SUBPART C STRUCTURE

GENERAL

JAR 25.301 Loads

(a) Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

(b) Unless otherwise provided the specified air, ground, and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the aeroplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. Methods used to determine load intensities and distribution must be validated by flight load measurement unless the methods used for determining those loading conditions are shown to be reliable. (See ACJ 25.301(b).)

(c) If deflections under load would significantly change the distribution of external or internal loads, this redistribution must be taken into account.

JAR 25.303 Factor of safety

Unless otherwise specified, a factor of safety of 1·5 must be applied to the prescribed limit load which are considered external loads on the structure. When loading condition is prescribed in terms of ultimate loads, a factor of safety need not be applied unless otherwise specified.

JAR 25.305 Strength and deformation

(a) The structure must be able to support limit loads without detrimental permanent deformation. At any load up to limit loads, the deformation may not interfere with safe operation.

(b) The structure must be able to support ultimate loads without failure for at least 3 seconds. However, when proof of strength is shown by dynamic tests simulating actual load conditions, the 3-second limit does not apply. Static tests conducted to ultimate load must include the ultimate deflections and ultimate deformation induced by the loading. When analytical methods are used to show compliance with the ultimate load strength requirements, it must be shown that —

(1) The effects of deformation are not significant;

(2) The deformations involved are fully accounted for in the analysis; or

(3) The methods and assumptions used are sufficient to cover the effects of these deformations.

JAR 25.305 (continued)

(c) Where structural flexibility is such that any rate of load application likely to occur in the operating conditions might produce transient stresses appreciably higher than those corresponding to static loads, the effects of this rate of application must be considered.

(d) [Revoked]

JAR 25.307 Proof of structure

(a) Compliance with the strength and deformation requirements of this Subpart must be shown for each critical loading condition. Structural analysis may be used only if the structure conforms to those for which experience has shown this method to be reliable. In other cases, substantiating load tests must be made. Where substantiating load tests are made these must cover loads up to the ultimate load, unless it is agreed with the Authority that in the circumstances of the case, equivalent substantiation can be obtained from tests to agreed lower levels. (See ACJ 25.307.)

(b) [1][Revoked]

(c) [1][Revoked]

(d) When static or dynamic tests are used to show compliance with the requirements of JAR 25.305 (b) for flight structures, appropriate material correction factors must be applied to the test results, unless the structure, or part thereof, being tested has features such that a number of elements contribute to the total strength of the structure and the failure of one element results in the redistribution of the load through alternate load paths.

FLIGHT LOADS

JAR 25.321 General

(a) Flight load factors represent the ratio of the aerodynamic force component (acting normal to the assumed longitudinal axis of the aeroplane) to the weight of the aeroplane. A positive load factor is one in which the aerodynamic force acts upward with respect to the aeroplane.

[1] Ch. 14 (Amend. 93/1, Eff. 8.3.93)
Ch. 14 (Amend. 91/1, Eff. 12.4.91)

JAR 25.321 (continued)

(b) Considering compressibility effects at each speed, compliance with the flight load requirements of this Subpart must be shown —

(1) At each critical altitude within the range of altitudes selected by the applicant;

(2) At each weight from the design minimum weight to the design maximum weight appropriate to each particular flight load condition; and

(3) For each required altitude and weight, for any practicable distribution of disposable load within the operating limitations recorded in the Aeroplane Flight Manual.

[(c) Enough points on and within the boundaries of the design envelope must be investigated to ensure that the maximum load for each part of the aeroplane structure is obtained.

(d) The significant forces acting on the aeroplane must be placed in equilibrium in a rational or conservative manner. The linear inertia forces must be considered in equilibrium with thrust and all aerodynamic loads, while the angular (pitching) inertia forces must be considered in equilibrium with thrust and all aerodynamic moments, including moments due to loads on components such as tail surfaces and nacelles. Critical thrust values in the range from zero to maximum continuous thrust must be considered.]

FLIGHT MANOEUVRE AND GUST CONDITIONS

[JAR 25.331 Symmetric manoeuvring conditions]

[(a) *Procedure.* For the analysis of the manoeuvring flight conditions specified in sub-paragraphs (b) and (c) of this paragraph, the following provisions apply:]

[(1)] Where sudden displacement of a control is specified, the assumed rate of control surface displacement may not be less than the rate that could be applied by the pilot through the control system.

[(2)] In determining elevator angles and chordwise load distribution (in the manoeuvring

JAR 25.331 (a) (2) (continued)

conditions of sub-paragraphs (b) and (c) of this paragraph) in turns and pullups, the effect of corresponding pitching velocities must be taken into account. The in-trim and out-of-trim flight conditions specified in JAR 25.255 must be considered.

(b) *Manoeuvring balanced conditions.* Assuming the aeroplane to be in equilibrium with zero pitching acceleration, the manoeuvring conditions A through I on the manoeuvring envelope in JAR 25.333 (b) must be investigated.

(c) *Manoeuvring pitching conditions.*

(1) *Maximum elevator displacement at V_A.* The aeroplane is assumed to be flying in steady level flight (point A1, JAR 25.333 (b)) and, except as limited by pilot effort in accordance with JAR 25.397 (b), the pitching control is suddenly moved to obtain extreme positive pitching acceleration (nose up). In defining the tail load condition, the response of the aeroplane may be taken into account. Loads occurring beyond the point in time where normal acceleration at the c.g. exceeds the maximum positive limit manoeuvring factor n may be ignored.

(2) *Checked manoeuvre between V_A and V_D.* A checked manoeuvre, based on a rational pitching control motion versus time profile must be established in which the design limit load factor specified in JAR 25.337 will not be exceeded. (See also ACJ 25.331 (c) (2).)

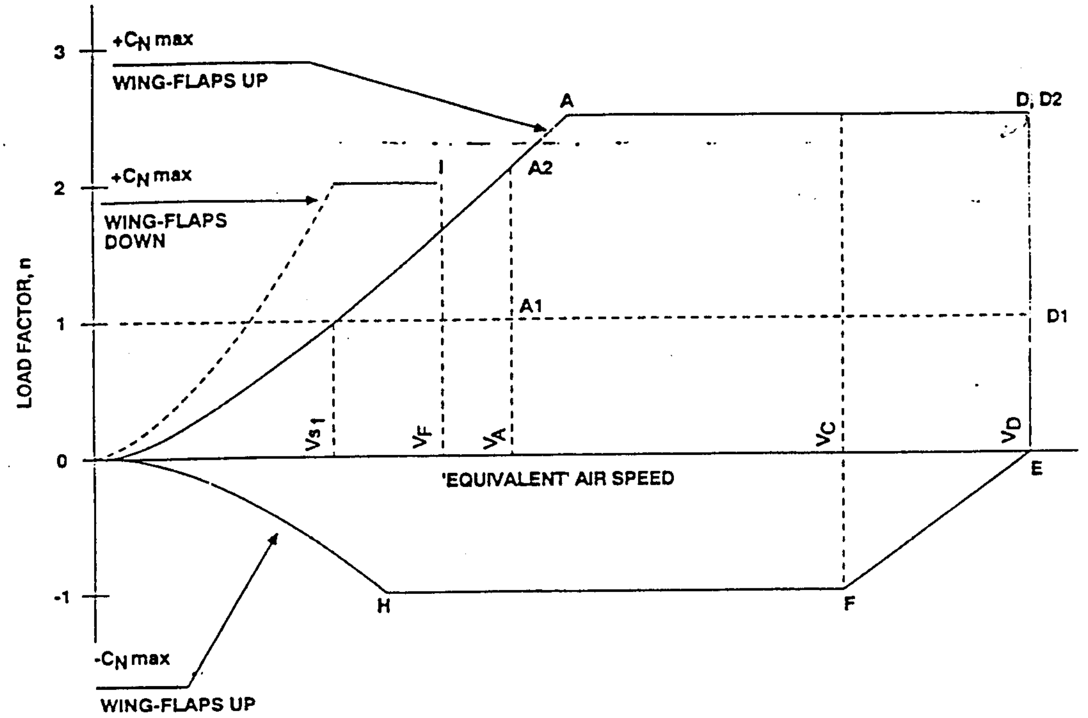
(d) [*Not required for JAR-25.*]

[JAR 25.333 Flight manoeuvring envelope]

(a) *General.* The strength requirements must be met at each combination of airspeed and load factor on and within the boundaries of the [representative manoeuvring envelope (V-n diagram) of sub-paragraph (b) of this paragraph. This envelope must also be used in determining the] aeroplane structural operating limitations as specified in JAR 25.1501.

JAR 25.333 (continued)

(b) *Manoeuvring envelope*



(c) [Revoked]

JAR 25.335 Design airspeeds

The selected design airspeeds are equivalent airspeeds (EAS). Estimated values of V_{S0} and V_{S1} must be conservative.

(a) *Design cruising speed, V_C.* For V_C, the following apply:

(1) The minimum value of V_C must be sufficiently greater than V_B to provide for inadvertent speed increases likely to occur as a result of severe atmospheric turbulence.

(2) In the absence of a rational investigation substantiating the use of other values, V_C may not be less than V_{Bmin} + 43 knots. However, it need not exceed the maximum speed in level flight at maximum continuous power for the corresponding altitude.

(3) At altitudes where V_D is limited by Mach number, V_C may be limited to a selected Mach number. (See JAR 25.1505.)

(b) *Design dive speed, V_D.* V_D must be selected so that V_C/M_C is not greater than 0·8 V_D/M_D, or so that the minimum speed margin between V_C/M_C and V_D/M_D is the greater of the following values:

(1) From an initial condition of stabilised flight at V_C/M_C, the aeroplane is upset, flown for 20 seconds along a flight path 7·5° below the initial path, and then pulled up at a load factor of 1·5 g (0·5 g acceleration increment). The speed increase occurring in this manoeuvre may be calculated if reliable or conservative aerodynamic data issued. Power as specified in JAR 25.175 (b) (1) (iv) is assumed until the pullup is initiated, at which time power reduction and the use of pilot controlled drag devices may be assumed;

(2) The minimum speed margin must be enough to provide for atmospheric variations (such as horizontal gusts, and penetration of jet streams and cold fronts) and for instrument errors and airframe production variations. These factors may be considered on a probability basis. However, the margin at altitude where M_C is limited by compressibility effects may not be less than 0·05 M. (See ACJ 25.335 (b) (2).)

(c) *Design manoeuvring speed, V_A.* For V_A, the following apply:

(1) V_A may not be less than $V_{S1}\ \sqrt{n}$ where —

(i) n is the limit positive manoeuvring load factor at V_C; and

(ii) V_{S1} is the stalling speed with wing-flaps retracted.

(2) V_A and V_S must be evaluated at the design weight and altitude under consideration.

(3) V_A need not be more than V_C or the speed at which the positive C_{Nmax} curve intersects the positive manoeuvre load factor line, whichever is less.

JAR 25.335 (continued)

(d) *Design speed for maximum gust intensity, V_B.*

(1) V_B may not be less than the speed [V_{Bmin}, the speed at which the load factor produced by the rough air gust equals the load factor which can be attained using the maximum positive lift C_{Nmax} at that same speed, or ($\sqrt{n_g}$)] V_{S1}, whichever is less, where —

(i) n_g is the positive aeroplane gust [load factor due to gust at speed V_C and] at the particular weight under consideration; and

(ii) V_{S1} is the stalling speed with the flaps retracted at the particular weight under consideration.

(2) V_B need not be greater than V_C. (See JAR 25X1517 and JAR 25.1585.)

[(3) For the purpose of determination of V_{Bmin}, the gust load factors must correspond to the following conditions:

(i) Positive rough air gusts of 66 fps EAS must be considered at altitudes between sea level and 20 000 ft. The rough air gust velocity may be reduced linearly from 66 fps EAS at 20 000 ft to 38 fps EAS at 50 000 ft.

(ii) Positive gusts of 50 fps EAS at V_C must be considered at altitudes between sea level and 20 000 ft. The gust velocity may be reduced linearly from 50 fps EAS at 20 000 ft to 25 fps EAS at 50 000 ft.

(iii) The shape of the gust must be taken as follows:

$$U = \frac{U_{de}}{2}\left[1-\cos\left(\frac{2\pi s}{25\,\bar{c}}\right)\right]$$

where —

s = distance penetrated into the gust (feet);

$\bar{c}$ = mean geometric chord of the wing (feet); and

U_{de} = the derived gust velocity as specified in sub-paragraphs (3) (i) and (3) (ii) of this paragraph as appropriate.

(See ACJ 25.335 (d).)]

(e) *Design wing-flap speeds, V_F.* For V_F, the following apply:

(1) The design wing-flap speed for each wing-flap position (established in accordance with JAR 25.697 (a)) must be sufficiently greater than the operating speed recommended for the corresponding stage of flight (including balked landings) to allow for probable variations in control of airspeed and for transition from one wing-flap position to another.

JAR 25.335 (e) (continued)

(2) If an automatic wing-flap positioning or load limiting device is used, the speeds and corresponding wing-flap positions programmed or allowed by the device may be used.

(3) V_F may not be less than —

(i) 1·6 V_{S1} with the wing-flaps in take-off position at maximum take-off weight;

(ii) 1·8 V_{S1} with the wing-flaps in approach position at maximum landing weight; and

(iii) 1·8 V_{S0} with the wing-flaps in landing position at maximum landing weight.

(f) *Design drag device speeds, V_{DD}.* The selected design speed for each drag device must be sufficiently greater than the speed recommended for the operation of the device to allow for probable variations in speed control. For drag devices intended for use in high speed descents, V_{DD} may not be less than V_D. When an automatic drag device positioning or load limiting means is used, the speeds and corresponding drag device positions programmed or allowed by the automatic means must be used for design.

JAR 25.337 Limit manoeuvring load factors

(a) Except where limited by maximum (static) lift coefficients, the aeroplane is assumed to be subjected to symmetrical manoeuvres resulting in the limit manoeuvring load factors prescribed in this paragraph. Pitching velocities appropriate to the corresponding pull-up and steady turn manoeuvres must be taken into account.

(b) The positive limit manoeuvring load factor 'n' for any speed up to V_D may not be less than $2{\cdot}1+\left(\frac{24\,000}{W+10\,000}\right)$ except that 'n' may not be less than 2·5 and need not be greater than 3·8 — where 'W' is the design maximum take-off weight (lb).

(c) The negative limit manoeuvring load factor —

(1) May not be less than -1·0 at speeds up to V_C; and

(2) Must vary linearly with speed from the value at V_C to zero at V_D.

(d) Manoeuvring load factors lower than those specified in this paragraph may be used if the aeroplane has design features that make it impossible to exceed these values in flight. (See ACJ 25.337 (d).)

[JAR 25.341 Gust and turbulence loads

(a) *Discrete Gust Design Criteria.* The] aeroplane is assumed to be subjected to symmetrical [vertical and lateral gusts in level flight. Limit gust loads must be determined in accordance with the following provisions:

(1) Loads on each part of the structure must be determined by dynamic analysis. The analysis must take account of unsteady aerodynamic characteristics and all significant structural degrees of freedom including rigid body motions.

(2) The shape of the gust must be taken as follows:

$$U = \frac{U_{ds}}{2}\left[1 - \cos\left(\frac{\pi s}{H}\right)\right]$$

or $0 \le s \le 2H$

where —

s = distance penetrated into the gust (feet);

U_{ds} = the design gust velocity as specified in sub-paragraph (a) (4) of this paragraph;

H = the gust gradient distance (feet).

(3) A sufficient number of gust gradient distances in the range 30 feet to 350 feet must be investigated to find the critical response for each load quantity.

(4) The design gust velocity must be determined from the relation —

$$U_{ds} = U_{ref} F_g$$

where —

U_{ref} = the reference gust velocity defined in sub-paragraphs (a) (5) (i) and (a) (5) (ii) of this paragraph;

F_g = the flight profile alleviation factor defined in sub-paragraph (a) (7) of this paragraph.

(5) For gusts with gradient distances equal to 350 feet the following amplitudes apply:

(i) At the aircraft design speed V_C - positive and negative gusts with reference gust velocities of 56·0 ft/sec EAS must be considered at sea level. The reference gust velocity may be reduced linearly from 56·0 ft/sec EAS at sea level to 44·0 ft/sec EAS at 15 000 feet. The reference gust velocity may be further reduced linearly from 44·0 ft/sec EAS at 15 000 feet to 26·0 ft/sec EAS at 50 000 feet.

(ii) At the aircraft design speed V_D - the reference gust velocity is given by 0·5 times the value obtained under (i).

JAR 25.341 (a) (continued)

(6) For gusts with gradient distances less than 350 feet then the gust velocities may be reduced below the prescribed reference gust velocities to a value proportional to the sixth root of the gust gradient distance.

(7) At sea level, the flight profile alleviation factor F_g is taken to be numerically equal to —

$$F_g = 0{\cdot}5\ (F_{gz} + F_{gm})$$

where —

$$F_{gz} = 1 - \frac{Z_{mo}}{250\,000};$$

$$F_{gm} = \left[R_2 \tan\left(\frac{\pi R_1}{4}\right)\right]^{0\cdot5};$$

$$R_1 = \frac{\text{maximum landing weight}}{\text{maximum take-off weight}};$$

$$R_2 = \frac{\text{maximum zero fuel weight}}{\text{maximum take-off weight}};$$

Z_{mo} = maximum operating altitude.

The flight profile alleviation factor should be increased linearly from this value at sea level to a value of 1·0 at the Maximum Operating Altitude.

(8) When a stability augmentation system is included in the analysis, the effect of any significant system non-linearities should be accounted for when deriving limit loads from limit gust conditions.

(b) *Continuous Gust Design Criteria.* The dynamic response to symmetrical vertical and lateral continuous turbulence must be taken into account. (See ACJ 25.341 (b).)

(c) *Not required for JAR-25.*]

JAR 25.343 Design fuel and oil loads

(a) The disposable load combinations must include each fuel and oil load in the range from zero fuel and oil to the selected maximum fuel and oil load. A structural reserve fuel condition, not exceeding 45 minutes of fuel under operating [1] [conditions in JAR 25.1001 (f), may be selected.]

(b) If a structural reserve fuel condition is selected, it must be used as the minimum fuel weight condition for showing compliance with the flight load requirements as prescribed in this Subpart. In addition —

(1) The structure must be designed for a condition of zero fuel and oil in the wing at limit loads corresponding to —

(i) A manoeuvring load factor of +2·25; and

[1] Ch. 14 (Amend. 93/1, Eff. 8.3.93)
Ch. 14 (Amend. 91/1, Eff. 12.4.91)