyre failures) that may be caused by the operation of the aeroplane with under-inflated tyres.

Instructions for Continued Airworthiness should be provided to ensure that the calibration of the tyre pressure monitoring system is maintained.

[Amdt 25/26]

CS 25.734 Protection against wheel and tyre failures

ED Decision 2013/033/R

(see AMC 25.734)

The safe operation of the aeroplane must be preserved in case of damaging effects on systems or structures from:

— tyre debris;

— tyre burst pressure;

— flailing tyre strip; and

— wheel flange debris.

[Amdt 25/14]

AMC 25.734 Protection against wheel and tyre failures

ED Decision 2013/033/R

1. Purpose

This AMC provides a set of models defining the threats originating from failures of tyres and wheels. Furthermore, protecting the aircraft against the threats defined in these models would also protect against threats originating from foreign objects projected from the runway.

These models should be used for protection of aeroplane structure and systems.

2. Related Certification Specifications and Acceptable Means of Compliance

CS 25.571 Damage tolerance and fatigue evaluation of structure

CS 25.734 Protection against wheel and tyre failures

CS 25.963(e) Fuel tanks: general

AMC 25.963(e) Fuel Tank Protection

CS 25.1309 Equipment, systems and installations

AMC 20-29 Composite Aircraft Structure

3. General

3.1. Threat models

The models provided below encompass the threats applicable to landing gear in the extended, retracting and retracted positions. The threats to be considered are tyre debris, flailing tyre strips, tyre burst pressure effect and wheel flange debris. The models defined below are applicable to brand-new tyres.

With the landing gear in the extended position, the following models are applicable:

— Model 1 — Tyre Debris Threat Model

— Model 2 — Wheel Flange Debris Threat Model

— Model 3E — Flailing Tyre Strip Threat Model

With the landing gear retracting or in the retracted position, the following models are applicable:

— Model 3R — Flailing Tyre Strip Threat Model

— Model 4 — Tyre Burst Pressure Effect Threat Model

3.2. Structural residual strength and damage tolerance

In-service experience shows that traditional large transport aeroplane configurations, featuring high aspect ratio wings built around a single torsion box manufactured of light metal alloy, have demonstrated inherent structural robustness with regard to wheel and tyre debris threats. This results from the intrinsic properties of the structure, including thick wing skin gauges, as well as the general geometric arrangement (relative position of the landing gear to the wing). Residual strength and damage tolerance evaluations might therefore not be required for aeroplanes featuring such design features. For aeroplanes with novel or unusual design features (configuration, material, fuel tank arrangement, etc.), for principal structural elements and primary structures, the debris models are threats to be considered with respect to the related residual strength and