of the input period and amplitude on the resulting aeroplane loads. This variation is intended to verify that there is no large and rapid increase in aeroplane loads.

[Amdt 25/13]

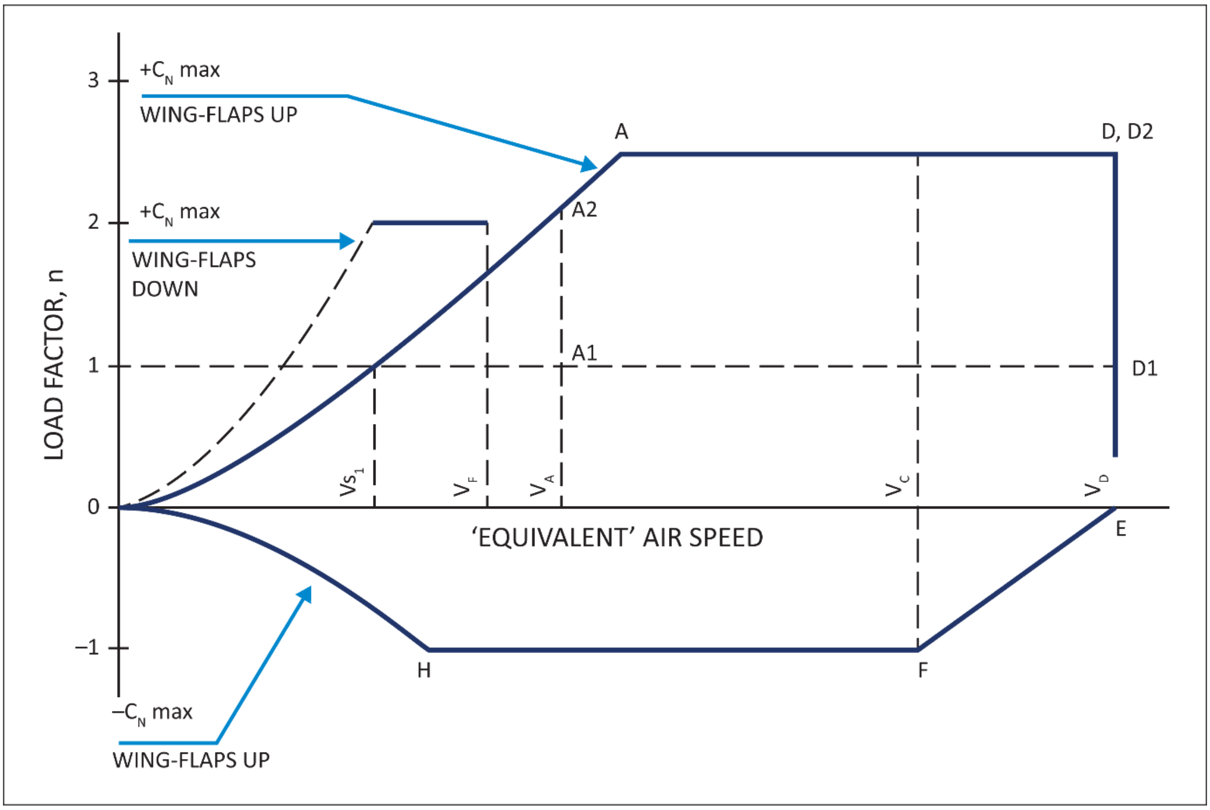
CS 25.333 Flight manoeuvring envelope

ED Decision 2016/010/R

(See AMC 25.333)

(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 CS 25.1501.

(b) *Manoeuvring envelope (See AMC 25.333(b))*



[Amdt 25/11]
[Amdt 25/13]
[Amdt 25/18]

AMC 25.333(b) Manoeuvring envelope

ED Decision 2013/010/R

For the calculation of structural design speeds, the stalling speeds V_{s0} and V_{s1} should be taken to be the 1-g stalling speeds in the appropriate flap configuration. This structural interpretation of stalling speed should be used in connection with the paragraphs CS 25.333(b), CS 25.335, CS 25.335(c)(d)(e), CS 25.479(a), and CS 25.481(a)(1).

[Amdt 25/13]

CS 25.335 Design airspeeds

ED Decision 2016/010/R

(See AMC 25.335)

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) Except as provided in sub-paragraph 25.335(d)(2), V_C may not be less than V_B + 1·32 U_{ref} (with U_{ref} as specified in sub-paragraph 25.341(a)(5)(i). However, V_C 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 CS 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) (i) For aeroplanes not equipped with a high speed protection function: 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 CS 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;

(ii) For aeroplanes equipped with a high speed protection function: In lieu of subparagraph (b)(1)(i), the speed increase above V_C/M_C resulting from the greater of the following manoeuvres must be established:

(A) From an initial condition of stabilised flight at V_C/M_C, the aeroplane is upset so as to take up a new flight path 7.5° below the initial path. Control application, up to full authority, is made to try and maintain this new flight path. Twenty seconds after achieving the new flight path, manual recovery is made at a load factor of 1.5 g (0.5 g acceleration increment), or such greater load factor that is automatically applied by the system with the pilot's pitch control neutral. The speed increase occurring in this manoeuvre may be calculated if reliable or conservative aerodynamic data is used. Power as specified in CS 25.175(b)(1)(iv) is assumed until recovery is made, at which time power reduction and the use of pilot controlled drag devices may be assumed.

(B) From a speed below V_C/M_C, with power to maintain stabilised level flight at this speed, the aeroplane is upset so as to accelerate through V_C/M_C at a flight path 15° below the initial path (or at the steepest nose down attitude that the system will permit with full control authority if less than 15°). Pilot controls may be in neutral position after reaching V_C/M_C and before recovery is initiated. Recovery may be initiated 3 seconds after operation of high speed, attitude, or other alerting system by application of a load factor of 1.5 g (0.5 g acceleration increment), or such greater load factor that is automatically applied by the system with the pilot's pitch control neutral. Power may be reduced simultaneously. All other means of decelerating the aeroplane, the use of which is authorised up to the highest speed reached in the manoeuvre, may be used. The interval between successive pilot actions must not be less than 1 second (See AMC 25.335(b)(1)(ii)).

(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. The margin at altitude where M_C is limited by compressibility effects must not be less than 0.07M unless a lower margin is determined using a rational analysis that includes the effects of any automatic systems. In any case, the margin may not be reduced to less than 0.05M. (See AMC 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.

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

(1) V_B may not be less than

$$V_{s1}\left[1+\frac{K_g U_{ref} V_c a}{498w}\right]^{1/2}$$

where –

V_{sl} = the 1-g stalling speed based on C_{NAmax} with the flaps retracted at the particular weight under consideration;

C_{NAmax} = the maximum aeroplane normal force coefficient;

V_c = design cruise speed (knots equivalent airspeed);

U_{ref} = the reference gust velocity (feet per second equivalent airspeed) from CS 25.341(a)(5)(i);

w = average wing loading (pounds per square foot) at the particular weight under consideration.

K_g = $\frac{.88\mu}{5.3+\mu}$

μ = $\frac{2w}{\rho\, cag}$

ρ = density of air (slugs/ft^3);

c = mean geometric chord of the wing (feet);

g = acceleration due to gravity (ft/sec^2);

a = slope of the aeroplane normal force coefficient curve, C_{NA} per radian;

(2) At altitudes where V_c is limited by Mach number –

(i) V_B may be chosen to provide an optimum margin between low and high speed buffet boundaries; and,

(ii) V_B need not be greater than V_C.

(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 CS 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.

(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.

[Amdt 25/13]
[Amdt 25/18]

AMC 25.335(b)(1)(ii) Design Dive Speed - High speed protection function

ED Decision 2013/010/R

In any failure condition affecting the high speed protection function, the conditions as defined in CS 25.335(b)(1)(ii) still remain applicable.

It implies that a specific value, which may be different from the V_D/M_D value in normal configuration, has to be associated with this failure condition for the definition of loads related to V_D/M_D as well as for the justification to CS 25.629. However, the strength and speed margin required will depend on the probability of this failure condition, according to the criteria of CS 25.302.

Alternatively, the operating speed V_{MO}/M_{MO} may be reduced to a value that maintains a speed margin between V_{MO}/M_{MO} and V_D/M_D that is consistent with showing compliance with CS 25.335(b)(1)(ii) without the benefit of the high speed protection system, provided that:

(a) Any failure of the high speed protection system that would affect the design dive speed determination is shown to be Remote;

(b) Failures of the system must be announced to the pilots, and:

(c) Aeroplane flight manual instructions should be provided that reduce the maximum operating speeds, V_{MO}/M_{MO}.

[Amdt 25/13]

AMC 25.335(b)(2) Design Dive Speed

ED Decision 2006/005/R

1. PURPOSE. This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-25 related to the minimum speed margin between design cruise speed and design dive speed.

2. RELATED CERTIFICATION SPECIFICATIONS. CS 25.335 "Design airspeeds".

3. BACKGROUND. CS 25.335(b) requires the design dive speed, V_D, of the aeroplane to be established so that the design cruise speed is no greater than 0.8 times the design dive speed, or that it be based on an upset criterion initiated at the design cruise speed, V_C. At altitudes where the cruise speed is limited by compressibility effects, CS 25.335(b)(2) requires the margin to be not less than 0.05 Mach. Furthermore, at any altitude, the margin must be great enough to provide for atmospheric variations (such as horizontal gusts and the penetration of jet streams), instrument errors, and production variations. This AMC provides a rational method for considering the atmospheric variations.

4. DESIGN DIVE SPEED MARGIN DUE TO ATMOSPHERIC VARIATIONS.

   a. In the absence of evidence supporting alternative criteria, compliance with CS 25.335(b)(2) may be shown by providing a margin between V_C/M_C and V_D/M_D sufficient to provide for the following atmospheric conditions:

      (1) Encounter with a Horizontal Gust. The effect of encounters with a substantially headon gust, assumed to act at the most adverse angle between 30 degrees above and 30 degrees below the flight path, should be considered. The gust velocity should be 15.2 m/s (50 fps) in equivalent airspeed (EAS) at altitudes up to 6096 m (20,000 feet). At altitudes above 6096 m (20,000 feet) the gust velocity may be reduced linearly from 15.2 m/s (50 fps) in EAS at 6096 m (20,000 feet) to 7.6 m/s (25 fps) in EAS at 15240 m (50,000 feet), above which the gust velocity is considered to be constant. The gust velocity should be assumed to build up in not more than 2 seconds and last for 30 seconds.

      (2) Entry into Jetstreams or Regions of High Windshear.

         (i) Conditions of horizontal and vertical windshear should be investigated taking into account the windshear data of this paragraph which are world-wide extreme values.

         (ii) Horizontal windshear is the rate of change of horizontal wind speed with horizontal distance. Encounters with horizontal windshear change the aeroplane apparent head wind in level flight as the aeroplane traverses into regions of changing wind speed. The horizontal windshear region is assumed to have no significant vertical gradient of wind speed.

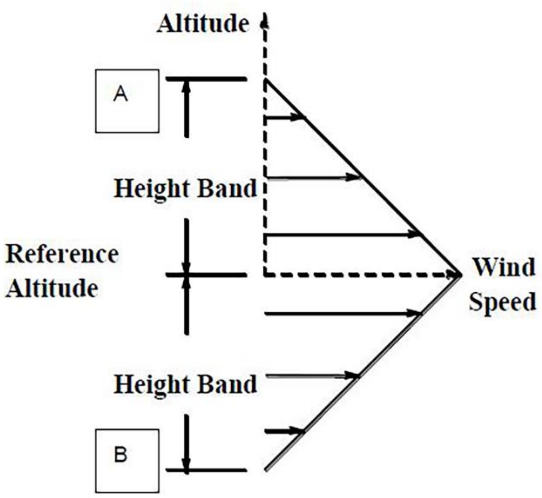
         (iii) Vertical windshear is the rate of change of horizontal wind speed with altitude. Encounters with windshear change the aeroplane apparent head wind as the aeroplane climbs or descends into regions of changing wind speed. The vertical windshear region changes slowly so that temporal or spatial changes in the vertical windshear gradient are assumed to have no significant affect on an aeroplane in level flight.

(iv) With the aeroplane at V_C/M_C within normal rates of climb and descent, the most extreme condition of windshear that it might encounter, according to available meteorological data, can be expressed as follows:

(A) Horizontal Windshear. The jet stream is assumed to consist of a linear shear of 3.6 KTAS/NM over a distance of 25 NM or of 2.52 KTAS/NM over a distance of 50 NM or of 1.8 KTAS/NM over a distance of 100 NM, whichever is most severe.

(B) Vertical Windshear. The windshear region is assumed to have the most severe of the following characteristics and design values for windshear intensity and height band. As shown in Figure 1, the total vertical thickness of the windshear region is twice the height band so that the windshear intensity specified in Table 1 applies to a vertical distance equal to the height band above and below the reference altitude. The variation of horizontal wind speed with altitude in the windshear region is linear through the height band from zero at the edge of the region to a strength at the reference altitude determined by the windshear intensity multiplied by the height band. Windshear intensity varies linearly between the reference altitudes in Table 1.

Figure 1 - Windshear Region



Note: The analysis should be conducted by separately descending from point “A” and climbing from point “B” into initially increasing headwind.

Table 1 - Vertical Windshear Intensity Characteristics

	Height Band - Ft.			
	1000	3000	5000	7000
Reference Altitude - Ft.	Vertical Windshear Units: ft./sec. per foot of height (KTAS per 1000 feet of height)			
0	0.095 (56.3)	0.05 (29.6)	0.035 (20.7)	0.03 (17.8)
40,000	0.145 (85.9)	0.075 (44.4)	0.055 (32.6)	0.04 (23.7)
45,000	0.265 (157.0)	0.135 (80.0)	0.10 (59.2)	0.075 (44.4)
Above 45,000	0.265 (157.0)	0.135 (80.0)	0.10 (59.2)	0.075 (44.4)
Windshear intensity varies linearly between specified altitudes.				

(v) The entry of the aeroplane into horizontal and vertical windshear should be treated as separate cases. Because the penetration of these large scale phenomena is fairly slow, recovery action by the pilot is usually possible. In the case of manual flight (i.e., when flight is being controlled by inputs made by the pilot), the aeroplane is assumed to maintain constant attitude until at least 3 seconds after the operation of the overspeed warning device, at which time recovery action may be started by using the primary aerodynamic controls and thrust at a normal acceleration of 1.5g, or the maximum available, whichever is lower.

b. At altitudes where speed is limited by Mach number, a speed margin of .07 Mach between M_C and M_D is considered sufficient without further investigation.

[Amdt 25/2]

CS 25.337 Limit manoeuvring load factors

ED Decision 2003/2/RM

(See AMC 25.337)

(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.

AMC 25.337 Limit manoeuvring load factors

ED Decision 2003/2/RM

The load factor boundary of the manoeuvring envelope is defined by CS 25.337(b) and (c). It is recognised that constraints which may limit the aircraft's ability to attain the manoeuvring envelope load factor boundary may be taken into account in the calculation of manoeuvring loads for each unique mass and flight condition, provided that those constraints are adequately substantiated. This substantiation should take account of critical combinations of vertical, rolling and yawing manoeuvres that may be invoked either statically or dynamically within the manoeuvring envelope.

Examples of the aforementioned constraints include aircraft $C_{N\text{-}max}$, mechanical and/or aerodynamic limitations of the pitch control, and limitations defined within any flight control software.]

CS 25.341 Gust and turbulence loads

ED Decision 2012/008/R

(See AMC 25.341)

(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 into account 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:

$$U = \frac{U_{ds}}{2}\left[1 - \cos\left(\frac{\pi s}{H}\right)\right] \qquad \text{for } 0 \le s \le 2H$$

$$U = 0 \qquad \text{for } s > 2H$$

where –

s = distance penetrated into the gust (metre);

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

H = the gust gradient which is the distance (metre) parallel to the aeroplane's flight path for the gust to reach its peak velocity.

(3) A sufficient number of gust gradient distances in the range 9 m (30 feet) to 107 m (350 feet) must be investigated to find the critical response for each load quantity.

(4) The design gust velocity must be:

$$U_{ds} = U_{ref}\, F_g \left(\frac{H}{107}\right)^{1/6}$$

where –

U_{ref} = the reference gust velocity in equivalent airspeed defined in sub-paragraph (a)(5) of this paragraph;

F_g = the flight profile alleviation factor defined in sub-paragraph (a)(6) of this paragraph.

(5) The following reference gust velocities apply:

(i) At aeroplane speeds between V_B and V_C: Positive and negative gusts with reference gust velocities of 17.07 m/s (56.0 ft/s) EAS must be considered at sea level. The reference gust velocity may be reduced linearly from 17.07 m/s (56.0 ft/s) EAS at sea level to 13.41 m/s (44.0 ft/s) EAS at 4572 m (15 000 ft). The reference gust velocity may be further reduced linearly from 13.41 m/s (44.0 ft/s) EAS at 4572 m (15 000 ft) to 6.36 m/s (20.86 ft/sec) EAS at 18288 m (60 000 ft).

(ii) At the aeroplane design speed V_D: The reference gust velocity must be 0·5 times the value obtained under CS 25.341(a)(5)(i).

(6) The flight profile alleviation factor, F_g, must be increased linearly from the sea level value to a value of 1.0 at the maximum operating altitude defined in CS 25.1527. At sea level, the flight profile alleviation factor is determined by the following equation.

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

where –

$$F_{gz} = 1 - \frac{Z_{mo}}{76200}; \quad \left(F_{gz} = 1 - \frac{Z_{mo}}{250\,000}\right);$$

$$F_{gm} = \sqrt{R_2 Tan\left(\pi R_{1}/_{4}\right)};$$

$$R_1 = \frac{Maximum\ Landing\ Weight}{Maximum\ Take-off\ Weight};$$

$$R_2 = \frac{Maximum\ Zero\ Fuel\ Weight}{Maximum\ Take-off\ Weight};$$

Z_{mo} maximum operating altitude (metres (feet)) defined in CS 25.1527.

(7) 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 Turbulence Design Criteria*. The dynamic response of the aeroplane to vertical and lateral continuous turbulence must be taken into account. The dynamic analysis must take into account unsteady aerodynamic characteristics and all significant structural degrees of freedom including rigid body motions. The limit loads must be determined for all critical altitudes, weights, and weight distributions as specified in CS 25.321(b), and all critical speeds within the ranges indicated in subparagraph (b)(3).

(1) Except as provided in subparagraphs (b)(4) and (b)(5) of this paragraph, the following equation must be used:

$$P_L = P_{L-1g} \pm U_\sigma \bar{A}$$

Where:

P_L = limit load;

P_{L-1g} = steady 1-g load for the condition;

A = ratio of root-mean-square incremental load for the condition to root-mean-square turbulence velocity; and

U_σ = limit turbulence intensity in true airspeed, specified in subparagraph (b)(3) of this paragraph.

(2) Values of Ā must be determined according to the following formula:

$$\bar{A} = \sqrt{\int_0^\infty |H(\Omega)|^2 \Phi_I(\Omega) d\Omega}$$

Where:

H(Ω) = the frequency response function, determined by dynamic analysis, that relates the loads in the aircraft structure to the atmospheric turbulence; and

$\Phi_I(\Omega)$ = normalised power spectral density of atmospheric turbulence given by:

$$\Phi_I(\Omega) = \frac{L}{\pi} \frac{1 + \frac{8}{3}(1.339\Omega L)^2}{[1 + (1.339\Omega L)^2]^{11/6}}$$

Where:

Ω = reduced frequency, rad/ft; and

L = scale of turbulence = 2,500 ft.

(3) The limit turbulence intensities, U_σ, in m/s (ft/s) true airspeed required for compliance with this paragraph are:

(i) At aeroplane speeds between V_B and V_C:

$$U_\sigma = U_{\sigma ref} \, F_g$$

Where:

$U_{\sigma ref}$ is the reference turbulence intensity that varies linearly with altitude from 27.43 m/s (90 ft/s) (TAS) at sea level to 24.08 m/s (79 ft/s) (TAS) at 7315 m (24000 ft) and is then constant at 24.08 m/s (79 ft/s) (TAS) up to the altitude of 18288 m (60000 ft); and

F_g is the flight profile alleviation factor defined in subparagraph (a)(6) of this paragraph;

(ii) At speed V_D: U_σ is equal to 1/2 the values obtained under subparagraph (3)(i) of this paragraph.

(iii) At speeds between V_C and V_D: Uσ is equal to a value obtained by linear interpolation.

(iv) At all speeds both positive and negative incremental loads due to continuous turbulence must be considered.

(4) When an automatic system affecting the dynamic response of the aeroplane is included in the analysis, the effects of system non-linearities on loads at the limit load level must be taken into account in a realistic or conservative manner.