



Designation: F3116/F3116M – 24

## Standard Specification for Design Loads and Conditions<sup>1</sup>

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 ( $\epsilon$ ) 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](http://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 non-conformance 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.*

<sup>1</sup> 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. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

F3060 Terminology for Aircraft

F3061/F3061M Specification for Systems and Equipment in Aircraft

F3331 Practice for Aircraft Water Loads

F3396/F3396M Practice for Aircraft Simplified Loads Criteria

#### 2.2 U.S. Code of Federal Regulations:<sup>3</sup>

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

#### 2.3 European Aviation Safety Agency Regulations:<sup>4</sup>

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.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [www.astm.org/contact](http://www.astm.org/contact). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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

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. 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 Practice **F3396/F3396M** provides, within the limitations specified within this practice, 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 6096 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 6096 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:

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

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 take-off 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:

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

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 (fps).

$\rho$  = density of air (slugs/ft<sup>3</sup>);

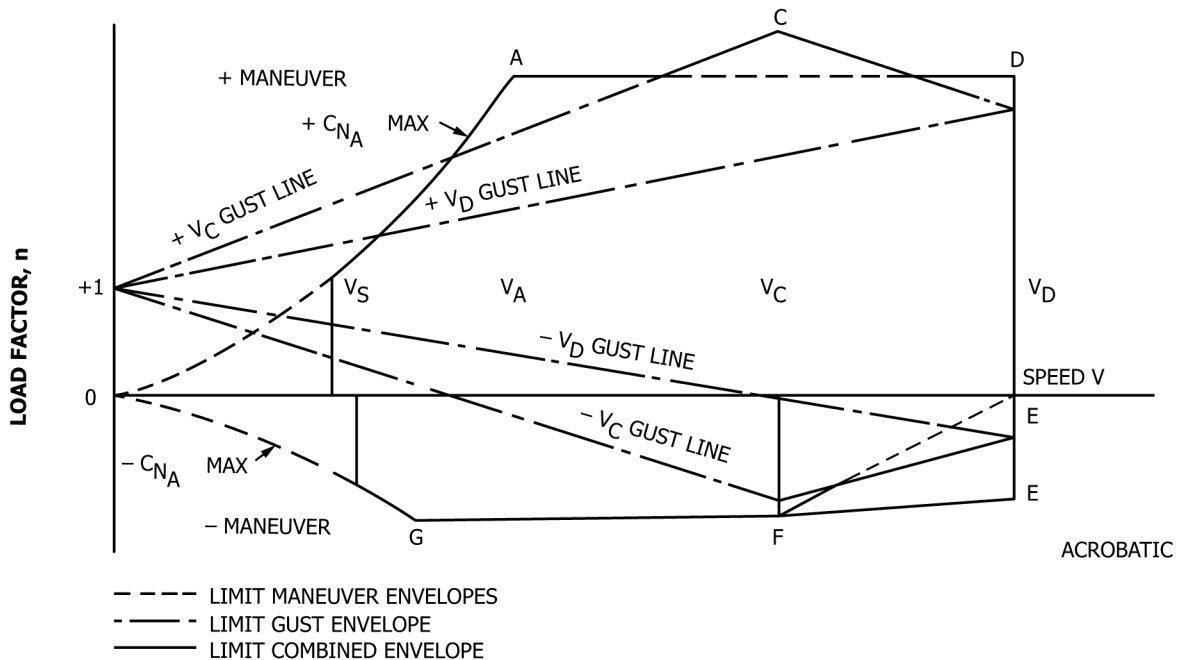
$W/S$  = wing loading (psf) due to the applicable weight of the airplane in the particular load case;

$C$  = mean geometric chord (ft);

$g$  = acceleration due to gravity (ft/s<sup>2</sup>);

$V$  = 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:

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

where:

$\Delta c_m$  = the moment coefficient increment; and

$\delta$  = 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:

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

where:

$W/S$  = wing loading (lb/ft<sup>2</sup>) 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 Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplanes), the distribution of horizontal tail balancing loads, Practice F3396/F3396M, Tail Surface Balancing and Maneuvering Load Distribution, 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 Practice F3396/F3396M, Control Surface Loading (Level 1 Aircraft), either the condition of 4.17.3 or 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 Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplane), the average loading of Practice F3396/F3396M, Acceptable Methods for Control Surface Loads Calculations, Control Surface Loads and the distribution for horizontal tail surfaces, Practice F3396/F3396M, Tail Surface, Horizontal Down Load Distribution, 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 <sup>2</sup> )
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 Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplanes), the maneuvering load increment in Practice F3396/F3396M, *Maneuvering Tail Load Increment (Up or Down)* and; for Down Loads, the distributions for horizontal tail surfaces, Practice F3396/F3396M, *Tail Surface, Horizontal Down Load Distribution* may be used. For Up Loads, the distributions for vertical tail surfaces, Practice F3396/F3396M, *Tail Surface Vertical and Horizontal Up Load Distribution* 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.

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 <sub>1</sub>	A	$n1 - 1$
	A	A <sub>1</sub>	$1 - n1$
	A <sub>1</sub>	G	$n4 - 1$
	G	A <sub>1</sub>	$1 - n4$
$V_D$	D <sub>1</sub>	D	$n2 - 1$
	D	D <sub>1</sub>	$1 - n2$
	D <sub>1</sub>	E	$n3 - 1$
	E	D <sub>1</sub>	$1 - n3$

4.17.4 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:

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

4.17.4.2 The loads are balanced by inertia forces;

4.17.4.3 The aerodynamic tail load increment is given by:

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

where:

- $\Delta P$  = horizontal tail load increment, positive upwards (N),
- $\Delta n$  = load factor increment,
- $M$  = mass of the airplane (kg),
- $g$  = acceleration due to gravity (m/s<sup>2</sup>),
- $X_{cg}$  = longitudinal distance of airplane c.g. aft of aerodynamic center of airplane less horizontal tail (m),
- $S_{ht}$  = horizontal tail area (m<sup>2</sup>),
- $a_{ht}$  = slope of horizontal tail lift curve per radian,
- $\frac{d\epsilon}{da}$  = rate of change of downwash angle with angle of attack,
- $\rho_0$  = density of air at sea-level (kg/m<sup>3</sup>),
- $l_t$  = tail arm (m),
- $S$  = wing area (m<sup>2</sup>), 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

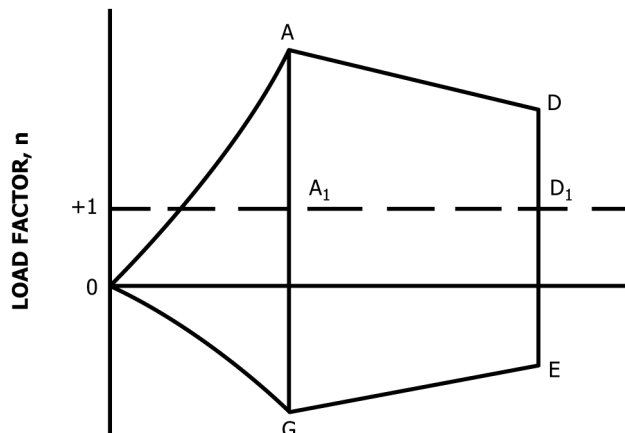


FIG. 2 Pitching Maneuvers



4.18.1.2 Positive and negative gusts of 7.62 m/s [25 fps] 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 Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplanes), the average loadings in Practice F3396/F3396M, *Up and Down Gust Loading on Horizontal Tail Surface*, and the distributions for vertical tail surfaces, Practice F3396/F3396M, *Tail Surface Vertical and Horizontal Up Load Distribution*, 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.

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:

$$\Delta L_{ht} = \frac{K_g U_{de} V_{a_{ht}} S_{ht}}{498} \left( 1 - \frac{d_e}{d_x} \right) \quad (6)$$

where:

$\Delta L_{ht}$  = incremental horizontal tail load (lb);  
 $K_g$  = gust alleviation factor defined in 4.6;  
 $U_{de}$  = derived gust velocity (fps);  
 $V$  = airplane equivalent speed (knots);  
 $a_{ht}$  = slope of aft horizontal tail lift curve (per radian);  
 $S_{ht}$  = area of aft horizontal lift surface (ft<sup>2</sup>); and  
 $\left( 1 - \frac{d_e}{d_x} \right)$  = 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 Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplanes), the average loading of Practice F3396/F3396M, *Limit Average Maneuvering Control Surface Loading* and the distributions in Practice F3396/F3396M, *Tail Balancing and Maneuver Load Distribution*, *Tail Surface, Horizontal Down Load Distribution*, *Tail Surface, Vertical and Horizontal Up Load Distribution*, 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

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:

$$L_{vt} = \frac{K_{gt} U_{de} V_{a_{vt}} S_{vt}}{498} \quad (7)$$

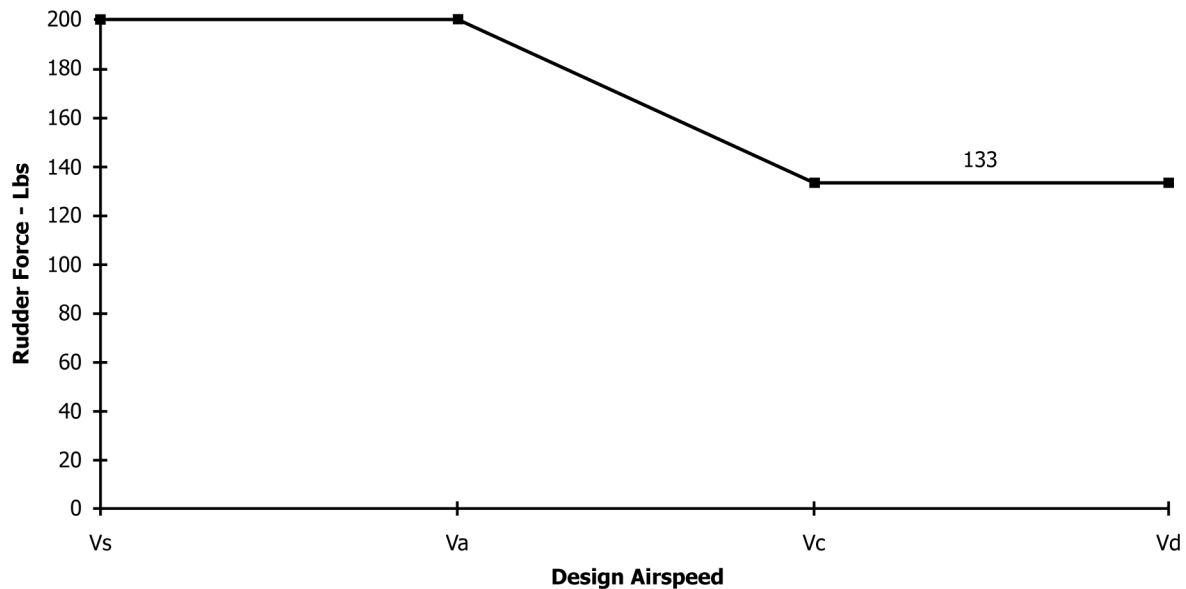


FIG. 3 Maximum Pilot Rudder Force

where:

$L_{vt}$	= vertical surface loads (lb);
$K_g = \frac{0.88\mu_g}{5.3 + \mu_{gt}}$	= gust alleviation factor;
$\mu_{gt} = \frac{2W}{\rho \bar{c}_t g a_{vt} S_{vt}} \left( \frac{K}{l_{vt}} \right)^2$	= lateral mass ratio;
$U_{de}$	= derived gust velocity (fps);
$\rho$	= air density (slugs/ft <sup>3</sup> );
$W$	= the applicable weight of the airplane in the particular load case (lb);
$S_{vt}$	= area of vertical surface (ft <sup>2</sup> );
$\bar{c}_t$	= 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 <sup>2</sup> ); and
$V$	= equivalent airspeed (knots).

4.21.4 For airplanes meeting the limitations of Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplanes), the average loading in Practice F3396/F3396M, *Gust Loading on Vertical Tail Surface*, and the distribution in Practice F3396/F3396M, *Tail Surface, Vertical and Horizontal Up Load Distribution*, 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 (for airplanes meeting the limitations of Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplanes)):*

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—(for airplanes meeting the limitations of Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplanes))—*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 Practice **F3396/F3396M**, Control Surface Loading (Level 1 Aeroplanes), the average loading of Practice **F3396/F3396M**, Control Surface Loading (Level 1 Aeroplanes), Control Surface Loads, and in Practice **F3396/F3396M**, The Limit Average Maneuvering Control Surface Loading, and the distribution in Practice **F3396/F3396M**, Aileron Load Distribution, 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<sup>2</sup>),  $V_C$  (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  $7.5^\circ$  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  $V_{S1} \sqrt{n_g}$ , 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)  $V_{S1}$  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 rpm, under either:

6.3.1.1 The conditions prescribed in 4.11 and 4.17; 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 Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplanes) and if allowed by the following paragraphs, the values of control surface loading in Practice F3396/F3396M, *Control Surface Loading (Level 1 Aeroplanes)*, 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 Practice F3396/F3396M, Control Surface Loading (Level 1 Aeroplanes), 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] <sup>A</sup>	Minimum forces or torques <sup>B</sup>
Aileron:		
Stick	298 N [67 lb]	178 N [40 lb]
Wheel <sup>C</sup>	222 D Nm [50 D in. lb] <sup>D</sup>	178 D Nm [40 D in.- lb] <sup>D</sup>
Elevator:		
Stick	743 N [167 lb]	445 N [100 lb]
Wheel (symmetrical)	890 N [200 lb]	445 N [100 lb]
Wheel (unsymmetrical) <sup>E</sup>		445 N [100 lb]
Rudder	890 N [200 lb]	667 N [150 lb]

<sup>A</sup> 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].

<sup>B</sup> 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.

<sup>C</sup> 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.

<sup>D</sup>  $D$  = wheel diameter (meters [inches]).

<sup>E</sup> 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 cases, the tabs are considered to be deflected in the direction that would assist the pilot. These deflections must correspond to the maximum degree of “out of trim” expected at the speed for the condition under consideration.

7.8 *Tabs*—Control surface tabs must be designed for the most severe combination of airspeed and tab deflection likely to be obtained within the flight envelope for any usable loading condition.

## 7.9 Ground Gust Conditions:

7.9.1 The control system must be investigated as follows for control surface loads due to ground gusts and taxiing downwind:

7.9.1.1 If an investigation of the control system for ground gust loads is not required by 7.9.1.2, but the applicant elects to design a part of the control system for these loads, these loads need only be carried from control surface horns through the nearest stops or gust locks and their supporting structures.

7.9.1.2 If pilot forces less than the minimums specified in 7.4.2 are used for design, the effects of surface loads due to ground gusts and taxiing downwind must be investigated for the entire control system according to the formula:

$$H = K c S q \quad (8)$$

where:

$H$  = limit hinge moment (ft.-lb);

$c$  = mean chord of the control surface aft of the hinge line (ft.);

$S$  = area of control surface aft of the hinge line (sq. ft.);

$q$  = dynamic pressure (psf) based on a design speed not less than  $14.6 \sqrt{W/S} + 14.6$  (fps) where  $W/S$  = wing loading at design maximum weight, except that the design speed need not exceed 88 (fps); and

$K$  = limit hinge moment factor for ground gusts derived in 7.9.2. (For ailerons and elevators, a positive value of  $K$  indicates a moment tending to depress the surface and a negative value of  $K$  indicates a moment tending to raise the surface).

7.9.2 The limit hinge moment factor  $K$  for ground gusts must be derived as follows:

Surface	$K$	Position of controls
(a) Aileron	0.75	Control column locked or lashed in mid-position
(b) Aileron	$\pm 0.50$	Ailerons at full throw, + moment on one aileron, – moment on the other
(c) Elevator	$\pm 0.75$	(c) Elevator full up (–)
(d) Elevator		(d) Elevator full down (+)
(e) Rudder	$\pm 0.75$	(e) Rudder in neutral
(f) Rudder		(f) Rudder at full throw

7.9.3 At all weights between the empty weight and the maximum weight declared for tie-down stated in the appropriate manual, any declared tie-down points and surrounding structure, control system, surfaces and associated gust locks, must be designed to withstand the limit load conditions that exist when the airplane is tied down and that result from wind speeds up to 65 knots horizontally from any direction.

## 8. Ground Loads

8.1 *General*—The limit ground loads specified in this subpart are considered to be external loads and inertia forces that act upon an airplane structure. In each specified ground load condition, the external reactions must be placed in equilibrium with the linear and angular inertia forces in a rational or conservative manner.

### 8.2 Ground Load Conditions and Assumptions:

8.2.1 The ground load requirements of this subpart must be complied with at the design maximum weight except that 8.4, 8.5, and 8.6 may be complied with at a design landing weight (the highest weight for landing conditions at the maximum descent velocity) allowed under 8.2.2 and 8.2.3.

8.2.2 The design landing weight may be as low as:





8.2.2.1 95 % of the maximum weight if the minimum fuel capacity is enough for at least one-half hour of operation at maximum continuous power plus a capacity equal to a fuel weight which is the difference between the design maximum weight and the design landing weight; or

8.2.2.2 The design maximum weight less the weight of 25 % of the total fuel capacity.

8.2.3 The design landing weight of a multi-engine airplane may be less than that allowed under 8.2.2 if:

8.2.3.1 The airplane meets the one-engine-inoperative climb requirements of 14 CFR Part 23, Sec. 23.67 (b)(1) or (c) and

8.2.3.2 Compliance is shown with the fuel jettisoning system requirements of 14 CFR Part 23, Sec. 23.1001.

8.2.4 The selected limit vertical inertia load factor at the center of gravity of the airplane for the ground load conditions prescribed in this subpart may not be less than that which would be obtained when landing with a descent velocity ( $V$ ), in feet per second equal to  $4.4 (W/S)^{1/4}$ , except that this velocity need not be more than 10 ft/s and may not be less than 7 ft/s.

8.2.5 Airplane lift not exceeding two-thirds of the weight of the airplane may be assumed to exist throughout the landing impact and to act through the center of gravity. The ground reaction load factor may be equal to the inertia load factor minus the ratio of the above assumed wing lift to the airplane weight.

8.2.6 If energy absorption tests are made to determine the limit load factor corresponding to the required limit descent velocities, these tests must be made under 8.15.1.

8.2.7 No inertia load factor used for design purposes may be less than 2.67, nor may the limit ground reaction  $n$  load factor be less than 2.0 at design maximum weight, unless these lower values will not be exceeded in taxiing at speeds up to takeoff speed over terrain as rough as that expected in service.

8.3 *Landing Gear Arrangement*—Sections 8.4 through 8.6, or the conditions in Appendix X1, apply to airplanes with conventional arrangements of main and nose gear, or main and tail gear.

#### 8.4 *Level Landing Conditions:*

8.4.1 For a level landing, the airplane is assumed to be in the following attitudes:

8.4.1.1 For airplanes with tail wheels, a normal level flight attitude.

8.4.1.2 For airplanes with nose wheels, attitudes in which:  
(1) The nose and main wheels contact the ground simultaneously; and

(2) The main wheels contact the ground and the nose wheel is just clear of the ground.

8.4.1.3 The attitude used in 8.4.1.2(1) of this section may be used in the analysis required under 8.4.1.2(2).

8.4.2 When investigating landing conditions, the drag components simulating the forces required to accelerate the tires and wheels up to the landing speed (spin-up) must be properly combined with the corresponding instantaneous vertical ground reactions, and the forward-acting horizontal loads resulting from rapid reduction of the spin-up drag loads (spring-back) must be combined with vertical ground reactions at the instant of the peak forward load, assuming wing lift and a tire-sliding coefficient of friction of 0.8. However, the drag

loads may not be less than 25 % of the maximum vertical ground reactions (neglecting wing lift).

8.4.3 In the absence of specific tests or a more rational analysis for determining the wheel spin-up and spring-back loads for landing conditions, the method set forth in Appendix X2 of this part must be used. If Appendix X2 of this part is used, the drag components used for design must not be less than those given by Appendix X1 of this part.

8.4.4 For airplanes with tip tanks or large overhung masses (such as turbo-propeller or jet engines) supported by the wing, the tip tanks and the structure supporting the tanks or overhung masses must be designed for the effects of dynamic responses under the level landing conditions of either 8.4.1.1 or 8.4.1.2(2). In evaluating the effects of dynamic response, an airplane lift equal to the weight of the airplane may be assumed.

#### 8.5 *Tail Down Landing Conditions:*

8.5.1 For a tail down landing, the airplane is assumed to be in the following attitudes:

8.5.1.1 For airplanes with tail wheels, an attitude in which the main and tail wheels contact the ground simultaneously.

8.5.1.2 For airplanes with nose wheels, a stalling attitude, or the maximum angle allowing ground clearance by each part of the airplane, whichever is less.

8.5.2 For airplanes with either tail or nose wheels, ground reactions are assumed to be vertical, with the wheels up to speed before the maximum vertical load is attained.

8.6 *One-Wheel Landing Conditions*—For the one-wheel landing condition, the airplane is assumed to be in the level attitude and to contact the ground on one side of the main landing gear. In this attitude, the ground reactions must be the same as those obtained on that side under 8.4.

#### 8.7 *Side Load Conditions:*

8.7.1 For the side load condition, the airplane is assumed to be in a level attitude with only the main wheels contacting the ground and with the shock absorbers and tires in their static positions.

8.7.2 The limit vertical load factor must be 1.33, with the vertical ground reaction divided equally between the main wheels.

8.7.3 The limit side inertia factor must be 0.83, with the side ground reaction divided between the main wheels so that:

8.7.3.1 0.5 ( $W$ ) is acting inboard on one side; and

8.7.3.2 0.33 ( $W$ ) is acting outboard on the other side.

8.7.4 The side loads prescribed in 8.7.3 are assumed to be applied at the ground contact point and the drag loads may be assumed to be zero.

8.8 *Braked Roll Conditions*—Under braked roll conditions, with the shock absorbers and tires in their static positions, the following apply:

8.8.1 The limit vertical load factor must be 1.33.

8.8.2 The attitudes and ground contacts must be those described in 8.4 for level landings.

8.8.3 A drag reaction equal to the vertical reaction at the wheel multiplied by a coefficient of friction of 0.8 must be applied at the ground contact point of each wheel with brakes,



except that the drag reaction need not exceed the maximum value based on limiting brake torque.

**8.9 Ground Loads—Supplementary Conditions for Tail Wheels**—In determining the ground loads on the tail wheel and affected supporting structures, the following apply:

8.9.1 For the obstruction load, the limit ground reaction obtained in the tail down landing condition is assumed to act up and aft through the axle at 45°. The shock absorber and tire may be assumed to be in their static positions.

8.9.2 For the side load, a limit vertical ground reaction equal to the static load on the tail wheel, in combination with a side component of equal magnitude, is assumed. In addition:

8.9.2.1 If a swivel is used, the tail wheel is assumed to be swiveled 90° to the airplane longitudinal axis with the resultant ground load passing through the axle;

8.9.2.2 If a lock, steering device, or shimmy damper is used, the tail wheel is also assumed to be in the trailing position with the side load acting at the ground contact point; and

8.9.2.3 The shock absorber and tire are assumed to be in their static positions.

8.9.3 If a tail wheel, bumper, or an energy absorption device is provided to show compliance with 14 CFR Part 23, Sec. 23.925 (b), the following applies:

8.9.3.1 Suitable design loads must be established for the tail wheel, bumper, or energy absorption device; and

8.9.3.2 The supporting structure of the tail wheel, bumper, or energy absorption device must be designed to withstand the loads established in **8.9.3.1**.

**8.10 Supplementary Conditions for Nose Wheels**—In determining the ground loads on nose wheels and affected supporting structures, and assuming that the shock absorbers and tires are in their static positions, the following conditions must be met:

8.10.1 For aft loads, the limit force components at the axle must be:

8.10.1.1 A vertical component of 2.25 times the static load on the wheel; and

8.10.1.2 A drag component of 0.8 times the vertical load.

8.10.2 For forward loads, the limit force components at the axle must be:

8.10.2.1 A vertical component of 2.25 times the static load on the wheel; and

8.10.2.2 A forward component of 0.4 times the vertical load.

8.10.3 For side loads, the limit force components at ground contact must be:

8.10.3.1 A vertical component of 2.25 times the static load on the wheel; and

8.10.3.2 A side component of 0.7 times the vertical load.

8.10.4 For airplanes with a steerable nose wheel that is controlled by hydraulic or other power, at design takeoff weight with the nose wheel in any steerable position, the application of 1.33 times the full steering torque combined with a vertical reaction equal to 1.33 times the maximum static reaction on the nose gear must be assumed. However, if a torque limiting device is installed, the steering torque can be reduced to the maximum value allowed by that device.

8.10.5 For airplanes with a steerable nose wheel that has a direct mechanical connection to the rudder pedals, the mechanism must be designed to withstand the steering torque for the maximum pilot forces specified in **7.4.2**.

nism must be designed to withstand the steering torque for the maximum pilot forces specified in **7.4.2**.

**8.11 Supplementary Conditions for Skiplanes**—In determining ground loads for skiplanes, and assuming that the airplane is resting on the ground with one main ski frozen at rest and the other skis free to slide, a limit side force equal to 0.036 times the design maximum weight must be applied near the tail assembly, with a factor of safety of 1.

**8.12 Jacking Loads:**

8.12.1 The airplane must be designed for the loads developed when it is supported on jacks at the design maximum weight assuming the following load factors for landing gear jacking points at a three-point attitude and for primary flight structure jacking points in the level attitude:

8.12.1.1 Vertical-load factor of 1.35 times the static reactions.

8.12.1.2 Fore, aft, and lateral load factors of 0.4 times the vertical static reactions.

8.12.2 The horizontal loads at the jack points must be reacted by inertia forces so as to result in no change in the direction of the resultant loads at the jack points.

8.12.3 The horizontal loads must be considered in all combinations with the vertical load.

**8.13 Towing Loads**—The towing loads of this section must be applied to the design of tow fittings and their immediate attaching structure.

8.13.1 The towing loads specified in **8.13.4** must be considered separately. These loads must be applied at the towing fittings and must act parallel to the ground. In addition:

8.13.1.1 A vertical load factor equal to 1.0 must be considered acting at the center of gravity; and

8.13.1.2 The shock struts and tires must be in their static positions.

8.13.2 For towing points not on the landing gear but near the plane of symmetry of the airplane, 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.

8.13.3 The towing loads specified in **8.13.4** must be reacted as follows:

8.13.3.1 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.

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

(1) 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 airplane inertia to achieve equilibrium must be applied.

(2) The loads must be reacted by airplane inertia.

8.13.4 The prescribed towing loads are as follows, where W is the design maximum weight:



## 8.15.1.3

Tow Point	Position	Magnitude	No.	Load Direction
Main Gear		0.225W per main gear unit	1.	Forward, parallel to drag axis
			2.	Forward, at 30° to drag axis
			3.	Aft, parallel to drag axis
			4.	Aft, at 30° to drag axis
Auxiliary Gear	Swiveled forward	0.3W	5.	Forward
			6.	Aft
	Swiveled aft	0.3W	7.	Forward
			8.	Aft
	Swiveled 45° from fwd	0.15W	9.	Forward, in plane of wheel
			10.	Aft, in plane of wheel
	Swiveled 45° from aft	0.15W	11.	Forward, in plane of wheel
			12.	Aft, in plane of wheel

8.14 *Ground Loads*—Ground load; unsymmetrical loads on multiple-wheel:

8.14.1 *Pivoting Loads*—The airplane is assumed to pivot about on side on the main gear with:

8.14.1.1 The brakes on the pivoting unit locked; and

8.14.1.2 Loads corresponding to a limit vertical load factor of 1, and coefficient of friction of 0.8, applied to the main gear and its supporting structure.

8.14.2 *Unequal Tire Loads*—The loads established under 8.1 through 8.6 must be applied in turn, in a 60/40 % distribution, to the dual wheels and tires in each dual wheel landing gear unit.

8.14.3 *Deflated Tire Loads*—For the deflated tire condition:

8.14.3.1 60 % of the loads established under 8.1 through 8.6 must be applied in turn to each wheel in a landing gear unit; and

8.14.3.2 60 % of the limit drag and side loads, and 100 % of the limit vertical load established under 8.7 and 8.8 or lesser vertical load obtained under 8.14.3.1, must be applied in turn to each wheel in the dual wheel landing gear unit.

8.15 *Shock Absorption Tests:*

8.15.1 Except as provided in 8.15.1.1 – 8.15.1.3, it must be shown by energy absorption tests that the limit load factors selected for design for takeoff and landing weights will not be exceeded.

8.15.1.1 For increases in previously approved takeoff or landing weights, or both, the requirements of 8.15.1 may be shown by analysis based on tests conducted on a landing gear system with identical energy absorption characteristics.

8.15.1.2

Level 1 and Low-Stall	All Others
The requirements of 8.15.1 may be shown by analysis based on previously approved wheel-type landing gear on aircraft with similar weights and performance.	Reserved

Level 1 and Low-Stall	All Others
The requirements of 8.15.1 may be shown by analysis based on landing gear for which adequate experience and substantiating data are available.	Reserved

8.15.2 The landing gear may not fail, but may yield, in a test showing its reserve energy absorption capacity, simulating a descent velocity of 1.2 times the limit descent velocity, assuming wing lift equal to the weight of the aeroplane.

8.16 *Limit Drop Tests:*

8.16.1 If compliance with 8.15.1 is shown by free drop tests, these tests must be made on the complete aeroplane, or on units consisting of wheel, tire, and shock absorber, in their proper relation, from free drop heights not less than those determined by the following formula in conjunction with Table 1:

$$h = C \cdot \left( \frac{W}{S} \right)^{1/2} \quad (9)$$

8.16.1.1 In complying with the requirements of 8.16.1, the free drop height may not be less than 0.234 m [9.2 in.] and need not be more than 0.475 m [18.7 in.].

8.16.2 If the effect of wing lift is provided for in free drop tests, the landing gear must be dropped with an effective weight equal to that derived from the following formula in conjunction with Table 2:

$$W_e = W \cdot \left( \frac{h + [d \cdot (1 - L)]}{h + d} \right) \quad (10)$$

8.16.3 The limit inertia load factor must be determined in a rational or conservative manner, during the drop test, using a landing gear unit attitude, and applied drag loads, that represent the landing conditions.

8.16.4 The value of  $d$  used in the computation of  $W_e$  in 8.16.2 may not exceed the value actually obtained in the drop test.

8.16.5 The limit inertia load factor must be determined from the drop test in 8.16.2 according to the following formula in conjunction with Table 3:

$$n = \frac{n_j \cdot W_e}{W} + L \quad (11)$$

8.16.6 The value of  $n$  determined in accordance with 8.16.5 may not be more than the limit inertia load factor used in the landing conditions.

8.17 *Ground Load Dynamic Tests:*

8.17.1 If compliance with the ground load requirements is shown dynamically by drop test, one drop test must be conducted that meets the requirements of 8.16 except that the drop height must be either: 2.25 times the drop height prescribed in 8.16.1; or, sufficient to develop 1.5 times the limit load factor.

TABLE 1 Legend for Drop Test Height Formula

Variable	Value	SI Units	English Units
$h$	Height of Free Drop Test	m	in.
$C$	Unit Correction Factor	0.0414	3.6
$W$	Design Maximum Takeoff Weight	kg	lb <sub>m</sub>
$S$	Wing Area (including fuselage projection)	m <sup>2</sup>	ft <sup>2</sup>



TABLE 2 Legend for Effective Weight Formula

Variable	Value	SI Units	English Units
$W_e$	Effective Weight to be used in Drop Test	kg	lb <sub>m</sub>
$h$	Specified Drop Height	m	in.
$d$	Deflection Under Impact of the Tire at the Approved Inflation Pressure PLUS Vertical Component of Axle Travel relative to the Drop Mass	m	in.
$W$	For Main Gear Units, $W_M$ (Static Weight on that Unit with the Aircraft in Level Attitude, with the Nose Wheel clear for nose-wheel type aircraft)	kg	lb <sub>m</sub>
	For Tail Gear Units, $W_T$ (Static Weight on the Tail Unit with the Aircraft in the Tail-Down Attitude)		
	For Nose Wheel Units, $W_N$ (Vertical Component of the Static Reaction at the Nose Wheel, assuming that the Mass of the Aircraft acts at the Center of Gravity and exerts a force of 1.0 g Downward and 0.33 g Forward)		
$L^A$	Ratio of Assumed Wing Lift to Aircraft Weight	—	—

<sup>A</sup> L need not be more than 0.667.

TABLE 3 Legend for Limit Inertia Load Factor Formula

Variable	Value	SI Units	English Units
$n$	Limit Inertia Load Factor	—	—
$n_j$	Acceleration (dv/dt, in g's) as recorded in the Drop Test PLUS 1.0	—	—
$W_e$	Effective Weight to be used in Drop Test	kg	lb <sub>m</sub>
$W$	For Main Gear Units, $W_M$ (Static Weight on that Unit with the Aircraft in Level Attitude, with the Nose Wheel clear for nose-wheel type aircraft)	kg	lb <sub>m</sub>
	For Tail Gear Units, $W_T$ (Static Weight on the Tail Unit with the Aircraft in the Tail-Down Attitude)		
	For Nose Wheel Units, $W_N$ (Vertical Component of the Static Reaction at the Nose Wheel, assuming that the Mass of the Aircraft acts at the Center of Gravity and exerts a force of 1.0 g Downward and 0.33 g Forward)		
$L^A$	Ratio of Assumed Wing Lift to Aircraft Weight	—	—

<sup>A</sup> L need not be more than 0.667.

8.17.2 The critical landing condition for each of the design conditions must be used for proof strength.

#### 8.18 Reserve Energy Absorption Drop Tests:

8.18.1 If compliance with the reserve energy absorption requirements in 8.15.2 is shown by free drop tests, the drop height may not be less than 1.44 times that specified in 8.16.

8.18.2 If the effect of wing lift is provided for, the units must be dropped with an effective weight equal to that derived from the following formula in conjunction with Table 4:

$$W_e = W \cdot \left( \frac{h}{h+d} \right) \quad (12)$$

TABLE 4 Legend for Reserve Energy Effective Weight Formula

Variable	Value	SI Units	English Units
$W_e$	Effective Weight to be used in Drop Test	kg	lb <sub>m</sub>
$h$	Specified Drop Height	m	in
$d$	Deflection Under Impact of the Tire at the Approved Inflation Pressure PLUS Vertical Component of Axle Travel relative to the Drop Mass	m	in
$W$	For Main Gear Units, $W_M$ (Static Weight on that Unit with the Aircraft in Level Attitude, with the Nose Wheel clear for nose-wheel type aircraft)	kg	lb <sub>m</sub>
	For Tail Gear Units, $W_T$ (Static Weight on the Tail Unit with the Aircraft in the Tail-Down Attitude)		
	For Nose Wheel Units, $W_N$ (Vertical Component of the Static Reaction at the Nose Wheel, assuming that the Mass of the Aircraft acts at the Center of Gravity and exerts a force of 1.0 g Downward and 0.33 g Forward)		



## 9. Water Loads

### 9.1 Water Load Conditions:

9.1.1 The structure of seaplanes and amphibians must be designed for water loads developed during takeoff and landing with the seaplane in any attitude likely to occur in normal operation at appropriate forward and sinking velocities under the most severe sea conditions likely to be encountered.

9.1.2 Unless sufficient satisfactory service experience is available, a rational analysis of the water loads, or the methods specified in Practice F3331 may be used.

9.1.3 Each seaplane main float must meet the requirements of this section.

## APPENDIXES

### (Nonmandatory Information)

## X1. BASIC LANDING CONDITIONS

### X1.1 Basic Landing Conditions

X1.1.1 Table X1.1 and Fig. X1.1 present the basic landing conditions that can be used when showing compliance with the requirements in Section 8.

**TABLE X1.1 Basic Landing Conditions**

Condition	Tail wheel type			Nose wheel type	
	Level landing	Tail-down landing	Level landing with inclined reactions	Level landing with nose wheel just clear of ground	Tail-down landing
Reference section	8.4.1.1	8.5.1.1	8.4.1.2(1)	8.4.1.2(2)	8.5.1.2 and 8.5.2
Vertical component at c.g.	$nW$	$nW$	$nW$	$nW$	$nW$
Fore and aft component at c.g.	$KnW$	0	$KnW$	$KnW$	0
Lateral component in either direction at c.g.	0	0	0	0	0
Shock absorber extension (hydraulic shock absorber)	(Note 2)	(Note 2)	(Note 2)	(Note 2)	(Note 2)
Shock absorber deflection (rubber or spring shock absorber)	100 %	100 %	100 %	100 %	100 %
Tire deflection	Static	Static	Static	Static	Static
Main wheel loads ( $V_i$ )	$(n-L)W$	$(n-L)Wbd$	$(n-L)Wa'/d'$	$(n-L)W$	$(n-L)W$
(both wheels) ( $D_i$ )	$KnW$	0	$KnWa'/d'$	$KnW$	0
Tail (nose) wheel ( $V_i$ )	0	$(n-L)Wa/d$	$(n-L)Wb/d'$	0	0
loads ( $D_i$ )	0	0	$KnWb/d'$	0	0
Notes	(Note 1), (Note 3), and (Note 4)	(Note 4)	(Note 1)	(Note 1), (Note 3), and (Note 4)	(Note 3) and (Note 4)

NOTE 1— $K$  may be determined as follows:  $K = 0.25$  for  $W = 1361$  kg [3000 lb] or less;  $K = 0.33$  for  $W = 2722$  kg [6000 lb] or greater, with linear variation of  $K$  between these weights.

NOTE 2—For the purpose of design, the maximum load factor is assumed to occur throughout the shock absorber stroke from 25 % deflection to 100 % deflection unless otherwise shown and the load factor must be used with whatever shock absorber extension is most critical for each element of the landing gear.

NOTE 3—Unbalanced moments must be balanced by a rational or conservative method.

NOTE 4— $L$  is defined in 14 CFR Part 23, Sec. 23.725 (b).

NOTE 5— $n$  is the limit inertia load factor, at the c.g. of the airplane, selected under 8.2.4, 8.2.6, and 8.2.7.



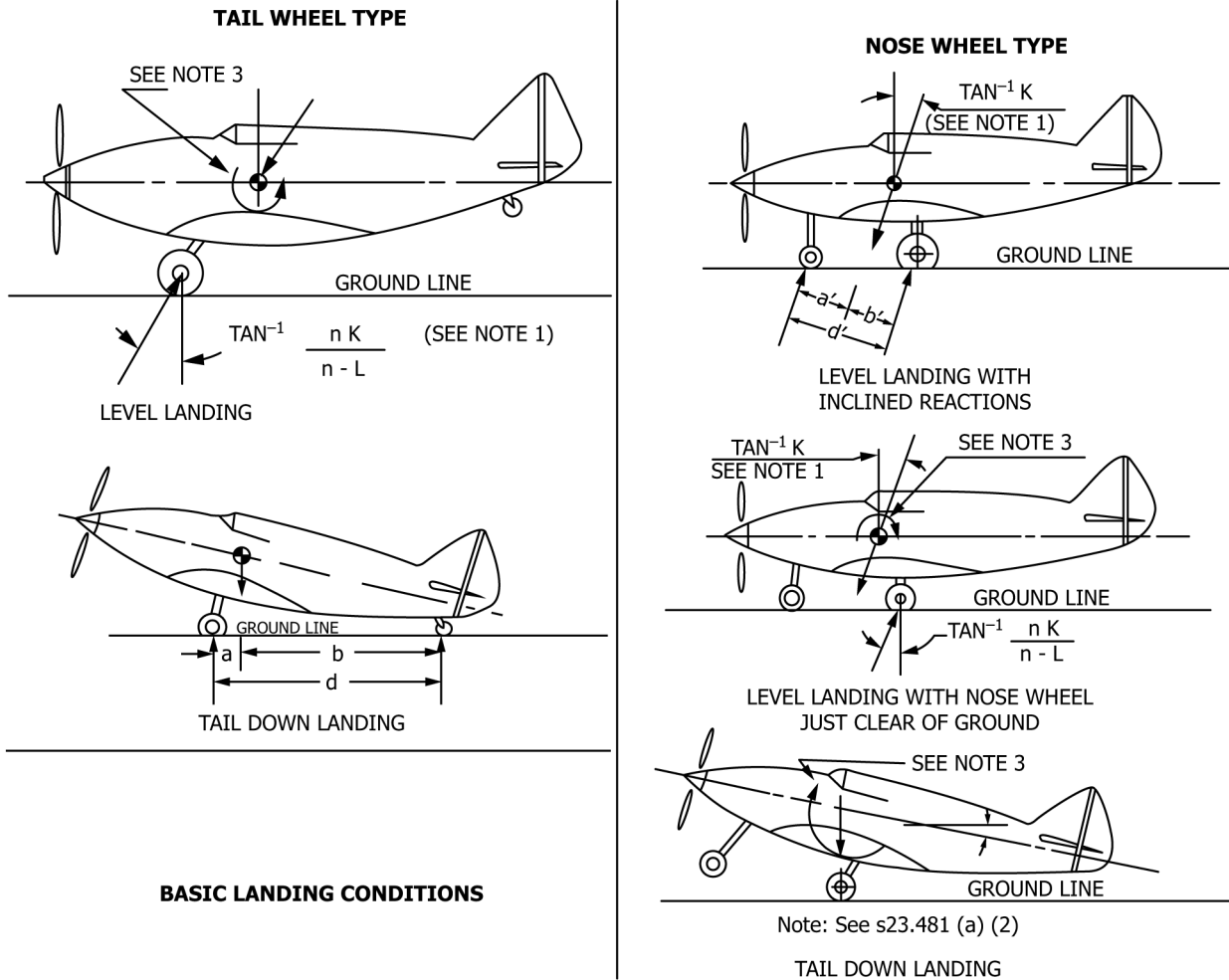


FIG. X1.1 Basic Landing Conditions

## X2. WHEEL SPIN-UP AND SPRING-BACK LOADS

### X2.1 Wheel Spin-Up Loads

X2.1.1 The following method for determining wheel spin-up loads for landing conditions is based on NACA T.N. 863. However, the drag component used for design may not be less than the drag load prescribed in 8.4.2.

$$F_{Hmax} = \frac{1}{r_e} \sqrt{\frac{2I_w(V_H - V_C)nF_{Vmax}}{t_z}} \quad (X2.1)$$

where:

- $F_{Hmax}$  = maximum rearward horizontal force acting on the wheel (in pounds);
- $r_e$  = effective rolling radius of wheel under impact based on recommended operating tire pressure (which may be assumed to be equal to the rolling radius under a static load of  $n_j W_e$ ) in feet;
- $I_w$  = rotational mass moment of inertia of rolling assembly (in slug feet);
- $V_H$  = linear velocity of airplane parallel to ground at instant of contact (assumed to be  $1.2 V_{SO}$ , in feet per second);

- $V_C$  = peripheral speed of tire, if pre-rotation is used (in feet per second) (there must be a positive means of pre-rotation before pre-rotation may be considered);
- $n$  = effective coefficient of friction (0.80 may be used);
- $F_{Vmax}$  = maximum vertical force on wheel (pounds) =  $n_j W_e$ , where  $W_e$  and  $n_j$  are defined in 14 CFR Part 23, Sec. 23.725; and
- $t_z$  = time interval between ground contact and attainment of maximum vertical force on wheel (seconds). (However, if the value of  $F_{Vmax}$  from the above equation exceeds  $0.8 F_{Vmax}$ , the latter value must be used for  $F_{Hmax}$ ).

X2.1.2 This equation assumes a linear variation of load factor with time until the peak load is reached and under this assumption, the equation determines the drag force at the time that the wheel peripheral velocity at radius  $r_e$  equals the airplane velocity. Most shock absorbers do not exactly follow a linear variation of load factor with time. Therefore, rational or conservative allowances must be made to compensate for these variations. On most landing gears, the time for wheel

spin-up will be less than the time required to develop maximum vertical load factor for the specified rate of descent and forward velocity. For exceptionally large wheels, a wheel peripheral velocity equal to the ground speed may not have been attained at the time of maximum vertical gear load. However, as stated above, the drag spin-up load need not exceed 0.8 of the maximum vertical loads.

X2.1.3 Dynamic spring-back of the landing gear and adjacent structure at the instant just after the wheels come up to speed may result in dynamic forward acting loads of consid-

erable magnitude. This effect must be determined, in the level landing condition, by assuming that the wheel spin-up loads calculated by the methods of this appendix are reversed. Dynamic spring-back is likely to become critical for landing gear units having wheels of large mass or high landing speeds.

### X3. REVISIONS

#### X3.1 Revisions to F3116/F3116M – 15 Approved November 1, 2018

**TABLE X3.1 Revisions**

Section	Change Description	Reason/Rationale for Change
2.1	Added F3331 Practice for Aircraft Water Loads	New Standard for Water Loads added to Reference Section.
9.1.2	Revised to change reference from Appendix X7 to Practice F3331.	Appendix X7 replaced by Practice F3331.
X7	Removed Appendix X7 Acceptable Means for Calculation of Water Loads.	Moved Appendix X7 material to Practice F3331.

#### X3.2 Revisions to F3116/F3116M – 18<sup>2</sup> Approved March 15, 2023

**TABLE X3.2 Revisions**

Section	Change Description	Reason/Rationale for Change
2	Added Practice F3396/F3396M for Aircraft Simplified Loads Criteria	New reference for standard on simplified loads.
Former X1 to X4	Removed Appendix X1, X2, X3, and X4.	Appendices replaced by Practice F3396/F3396M.
Multiple throughout	Added or revised references to Practice F3396/F3396M throughout.	Reference to Practice F3396/F3396M to avoid duplication of information.

#### X3.3 Revisions to F3116/F3116M – 23 Approved Oct. 1, 2023

**TABLE X3.3 Revisions**

Section	Change Description	Reason/Rationale for Change
4.21.3	Revised the equation for lateral mass ratio in Eq 7.	

#### X3.4 Revisions to F3116/F3116M – 23a Approved Dec. 1, 2024

**TABLE X3.4 Revisions**

Section	Change Description	Reason/Rationale for Change
Added 8.15, 8.16, 8.17, 8.18	Landing gear drop test requirements from Specification F3061/F3061M are removed and added to Specification F3116/F3116M.	Moving the landing gear drop test requirements into F3116/F3116M with the standards that reference them improves clarity and visibility to F44.30.



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