Regulamento Aeronáutico
Estruturas & Cargas

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Departamento de Engenharia Mecânica

Escola Politécnica da Universidade de São Paulo

Regulamento Aeronáutico

RBAC – Regulamentos Brasileiros da Aviação Civil

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http://www.anac.gov.br/assuntos/legislacao/legislacao-1/rbha-e-rbac/rba

RDBC

Regulamento Aeronáutico

RBAC023 EMD62	Requisitos de aeronavegabilidade: aviões categoria normal, utilidade, acrobática e transporte regional.	11/09/2017
RBAC025 EMD136	Requisitos de aeronavegabilidade: aviões categoria transporte	07/02/2014

FAR23

FAR25

REGULAMENTO BRASILEIRO DA AVIAÇÃO CIVIL

RBAC Nº 23

EMENDA Nº 62

Título:	**REQUISITOS DE AERONAVEGABILIDADE: AVIÕES CATEGORIA NORMAL, UTILIDADE, ACROBÁTICA E TRANSPORTE REGIONAL.**
Aprovação:	Resolução nº 446, de 6 de setembro de 2017. **Origem:** SAR

FAR23

(a) Geral

Para concessão de certificados de tipo para aviões categoria normal, utilidade, acrobática e transporte regional, será adotado integralmente, na língua inglesa, o regulamento **Title 14 Code of Federal Regulations Part 23**, Emenda 23-62, efetiva em 31 de janeiro de 2012, da autoridade de aviação civil, **Federal Aviation Administration – FAA**, do **Department of Transportation** dos Estados Unidos da América, o qual é republicado no Apêndice A-I deste RBAC a partir do contido no sítio de publicação do regulamento adotado em pauta: https://www.ecfr. gov.

(b) Divergência editorial

Qualquer divergência editorial contida no Apêndice A-I decorrente da republicação ali contida e o texto oficial da **FAA** deverá prevalecer, mediante anuência da ANAC, o texto oficial da **FAA**.

(c) Republicação

Sempre que houver emenda no regulamento **14 Code of Federal Regulations Part 23**, a ANAC republicará o texto do regulamento adotado na forma do Apêndice A-I, por meio de emendas a este RBAC.

(d) Emenda deste RBAC

Especificamente para este RBAC a indicação de sua emenda também é através da adoção da emenda do regulamento adotado e republicado no Apêndice A-I deste RBAC, portanto seguindo a indicação da emenda do regulamento adotado e indicado no parágrafo (a) desta seção.

Title 14: Aeronautics and Space

PART 23—AIRWORTHINESS STANDARDS:
NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

Subpart A—GENERAL

§23.2000 Applicability and definitions.

(a) This part prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for airplanes in the normal category.

(b) For the purposes of this part, the following definition applies:

Continued safe flight and landing means an airplane is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. Upon landing, some airplane damage may occur as a result of a failure condition.

Title 14: Aeronautics and Space

PART 23—AIRWORTHINESS STANDARDS:
NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

Subpart B—FLIGHT
PERFORMANCE

§23.2100 Weight and center of gravity.

(a) The applicant must determine limits for weights and centers of gravity that provide for the safe operation of the airplane.
(b) The applicant must comply with each requirement of this subpart at critical combinations of weight and center of gravity within the airplane's range of loading conditions using tolerances acceptable to the Administrator.
(c) The condition of the airplane at the time of determining its empty weight and center of gravity must be well defined and easily repeatable.

Title 14: Aeronautics and Space

PART 23—AIRWORTHINESS STANDARDS:
NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

Subpart C—STRUCTURES

§23.2200 Structural design envelope.

§23.2205 Interaction of systems and structures.

§23.2200 Structural design envelope.

The applicant must determine the structural design envelope, which describes the range and limits of airplane design and operational parameters for which the applicant will show compliance with the requirements of this subpart.

The applicant must account for all airplane design and operational parameters that affect structural loads, strength, durability, and aeroelasticity, including:

(a) Structural design airspeeds, landing descent speeds, and any other airspeed limitation at which the applicant must show compliance to the requirements of this subpart. The structural design airspeeds must—

(1) Be sufficiently greater than the stalling speed of the airplane to safeguard against loss of control in turbulent air; and

(2) Provide sufficient margin for the establishment of practical operational limiting airspeeds.

(b) Design maneuvering load factors not less than those, which service history shows, may occur within the structural design envelope.

(c) Inertial properties including weight, center of gravity, and mass moments of inertia, accounting for—

(1) Each critical weight from the airplane empty weight to the maximum weight; and

(2) The weight and distribution of occupants, payload, and fuel.

(d) Characteristics of airplane control systems, including range of motion and tolerances for control surfaces, high lift devices, or other moveable surfaces.

(e) Each critical altitude up to the maximum altitude.

Title 14: Aeronautics and Space

PART 23—AIRWORTHINESS STANDARDS:
NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

STRUCTURAL LOADS

§23.2210 Structural design loads.

§23.2215 Flight load conditions.

§23.2220 Ground and water load conditions.

§23.2225 Component loading conditions.

§23.2230 Limit and ultimate loads.

§23.2210 Structural design loads.

(a) The applicant must:

(1) Determine the applicable structural design loads resulting from likely externally or internally applied pressures, forces, or moments that may occur in flight, ground and water operations, ground and water handling, and while the airplane is parked or moored.

(2) Determine the loads required by paragraph (a)(1) of this section at all critical combinations of parameters, on and within the boundaries of the structural design envelope.

(b) The magnitude and distribution of the applicable structural design loads required by this section must be based on physical principles.

§23.2215   Flight load conditions.

The applicant must determine the structural design loads resulting from the following flight conditions:

(a) Atmospheric gusts where the magnitude and gradient of these gusts are based on measured gust statistics.

(b) Symmetric and asymmetric maneuvers.

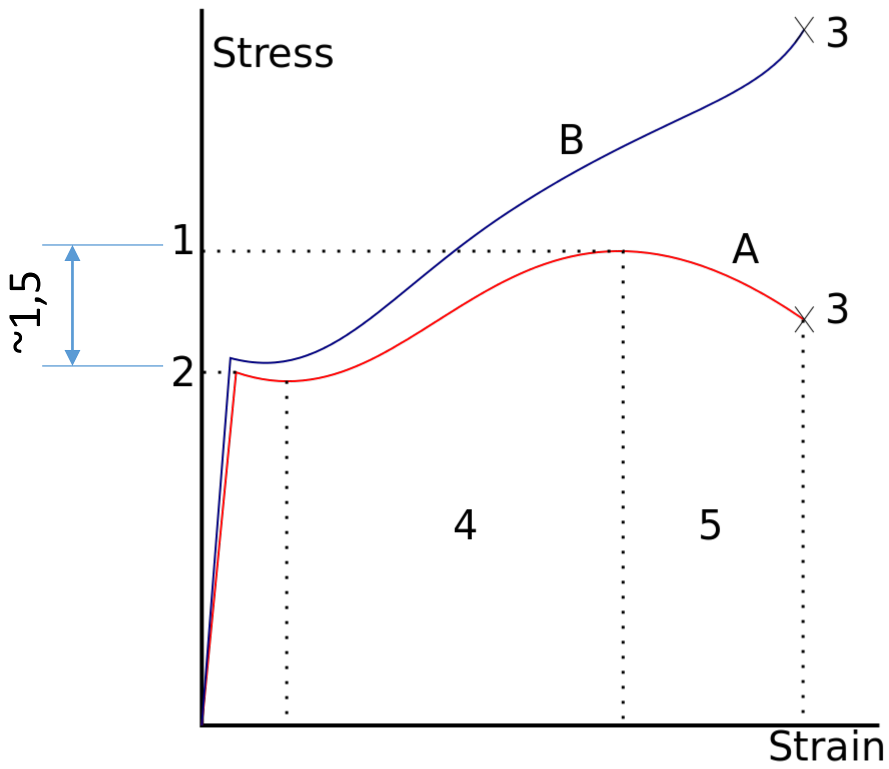
(c) Asymmetric thrust resulting from the failure of a powerplant unit.

§23.2230 Limit and ultimate loads.

The applicant must determine—

(a) The limit loads, which are equal to the structural design loads unless otherwise specified elsewhere in this part; and

(b) The ultimate loads, which are equal to the limit loads multiplied by a 1.5 factor of safety unless otherwise specified elsewhere in this part.



- figure 2: "Engineering" (red) and "true" (blue) stress–strain curve typical of structural steel.1: **Ultimate strength**
- 2: Yield strength (yield point)
- 3: Rupture
- 4: Strain hardening region
- 5: Necking region
- A: Apparent stress (F/A_0)
- B: Actual stress (F/A)

https://en.wikipedia.org/wiki/Ultimate_tensile_strength

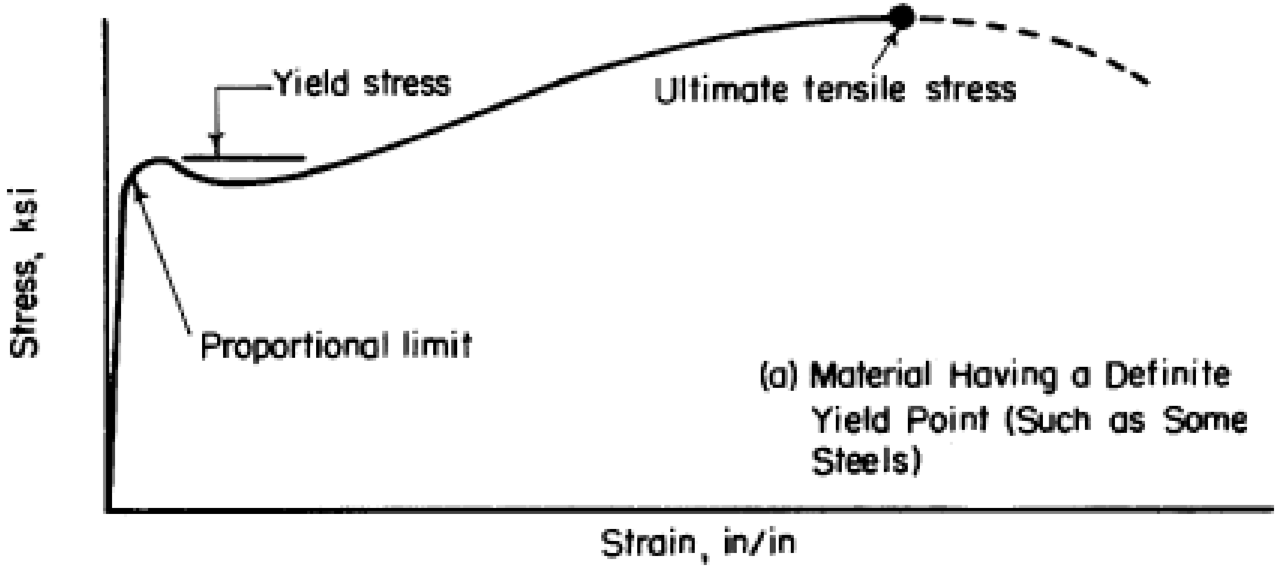


Figure 1.4.4. Typical tensile stress-strain diagrams.

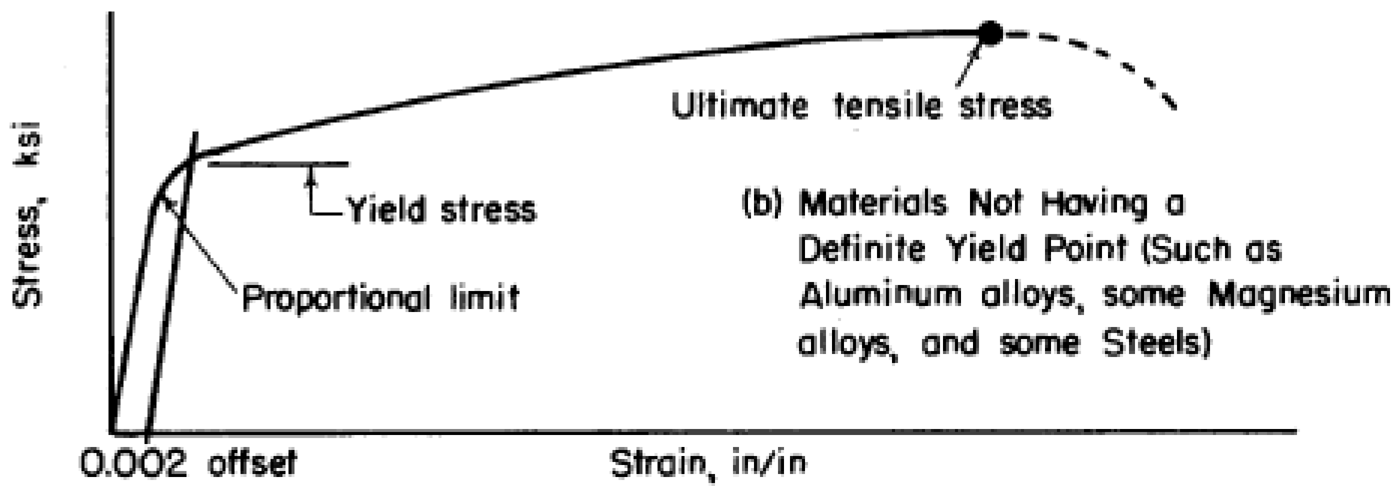


Figure 1.4.4. Typical tensile stress-strain diagrams.

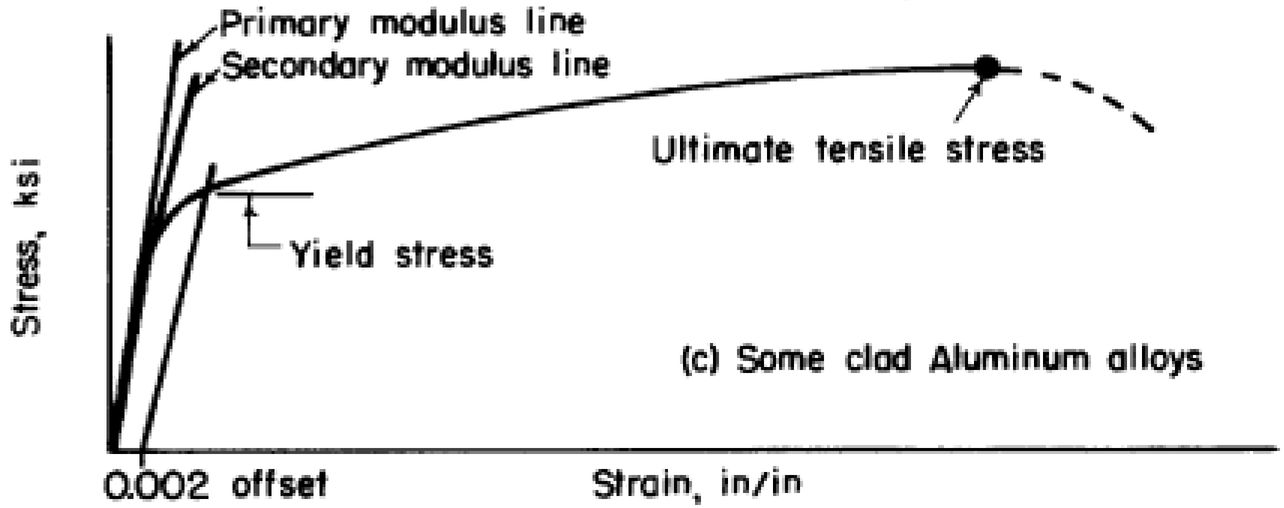


Figure 1.4.4. Typical tensile stress-strain diagrams.

Material	Yield Strength S_y (MPa)	Ultimate Tensile Strenght S_u (MPa)	Ratio S_u / S_y	Density ρ (g/cm³)	Ratio S_u/ρ (s^{-2})
Steel AISI 4130	951	1110	1,17	7,85	0,14
Aluminium Alloy 2014-T6	414	483	1,17	2,8	0,17
Titanium	850-1000		1,14	4,54	0,21-0,25
Carbon Fiber - laminates		1600		1,8	0,89
Carbon Fiber - fiber		6370		1,8	3,5
S-Glass		4710		2,48	1,9
Aramid (Kevler / Twaron)	3650	3757	1,03	1,44	2,6
Bamboo		350-500		0,4	0,88-1,3
Carbon Nanotube		11000-63000		0,037-1,34	45

https://en.wikipedia.org/wiki/Ultimate_tensile_strength

Aerospace and marine

Because titanium alloys have high tensile strength to density ratio, high corrosion resistance, fatigue resistance, high crack resistance, and ability to withstand moderately high temperatures without creeping, they are used in aircraft.

The titanium 6AL-4V alloy accounts for almost 50% of all alloys used in aircraft applications.

The Lockheed A-12 and its development the SR-71 "Blackbird" were two of the first aircraft frames where titanium was used, paving the way for much wider use in modern military and commercial aircraft.

Boeing 777	59 ton
Boeing 747	45 ton
Boeing 737	18 ton
Airbus A340	32 ton
Airbus A330	18 ton
Airbus A320	12 ton
Airbus A380	66 ton

https://en.wikipedia.org/wiki/Titanium

Title 14: Aeronautics and Space

PART 23—AIRWORTHINESS STANDARDS:
NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

STRUCTURAL PERFORMANCE

§23.2235 Structural strength.
§23.2240 Structural durability.
§23.2245 Aeroelasticity.

§23.2235 Structural strength.

The structure must support:

(a) Limit loads without—

(1) Interference with the safe operation of the airplane; and

(2) Detrimental permanent deformation.

(b) Ultimate loads.

§23.2240 Structural durability.

(a) The applicant must develop and implement inspections or other procedures to prevent structural failures due to foreseeable causes of strength degradation, which could result in serious or fatal injuries, or extended periods of operation with reduced safety margins. Each of the inspections or other procedures developed under this section must be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by §23.1529.

(b) For Level 4 airplanes, the procedures developed for compliance with paragraph (a) of this section must be capable of detecting structural damage before the damage could result in structural failure.

(c) For pressurized airplanes:

(1) The airplane must be capable of continued safe flight and landing following a sudden release of cabin pressure, including sudden releases caused by door and window failures.

(2) For airplanes with maximum operating altitude greater than 41,000 feet, the procedures developed for compliance with paragraph (a) of this section must be capable of detecting damage to the pressurized cabin structure before the damage could result in rapid decompression that would result in serious or fatal injuries.

(d) The airplane must be designed to minimize hazards to the airplane due to structural damage caused by high-energy fragments from an uncontained engine or rotating machinery failure.

§23.2245 Aeroelasticity.

(a) The airplane must be free from flutter, control reversal, and divergence—

(1) At all speeds within and sufficiently beyond the structural design envelope;

(2) For any configuration and condition of operation;

(3) Accounting for critical degrees of freedom; and

(4) Accounting for any critical failures or malfunctions.

(b) The applicant must establish tolerances for all quantities that affect flutter.

Title 14: Aeronautics and Space

PART 23—AIRWORTHINESS STANDARDS:
NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

DESIGN

§23.2250 Design and construction principles.

§23.2255 Protection of structure.

§23.2260 Materials and processes.

§23.2265 Special factors of safety.

§23.2250 Design and construction principles.

(a) The applicant must design each part, article, and assembly for the expected operating conditions of the airplane.
(b) Design data must adequately define the part, article, or assembly configuration, its design features, and any materials and processes used.
(c) The applicant must determine the suitability of each design detail and part having an important bearing on safety in operations.
(d) The control system must be free from jamming, excessive friction, and excessive deflection when the airplane is subjected to expected limit airloads.
(e) Doors, canopies, and exits must be protected against inadvertent opening in flight, unless shown to create no hazard when opened in flight.

§23.2255 Protection of structure.

(a) The applicant must protect each part of the airplane, including small parts such as fasteners, against deterioration or loss of strength due to any cause likely to occur in the expected operational environment.

(b) Each part of the airplane must have adequate provisions for ventilation and drainage.

(c) For each part that requires maintenance, preventive maintenance, or servicing, the applicant must incorporate a means into the aircraft design to allow such actions to be accomplished.

§23.2260 Materials and processes.

(a) The applicant must determine the suitability and durability of materials used for parts, articles, and assemblies, accounting for the effects of likely environmental conditions expected in service, the failure of which could prevent continued safe flight and landing.

(b) The methods and processes of fabrication and assembly used must produce consistently sound structures. If a fabrication process requires close control to reach this objective, the applicant must perform the process under an approved process specification.

(c) Except as provided in paragraphs (f) and (g) of this section, the applicant must select design values that ensure material strength with probabilities that account for the criticality of the structural element. Design values must account for the probability of structural failure due to material variability.

(d) If material strength properties are required, a determination of those properties must be based on sufficient tests of material meeting specifications to establish design values on a statistical basis.

(e) If thermal effects are significant on a critical component or structure under normal operating conditions, the applicant must determine those effects on allowable stresses used for design.

(f) Design values, greater than the minimums specified by this section, may be used, where only guaranteed minimum values are normally allowed, if a specimen of each individual item is tested before use to determine that the actual strength properties of that particular item will equal or exceed those used in the design.

(g) An applicant may use other material design values if approved by the Administrator.

REGULAMENTO BRASILEIRO DA AVIAÇÃO CIVIL

RBAC nº 25

EMENDA nº 136

Título:	**REQUISITOS DE AERONAVEGABILIDADE: AVIÕES CATEGORIA TRANSPORTE**

Aprovação:	Resolução nº 303, de 5 de fevereiro de 2014, publicada no Diário Oficial da União de 7 de fevereiro de 2014, Seção 1, página 8.	**Origem:** SAR

FAR25

25.00 Requisitos da adoção

(a) Geral

Para concessão de certificados de tipo para aviões categoria transporte, será adotado integral-mente, na língua inglesa, o regulamento **Title 14 Code of Federal Regulations Part 25**, Emen-da 25-136, em vigor desde 12 de março de 2012, da autoridade de aviação civil, **Federal Avia-tion Administration – FAA**, do **Department of Transportation** dos Estados Unidos da América, o qual é republicado no Apêndice A-I deste RBAC a partir do original contido no sítio oficial de publicação do regulamento adotado em pauta: http://www.ecfr.gov.

(b) Divergência editorial

Qualquer divergência editorial contida no Apêndice A-I decorrente da republicação ali contida e o texto original deverá prevalecer, mediante anuência da ANAC, o texto original.

(c) Republicação

Sempre que houver emenda no regulamento **14 Code of Federal Regulations Part 25**, a ANAC republicará o texto do regulamento adotado na forma do Apêndice A-I, por meio de emendas a este RBAC.

(d) Emenda deste RBAC

Especificamente para este RBAC, a indicação de sua emenda também é através da adoção da emenda do regulamento adotado e republicado no Apêndice A-I deste RBAC, seguindo, portan-to, a indicação da emenda do regulamento adotado e indicado no parágrafo (a) desta seção.

Title 14: Aeronautics and Space

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

Subpart A—GENERAL

§25.1 Applicability.

§25.2 Special retroactive requirements.

§25.3 Special provisions for ETOPS type design approvals.

§25.5 Incorporations by reference.

§25.1 Applicability.

(a) This part prescribes airworthiness standards for the issue of type certificates, and changes to those certificates, for transport category airplanes.

(b) Each person who applies under Part 21 for such a certificate or change must show compliance with the applicable requirements in this part.

Title 14: Aeronautics and Space

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

Subpart B—FLIGHT

GENERAL

§25.21 Proof of compliance.

§25.23 Load distribution limits.

§25.25 Weight limits.

§25.27 Center of gravity limits.

§25.29 Empty weight and corresponding center of gravity.

§25.31 Removable ballast.

§25.33 Propeller speed and pitch limits.

§25.21 Proof of compliance.

(a) Each requirement of this subpart must be met at each appropriate combination of weight and center of gravity within the range of loading conditions for which certification is requested. This must be shown—

(1) By tests upon an airplane of the type for which certification is requested, or by calculations based on, and equal in accuracy to, the results of testing; and

(2) By systematic investigation of each probable combination of weight and center of gravity, if compliance cannot be reasonably inferred from combinations investigated.

(b) [Reserved]

(c) The controllability, stability, trim, and stalling characteristics of the airplane must be shown for each altitude up to the maximum expected in operation.

(d) Parameters critical for the test being conducted, such as weight, loading (center of gravity and inertia), airspeed, power, and wind, must be maintained within acceptable tolerances of the critical values during flight testing.

(e) If compliance with the flight characteristics requirements is dependent upon a stability augmentation system or upon any other automatic or power-operated system, compliance must be shown with §§25.671 and 25.672.

(f) In meeting the requirements of §§25.105(d), 25.125, 25.233, and 25.237, the wind velocity must be measured at a height of 10 meters above the surface, or corrected for the difference between the height at which the wind velocity is measured and the 10-meter height.

(g) The requirements of this subpart associated with icing conditions apply only if the applicant is seeking certification for flight in icing conditions.

§25.23 Load distribution limits.

(a) Ranges of weights and centers of gravity within which the airplane may be safely operated must be established. If a weight and center of gravity combination is allowable only within certain load distribution limits (such as spanwise) that could be inadvertently exceeded, these limits and the corresponding weight and center of gravity combinations must be established.

(b) The load distribution limits may not exceed—

(1) The selected limits;

(2) The limits at which the structure is proven; or

(3) The limits at which compliance with each applicable flight requirement of this subpart is shown.

§25.25 Weight limits.

(a) *Maximum weights.* Maximum weights corresponding to the airplane operating conditions (such as ramp, ground or water taxi, takeoff, en route, and landing), environmental conditions (such as altitude and temperature), and loading conditions (such as zero fuel weight, center of gravity position and weight distribution) must be established so that they are not more than—

(1) The highest weight selected by the applicant for the particular conditions; or

(2) The highest weight at which compliance with each applicable structural loading and flight requirement is shown, except that for airplanes equipped with standby power rocket engines the maximum weight must not be more than the highest weight established in accordance with appendix E of this part; or

(3) The highest weight at which compliance is shown with the certification requirements of Part 36 of this chapter.

(b) *Minimum weight.* The minimum weight (the lowest weight at which compliance with each applicable requirement of this part is shown) must be established so that it is not less than—

(1) The lowest weight selected by the applicant;

(2) The design minimum weight (the lowest weight at which compliance with each structural loading condition of this part is shown); or

(3) The lowest weight at which compliance with each applicable flight requirement is shown.

Title 14: Aeronautics and Space

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

PERFORMANCE

§25.101 General.
§25.103 Stall speed.
§25.105 Takeoff.
§25.107 Takeoff speeds.
§25.109 Accelerate-stop distance.
§25.111 Takeoff path.
§25.113 Takeoff distance and takeoff run.
§25.115 Takeoff flight path.
§25.117 Climb: general.
§25.119 Landing climb: All-engines-operating.
§25.121 Climb: One-engine-inoperative.
§25.123 En route flight paths.
§25.125 Landing.

§25.103 Stall speed.

(a) The reference stall speed, V_{SR}, is a calibrated airspeed defined by the applicant. V_{SR} may not be less than a 1-g stall speed. V_{SR} is expressed as:

$$V_{SR} \geq \frac{V_{CL_{MAX}}}{\sqrt{n_{ZW}}}$$

where:

V_{CLMAX} = Calibrated airspeed obtained when the load factor-corrected lift coefficient

$$\left(\frac{n_{ZW} W}{qS}\right)$$

is first a maximum during the maneuver prescribed in paragraph (c) of this section. In addition, when the maneuver is limited by a device that abruptly pushes the nose down at a selected angle of attack (e.g., a stick pusher), V_{CLMAX} may not be less than the speed existing at the instant the device operates;

n_{ZW} = Load factor normal to the flight path at V_{CLMAX}

W = Airplane gross weight;

S = Aerodynamic reference wing area; and

q = Dynamic pressure.

(b) V_{CLMAX} is determined with:

(1) Engines idling, or, if that resultant thrust causes an appreciable decrease in stall speed, not more than zero thrust at the stall speed;

(2) Propeller pitch controls (if applicable) in the takeoff position;

(3) The airplane in other respects (such as flaps, landing gear, and ice accretions) in the condition existing in the test or performance standard in which V_{SR} is being used;

(4) The weight used when V_{SR} is being used as a factor to determine compliance with a required performance standard;

(5) The center of gravity position that results in the highest value of reference stall speed; and

(6) The airplane trimmed for straight flight at a speed selected by the applicant, but not less than $1.13V_{SR}$ and not greater than $1.3V_{SR}$.

(c) Starting from the stabilized trim condition, apply the longitudinal control to decelerate the airplane so that the speed reduction does not exceed one knot per second.

(d) In addition to the requirements of paragraph (a) of this section, when a device that abruptly pushes the nose down at a selected angle of attack (e.g., a stick pusher) is installed, the reference stall speed, V_{SR}, may not be less than 2 knots or 2 percent, whichever is greater, above the speed at which the device operates.

Title 14: Aeronautics and Space

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

Subpart C—STRUCTURE
GENERAL
§25.301 Loads.
§25.303 Factor of safety.
§25.305 Strength and deformation.
§25.307 Proof of structure.

§25.301 Loads.

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

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

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

§25.303 Factor of safety.

Unless otherwise specified, a factor of safety of 1.5 must be applied to the prescribed limit load which are considered external loads on the structure. When a loading condition is prescribed in terms of ultimate loads, a factor of safety need not be applied unless otherwise specified

§25.305 Strength and deformation.

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

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

(1) The effects of deformation are not significant;

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

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

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

(d) [Reserved]
(e) The airplane must be designed to withstand any vibration and buffeting that might occur in any likely operating condition up to V_D/M_D, including stall and probable inadvertent excursions beyond the boundaries of the buffet onset envelope. This must be shown by analysis, flight tests, or other tests found necessary by the Administrator.
(f) Unless shown to be extremely improbable, the airplane must be designed to withstand any forced structural vibration resulting from any failure, malfunction or adverse condition in the flight control system. These must be considered limit loads and must be investigated at airspeeds up to V_C/M_C.

§25.307 Proof of structure.

(a) Compliance with the strength and deformation requirements of this subpart must be shown for each critical loading condition. Structural analysis may be used only if the structure conforms to that for which experience has shown this method to be reliable. In other cases, substantiating tests must be made to load levels that are sufficient to verify structural behavior up to loads specified in §25.305.

(b)-(c) [Reserved]

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

FLIGHT LOADS

§25.321 General.

§25.321 General.

(a) Flight load factors 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 load factor is one in which the aerodynamic force acts upward with respect to the airplane.

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

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

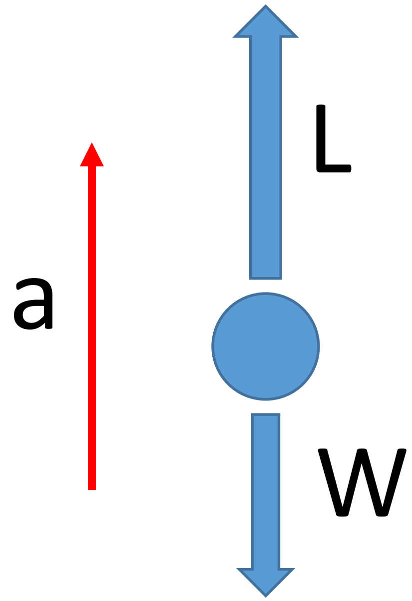
(2) At each weight from the design minimum weight to the design maximum weight appropriate to each particular flight load condition; and

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

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

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

FATOR DE CARGA

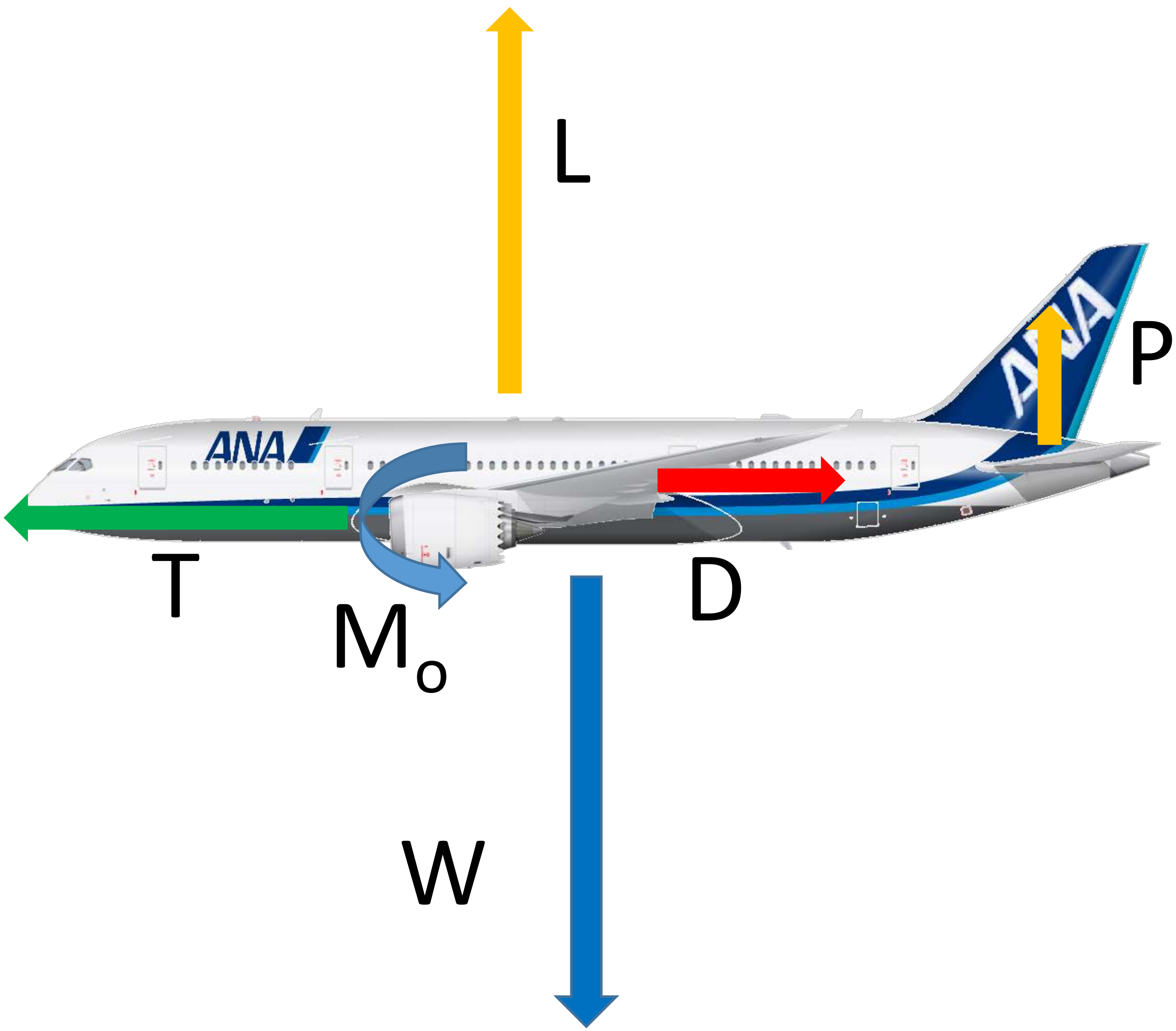


$$L = n\,W$$

$$\frac{W}{g}a = L - W$$

n$= 1 + \frac{a}{g}$

EQUILÍBRIO DINÂMICO



Title 14: Aeronautics and Space

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

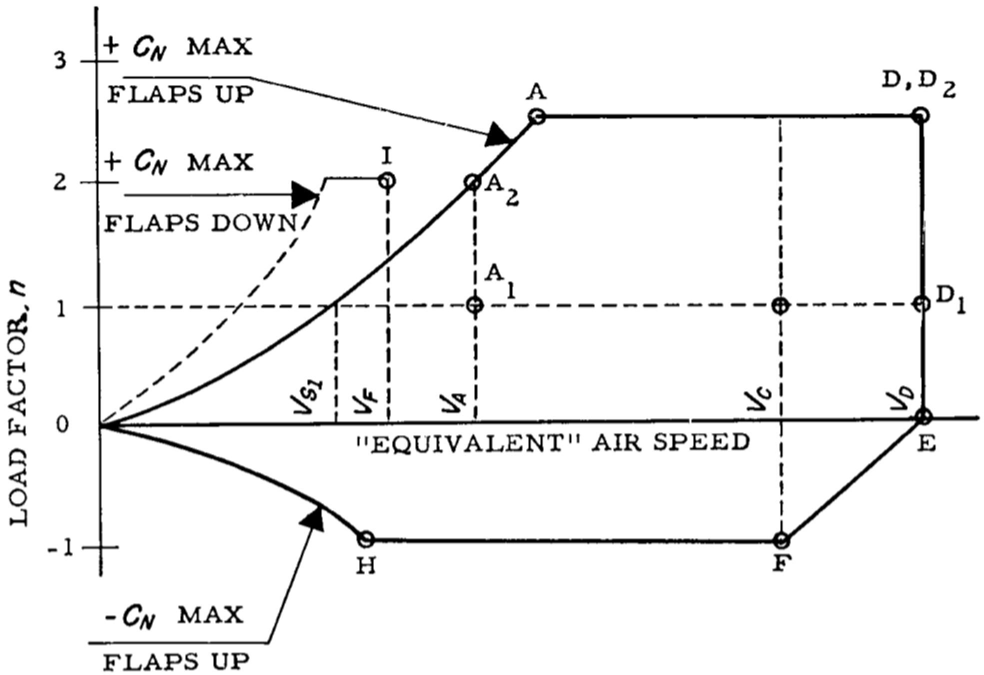
FLIGHT MANEUVER AND GUST CONDITIONS

§25.331 Symmetric maneuvering conditions.
§25.333 Flight maneuvering envelope.
§25.335 Design airspeeds.
§25.337 Limit maneuvering load factors.
§25.341 Gust and turbulence loads.
§25.343 Design fuel and oil loads.
§25.345 High lift devices.
§25.349 Rolling conditions.
§25.351 Yaw maneuver conditions.

§25.333 Flight maneuvering envelope.

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

(b) *Maneuvering envelope.*



§25.335 Design airspeeds.

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

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

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

(2) Except as provided in §25.335(d)(2), V_C may not be less than V_B + 1.32 U_{REF} (with U_{REF} as specified in §25.341(a)(5)(i)). However V_C need not exceed the maximum speed in level flight at maximum continuous power for the corresponding altitude.

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

(b) *Design dive speed, V_D*. V_D must be selected so that V_C/M_C is not greater than 0.8 V_D/M_D, or so that the minimum speed margin between V_C/M_C and V_D/M_D is the greater of the following values:

(1) From an initial condition of stabilized flight at V_C/M_C, the airplane is upset, flown for 20 seconds along a flight path 7.5° below the initial path, and then pulled up at a load factor of 1.5*g* (0.5*g* acceleration increment). The speed increase occurring in this maneuver may be calculated if reliable or conservative aerodynamic data is used. Power as specified in §25.175(b)(1)(iv) is assumed until the pullup is initiated, at which time power reduction and the use of pilot controlled drag devices may be assumed;

(2) The minimum speed margin must be enough to provide for atmospheric variations (such as horizontal gusts, and penetration of jet streams and cold fronts) and for instrument errors and airframe production variations. These factors may be considered on a probability basis. The margin at altitude where M_C is limited by compressibility effects must not less than 0.07M unless a lower margin is determined using a rational analysis that includes the effects of any automatic systems. In any case, the margin may not be reduced to less than 0.05M.

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

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

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

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

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

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

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

(1) V_B may not be less than

$$V_{S1}\left[1+\frac{K_g U_{ref} V_c a}{498w}\right]^{1/2}$$

where—

V_{S1} = the 1-g stalling speed based on C_{NAmax} with the flaps retracted at the particular weight under consideration;

V_c = design cruise speed (knots equivalent airspeed);

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

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

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

$$\mu = \frac{2w}{\rho c a g}$$

ρ = density of air (slugs/ft^3);

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

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

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

(2) At altitudes where V_C is limited by Mach number—

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

(ii) V_B need not be greater than V_C.

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

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

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

(3) V_F may not be less than—

(i) 1.6 V_{S1} with the flaps in takeoff position at maximum takeoff weight;

(ii) 1.8 V_{S1} with the flaps in approach position at maximum landing weight, and

(iii) 1.8 V_{S0} with the flaps in landing position at maximum landing weight.

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

§25.337 Limit maneuvering load factors.

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

(b) The positive limit maneuvering load factor *n* for any speed up to *Vn* may not be less than 2.1 + 24,000/ (*W* + 10,000) except that *n* may not be less than 2.5 and need not be greater than 3.8—where *W* is the design maximum takeoff weight.

(c) The negative limit maneuvering load factor—

(1) May not be less than −1.0 at speeds up to V_C; and

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

(d) 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.

§25.341 Gust and turbulence loads.

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

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

(2) The shape of the gust must be:

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

for $0 \leq s \leq 2H$

where—

s = distance penetrated into the gust (feet);

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

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

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

(4) The design gust velocity must be:

$$U_{ds} = U_{ref} F_g \left(H / 350 \right)^{1/6}$$

where—

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

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

(5) The following reference gust velocities apply:

(i) At airplane speeds between V_B and V_C: Positive and negative gusts with reference gust velocities of 56.0 ft/sec EAS must be considered at sea level. The reference gust velocity may be reduced linearly from 56.0 ft/sec EAS at sea level to 44.0 ft/sec EAS at 15,000 feet. The reference gust velocity may be further reduced linearly from 44.0 ft/sec EAS at 15,000 feet to 20.86 ft/sec EAS at 60,000 feet.

(ii) At the airplane design speed V_D: The reference gust velocity must be 0.5 times the value obtained under §25.341(a)(5)(i).

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

$$F_g = 0.5\left(F_{gz} + F_{gm}\right)$$

Where:

$$F_{gz} = 1 - \frac{Z_{mo}}{250000};$$

$$F_{gm} = \sqrt{R_2 \operatorname{Tan}\left(\pi R_1 / 4\right)};$$

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

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

Z_{mo} = Maximum operating altitude defined in §25.1527 (feet).

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

(b) *Continuous turbulence design criteria.* The dynamic response of the airplane to vertical and lateral continuous turbulence must be taken into account. The dynamic analysis must take into account unsteady aerodynamic characteristics and all significant structural degrees of freedom including rigid body motions. The limit loads must be determined for all critical altitudes, weights, and weight distributions as specified in §25.321(b), and all critical speeds within the ranges indicated in §25.341(b)(3).

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

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

Where—

P_L = limit load;

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

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

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

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

$$\overline{A} = \sqrt{\int_0^\infty \left|H(\Omega)\right|^2 \Phi(\Omega)\, d\Omega}$$

Where—

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

Φ(Ω) = normalized power spectral density of atmospheric turbulence given by—

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

Where—

Ω = reduced frequency, radians per foot; and

L = scale of turbulence = 2,500 ft.

(3) The limit turbulence intensities, U_σ, in feet per second true airspeed required for compliance with this paragraph are—

(i) At airplane speeds between V_B and V_C:

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

Where—

$U_{\sigma ref}$ is the reference turbulence intensity that varies linearly with altitude from 90 fps (TAS) at sea level to 79 fps (TAS) at 24,000 feet and is then constant at 79 fps (TAS) up to the altitude of 60,000 feet.

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

(ii) At speed V_D: U_σ is equal to ½ the values obtained under paragraph (b)(3)(i) of this section.

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

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

(4) When an automatic system affecting the dynamic response of the airplane is included in the analysis, the effects of system non-linearities on loads at the limit load level must be taken into account in a realistic or conservative manner.
(5) If necessary for the assessment of loads on airplanes with significant non-linearities, it must be assumed that the turbulence field has a root-mean-square velocity equal to 40 percent of the U_σ values specified in paragraph (b)(3) of this section. The value of limit load is that load with the same probability of exceedance in the turbulence field as AU_σ of the same load quantity in a linear approximated model.

(c) *Supplementary gust conditions for wing-mounted engines.* For airplanes equipped with wing-mounted engines, the engine mounts, pylons, and wing supporting structure must be designed for the maximum response at the nacelle center of gravity derived from the following dynamic gust conditions applied to the airplane:

(1) A discrete gust determined in accordance with §25.341(a) at each angle normal to the flight path, and separately,

(2) A pair of discrete gusts, one vertical and one lateral. The length of each of these gusts must be independently tuned to the maximum response in accordance with §25.341(a). The penetration of the airplane in the combined gust field and the phasing of the vertical and lateral component gusts must be established to develop the maximum response to the gust pair. In the absence of a more rational analysis, the following formula must be used for each of the maximum engine loads in all six degrees of freedom:

$$P_L = P_{L-1g} \pm 0.85\sqrt{L_V^2 + L_L^2}$$

Where—

P_L = limit load;

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

L_V = peak incremental response load due to a vertical gust according to §25.341(a); and

L_L = peak incremental response load due to a lateral gust according to §25.341(a)

§25.351 Yaw maneuver conditions.

The airplane must be designed for loads resulting from the yaw maneuver conditions specified in paragraphs (a) through (d) of this section at speeds from V_{MC} to V_D. Unbalanced aerodynamic moments about the center of gravity must be reacted in a rational or conservative manner considering the airplane inertia forces. In computing the tail loads the yawing velocity may be assumed to be zero.

(a) With the airplane in unaccelerated flight at zero yaw, it is assumed that the cockpit rudder control is suddenly displaced to achieve the resulting rudder deflection, as limited by:

(1) The control system on control surface stops; or

(2) A limit pilot force of 300 pounds from V_{MC} to V_A and 200 pounds from V_C/M_C to V_D/M_D, with a linear variation between V_A and V_C/M_C.

(b) With the cockpit rudder control deflected so as always to maintain the maximum rudder deflection available within the limitations specified in paragraph (a) of this section, it is assumed that the airplane yaws to the overswing sideslip angle.

(c) With the airplane yawed to the static equilibrium sideslip angle, it is assumed that the cockpit rudder control is held so as to achieve the maximum rudder deflection available within the limitations specified in paragraph (a) of this section.

(d) With the airplane yawed to the static equilibrium sideslip angle of paragraph (c) of this section, it is assumed that the cockpit rudder control is suddenly returned to neutral.

Title 14: Aeronautics and Space

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

SUPLEMENTARY CONDITIONS

§25.361 Engine and auxiliary power unit torque.
§25.362 Engine failure loads.
§25.363 Side load on engine and auxiliary power unit mounts.
§25.365 Pressurized compartment loads.
§25.367 Unsymmetrical loads due to engine failure.
§25.371 Gyroscopic loads.
§25.373 Speed control devices.

§25.365 Pressurized compartment loads.

For airplanes with one or more pressurized compartments the following apply:

(a) 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.

(b) The external pressure distribution in flight, and stress concentrations and fatigue effects must be accounted for.

(c) If landings may be made with the compartment pressurized, landing loads must be combined with pressure differential loads from zero up to the maximum allowed during landing.

(d) The airplane structure must be designed to be able to withstand the pressure differential loads corresponding to the maximum relief valve setting multiplied by a factor of 1.33 for airplanes to be approved for operation to 45,000 feet or by a factor of 1.67 for airplanes to be approved for operation above 45,000 feet, omitting other loads.

(e) Any structure, component or part, inside or outside a pressurized compartment, the failure of which could interfere with continued safe flight and landing, must be designed to withstand the effects of a sudden release of pressure through an opening in any compartment at any operating altitude resulting from each of the following conditions:

(1) The penetration of the compartment by a portion of an engine following an engine disintegration;

(2) Any opening in any pressurized compartment up to the size H_o in square feet; however, small compartments may be combined with an adjacent pressurized compartment and both considered as a single compartment for openings that cannot reasonably be expected to be confined to the small compartment. The size H_o must be computed by the following formula:

$$H_o = PA_s$$

where,

H_o = Maximum opening in square feet, need not exceed 20 square feet.

$P = (A_s/6240) + .024$

A_s = Maximum cross-sectional area of the pressurized shell normal to the longitudinal axis, in square feet; and

(3) The maximum opening caused by airplane or equipment failures not shown to be extremely improbable.

(f) In complying with paragraph (e) of this section, the fail-safe features of the design may be considered in determining the probability of failure or penetration and probable size of openings, provided that possible improper operation of closure devices and inadvertent door openings are also considered. Furthermore, the resulting differential pressure loads must be combined in a rational and conservative manner with 1-g level flight loads and any loads arising from emergency depressurization conditions. These loads may be considered as ultimate conditions; however, any deformations associated with these conditions must not interfere with continued safe flight and landing. The pressure relief provided by intercompartment venting may also be considered.

(g) Bulkheads, floors, and partitions in pressurized compartments for occupants must be designed to withstand the conditions specified in paragraph (e) of this section. In addition, reasonable design precautions must be taken to minimize the probability of parts becoming detached and injuring occupants while in their seats.

§25.473 Landing load conditions and assumptions.

(a) For the landing conditions specified in §25.479 to §25.485 the airplane is assumed to contact the ground—

(1) In the attitudes defined in §25.479 and §25.481;

(2) With a limit descent velocity of 10 fps at the design landing weight (the maximum weight for landing conditions at maximum descent velocity); and

(3) With a limit descent velocity of 6 fps at the design take-off weight (the maximum weight for landing conditions at a reduced descent velocity).

(4) The prescribed descent velocities may be modified if it is shown that the airplane has design features that make it impossible to develop these velocities.

(b) Airplane lift, not exceeding airplane weight, may be assumed unless the presence of systems or procedures significantly affects the lift.

(c) The method of analysis of airplane and landing gear loads must take into account at least the following elements:

(1) Landing gear dynamic characteristics.

(2) Spin-up and springback.

(3) Rigid body response.

(4) Structural dynamic response of the airframe, if significant.

(d) The landing gear dynamic characteristics must be validated by tests as defined in §25.723(a).

(e) The coefficient of friction between the tires and the ground may be established by considering the effects of skidding velocity and tire pressure. However, this coefficient of friction need not be more than 0.8

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PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

EMERGENCY LANDING CONDITIONS

§25.561 General.

§25.562 Emergency landing dynamic conditions.

§25.563 Structural ditching provisions.

§25.561 General.

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

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

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

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

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

(i) Upward, 3.0g

(ii) Forward, 9.0g

(iii) Sideward, 3.0g on the airframe; and 4.0g on the seats and their attachments.

(iv) Downward, 6.0g

(v) Rearward, 1.5g

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

(1) Except as provided in paragraph (c)(2) of this section, these items must be positioned so that if they break loose they will be unlikely to:

(i) Cause direct injury to occupants;

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

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

(2) When such positioning is not practical (e.g. fuselage mounted engines or auxiliary power units) each such item of mass shall be restrained under all loads up to those specified in paragraph (b)(3) of this section. The local attachments for these items should be designed to withstand 1.33 times the specified loads if these items are subject to severe wear and tear through frequent removal (e.g. quick change interior items).

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

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PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

FATIGUE EVALUATION

§25.571 Damage—tolerance and fatigue evaluation of structure.

§25.571 Damage—tolerance and fatigue evaluation of structure.

(a) *General.* An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, corrosion, manufacturing defects, or accidental damage, will be avoided throughout the operational life of the airplane. This evaluation must be conducted in accordance with the provisions of paragraphs (b) and (e) of this section, except as specified in paragraph (c) of this section, for each part of the structure that could contribute to a catastrophic failure (such as wing, empennage, control surfaces and their systems, the fuselage, engine mounting, landing gear, and their related primary attachments). For turbojet powered airplanes, those parts that could contribute to a catastrophic failure must also be evaluated under paragraph (d) of this section. In addition, the following apply:

(1) Each evaluation required by this section must include—

(i) The typical loading spectra, temperatures, and humidities expected in service;

(ii) The identification of principal structural elements and detail design points, the failure of which could cause catastrophic failure of the airplane; and

(iii) An analysis, supported by test evidence, of the principal structural elements and detail design points identified in paragraph (a)(1)(ii) of this section.

(2) The service history of airplanes of similar structural design, taking due account of differences in operating conditions and procedures, may be used in the evaluations required by this section.

(3) Based on the evaluations required by this section, inspections or other procedures must be established, as necessary, to prevent catastrophic failure, and must be included in the Airworthiness Limitations section of the Instructions for Continued Airworthiness required by §25.1529. The limit of validity of the engineering data that supports the structural maintenance program (hereafter referred to as LOV), stated as a number of total accumulated flight cycles or flight hours or both, established by this section must also be included in the Airworthiness Limitations section of the Instructions for Continued Airworthiness required by §25.1529. Inspection thresholds for the following types of structure must be established based on crack growth analyses and/or tests, assuming the structure contains an initial flaw of the maximum probable size that could exist as a result of manufacturing or service-induced damage:

(i) Single load path structure, and

(ii) Multiple load path “fail-safe” structure and crack arrest “fail-safe” structure, where it cannot be demonstrated that load path failure, partial failure, or crack arrest will be detected and repaired during normal maintenance, inspection, or operation of an airplane prior to failure of the remaining structure.

(b) *Damage-tolerance evaluation.* The evaluation must include a determination of the probable locations and modes of damage due to fatigue, corrosion, or accidental damage. Repeated load and static analyses supported by test evidence and (if available) service experience must also be incorporated in the evaluation. Special consideration for widespread fatigue damage must be included where the design is such that this type of damage could occur. An LOV must be established that corresponds to the period of time, stated as a number of total accumulated flight cycles or flight hours or both, during which it is demonstrated that widespread fatigue damage will not occur in the airplane structure. This demonstration must be by full-scale fatigue test evidence. The type certificate may be issued prior to completion of full-scale fatigue testing, provided the Administrator has approved a plan for completing the required tests. In that case, the Airworthiness Limitations section of the Instructions for Continued Airworthiness required by §25.1529 must specify that no airplane may be operated beyond a number of cycles equal to ½ the number of cycles accumulated on the fatigue test article, until such testing is completed. The extent of damage for residual strength evaluation at any time within the operational life of the airplane must be consistent with the initial detectability and subsequent growth under repeated loads. The residual strength evaluation must show that the remaining structure is able to withstand loads (considered as static ultimate loads) corresponding to the following conditions:

(1) The limit symmetrical maneuvering conditions specified in §25.337 at all speeds up to V_c and in §25.345.
(2) The limit gust conditions specified in §25.341 at the specified speeds up to V_C and in §25.345.
(3) The limit rolling conditions specified in §25.349 and the limit unsymmetrical conditions specified in §§25.367 and 25.427 (a) through (c), at speeds up to V_C.
(4) The limit yaw maneuvering conditions specified in §25.351(a) at the specified speeds up to V_C.
(5) For pressurized cabins, the following conditions:

(i) The normal operating differential pressure combined with the expected external aerodynamic pressures applied simultaneously with the flight loading conditions specified in paragraphs (b)(1) through (4) of this section, if they have a significant effect.

(ii) The maximum value of normal operating differential pressure (including the expected external aerodynamic pressures during 1 g level flight) multiplied by a factor of 1.15, omitting other loads.

(6) For landing gear and directly-affected airframe structure, the limit ground loading conditions specified in §§25.473, 25.491, and 25.493.

If significant changes in structural stiffness or geometry, or both, follow from a structural failure, or partial failure, the effect on damage tolerance must be further investigated.

(c) *Fatigue (safe-life) evaluation.* Compliance with the damage-tolerance requirements of paragraph (b) of this section is not required if the applicant establishes that their application for particular structure is impractical. This structure must be shown by analysis, supported by test evidence, to be able to withstand the repeated loads of variable magnitude expected during its service life without detectable cracks. Appropriate safe-life scatter factors must be applied.

(d) *Sonic fatigue strength.* It must be shown by analysis, supported by test evidence, or by the service history of airplanes of similar structural design and sonic excitation environment, that—

(1) Sonic fatigue cracks are not probable in any part of the flight structure subject to sonic excitation; or

(2) Catastrophic failure caused by sonic cracks is not probable assuming that the loads prescribed in paragraph (b) of this section are applied to all areas affected by those cracks

(e) *Damage-tolerance (discrete source) evaluation*. The airplane must be capable of successfully completing a flight during which likely structural damage occurs as a result of—

(1) Impact with a 4-pound bird when the velocity of the airplane relative to the bird along the airplane's flight path is equal to V_c at sea level or $0.85V_c$ at 8,000 feet, whichever is more critical;

(2) Uncontained fan blade impact;

(3) Uncontained engine failure; or

(4) Uncontained high energy rotating machinery failure.

The damaged structure must be able to withstand the static loads (considered as ultimate loads) which are reasonably expected to occur on the flight. Dynamic effects on these static loads need not be considered. Corrective action to be taken by the pilot following the incident, such as limiting maneuvers, avoiding turbulence, and reducing speed, must be considered. If significant changes in structural stiffness or geometry, or both, follow from a structural failure or partial failure, the effect on damage tolerance must be further investigated.

In **safe-life design** products are designed to survive a specific design life with a chosen reserve.

Safe life is particularly relevant to metal aircraft, where airframe components are subjected to varying loads over the lifetime of the aircraft which makes them susceptible to metal fatigue. In certain areas such as in wing or tail components structural failure in flight would be catastrophic.

The safe-life design technique is employed in critical systems which are either very difficult to repair or may cause severe damage to life and property. These systems are designed to work for years without requirement of any repairs.

The drawback is that products designed with a safe-life approach are over-built or allocated more resources than they are expected to need, which may be uneconomical. In order to maintain the designed safety, they will have to be replaced after the design life has expired, while they may still have a considerable life ahead of them. To counter these drawbacks, alternative design philosophies like fail-safe design and fault-tolerant design were developed.

https://en.wikipedia.org/wiki/Safe-life_design

A **fail-safe** in engineering is a design feature or practice that in the event of a specific type of failure, inherently responds in a way that will cause no or minimal harm to other equipment, the environment or to people.

Unlike inherent safety to a particular hazard, a system being "fail-safe" does not mean that failure is impossible or improbable, but rather that the system's design prevents or mitigates unsafe consequences of the system's failure. That is, if and when a "fail-safe" system "fails", it is "safe" or at least no less safe than when it was operating correctly.

Since many types of failure are possible, failure mode and effects analysis is used to examine failure situations and recommend safety design and procedures.

Some systems can never be made fail safe, as continuous availability is needed. Redundancy, fault tolerance, or recovery procedures are used for these situations (e.g. multiple independent controlled and fuel fed engines). This also makes the system less sensitive for the reliability prediction errors or quality induced uncertainty for the separate items. On the other hand, failure detection & correction and avoidance of common cause failures becomes here increasingly important to ensure system level reliability.

https://en.wikipedia.org/wiki/Fail-safe

Damage tolerance is a property of a structure relating to its ability to sustain defects safely until repair can be effected. The approach to engineering design to account for damage tolerance is based on the assumption that flaws can exist in any structure and such flaws propagate with usage. This approach is commonly used in aerospace engineering to manage the extension of cracks in structure through the application of the principles of fracture mechanics.

In aerospace engineering, structure is considered to be damage tolerant if a maintenance program has been implemented that will result in the detection and repair of accidental damage, corrosion and fatigue cracking before such damage reduces the residual strength of the structure below an acceptable limit. As one such approach to crack repair, the placement of a hole at a crack tip to reduce stress concentration and inhibit crack propagation is widely studied and implemented.

https://en.wikipedia.org/wiki/Damage_tolerance

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PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

Subpart D—DESIGN AND CONSTRUCTION

GENERAL

§25.601 General.
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§25.601 General.

The airplane may not have design features or details that experience has shown to be hazardous or unreliable. The suitability of each questionable design detail and part must be established by tests.

§25.603 Materials.

The suitability and durability of materials used for parts, the failure of which could adversely affect safety, must—

(a) Be established on the basis of experience or tests;

(b) Conform to approved specifications (such as industry or military specifications, or Technical Standard Orders) that ensure their having the strength and other properties assumed in the design data; and

(c) Take into account the effects of environmental conditions, such as temperature and humidity, expected in service

§25.605 Fabrication methods.

(a) The methods of fabrication used must produce a consistently sound structure. If a fabrication process (such as gluing, spot welding, or heat treating) requires close control to reach this objective, the process must be performed under an approved process specification.

(b) Each new aircraft fabrication method must be substantiated by a test program.

§25.609 Protection of structure.

Each part of the structure must—

(a) Be suitably protected against deterioration or loss of strength in service due to any cause, including—

(1) Weathering;

(2) Corrosion; and

(3) Abrasion; and

(b) Have provisions for ventilation and drainage where necessary for protection.

§25.611 Accessibility provisions.

(a)Means must be provided to allow inspection (including inspection of principal structural elements and control systems), replacement of parts normally requiring replacement, adjustment, and lubrication as necessary for continued airworthiness. The inspection means for each item must be practicable for the inspection interval for the item. Nondestructive inspection aids may be used to inspect structural elements where it is impracticable to provide means for direct visual inspection if it is shown that the inspection is effective and the inspection procedures are specified in the maintenance manual required by §25.1529.

(b) EWIS must meet the accessibility requirements of §25.1719.

§25.613 Material strength properties and material design values.

(a) Material strength properties must be based on enough tests of material meeting approved specifications to establish design values on a statistical basis.

(b) Material design values must be chosen to minimize the probability of structural failures due to material variability. Except as provided in paragraphs (e) and (f) of this section, compliance must be shown by selecting material design values which assure material strength with the following probability:

> (1) Where applied loads are eventually distributed through a single member within an assembly, the failure of which would result in loss of structural integrity of the component, 99 percent probability with 95 percent confidence.
>
> (2) For redundant structure, in which the failure of individual elements would result in applied loads being safely distributed to other load carrying members, 90 percent probability with 95 percent confidence.

(c) The effects of environmental conditions, such as temperature and moisture, on material design values used in an essential component or structure must be considered where these effects are significant within the airplane operating envelope.
(d) [Reserved]
(e) Greater material design values may be used if a “premium selection” of the material is made in which a specimen of each individual item is tested before use to determine that the actual strength properties of that particular item will equal or exceed those used in design.
(f) Other material design values may be used if approved by the Administrator.

MMPDS - Metallic Materials Properties Development and Standardization

MILHDBK-5


Metallic Materials Properties Development and Standardization (MMPDS)

Metallic Materials Properties Development and Standardization (MMPDS-01)

The 2003 Metallic Material Properties Development and Standardization (MMPDS) Handbook is the replacement document for MILHDBK- 5. It is recognized internationally as a reliable source of aircraft materials data for aerospace materials selection and analysis. Consistent and reliable methods are used to collect, analyze, and present statistically based material and fastener allowable properties. Contains extensive information and data for other material properties and characteristics, such as fracture toughness, fatigue, creep strength, rupture strength, fatigue-crack propagation rate, and resistance to stress corrosion cracking.

MILHDBK-5

MMPDS - Metallic Materials Properties Development and Standardization

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Table 3.2.3.0(b$_1$). Design Mechanical and Physical Properties of 2024 Aluminum Alloy Sheet and Plate

Specification	AMS 4037 and AMS-QQ-A-250/4																	AMS-QQ-A-250/4		
Form	Sheet					Plate												Sheet		Plate
Temper	T3					T351												T361		
Thickness, in.	0.008-0.009	0.010-0.128		0.129-0.249		0.250-0.499		0.500-1.000		1.001-1.500		1.501-2.000		2.001-3.000		3.001-4.000		0.020-0.062	0.063-0.249	0.250-0.500
Basis	S	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	S	S	S
Mechanical Properties:																				
F_{tu}, ksi:																				
L	64	64	65	65	66	64	66	63	65	62	64	62	64	60	62	57	59	68	69	67
LT	63	63	64	64	65	64	66	63	65	62	64	62	64	60	62	57	59	67	68	66
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	52[a]	54[a]	49[a]	51[a]	...	...	...
F_{ty}, ksi:																				
L	47	47	48	47	48	48	50	48	50	47	50	47	49	46	48	43	46	56	56	54
LT	42	42	43	42	43	42	44	42	44	42	44	42	44	42	44	41	43	50	51	49
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	38[a]	40[a]	38[a]	39[a]	...	...	...
F_{cy}, ksi:																				
L	39	39	40	39	40	39	41	39	41	39	40	38	40	37	39	35	37	47	48	46
LT	45	45	46	45	46	45	47	45	47	44	46	44	46	43	45	41	43	53	54	52
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	46	48	44	47	...	...	...
F_{su}, ksi	39	39	40	40	41	38	39	37	38	37	38	37	38	35	37	34	35	42	42	41
F_{bru}[b], ksi:																				
(e/D = 1.5)	104	104	106	106	107	97	100	95	98	94	97	94	97	91	94	86	89	111	112	109
(e/D = 2.0)	129	129	131	131	133	119	122	117	120	115	119	115	119	111	115	106	109	137	139	135
F_{bry}[b], ksi:																				
(e/D = 1.5)	73	73	75	73	75	72	76	72	76	72	76	72	76	72	76	70	74	82	84	81
(e/D = 2.0)	88	88	90	88	90	86	90	86	90	86	90	86	90	86	90	84	88	97	99	96
e, percent (S-basis):																				
LT	10	[c]	...	[c]	...	12	...	8	...	7	...	6	...	4	...	4	...	8	9	9[d]
E, 10^3 ksi	10.5					10.7												10.5		10.7
E_c, 10^3 ksi	10.7					10.9												10.7		10.9
G, 10^3 ksi	4.0					4.0												4.0		4.0
μ	0.33					0.33												0.33		0.33
Physical Properties:																				
ω, lb/in.	0.100																			
C, K, and α	See Figure 3.2.3.0																			

a Caution: This specific alloy, temper, and product form exhibits poor stress-corrosion cracking resistance in this grain direction. It corresponds to an SCC resistance rating of D, as indicated in Table 3.1.2.3.1(a).
b Bearing values are "dry pin" values per Section 1.4.7.1. See Table 3.1.2.1.1.
c See Table 3.2.3.0(c).
d 10% for 0.500 inch.

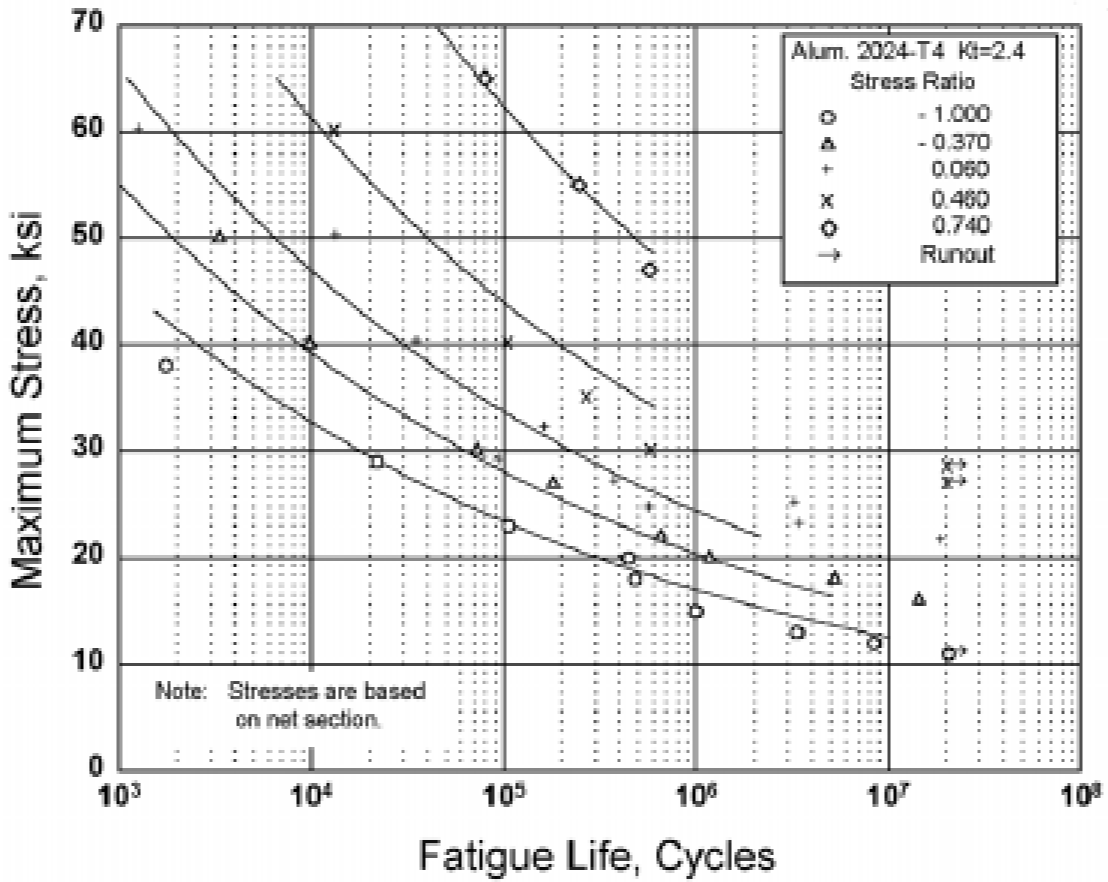

Figure 3.2.3.1.8(c). Best-fit S/N curves for notched, K_t = 2.4, 2024-T4 aluminum alloy bar, longitudinal direction.

§25.619 Special factors.

The factor of safety prescribed in §25.303 must be multiplied by the highest pertinent special factor of safety prescribed in §§25.621 through 25.625 for each part of the structure whose strength is—

(a) Uncertain;

(b) Likely to deteriorate in service before normal replacement; or

(c) Subject to appreciable variability because of uncertainties in manufacturing processes or inspection methods.

Title 14: Aeronautics and Space

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

CONTROL SURFACES

§25.651 Proof of strength.

§25.655 Installation.

§25.657 Hinges.

§25.651 Proof of strength.

(a) Limit load tests of control surfaces are required. These tests must include the horn or fitting to which the control system is attached.

(b) Compliance with the special factors requirements of §§25.619 through 25.625 and 25.657 for control surface hinges must be shown by analysis or individual load tests.