CS 25.493 Braked roll conditions

ED Decision 2003/2/RM

(a) An aeroplane with a tail wheel is assumed to be in the level attitude with the load on the main wheels, in accordance with Figure 6 of Appendix A. The limit vertical load factor is 1·2 at the design landing weight, and 1·0 at the design ramp weight. A drag reaction equal to the vertical reaction multiplied by a coefficient of friction of 0·8, must be combined with the vertical ground reaction and applied at the ground contact point.

(b) For an aeroplane with a nose wheel, the limit vertical load factor is 1·2 at the design landing weight, and 1·0 at the design ramp weight. A drag reaction equal to the vertical reaction, multiplied by a coefficient of friction of 0·8, must be combined with the vertical reaction and applied at the ground contact point of each wheel with brakes. The following two attitudes, in accordance with Figure 6 of Appendix A, must be considered:

(1) The level attitude with the wheels contacting the ground and the loads distributed between the main and nose gear. Zero pitching acceleration is assumed.

(2) The level attitude with only the main gear contacting the ground and with the pitching moment resisted by angular acceleration.

(c) A drag reaction lower than that prescribed in this paragraph may be used if it is substantiated that an effective drag force of 0·8 times the vertical reaction cannot be attained under any likely loading condition.

(d) An aeroplane equipped with a nose gear must be designed to withstand the loads arising from the dynamic pitching motion of the aeroplane due to sudden application of maximum braking force. The aeroplane is considered to be at design takeoff weight with the nose and main gears in contact with the ground, and with a steady state vertical load factor of 1·0. The steady state nose gear reaction must be combined with the maximum incremental nose gear vertical reaction caused by sudden application of maximum braking force as described in sub-paragraphs (b) and (c) of this paragraph.

(e) In the absence of a more rational analysis, the nose gear vertical reaction prescribed in subparagraph (d) of this paragraph must be calculated in accordance with the following formula:

$$V_N = \frac{W_T}{A+B}\left\{B + \frac{f\mu AE}{A+B+\mu E}\right\}$$

Where:

V_N = Nose gear vertical reaction

W_T = Design take-off weight

A = Horizontal distance between the c.g. of the aeroplane and the nose wheel.

B = Horizontal distance between the c.g. of the aeroplane and the line joining the centres of the main wheels.

E = Vertical height of the c.g. of the aeroplane above the ground in the 1·0 g static condition.

μ = Coefficient of friction of 0·8.

f = Dynamic response factor; 2·0 is to be used unless a lower factor is substantiated.

In the absence of other information, the dynamic response factor f may be defined by the equation.

$$f = 1 + exp\left[\frac{-\pi\xi}{\sqrt{1-\xi^2}}\right]$$

Where: ξ is the critical damping ratio of the rigid body pitching mode about the main landing gear effective ground contact point.

CS 25.495 Turning

ED Decision 2003/2/RM

In the static position, in accordance with Figure 7 of Appendix A, the aeroplane is assumed to execute a steady turn by nose gear steering, or by application of sufficient differential power, so that the limit load factors applied at the centre of gravity are 1·0 vertically and 0·5 laterally. The side ground reaction of each wheel must be 0·5 of the vertical reaction.

CS 25.497 Tail-wheel yawing

ED Decision 2003/2/RM

(a) A vertical ground reaction equal to the static load on the tail wheel, in combination with a side component of equal magnitude, is assumed.

(b) If there is a swivel, the tail wheel is assumed to be swivelled 90° to the aeroplane longitudinal axis with the resultant load passing through the axle.

(c) If there is a lock, steering device, or shimmy damper the tail wheel is also assumed to be in the trailing position with the side load acting at the ground contact point.

CS 25.499 Nose-wheel yaw and steering

ED Decision 2003/2/RM

(a) A vertical load factor of 1·0 at the aeroplane centre of gravity, and a side component at the nose wheel ground contact equal to 0·8 of the vertical ground reaction at that point are assumed.

(b) With the aeroplane assumed to be in static equilibrium with the loads resulting from the use of brakes on one side of the main landing gear, the nose gear, its attaching structure, and the fuselage structure forward of the centre of gravity must be designed for the following loads:

(1) A vertical load factor at the centre of gravity of 1·0.

(2) A forward acting load at the aeroplane centre of gravity of 0·8 times the vertical load on one main gear.

(3) Side and vertical loads at the ground contact point on the nose gear that are required for static equilibrium.

(4) A side load factor at the aeroplane centre of gravity of zero.

(c) If the loads prescribed in sub-paragraph (b) of this paragraph result in a nose gear side load higher than 0·8 times the vertical nose gear load, the design nose gear side load may be limited to 0·8 times the vertical load, with unbalanced yawing moments assumed to be resisted by aeroplane inertia forces.

(d) For other than the nose gear, its attaching structure, and the forward fuselage structure the loading conditions are those prescribed in sub-paragraph (b) of this paragraph, except that –

(1) A lower drag reaction may be used if an effective drag force of 0·8 times the vertical reaction cannot be reached under any likely loading condition; and

(2) The forward acting load at the centre of gravity need not exceed the maximum drag reaction on one main gear, determined in accordance with CS 25.493(b).

(e) With the aeroplane at design ramp weight, and the nose gear in any steerable position, the combined application of full normal steering torque and vertical force equal to 1·33 times the maximum static reaction on the nose gear must be considered in designing the nose gear, its attaching structure and the forward fuselage structure.

CS 25.503 Pivoting

ED Decision 2003/2/RM

(a) The aeroplane is assumed to pivot about one side of the main gear with the brakes on that side locked. The limit vertical load factor must be 1·0 and the coefficient of friction 0·8.

(b) The aeroplane is assumed to be in static equilibrium, with the loads being applied at the ground contact points, in accordance with Figure 8 of Appendix A.

CS 25.507 Reversed braking

ED Decision 2003/2/RM

(a) The aeroplane must be in a three point static ground attitude. Horizontal reactions parallel to the ground and directed forward must be applied at the ground contact point of each wheel with brakes. The limit loads must be equal to 0·55 times the vertical load at each wheel or to the load developed by 1·2 times the nominal maximum static brake torque, whichever is less.

(b) For aeroplanes with nose wheels, the pitching moment must be balanced by rotational inertia.

(c) For aeroplanes with tail wheels, the resultant of the ground reactions must pass through the centre of gravity of the aeroplane.

CS 25.509 Towing Loads

ED Decision 2013/010/R

(See AMC 25.509)

(a) The towing loads specified in sub-paragraph (d) of this paragraph must be considered separately. These loads must be applied at the towing fittings and must act parallel to the ground. In addition –

(1) A vertical load factor equal to 1·0 must be considered acting at the centre of gravity;

(2) The shock struts and tyres must be in their static positions; and

(3) With W_T as the design ramp weight, the towing load, F_{TOW} is –

(i) 0.3 W_T for W_T less than 30 000 pounds;

(ii) $\frac{6W_T + 450\,000}{70}$ for W_T between 30 000 and 100 000 pounds; and

(iii) 0·15 W_T for W_T over 100 000 pounds.

(b) For towing points not on the landing gear but near the plane of symmetry of the aeroplane, the drag and side tow load components specified for the auxiliary gear apply. For towing points located outboard of the main gear, the drag and side tow load components specified for the main gear apply. Where the specified angle of swivel cannot be reached, the maximum obtainable angle must be used.

(c) The towing loads specified in sub-paragraph (d) of this paragraph must be reacted as follows:

(1) The side component of the towing load at the main gear must be reacted by a side force at the static ground line of the wheel to which the load is applied.

(2) The towing loads at the auxiliary gear and the drag components of the towing loads at the main gear must be reacted as follows:

(i) A reaction with a maximum value equal to the vertical reaction must be applied at the axle of the wheel to which the load is applied. Enough aeroplane inertia to achieve equilibrium must be applied.

(ii) The loads must be reacted by aeroplane inertia.

(d) The prescribed towing loads are as specified in the following Table:

Tow Point	Position	Load		
		Magnitude	No.	Direction
Main gear		0·75 F_{TOW} per main gear unit	1 2 3 4	Forward, parallel to drag axis Forward, at 30° to drag axis Aft, parallel to drag axis Aft, at 30° to drag axis
Auxiliary gear	Swivelled forward	1·0 F_{TOW}	5 6	Forward Aft
	Swivelled aft		7 8	Forward Aft
	Swivelled 45° from forward	0·5 F_{TOW}	9 10	Forward, in plane of wheel Aft, in plane of wheel
	Swivelled 45° from aft		11 12	Forward, in plane of wheel Aft, in plane of wheel

[Amdt 25/13]

AMC 25.509 Towbarless towing

ED Decision 2013/010/R

(a) General

Towbarless towing vehicles are generally considered as ground equipment and are as such not subject to direct approval by the (aircraft) certifying agencies. However, these vehicles should be qualified in accordance with the applicable SAE ARP documents. It should be ensured that the nose landing gear and supporting structure is not being overloaded (by static and dynamic (including fatigue) loads) during towbarless towing operations with these vehicles. This should be ensured by the aircraft manufacturer, either by specific investigations as described in subparagraphs (b) and (c) below, or alternatively, by publishing aircraft load limitations in a towbarless towing vehicle assessment document, to allow towbarless towing vehicle manufacturers to demonstrate their vehicles will not overload the aircraft.

(b) Limit static load cases

For the limit static load cases, the investigation may be conducted by rational analysis supported by test evidence. The investigation should take into account the influence on the towing loads of the tractive force of the towing vehicle including consideration of its weight and pavement roughness.

Furthermore, the investigation should include, but may not be limited to, the following towbarless towing operation scenarios:

(1) Pushback towing: Moving a fully loaded aircraft (up to Maximum Ramp Weight (MRW)) from the parking position to the taxiway. Movement includes: pushback with turn, a stop, and short tow forward to align aircraft and nose wheels. Engines may or may not be operating. Aeroplane movement is similar to a conventional pushback operation with a towbar.

(2) Maintenance towing: The movement of an aeroplane for maintenance/remote parking purposes (e.g. from the gate to a maintenance hangar). Aircraft is typically unloaded with minimal fuel load.

(3) Dispatch (operational) towing: Towing a revenue aircraft (loaded with passengers, fuel, and cargo up to Maximum Ramp Weight (MRW) from the terminal gate/remote parking area to a location near the active runway. The movement may cover several kilometres with speeds according to SAE ARP 5283 technical standards, with several starts, stops, and turns. It replaces typical taxiing operations prior to take-off.

Operations that are explicitly prohibited need not to be addressed.

(c) Fatigue evaluation

Fatigue evaluation of the impact of towbarless towing on the airframe should be conducted under the provision of CS 25.571 and CS 25.1529.

Specifically, the contribution of the towbarless towing operational loads to the fatigue load spectra for the nose landing gear and its support structure needs to be evaluated. The impact of the towbarless towing on the certified life limits of the landing gear and supporting structure needs to be determined.

The fatigue spectra used in the evaluation should consist of typical service loads encountered during towbarless towing operations, which cover the loading scenarios noted above for static considerations. Furthermore, the spectra should be based on measured statistical data derived from simulated service operation or from applicable industry studies.

(d) Other considerations

Specific combinations of towbarless towing vehicle(s) and aircraft that have been assessed as described above and have been found to be acceptable, along with any applicable towing instructions and/or limitations should be specified in the Instructions for Continued Airworthiness as described in Appendix H, paragraph H25.3(a)(4) and in the Aeroplane Flight Manual as specified in AMC 25.745(d).

Aircraft braking, while the aircraft is under tow, may result in loads exceeding the aircraft's design load and may result in structural damage and/or nose gear collapse. For these reasons, the aircraft manufacturer should ensure that the appropriate information is provided in the Aeroplane Maintenance Manual and in the Aeroplane Flight Manual to preclude aircraft braking during normal towbarless towing. Appropriate information should also be provided in the Instructions for Continued Airworthiness to inspect the affected structure should aircraft braking occur, for example in an emergency situation.

[Amdt 25/13]

CS 25.511 Ground load: unsymmetrical loads on multiple-wheel units

ED Decision 2003/2/RM

(a) *General*. Multiple-wheel landing gear units are assumed to be subjected to the limit ground loads prescribed in this Subpart under sub-paragraphs (b) through (f) of this paragraph. In addition –

(1) A tandem strut gear arrangement is a multiple-wheel unit; and

(2) In determining the total load on a gear unit with respect to the provisions of sub-paragraphs (b) through (f) of this paragraph, the transverse shift in the load centroid, due to unsymmetrical load distribution on the wheels, may be neglected.

(b) *Distribution of limit loads to wheels; tyres inflated*. The distribution of the limit loads among the wheels of the landing gear must be established for each landing, taxying, and ground handling condition, taking into account the effects of the following factors:

(1) The number of wheels and their physical arrangements. For truck type landing gear units, the effects of any see-saw motion of the truck during the landing impact must be considered in determining the maximum design loads for the fore and aft wheel pairs.

(2) Any differentials in tyre diameters resulting from a combination of manufacturing tolerances, tyre growth, and tyre wear. A maximum tyre-diameter differential equal to two-thirds of the most unfavourable combination of diameter variations that is obtained when taking into account manufacturing tolerances, tyre growth and tyre wear, may be assumed.

(3) Any unequal tyre inflation pressure, assuming the maximum variation to be ±5% of the nominal tyre inflation pressure.

(4) A runway crown of zero and a runway crown having a convex upward shape that may be approximated by a slope of 1·5% with the horizontal. Runway crown effects must be considered with the nose gear unit on either slope of the crown.

(5) The aeroplane attitude.

(6) Any structural deflections.

(c) *Deflated tyres.* The effect of deflated tyres on the structure must be considered with respect to the loading conditions specified in sub-paragraphs (d) through (f) of this paragraph, taking into account the physical arrangement of the gear components. In addition –

(1) The deflation of any one tyre for each multiple wheel landing gear unit, and the deflation of any two critical tyres for each landing gear unit using four or more wheels per unit, must be considered; and

(2) The ground reactions must be applied to the wheels with inflated tyres except that, for multiple-wheel gear units with more than one shock strut, a rational distribution of the ground reactions between the deflated and inflated tyres, accounting for the differences in shock strut extensions resulting from a deflated tyre, may be used.

(d) *Landing conditions*. For one and for two deflated tyres, the applied load to each gear unit is assumed to be 60% and 50%, respectively, of the limit load applied to each gear for each of the prescribed landing conditions. However, for the drift landing condition of CS 25.485, 100% of the vertical load must be applied.

(e) *Taxying and ground handling conditions.* For one and for two deflated tyres –

(1) The applied side or drag load factor, or both factors, at the centre of gravity must be the most critical value up to 50% and 40%, respectively, of the limit side or drag load factors, or both factors, corresponding to the most severe condition resulting from consideration of the prescribed taxying and ground handling conditions.

(2) For the braked roll conditions of CS 25.493(a) and (b)(2), the drag loads on each inflated tyre may not be less than those at each tyre for the symmetrical load distribution with no deflated tyres;

(3) The vertical load factor at the centre of gravity must be 60% and 50% respectively, of the factor with no deflated tyres, except that it may not be less than 1 g; and

(4) Pivoting need not be considered.

(f) *Towing conditions*. For one and for two deflated tyres, the towing load, F_{TOW}, must be 60% and 50% respectively, of the load prescribed.

CS 25.519 Jacking and tie-down provisions

ED Decision 2003/2/RM

(a) *General*. The aeroplane must be designed to withstand the limit load conditions resulting from the static ground load conditions of sub-paragraph (b) of this paragraph and, if applicable, sub-paragraph (c) of this paragraph at the most critical combinations of aeroplane weight and centre of gravity. The maximum allowable load at each jack pad must be specified.

(b) *Jacking*. The aeroplane must have provisions for jacking and must withstand the following limit loads when the aeroplane is supported on jacks:

(1) For jacking by the landing gear at the maximum ramp weight of the aeroplane, the aeroplane structure must be designed for a vertical load of 1·33 times the vertical static reaction at each jacking point acting singly and in combination with a horizontal load of 0·33 times the vertical static reaction applied in any direction.

(2) For jacking by other aeroplane structure at maximum approved jacking weight:

(i) The aeroplane structure must be designed for a vertical load of 1·33 times the vertical reaction at each jacking point acting singly and in combination with a horizontal load of 0·33 times the vertical static reaction applied in any direction.

(ii) The jacking pads and local structure must be designed for a vertical load of 2·0 times the vertical static reaction at each jacking point, acting singly and in combination with a horizontal load of 0·33 times the vertical static reaction applied in any direction.

(c) *Tie-down.* If tie-down points are provided, the main tie-down points and local structure must withstand the limit loads resulting from a 120 km/h (65-knot) horizontal wind from any direction.

EMERGENCY LANDING CONDITIONS

CS 25.561 General

ED Decision 2003/2/RM

(See AMC 25.561.)

(a) The aeroplane, although it may be damaged in emergency landing conditions on land or water, must be designed as prescribed in this paragraph to protect each occupant under those conditions.

(b) The structure must be designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing when –

(1) Proper use is made of seats, belts, and all other safety design provisions;

(2) The wheels are retracted (where applicable); and

(3) The occupant experiences the following ultimate inertia forces acting separately relative to the surrounding structure:

(i) Upward, 3·0g

(ii) Forward, 9·0g

(iii) Sideward, 3·0g on the airframe and 4·0g on the seats and their attachments

(iv) Downward, 6·0g

(v) Rearward, 1·5g (See AMC 25.561(b)(3).)

(c) For equipment, cargo in the passenger compartments and any other large masses, the following apply:

(1) These items must be positioned so that if they break loose they will be unlikely to:

(i) Cause direct injury to occupants;

(ii) Penetrate fuel tanks or lines or cause fire or explosion hazard by damage to adjacent systems; or

(iii) Nullify any of the escape facilities provided for use after an emergency landing.

(2) When such positioning is not practical (e.g. fuselage mounted engines or auxiliary power units) each such item of mass must be restrained under all loads up to those specified in sub-paragraph (b)(3) of this paragraph. The local attachments for these items should be designed to withstand 1·33 times the specified loads if these items are subject to severe wear and tear through frequent removal (e.g. quick change interior items).

(d) Seats and items of mass (and their supporting structure) must not deform under any loads up to those specified in sub-paragraph (b)(3) of this paragraph in any manner that would impede subsequent rapid evacuation of occupants. (See AMC 25.561(d).)

AMC 25.561 General

ED Decision 2003/2/RM

In complying with the provisions of CS 25.561(b) & (c), the loads arising from the restraint of seats and items of equipment etc. should be taken into the structure to a point where the stresses can be dissipated (e.g. for items attached to the fuselage floor, the load paths from the attachments through to the fuselage primary structure should be taken into account).

AMC 25.561(b)(3) Commercial Accommodation Equipment

ED Decision 2011/004/R

Commercial accommodation equipment complying only with FAR 25.561 pre-Amendment 25-91 need additional substantiation by analysis, tests or combination thereof to cover the 1·33 factor for their attachments as specified in CS 25.561(c).

[Amdt 25/11]

AMC 25.561(d) General

ED Decision 2003/2/RM

For the local attachments of seats and items of mass it should be shown by analysis and/or tests that under the specified load conditions, the intended retaining function in each direction is still available.

CS 25.562 Emergency landing dynamic conditions

ED Decision 2018/005/R

(See AMC 25.562)

(a) The seat and restraint system in the aeroplane must be designed as prescribed in this paragraph to protect each occupant during an emergency landing condition when –

(1) Proper use is made of seats, safety belts, and shoulder harnesses provided for in the design; and

(2) The occupant is exposed to loads resulting from the conditions prescribed in this paragraph.

(b) Each seat type design approved for occupancy must successfully complete dynamic tests or be demonstrated by rational analysis based on dynamic tests of a similar seat type, in accordance with each of the following emergency landing conditions. The tests must be conducted with an occupant simulated by a 77kg (170 lb) anthropomorphic, test dummy sitting in the normal upright position:

(1) A change in downward vertical velocity, (Δv) of not less than 10·7 m/s, (35 ft/s) with the aeroplane's longitudinal axis canted downward 30 degrees with respect to the horizontal plane and with the wings level. Peak floor deceleration must occur in not more than 0·08 seconds after impact and must reach a minimum of 14 g.

(2) A change in forward longitudinal velocity (Δv) of not less than 13·4 m/s, (44 ft/s) with the aeroplane's longitudinal axis horizontal and yawed 10 degrees either right or left, whichever would cause the greatest likelihood of the upper torso restraint system (where installed) moving off the occupant's shoulder, and with the wings level. Peak floor deceleration must occur in not more than 0·09 seconds after impact and must reach a minimum of 16 g. With the exception of flight deck crew seats that are mounted in the forward conical area of the fuselage, where floor rails or floor fittings are used to attach

the seating devices to the test fixture, the rails or fittings must be misaligned with respect to the adjacent set of rails or fittings by at least 10 degrees vertically (i.e. out of parallel) with one rolled 10 degrees.

(c) The following performance measures must not be exceeded during the dynamic tests conducted in accordance with sub-paragraph (b) of this paragraph:

(1) Where upper torso straps are used tension loads in individual straps must not exceed 794 kg. (1750lb) If dual straps are used for restraining the upper torso, the total strap tension loads must not exceed 907kg (2000 lb)).

(2) The maximum compressive load measured between the pelvis and the lumbar column of the anthropomorphic dummy must not exceed 680 kg. (1500lb)

(3) The upper torso restraint straps (where installed) must remain on the occupant's shoulder during the impact.

(4) The lap safety belt must remain on the occupant's pelvis during the impact.

(5) Each occupant must be protected from serious head injury under the conditions prescribed in sub-paragraph (b) of this paragraph. Where head contact with seats or other structure can occur, protection must be provided so that the head impact does not exceed a Head Injury Criterion (HIC) of 1000 units. The level of HIC is defined by the equation –

$$HIC = \left\{ (t_2 - t_1) \left[\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a(t)dt \right]^{2.5} \right\}_{max}$$

Where –

t_1 is the initial integration time,

t_2 is the final integration time, and

a(t) is the total acceleration vs. time curve for the head strike, and where

(t) is in seconds, and (a) is in units of gravity (g).

(6) Where leg injuries may result from contact with seats or other structure, protection must be provided to prevent axially compressive loads exceeding 1021 kg (2250 lb) in each femur.

(7) The seat must remain attached at all points of attachment, although the structure may have yielded.

(8) Seats must not yield under the tests specified in sub-paragraphs (b)(1) and (b)(2) of this paragraph to the extent they would impede rapid evacuation of the aeroplane occupants.

[Amdt 25/15]
[Amdt 25/17]
[Amdt 25/21]