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Standard Specification for Design Loads and Conditions[1]

This standard is issued under the fixed designation F3116/F3116M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification addresses the airworthiness requirements for the design loads and conditions of small airplanes.

1.2 This specification is applicable to small airplanes as defined in the F44 terminology standard. Use of the term airplane is used throughout this specification and will mean "small airplane."

1.3 The applicant for a design approval must seek individual guidance from their respective CAA body concerning the use of this standard as part of a certification plan. For information on which CAA regulatory bodies have accepted this standard (in whole or in part) as a means of compliance to their Small Airplane Airworthiness Rules (hereinafter referred to as "the Rules"), refer to ASTM F44 webpage (www.ASTM.org/COMMITTEE/F44.htm) which includes CAA website links.

1.4 *Units*—Currently there is a mix of SI and Imperial units. In many locations, SI units have been included otherwise units are as they appear in Amendment 62 of 14 CFR Part 23. In a future revision values will be consistently stated in SI units followed by Imperial units in square brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F3060 Terminology for Aircraft

F3331 Practice for Aircraft Water Loads

2.2 *U.S. Code of Federal Regulations:*[3]

14 CFR Part 23 Airworthiness Standards: Normal, Utility, Aerobatic and Commuter Category Airplanes (Amendment 62)

2.3 *European Aviation Safety Agency Regulations:*[4]

Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes (CS-23, Amendment 3)

Certification Specifications for Very Light Aeroplanes (CS-VLA, Amendment 1)

3. Terminology

3.1 A listing of terms, abbreviations, acronyms, and symbols related to aircraft covered by ASTM Committees F37 and F44 airworthiness design standards can be found in Terminology F3060. Items listed below are more specific to this standard.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *chordwise, n*—directed, moving, or placed along the chord of an airfoil section.

3.2.2 *downwash, n*—the downward deflection of an airstream by an aircraft wing.

3.2.3 *flight envelope, n*—any combination of airspeed and load factor on and within the boundaries of a flight envelope that represents the envelope of the flight loading conditions specified by the maneuvering and gust criteria.

3.2.4 *flight load factor, n*—represents the ratio of the aerodynamic force component (acting normal to the assumed longitudinal axis of the airplane) to the weight of the airplane.

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[1] This specification is under the jurisdiction of ASTM Committee F44 on General Aviation Aircraft and is the direct responsibility of Subcommittee F44.30 on Structures.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from U.S. Government Publishing Office (GPO), 732 N. Capitol St., NW, Washington, DC 20401, http://www.gpo.gov.

[4] Available from European Aviation Safety Agency (EASA), Postfach 10 12 53, D-50452 Cologne, Germany, https://www.easa.europa.eu/.

A positive flight load factor is one in which the aerodynamic force acts upward, with respect to the airplane.

3.2.5 *propeller slipstream, n*—the airstream pushed back by a revolving aircraft propeller.

3.2.6 *spanwise, n*—directed, moving, or placed along the span of an airfoil.

3.2.7 *winglet, n*—a nearly vertical airfoil at an airplane's wingtip.

3.3 *Acronyms:*

3.3.1 *MCP*—maximum continuous power

3.4 *Symbols:*

C_{NA} = maximum airplane normal force coefficient
M_C = design cruising speed (Mach number)
V_E = design dive speed at zero or negative load factor
V_{SF} = stalling speed with flaps fully extended

4. Flight Loads

4.1 *Loads:*

4.1.1 Unless otherwise provided, prescribed loads are limit loads.

4.1.2 Unless otherwise provided, the air, ground, and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the airplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. Methods used to determine load intensities and distribution on canard and tandem wing configurations must be validated by flight test measurement unless the methods used for determining those loading conditions are shown to be reliable or conservative on the configuration under consideration.

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

4.1.4 Appendix X1 through Appendix X4 provides, within the limitations specified within the appendix, a simplified means of compliance with several of the requirements set forth in 4.2 to 4.26 and 7.1 to 7.9 that can be applied as one (but not the only) means to comply.

4.2 *General:*

4.2.1 Flight load factors, *n*, represent the ratio of the aerodynamic force component (acting normal to the assumed longitudinal axis of the airplane) to the weight of the airplane. A positive flight load factor is one in which the aerodynamic force acts upward, with respect to the airplane.

4.2.2 Compliance with the flight load requirements of this subpart must be shown:

4.2.2.1 At each critical altitude within the range in which the airplane may be expected to operate;

4.2.2.2 At each weight from the design minimum weight to the design maximum weight; and

4.2.2.3 For each required altitude and weight, for any practicable distribution of disposable load within the operating limitations specified in 14 CFR Part 23, Sections 23.1583 through 23.1589.

4.2.3 When significant, the effects of compressibility must be taken into account.

4.3 *Symmetrical Flight Conditions:*

4.3.1 The appropriate balancing horizontal tail load must be accounted for in a rational or conservative manner when determining the wing loads and linear inertia loads corresponding to any of the symmetrical flight conditions specified in 4.4 through 4.6.

4.3.2 The incremental horizontal tail loads due to maneuvering and gusts must be reacted by the angular inertia of the airplane in a rational or conservative manner.

4.3.3 Mutual influence of the aerodynamic surfaces must be taken into account when determining flight loads.

4.4 *Flight Envelope:*

4.4.1 *General*—Compliance with the strength requirements of this subpart must be shown at any combination of airspeed and load factor on and within the boundaries of a flight envelope (similar to the one in 4.4.4) that represents the envelope of the flight loading conditions specified by the maneuvering and gust criteria of 4.4.2 and 4.4.3 respectively.

4.4.2 *Maneuvering Envelope*—Except where limited by maximum (static) lift coefficients, the airplane is assumed to be subjected to symmetrical maneuvers resulting in the following limit load factors:

4.4.2.1 The positive maneuvering load factor specified in 4.5 at speeds up to V_D;

4.4.2.2 The negative maneuvering load factor specified in 4.5 at V_C; and

4.4.2.3 Factors varying linearly with speed from the specified value at V_C to 0.0 at V_D. For airplanes with a positive limit maneuvering load factor greater than 3.8, use a value of –1.0 at V_D.

4.4.3 *Gust Envelope:*

4.4.3.1 The airplane is assumed to be subjected to symmetrical vertical gusts in level flight. The resulting limit load factors must correspond to the conditions determined as follows:

(1) Positive (up) and negative (down) gusts of 15.24 m/s [50 fps] at V_C must be considered at altitudes between sea level and 6,096 m [20 000 ft]. The gust velocity may be reduced linearly from 15.24 m/s [50 fps] at 6096 m [20 000 ft] to 7.62 m/s [25 fps] at 15 240 m [50 000 ft]; and

(2) Positive and negative gusts of 7.62 m/s [25 fps] at V_D must be considered at altitudes between sea level and 6,096 m [20 000 ft]. The gust velocity may be reduced linearly from 7.62 m/s [25 fps] at 6096 m [20 000 ft] to 3.81 m/s [12.5 fps] at 15 240 m [50 000 ft].

(3) In addition, for level 4 airplanes, positive (up) and negative (down) rough air gusts of 20.12 m/s [66 fps] at V_B must be considered at altitudes between sea level and 6096 m [20 000 ft]. The gust velocity may be reduced linearly from 20.12 m/s [66 fps] at 6096 m [20 000 ft] to 11.58 m/s [38 fps] at 15 240 m [50 000 ft].

4.4.3.2 The following assumptions must be made:

(1) The shape of the gust is:

$$U = \frac{U_{de}}{2}\left(1 - \cos\frac{2\pi s}{25C}\right) \tag{1}$$

where:

s = distance penetrated into gust (m or [ft]);

C = mean geometric chord of wing (m or [ft]); and

U_{de} = derived gust velocity referred to in 4.4.3.1 (m/s or [fps]).

(2) Gust load factors vary linearly with speed between V_C and V_D.

4.4.4 *Flight Envelope*—See Fig. 1.

4.5 *Limit Maneuvering Load Factors:*

4.5.1 The positive limit maneuvering load factor *n* may not be less than:

4.5.1.1 $2.1 + \frac{24{,}000}{W + 10{,}000}$, where *W* = design maximum takeoff weight (lb), except that *n* need not be more than 3.8;

4.5.1.2 6.0 for airplanes approved for aerobatics.

4.5.2 The negative limit maneuvering load factor may not be less than:

4.5.2.1 0.4 times the positive load factor;

4.5.2.2 0.5 times the positive load factor for airplanes approved for aerobatics.

4.5.3 Maneuvering load factors lower than those specified in this section may be used if the airplane has design features that make it impossible to exceed these values in flight.

4.6 *Gust Load Factors:*

4.6.1 Each airplane must be designed to withstand loads on each lifting surface resulting from gusts specified in 4.4.3.

4.6.2 The gust load factors for a canard or tandem wing configuration must be computed using a rational analysis, or may be computed in accordance with 4.6.3, provided that the resulting net loads are shown to be conservative with respect to the gust criteria of 4.4.3.

4.6.3 In the absence of a more rational analysis, the gust load factors must be computed as follows:

$$n = 1 + \frac{K_g U_{de} V a}{498\left(\frac{W}{S}\right)} \qquad (2)$$

where:

$K_g = \frac{0.88\mu_g}{5.3 + \mu_g}$ = gust alleviation factor;

$\mu_g = \frac{2(W/S)}{\rho C a g}$ = airplane mass ratio;

U_{de} = derived gust velocities referred to in 4.4.3 (f.p.s.).

ρ = density of air (slugs/ft^3);

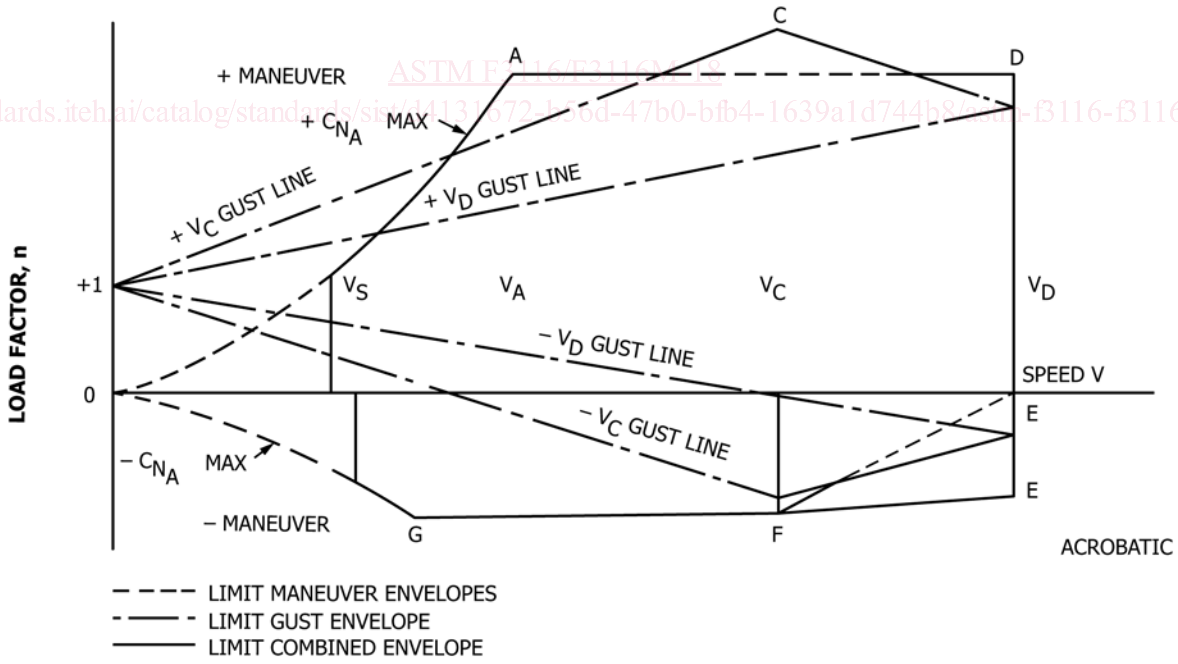
W/S = wing loading (p.s.f.) due to the applicable weight of the airplane in the particular load case;

C = mean geometric chord (ft);

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

V = airplane equivalent speed (knots); and

a = slope of the airplane normal force coefficient curve C_{NA} per radian if the gust loads are applied to the wings and horizontal tail surfaces simultaneously by a rational method. The wing lift curve slope C_L per radian may be used when the gust load is applied to the wings only and the horizontal tail gust loads are treated as a separate condition.



NOTE 1—Point G need not be investigated when the supplementary condition specified in 4.14 is investigated.

FIG. 1 Flight Envelope

4.7 *Design Fuel Loads:*

4.7.1 The disposable load combinations must include each fuel load in the range from zero fuel to the selected maximum fuel load.

4.7.2 If fuel is carried in the wings, the maximum allowable weight of the airplane without any fuel in the wing tank(s) must be established as "maximum zero wing fuel weight," if it is less than the maximum weight.

4.7.3 For level 4 airplanes, a structural reserve fuel condition, not exceeding fuel necessary for 45 min of operation at maximum continuous power, may be selected. 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 prescribed in this part and:

4.7.3.1 The structure must be designed to withstand a condition of zero fuel in the wing at limit loads corresponding to:

(1) 90 % of the maneuvering load factors defined in 4.5, and

(2) Gust velocities equal to 85 % of the values prescribed in 4.4.3.

4.7.3.2 The fatigue evaluation of the structure must account for any increase in operating stresses resulting from the design condition of 4.7.3.1.

4.7.3.3 The flutter, deformation, and vibration requirements must also be met with zero fuel in the wings.

4.8 *High Lift Devices:*

4.8.1 If wing flaps or similar high lift devices are installed for use in take-off, approach, or landing, the airplane, with the flaps fully deflected at V_F, is assumed to be subjected to symmetrical maneuvers and gusts resulting in limit load factors within the range determined by:

4.8.1.1 Maneuvering, to a positive limit load factor of 2.0; and

4.8.1.2 Positive and negative gust of 7.62 m/s [25 fps] acting normal to the flight path in level flight.

4.8.1.3 However, if an automatic flap load limiting device is used, the airplane may be designed for the critical combinations of airspeed and flap position allowed by that device.

4.8.2 V_F must be assumed to be not less than 1.4 V_S or 1.8 V_{SF}, whichever is greater, where:

4.8.2.1 V_S is the 1g computed stalling speed with flaps retracted at the design weight; and

4.8.2.2 V_{SF} is the 1g computed stalling speed with flaps fully extended at the design weight.

4.8.3 In determining external loads on the airplane as a whole, thrust, slipstream, and pitching acceleration may be assumed to be zero.

4.8.4 The flaps, their operating mechanism, and their supporting structures, must be designed for the conditions prescribed in 4.8.1. In addition, with the flaps fully extended at V_F, the following conditions, taken separately, must be accounted for:

4.8.4.1 A head-on gust having a velocity of 7.62 m/s [25 fps] (EAS), combined with propeller slipstream corresponding to 75 % of maximum continuous power; and

4.8.4.2 The effects of propeller slipstream corresponding to maximum takeoff power.

4.8.4.3 For the investigation of slipstream effects, the load factor may be assumed to be 1.0.

4.9 *Unsymmetrical Flight Conditions:*

4.9.1 The airplane is assumed to be subjected to the unsymmetrical flight conditions of 4.10 and 4.11. Unbalanced aerodynamic moments about the center of gravity must be reacted in a rational or conservative manner, considering the principal masses furnishing the reacting inertia forces.

4.9.2 Airplanes approved for aerobatics must be designed for additional asymmetric loads acting on the wing and the horizontal tail.

4.10 *Rolling Conditions*—The wing and wing bracing must be designed for the following loading conditions:

4.10.1 Unsymmetrical wing loads. Unless the following values result in unrealistic loads, the rolling accelerations may be obtained by modifying the symmetrical flight conditions in 4.4.4 as follows:

4.10.1.1 In Condition A, assume that 100 % of the semispan wing airload acts on one side of the airplane and 70 % of this load acts on the other side. For airplanes of more than 454 kg [1000 lb] design weight, the latter percentage may be increased linearly with weight up to 75 % at 5670 kg [12 500 lb].

4.10.1.2 For airplanes approved for aerobatics, in conditions A and F, assume that 100 % of the semispan wing airload acts on one side of the plane of symmetry and 60 % of this load acts on the other side.

4.10.2 The loads resulting from the aileron deflections and speeds specified in 4.25, in combination with an airplane load factor of at least two thirds of the positive maneuvering load factor used for design. Unless the following values result in unrealistic loads, the effect of aileron displacement on wing torsion may be accounted for by adding the following increment to the basic airfoil moment coefficient over the aileron portion of the span in the critical condition determined in 4.4.4:

$$\Delta c_m = -0.01\ \delta \qquad (3)$$

where:

Δc_m = the moment coefficient increment; and

δ = the down aileron deflection in degrees in the critical condition.

4.11 *Yawing Conditions*—The airplane must be designed for yawing loads on the vertical surfaces resulting from the loads specified in 4.20 through 4.22.

4.12 *Pressurized Cabin Loads*—For each pressurized compartment, the following applies:

4.12.1 The airplane structure must be strong enough to withstand the flight loads combined with pressure differential loads from zero up to the maximum relief valve setting.

4.12.2 The external pressure distribution in flight, and any stress concentrations, must be accounted for.

4.12.3 If landings may be made with the cabin pressurized, landing loads must be combined with pressure differential loads from zero up to the maximum allowed during landing.

4.12.4 The airplane structure must be strong enough to withstand the pressure differential loads corresponding to the maximum relief valve setting multiplied by a factor of 1.33, omitting other loads.

4.12.5 If a pressurized cabin has two or more compartments separated by bulkheads or a floor, the primary structure must be designed for the effects of sudden release of pressure in any compartment with external doors or windows. This condition must be investigated for the effects of failure of the largest opening in the compartment. The effects of intercompartmental venting may be considered.

4.13 *Unsymmetrical Loads Due to Engine Failure:*

4.13.1 Multi-engine airplanes must be designed for the unsymmetrical loads resulting from the failure of the critical engine including the following conditions in combination with a single malfunction of the propeller drag limiting system, considering the probable pilot corrective action on the flight controls:

4.13.1.1 At speeds between V_{MC} and V_D, the loads resulting from power failure because of fuel flow interruption are considered to be limit loads.

4.13.1.2 At speeds between V_{MC} and V_C, the loads resulting from the disconnection of the engine compressor from the turbine or from loss of the turbine blades are considered to be ultimate loads.

4.13.1.3 The time history of the thrust decay and drag buildup occurring as a result of the prescribed engine failures must be substantiated by test or other data applicable to the particular engine-propeller combination.

4.13.1.4 The timing and magnitude of the probable pilot corrective action must be conservatively estimated, considering the characteristics of the particular engine-propeller-airplane combination.

4.13.2 Pilot corrective action may be assumed to be initiated at the time maximum yawing velocity is reached, but not earlier than 2 s after the engine failure. The magnitude of the corrective action may be based on the limit pilot forces specified in 7.4 except that lower forces may be assumed where it is shown by analysis or test that these forces can control the yaw and roll resulting from the prescribed engine failure conditions.

4.14 *Rear Lift Truss:*

4.14.1 If a rear lift truss is used, it must be designed for conditions of reversed airflow at a design speed of:

$$V = 8.7\sqrt{\frac{W}{S}} + 8.7 \text{ (knots)} \qquad (4)$$

where:

W/S = wing loading (lb/ft^2) at design maximum takeoff weight.

4.14.2 Either aerodynamic data for the particular wing section used, or a value of C_L equalling –0.8 with a chordwise distribution that is triangular between a peak at the trailing edge and zero at the leading edge, must be used.

4.15 *Speed Control Devices*—If speed control devices (such as spoilers and drag flaps) are incorporated for use in enroute conditions:

4.15.1 The airplane must be designed for the symmetrical maneuvers and gusts prescribed in 4.4, 4.5, and 4.6, and the yawing maneuvers and lateral gusts in 4.20 and 4.21, with the device extended at speeds up to the placard device extended speed; and

4.15.2 If the device has automatic operating or load limiting features, the airplane must be designed for the maneuver and gust conditions prescribed in 4.15.1 at the speeds and corresponding device positions that the mechanism allows.

4.16 *Balancing Loads:*

4.16.1 A horizontal surface balancing load is a load necessary to maintain equilibrium in any specified flight condition with no pitching acceleration.

4.16.2 Horizontal balancing surfaces must be designed for the balancing loads occurring at any point on the limit maneuvering envelope and in the flap conditions specified in 4.8.

4.16.3 For airplanes meeting the limitations of X4.1, the distribution in Fig. X4.5 of Appendix X4 may be used.

4.17 *Maneuvering Loads for Horizontal Surfaces*—Each horizontal surface and its supporting structure, and the main wing of a canard or tandem wing configuration, if that surface has pitch control, must be designed for the maneuvering loads imposed by conditions 4.17.1 and 4.17.2. For airplanes meeting the limitations of X4.1, either condition 4.17.3 or condition 4.17.4 can be used instead of the loads determined in conditions 4.17.1 and 4.17.2.

4.17.1 A sudden movement of the pitching control at the speed V_A,

4.17.1.1 to the maximum aft movement (upward deflection), and

4.17.1.2 the maximum forward movement (downward deflection), as limited by the control stops, or pilot effort, whichever is critical.

4.17.1.3 For airplanes meeting the limitations of X4.1, the average loading of X4.3 of Appendix X4 and the distribution in Fig. X4.6 of Appendix X4 may be used.

4.17.2 A sudden aft movement of the pitching control at speeds above V_A, followed by a forward movement of the pitching control resulting in the following combinations of normal and angular acceleration:

Condition	Normal acceleration (n)	Angular acceleration (radian/s^2)
Nose-up pitching (down load)	1.0	$+\frac{39}{V}n_m(n_m - 1.5)$
Nose-down pitching (up load)	n_m	$-\frac{39}{V}n_m(n_m - 1.5)$

where:

n_m = positive limit maneuvering load factor used in the design of the airplane; and

V = initial speed in knots.

4.17.2.1 The conditions in this section involve loads corresponding to the loads that may occur in a "checked maneuver" (a maneuver in which the pitching control is suddenly displaced in one direction and then suddenly moved in the opposite direction). The deflections and timing of the "checked maneuver" must avoid exceeding the limit maneuvering load factor. The total horizontal surface load for both nose-up and nose-down pitching conditions is the sum of the balancing loads at V and the specified value of the normal load factor n, plus the maneuvering load increment due to the specified value of the angular acceleration. For airplanes meeting the limitations of X4.1, the maneuvering load increment in Fig. X4.2 of Appendix X4 and the distributions in Fig. X4.6 (for down loads) and in Fig. X4.7 (for up loads) of Appendix X4 may be used.

4.17.3 A sudden deflection of the elevator, the following cases must be considered:

4.17.3.1 Speed V_A, maximum upward deflection;

4.17.3.2 Speed V_A, maximum downward deflection;

4.17.3.3 Speed V_D, one-third maximum upward deflection;

4.17.3.4 Speed V_D, one-third maximum downward deflection.

4.17.3.5 The following assumptions must be made:

(1) The airplane is initially in level flight, and its attitude and air speed do not change.

(2) The loads are balanced by inertia forces.

4.17.4 A sudden deflection of the elevator such as to cause the normal acceleration to change from an initial value to a final value, the following cases being considered (see Fig. 2):

Speed	Initial Condition	Final Condition	Load Factor Increment
V_A	A_1	A	n1 – 1
	A	A_1	1 – n1
	A_1	G	n4 – 1
	G	A_1	1 – n4
V_D	D_1	D	n2 – 1
	D	D_1	1 – n2
	D_1	E	n3 – 1
	E	D_1	1 – n3

4.17.5 For the purpose of this calculation the difference in air speed between V_A and the value corresponding to point G on the maneuvering envelope can be ignored. The following assumptions must be made:

4.17.5.1 The airplane is initially in level flight, and its attitude and airspeed do not change;

4.17.5.2 The loads are balanced by inertia forces;

4.17.5.3 The aerodynamic tail load increment is given by:

$$\Delta P = \Delta n M g \left[\frac{X_{cg}}{l_t} - \frac{S_{ht}}{S} \frac{a_{ht}}{a} \left(1 - \frac{d\epsilon}{d\alpha} \right) - \frac{\rho_0}{2} \left(\frac{S_{ht} a_{ht} l_t}{M} \right) \right] \quad (5)$$

where:

ΔP = horizontal tail load increment, positive upwards (N),
Δn = load factor increment,
M = mass of the airplane (kg),
g = acceleration due to gravity (m/s^2),
X_{cg} = longitudinal distance of airplane c.g. aft of aerodynamic center of airplane less horizontal tail (m),
S_{ht} = horizontal tail area (m^2),
a_{ht} = slope of horizontal tail lift curve per radian,
$\frac{d\epsilon}{d\alpha}$ = rate of change of downwash angle with angle of attack,
ρ_0 = density of air at sea-level (kg/m^3),
l_t = tail arm (m),
S = wing area (m^2), and
a = slope of wing lift curve per radian.

4.18 *Gust Loads for Horizontal Surfaces:*

4.18.1 Each horizontal surface, other than a main wing, must be designed for loads resulting from:

4.18.1.1 Gust velocities specified in 4.4.3 with flaps retracted; and

4.18.1.2 Positive and negative gusts of 7.62 m/s [25 f.p.s.] nominal intensity at V_F, corresponding to the flight conditions specified in 4.8.1.2.

4.18.2 For airplanes meeting the limitations of X4.1, the average loadings in Fig. X4.3 and the distribution of Fig. X4.7 may be used to determine the incremental gust loads for the requirements of 4.18.1 applied as both up and down increments for 4.18.3.

4.18.3 When determining the total load on the horizontal surfaces for the conditions specified in 4.18.1, the initial balancing loads for steady unaccelerated flight at the pertinent design speeds V_F, V_C, and V_D must first be determined. The incremental load resulting from the gusts must be added to the initial balancing load to obtain the total load.

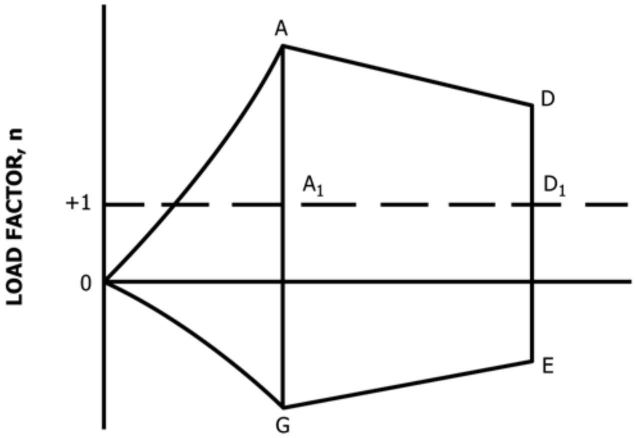


FIG. 2 Pitching Maneuvers

4.18.4 In the absence of a more rational analysis, the incremental load due to the gust must be computed as follows only on airplane configurations with aft-mounted, horizontal surfaces, unless its use elsewhere is shown to be conservative:

$$\Delta L_{ht} = \frac{K_g U_{de} V a_{ht} S_{ht}}{498} \left(1 - \frac{d_e}{d_\propto}\right) \tag{6}$$

where:

ΔL_{ht} = incremental horizontal tail load (lb);
K_g = gust alleviation factor defined in 4.6;
U_{de} = derived gust velocity (f.p.s.);
V = airplane equivalent speed (knots);
a_{ht} = slope of aft horizontal tail lift curve (per radian);
S_{ht} = area of aft horizontal lift surface (ft^2); and
$\left(1 - \frac{d_e}{d_\propto}\right)$ = downwash factor.

4.19 *Unsymmetrical Loads:*

4.19.1 Horizontal surfaces other than main wing and their supporting structure must be designed for unsymmetrical loads arising from yawing and slip-stream effects, in combination with the loads prescribed for the flight conditions set forth in 4.16 through 4.18.

4.19.2 In the absence of more rational data for airplanes that are conventional in regard to location of engines, wings, horizontal surfaces other than main wing, and fuselage shape:

4.19.2.1 100 % of the maximum loading from the symmetrical flight conditions may be assumed on the surface on one side of the plane of symmetry; and

4.19.2.2 The following percentage of that loading must be applied to the opposite side: Percent = 100 – 10 (n – 1), where n is the specified positive maneuvering load factor, but this value may not be more than 80 %.

4.19.3 For airplanes that are not conventional (such as airplanes with horizontal surfaces other than main wing having appreciable dihedral or supported by the vertical tail surfaces) the surfaces and supporting structures must be designed for combined vertical and horizontal surface loads resulting from each prescribed flight condition taken separately.

4.20 *Maneuvering Loads for Vertical Surfaces:*

4.20.1 At speeds up to V_A, the vertical surfaces must be designed to withstand the following conditions. In computing the loads, the yawing velocity may be assumed to be zero:

4.20.1.1 With the airplane in unaccelerated flight at zero yaw, it is assumed that the rudder control is suddenly displaced to the maximum deflection, as limited by the control stops or by limit pilot forces.

4.20.1.2 With the rudder deflected as specified in 4.20.1.1, it is assumed that the airplane yaws to the overswing sideslip angle. In lieu of a rational analysis, an overswing angle may be assumed equal to 1.5 times the static sideslip angle of 4.20.1.3.

4.20.1.3 A yaw angle of 15° with the rudder control maintained in the neutral position (except as limited by pilot strength).

4.20.2 For airplanes meeting the limitations of X4.1, the average loading of Appendix X4, X4.3 and Fig. X4.1 of Appendix X4 and the distribution in Fig. X4.5, Fig. X4.6 and Fig. X4.7 of Appendix X4 may be used instead of the requirements of 4.20.1.2, 4.20.1.1, and 4.20.1.3, respectively.

4.20.3 For level 4 airplanes, the loads imposed by the following additional maneuver must be substantiated at speeds from V_A to V_D/M_D. When computing the tail loads:

4.20.3.1 The airplane must be yawed to the largest attainable steady state sideslip angle, with the rudder at maximum deflection caused by any one of the following:

(1) Control surface stops;
(2) Maximum available booster effort;
(3) Maximum pilot rudder force as shown in Fig. 3.

4.20.3.2 The rudder must be suddenly displaced from the maximum deflection to the neutral position.

4.20.4 The yaw angles specified in 4.20.1.3 may be reduced if the yaw angle chosen for a particular speed cannot be exceeded in:

4.20.4.1 Steady slip conditions;

4.20.4.2 Uncoordinated rolls from steep banks; or

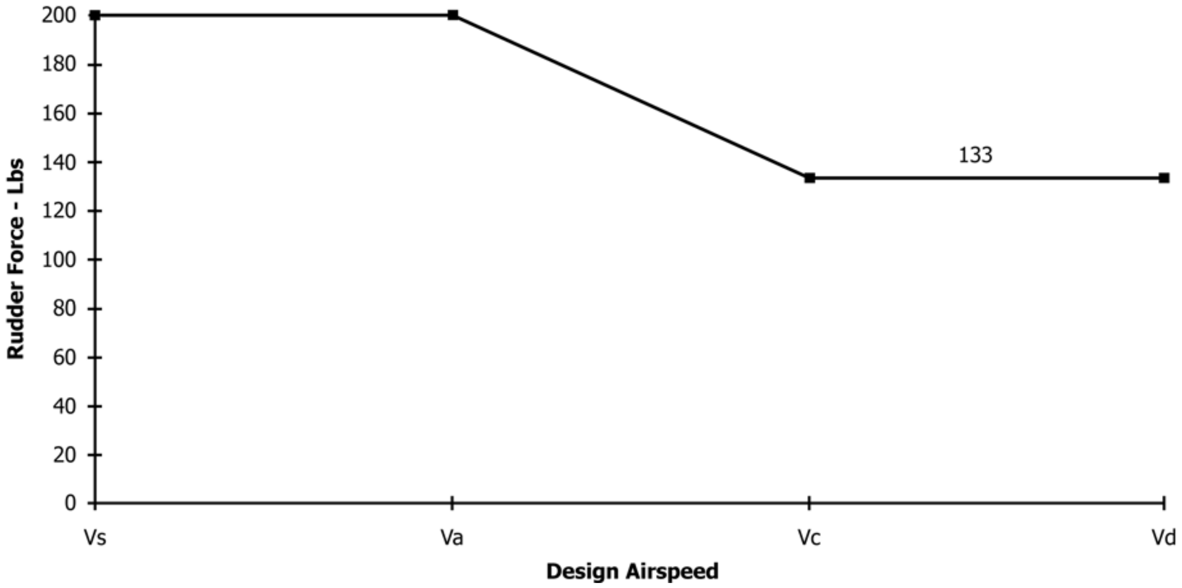


FIG. 3 Maximum Pilot Rudder Force

4.20.4.3 For multi-engine airplanes, the sudden failure of the critical engine with delayed corrective action.

4.21 *Gust Loads for Vertical Surfaces:*

4.21.1 Vertical surfaces must be designed to withstand, in unaccelerated flight at speed V_C, lateral gusts or the values prescribed for V_C in 4.4.3.

4.21.2 In addition, for level 4 airplanes, the airplane is assumed to encounter derived gusts normal to the plane of symmetry while in unaccelerated flight at V_B, V_C, V_D, and V_F. The derived gusts and airplane speeds corresponding to these conditions, as determined by 4.6 and 4.8, must be investigated. The shape of the gust must be as specified in 4.4.3.2*(1)*.

4.21.3 In the absence of a more rational analysis, the gust load must be computed as follows:

$$L_{vt} = \frac{K_{gt} U_{de} V a_{vt} S_{vt}}{498} \tag{7}$$

where:

L_{vt} = vertical surface loads (lb);
$K_g = \frac{0.88\mu_g}{5.3+\mu_{gt}}$ = gust alleviation factor;
$\mu_{gt} = \frac{2W}{\rho \bar{c}_t g a_{vt} S_{vt}} \frac{K^2}{l_{vt}}$ = lateral mass ratio;
U_{de} = derived gust velocity (f.p.s.);
ρ = air density (slugs/ft^3);
W = the applicable weight of the airplane in the particular load case (lb);
S_{vt} = area of vertical surface (ft^2);
$\bar{c}_t$ = mean geometric chord of vertical surface (ft);
a_{vt} = lift curve slope of vertical surface (per radian);
K = radius of gyration in yaw (ft);
l_{vt} = distance from airplane c.g. to lift center of vertical surface (ft);
g = acceleration due to gravity (ft/s^2); and
V = equivalent airspeed (knots).

4.21.4 For airplanes meeting the limitations of X4.1, the average loading in Fig. X4.4 and the distribution in Fig. X4.7 of Appendix X4 may be used.

4.22 *Outboard Fins or Winglets:*

4.22.1 If outboard fins or winglets are included on the horizontal surfaces or wings, the horizontal surfaces or wings must be designed for their maximum load in combination with loads induced by the fins or winglets and moments or forces exerted on the horizontal surfaces or wings by the fins or winglets.

4.22.2 If outboard fins or winglets extend above and below the horizontal surface, the critical vertical surface loading (the load per unit area as determined under 4.20 and 4.21) must be applied to:

4.22.2.1 The part of the vertical surfaces above the horizontal surface with 80 % of that loading applied to the part below the horizontal surface; and

4.22.2.2 The part of the vertical surfaces below the horizontal surface with 80 % of that loading applied to the part above the horizontal surface.

4.22.3 The end plate effects of outboard fins or winglets must be taken into account in applying the yawing conditions of 4.20 and 4.21 to vertical surfaces in 4.22.2.

4.22.4 When rational methods are used for computing loads, the maneuvering loads of 4.20 on the vertical surfaces and the one-g horizontal surface load, including induced loads on the horizontal surface and moments or forces exerted on the horizontal surfaces by the vertical surfaces, must be applied simultaneously for the structural loading condition.

4.23 *Combined Loads on Tail Surfaces:*

4.23.1 With the airplane in a loading condition corresponding to point A or D in the V-n diagram (whichever condition leads to the higher balance load) the loads on the horizontal tail must be combined with those on the vertical tail as specified in 4.20.

4.23.2 75% of the loads according to 4.17 for the horizontal tail and 4.20 for the vertical tail must be assumed to be acting simultaneously.

4.24 *Additional Loads Applicable to V-tails*—An airplane with V-tail must be designed for a gust acting perpendicularly with respect to one of the tail surfaces at speed V_E. This case is supplemental to the equivalent horizontal and vertical tail cases specified. Mutual interference between the V-tail surfaces must be adequately accounted for.

4.25 *Ailerons:*

4.25.1 The ailerons must be designed for the loads to which they are subjected:

4.25.1.1 In the neutral position during symmetrical flight conditions; and

4.25.1.2 By the following deflections (except as limited by pilot effort), during unsymmetrical flight conditions:

(1) Sudden maximum displacement of the aileron control at V_A. Suitable allowance may be made for control system deflections.

(2) Sufficient deflection at V_C, where V_C is more than V_A, to produce a rate of roll not less than obtained in 4.25.1.2.

(3) Sufficient deflection at V_D to produce a rate of roll not less than one-third of that obtained in 4.25.1.2.

4.25.2 For airplanes meeting the limitations of X4.1, the average loading in Appendix X4, X4.3 and Fig. X4.1 of Appendix X4 and the distribution in Fig. X4.8 of Appendix X4 may be used.

4.26 *Special Devices*—The loading for special devices using aerodynamic surfaces (such as slots, slats, and spoilers) must be determined from test data.

5. Design Airspeeds

5.1 *Design Airspeeds*—Except as provided in 5.1.1.4, the selected design airspeeds are equivalent airspeeds (EAS).

5.1.1 *Design Cruising Speed, V_C*—For V_C, the following apply:

5.1.1.1 Where *W/S* = wing loading at the design maximum takeoff weight (lb/ft^2), V_C (in knots) may not be less than:

(1) $33\sqrt{W/S}$; and

(2) $36\sqrt{W/S}$ (for airplanes approved for aerobatics).

5.1.1.2 For values of *W/S* more than 20, the multiplying factors may be decreased linearly with *W/S* to a value of 28.6 where *W/S* = 100.

5.1.1.3 V_C need not be more than 0.9 V_H at sea level.

5.1.1.4 At altitudes where an M_D is established, a cruising speed M_C limited by compressibility may be selected.

5.1.2 *Design Dive Speed, V_D*—For V_D, the following apply:

5.1.2.1 V_D/M_D may not be less than 1.25 V_C/M_C: and

5.1.2.2 With V_C min, the required minimum design cruising speed, V_D (in knots) may not be less than:

(1) 1.40 V_C min; and

(2) 1.55 V_C min (for airplanes approved for aerobatics).

5.1.2.3 For values of *W/S* more than 20, the multiplying factors in 5.1.2.2 may be decreased linearly with *W/S* to a value of 1.35 where *W/S* = 100.

5.1.2.4 Compliance with 5.1.2.1 and 5.1.2.2 need not be shown if V_D/M_D is selected so that the minimum speed margin between V_C/M_C and V_D/M_D is the greater of the following:

(1) The speed increase resulting when, from the initial condition of stabilized flight at V_C/M_C, the airplane is assumed to be upset, flown for 20 s along a flight path 7.5° below the initial path, and then pulled up with a load factor of 1.5 (0.5 g. acceleration increment). At least 75 % maximum continuous power for reciprocating engines, and maximum cruising power for turbines, or, if less, the power required for V_C/M_C for both kinds of engines, must be assumed until the pullup is initiated, at which point power reduction and pilot-controlled drag devices may be used; and either:

(2) Mach 0.05 (at altitudes where M_D is established); or

(3) Mach 0.07 for level 4 airplanes (at altitudes where M_D is established) unless a rational analysis, including the effects of automatic systems, is used to determine a lower margin. If a rational analysis is used, the minimum speed margin must be enough to provide for atmospheric variations (such as horizontal gusts), and the penetration of jet streams or cold fronts), instrument errors, airframe production variations, and must not be less than Mach 0.05.

5.1.3 *Design Maneuvering Speed V_A*—For V_A, the following applies:

5.1.3.1 V_A may not be less than $V_S\sqrt{n}$ where:

(1) V_S is a 1g computed stalling speed with flaps retracted (normally based on the maximum airplane normal force coefficients, C_{NA}) at either *(1)* the particular weight under consideration or *(2)* the design maximum takeoff weight; and

(2) *n* is the limit maneuvering load factor used in design.

5.1.3.2 The value of V_A need not exceed the value of V_C used in design.

5.1.4 *Design Speed for Maximum Gust Intensity, V_B*—For V_B, the following apply:

5.1.4.1 V_B may not be less than the speed determined by the intersection of the line representing the maximum positive lift, C_{NMAX}, and the line representing the rough air gust velocity on the gust V-n diagram, or $V_{S_1}\sqrt{n_g}$, whichever is less, where:

(1) n_g is the positive airplane gust load factor due to gust, at speed V_C (in accordance with 4.6), and at the particular weight under consideration; and

(2) V_{S_1} is the 1g stalling speed with the flaps retracted at the particular weight under consideration.

5.1.4.2 V_B need not be greater than V_C.

6. Engine Mount Loads

6.1 *Engine Torque:*

6.1.1 Each engine mount and its supporting structure must be designed for the effects of:

6.1.1.1 A limit engine torque corresponding to takeoff power and, if applicable, propeller speed acting simultaneously with 75 % of the limit loads from flight condition A of 4.4.4;

6.1.1.2 The limit engine torque as specified in 6.1.3 acting simultaneously with the limit loads from flight condition A of 4.4.4; and

6.1.1.3 For turbo-propeller installations, in addition to the conditions specified in 6.1.1.1 and 6.1.1.2, a limit engine torque corresponding to takeoff power and propeller speed, multiplied by a factor accounting for propeller control system malfunction, including quick feathering, acting simultaneously with 1g level flight loads. In the absence of a rational analysis, a factor of 1.6 must be used.

6.1.2 For turbine engine installations, the engine mounts and supporting structure must be designed to withstand each of the following:

6.1.2.1 A limit engine torque load imposed by sudden engine stoppage due to malfunction or structural failure (such as compressor jamming).

6.1.2.2 A limit engine torque load imposed by the maximum acceleration of the engine.

6.1.3 The limit engine torque to be considered under 6.1.1 must be obtained by multiplying the mean torque for maximum continuous power by a factor determined as follows:

6.1.3.1 1.25 for turbo-propeller installations;

6.1.3.2 For four-stroke engines:

(1) 1.33 for engines with five or more cylinders,

(2) 2, 3, 4, or 8 for engines with four, three, two, or one cylinders, respectively.

6.1.3.3 For two-stroke engines:

(1) 2 for engines with three or more cylinders,

(2) 3 or 6, for engines with two or one cylinders respectively.

6.2 *Side Load on Engine Mount:*

6.2.1 Each engine mount and its supporting structure must be designed for a limit load factor in a lateral direction, for the side load on the engine mount, of not less than:

6.2.1.1 1.33, or

6.2.1.2 One-third of the limit load factor for flight condition A.

6.2.2 The side load prescribed in 6.2.1 may be assumed to be independent of other flight conditions.

6.3 *Gyroscopic and Aerodynamic Loads:*

6.3.1 Each engine mount and its supporting structure must be designed for the gyroscopic, inertial, and aerodynamic loads that result, with the engine(s) and propeller(s), if applicable, at maximum continuous r.p.m., under either:

6.3.1.1 The conditions prescribed in 4.11 and 4.22; or

6.3.1.2 All possible combinations of the following:

(1) A yaw velocity of 2.5 radians per second;

(2) A pitch velocity of 1.0 radian per second;

(3) A normal load factor of 2.5; and

(4) Maximum continuous thrust.

6.3.2 For airplanes approved for aerobatics, each engine mount and its supporting structure must meet the requirements of 6.3.1 and be designed to withstand the load factors expected during combined maximum yaw and pitch velocities.

6.3.3 For level 4 airplanes, each engine mount and its supporting structure must meet the requirements of 6.3.1 and the gust conditions specified in 4.6.

7. Flight Control Loads

7.1 *Control Surface Loads:*

7.1.1 The control surface loads specified in 4.16 through 4.26 and 7.4 through 7.9 are assumed to occur in the conditions described in 4.3 through 4.11.

7.1.2 For airplanes meeting the limitations of X4.1 and if allowed by the following paragraphs, the values of control surface loading in Appendix X4 may be used to determine the detailed rational requirements of 4.16 through 4.26 and 7.4 through 7.9, unless these values result in unrealistic loads.

7.2 *Loads Parallel to Hinge Line:*

7.2.1 Control surfaces and supporting hinge brackets must be designed to withstand inertial loads acting parallel to the hinge line.

7.2.2 In the absence of more rational data, the inertia loads may be assumed to be equal to KW, where:

7.2.2.1 K = 24 for vertical surfaces;

7.2.2.2 K = 12 for horizontal surfaces; and

7.2.2.3 W = weight of the movable surfaces.

7.3 *Control System Loads:*

7.3.1 Each flight control system and its supporting structure must be designed for loads corresponding to at least 125 % of the computed hinge moments of the movable control surface in the conditions prescribed in 4.16 through 4.26 and 7.1 through 7.9. In addition, the following apply:

7.3.1.1 The system limit loads need not exceed the higher of the loads that can be produced by the pilot and automatic devices operating the controls. However, autopilot forces need not be added to pilot forces. The system must be designed for the maximum effort of the pilot or autopilot, whichever is higher. In addition, if the pilot and the autopilot act in opposition, the part of the system between them may be designed for the maximum effort of the one that imposes the lesser load. Pilot forces used for design need not exceed the maximum forces prescribed in 7.4.2.

7.3.1.2 The design must, in any case, provide a rugged system for service use, considering jamming, ground gusts, taxiing downwind, control inertia, and friction. Compliance with this subparagraph may be shown by designing for loads resulting from application of the minimum forces prescribed in 7.4.2.

7.3.2 A 1.25 factor on computed hinge moments must be used to design elevator, aileron, and rudder systems. However, a factor as low as 1.0 may be used if hinge moments are based on accurate flight test data, the exact reduction depending upon the accuracy and reliability of the data.

7.3.3 Pilot forces used for design are assumed to act at the appropriate control grips or pads as they would in flight, and to react at the attachments of the control system to the control surface horns.

7.3.4 For airplanes meeting the limitations of X4.1, the rudder control system must be designed to a load of 1000 N [225 lb] per pedal, acting simultaneously on both pedals in the forward direction.

7.4 *Limit Control Forces and Torques:*

7.4.1 In the control surface flight loading condition, the air loads on movable surfaces and the corresponding deflections need not exceed those that would result in flight from the application of any pilot force within the ranges specified in 7.4.2. In applying this criterion, the effects of control system boost and servo-mechanisms, and the effects of tabs must be considered. The automatic pilot effort must be used for design if it alone can produce higher control surface loads than the human pilot.

7.4.2 The limit pilot forces and torques are as follows:

Control	Maximum forces or torques for design maximum takeoff weight, W, equal to or less than 2268 kg [5000 lb][A]	Minimum forces or torques[B]
Aileron:		
Stick	298 N [67 lb]	178 N [40 lb]
Wheel[C]	222 D Nm [50 D in. lb][D]	178 D Nm [40 D in.- lb][D]
Elevator:		
Stick	743 N [167 lb]	445 N [100 lb]
Wheel (symmetrical)	890 N [200 lb]	445 N [100 lb]
Wheel (unsymmetrical)[E]		445 N [100 lb]
Rudder	890 N [200 lb]	667 N [150 lb]

[A] For design maximum takeoff weight (W) more than 2268 kg [5000 lb], the specified maximum values must be increased linearly with weight to 1.35 times the specified values at a design maximum takeoff weight of 8618 kg [19 000 lb].

[B] If the design of any individual set of control systems or surfaces makes these specified minimum forces or torques inapplicable, values corresponding to the present hinge moments obtained under 7.9, but not less than 0.6 of the specified minimum forces or torques, may be used.

[C] The critical parts of the aileron control system must also be designed for a single tangential force with a limit value of 1.25 times the couple force determined from the above criteria.

[D] D = wheel diameter (meters [inches]).

[E] The unsymmetrical force must be applied at one of the normal handgrip points on the control wheel.

7.5 *Dual Control System:*

7.5.1 Each dual control system must be designed to withstand the force of the pilots operating in opposition, using individual pilot forces not less than the greater of:

7.5.1.1 0.75 times those obtained under 7.3; or

7.5.1.2 The minimum forces specified in 7.4.2.

7.5.2 Each dual control system must be designed to withstand the force of the pilots applied together, in the same direction, using individual pilot forces not less than 0.75 times those obtained under 7.3.

7.6 *Secondary Control System*—Secondary controls, such as wheel brakes, spoilers, and tab controls, must be designed for the maximum forces that a pilot is likely to apply to those controls.

7.7 *Trim Tab Effects*—The effects of trim tabs on the control surface design conditions must be accounted for only where the surface loads are limited by maximum pilot effort. In these