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NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

# Civil Air Regulations Part 4b

**( 39** Pages)

CIVIL AIR REGULATIONS

# PART 4b-AIRPLANE AIRWORTHINESS TRANSPORT CATEGORIES

**As amended to December 31, 1953**

CIVIL AERONAUTICS BOARD

WASHINGTON, D.C.

# TITLE 14—CIVIL AVIATION

## Chapter 1—Civil Aeronautics Board

### Subpart A—Civil Air Regulations

### Part 4b—AIRPLANE AIRWORTHINESS; TRANSPORT CATEGORIES

#### RECAPITULATION OF PART

Because of the number of outstanding amendments to Part 4b there follows a recapitulation Part 4b incorporating all amendments up to December 31, 1953.

### Subpart A—General

#### Personnel and Cargo Accommodations

4b.350 Pilot compartment; general.
4b.351 Pilot compartment; vision.
4b.352 Windshield and windows.
4b.353 Controls.
4b.354 Instrument arrangement.
4b.355 Instrument marking.
4b.356 Doors.
4b.357 Door louvres.
4b.358 Seats, berths, and safety belts.
4b.359 Cargo and baggage compartments.

#### Emergency Provisions

4b.360 General.
4b.361 Ditching
4b.362 Emergency evacuation.

#### Ventilation, Heating, and Pressurization

4b.370 General.
4b.371 Ventilation.
4b.372 Heating systems.
4b.373 Pressurized cabins; general.
4b.374 Pressure supply.
4b.375 Pressure control.
4b.376 Tests.

#### Fire Protection

4b.380 General.
4b.381 Cabin interiors.
4b.382 Cargo and baggage compartments.
4b.383 Cargo compartment classification.
4b.384 Proof of compliance.
4b.385 Flammable fluid fire protection.
4b.386 Combustion heater fire protection.

#### Miscellaneous

4b.390 Reinforcement near propellers.
4b.391 Leveling marks.

### Subpart E—Powerplant Installation

#### Installation

4b.400 General.
4b.401 Engines.
4b.402 Propellers.
4b.403 Propeller vibration.
4b.404 Propeller pitch and speed limitations.
4b.405 Propeller clearance.
4b.406 Propeller de-icing provisions.

#### Fuel System Operation and Arrangement

4b.410 General.
4b.411 Fuel system independents.
4b.412 Pressure cross-feed arrangements.
4b.413 Fuel flow rate.
4b.414 Pump systems.
4b.415 Transfer systems
4b.416 Determination of unusable fuel supply and fuel system operation on low fuel.
4b.417 Fuel system hot weather operation.
4b.418 Flow between interconnected tanks.

#### Fuel System Construction and Installation

4b.420 General.
4b.421 Fuel tank tests.
4b.422 Fuel tank installation.
4b.423 Fuel tank expansion space.
4b.424 Fuel tank sump.
4b.425 Fuel tank filler connection.
4b.426 Fuel tank vents and carburetor vapor vents.
4b.427 Fuel tank outlet.
4b.428 Under-wing fueling provisions.

#### Fuel System Components

4b.430 Fuel pumps.
4b.431 Fuel pump installation.
4b.432 Fuel system lines and fittings.
4b.433 Fuel lines and fittings in designated fire zones.
4b.434 Fuel valves.
4b.435 Fuel strainer.
4b.436 Fuel system drains.
4b.437 Fuel jettisoning system.

#### Oil System

4b.440 General.
4b.441 Oil tank construction.
4b.442 Oil tank tests.
4b.443 Oil tank installation.
4b.444 Oil lines and fittings.
4b.445 Oil valves.
4b.446 Oil radiators.
4b.447 Oil filters.
4b.448 Oil system drains.
4b.449 Propeller feathering system.

#### Cooling System

4b.450 General.
4b.451 Cooling tests.
4b.452 Climb cooling test procedure.
4b.453 Take-off cooling test procedure.
4b.454 Cooling test procedure for flying boat operation.
4b.455 Liquid cooling systems.
4b.456 Coolant tank.
4b.457 Coolant system installation.

#### Induction and Exhaust Systems

4b.460 General.
4b.461 Induction system de-icing and anti-icing provisions.
4b.462 Carburetor air preheater design.
4b.463 Induction system ducts
4b.464 Induction system screens.
4b.465 Carburetor air cooling.
4b.466 Inter-coolers and after-coolers.

AUTHORITY: §§ 4b.0 to 4b.751 issued under sec. 205, 52 Stat. 984, as amended: 49 U.S.C. 425. Interpret or apply secs. 601, 603, 52 Stat. 1007, as amended, 1009, as amended; 49 U.S.C. 551, 553.

## SUBPART A—GENERAL

### APPLICABILITY AND DEFINITIONS

§ 4b.0 *Applicability of this part.* This part establishes standards with which compliance shall be demonstrated for the issuance of a type certificate for transport category airplanes. This part, until superseded or rescinded, shall apply to all transport category airplanes for which applications for type certification in the transport category are made after the effective date of this part (November 9, 1945).

§ 4b.1 *Definitions.* As used in this part terms are defined as follows:

(a) *Administration —(1) Administrator.* The Administrator is the Administrator of Civil Aeronautics.

(2) *Applicant.* An applicant is a person or persons applying for approval of an airplane or any part thereof

(3) *Approved.* Approved, when used alone or as modifying terms such as means, devices, specifications, etc., shall mean approved by the Administrator. (See § 4b.18.)

(b) *General design—(1) Standard atmosphere.* The standard atmosphere is an atmosphere defined as follows:

(i) The air is a dry, perfect gas,

(ii) The temperature at sea level is 59° F.,

(iii) The pressure at sea level is 29.92 inches Hg,

(iv) The temperature gradient from sea level to the altitude at which the temperature equals -67° F. is -0.003566° F./ft. and zero there above

(v) The density $\rho_0$ at sea level under the above conditions is 0.002378 pounds sec.$^2$/ft.$^4$.

(2) *Maximum anticipated air temperature.* The maximum anticipated air temperature is a temperature specified for the purpose of compliance with the powerplant cooling standard. (See § 4b.451(b).)

(3) *Airplane configuration.* Airplane configuration is a term referring to the position of the various elements affecting the aerodynamics characteristics of the airplane (e.g., wing flaps, landing gear).

(4) *Aerodynamic coefficients.* Aerodynamic coefficients are nondimensional coefficients for forces and moments. They correspond with those adopted by the U.S. National Advisory Committee for Aeronautics.

(5) *Critical engine(s).* The critical engine is that engine(s) the failure of which gives the most adverse effect on the airplane flight characteristics relative to the case under consideration.

(6) *Critical-engine-failure speed.* The critical-engine-failure speed is the airplane speed used in the determination of the take-off at which the critical engine is assumed to fail. (See § 4b.114).

*(c) Weights—(1) Maximum weight.* The maximum weight of the airplane is that maximum at which compliance with the requirements of this part is demonstrated. (See § 4b.101 (a).)

(2) *Minimum weight.* The minimum weight of the airplane is that minimum at which compliance with the requirements of this part is demonstrated. (See 4b.101 (c).)

(3) *Empty weight.* The empty weight of the airplane is a readily reproducible weight which is used in the determination of the operating weights. (See § 4b.104.)

(4) *Design maximum weight.* The design maximum weight is the maximum weight of the airplane used in structural design for flight load conditions. (See § 4b.210.)

(5) *Design minimum weight.* The design minimum weight is the minimum weight of the airplane at which compliance is shown with the structural loading conditions. (See § 4b.210.)

(6) *Design take-off weight.* The design take-off weight is the maximum airplane weight used in structural design for taxying conditions, and for landing conditions at a reduced velocity of descent. (See § 4b.210.)

(7) *Design landing weight.* The design landing weight is the maximum airplane weight used in

(a) The operating pressures on the braking system shall not be in excess of those approved by the manufacturer of the brakes,

(b) The brakes shall not be used in such manner as to produce excessive wear of brakes or tires,

(c) Means other than wheel brakes may be used in determining the landing distance: *Provided*, That:

(1) Exceptional skin is not required to control the airplane,

(2) The manner of their employment is such that consistent results could be expected under normal service, and

(3) They are regarded as reliable.

§ 4b.124 *Seaplanes or float planes.* The landing distance referred to in § 4b.122 shall be determined on smooth water.

§ 4b.125 *Skiplanes.* The landing distance referred to in § 4b.122 shall be determined on smooth, dry snow.

**CONTROLLABILITY**

§ 4b.130 *Controllability; general.* (a) The airplane shall be safely controllable and maneuverable during take-off, climb, level flight, descent, and landing.

(b) It shall be possible to make a smooth transition from one flight condition to another, including turns and slips, without requiring an exceptional degree of skill, alertness, or strength on the part of the pilot and without danger of exceeding the limit load factor under all conditions of operation probable for the type, including those conditions normally encountered in the event of sudden failure of any engine.

§ 4b.131 *Longitudinal control.* (a) It shall be possible at all speeds between 1.4 $V_{s1}$ and $V_{s1}$ to pitch the nose downward so that a prompt recovery to a speed equal to 1.4 $V_{s1}$, can be made with the following combinations of configuration:

(1) The airplane trimmed at 1.4 $V_{s1}$,

(2) The landing gear extended,

(3) The wing flaps in a retracted, and in an extended position,

(4) Power off, and maximum continuous power on all engines.

(b) During each of the following controllability demonstrations a change in the trim control, or the exertion of more control force than can be readily applied with one hand for a short period, shall not be required. Each maneuver shall be performed with the landing gear extended.

(1) With power off, flaps retracted, and the airplane trimmed at 1.4 $V_{s1}$, the flaps shall be extended as rapidly as possible while maintaining the air speed approximately 40 percent above the stalling speed prevailing at any instant throughout the maneuver.

(2) The maneuver of subparagraph (1) of this paragraph shall be repeated, except that it shall be started with flaps extended and the airplane trimmed at 1.4 $V_{s1}$, after which the flaps shall be retracted as rapidly as possible.

(3) The maneuver of subparagraph (2) of this paragraph shall be repeated, except that take-off power shall be used.

(4) With power off, flaps retracted, and the airplane trimmed at 1.4 $V_{s1}$, take-off power shall be applied quickly while maintaining the same air speed.

(5) The maneuver of subparagraph (4) of this paragraph shall be repeated, except that the flaps shall be extended.

(6) With power off, flaps extended, and the airplane trimmed at 1.4 $V_{s1}$, air speeds within the range of 1.1 $V_{s1}$ to 1.7 $V_{s1}$ or to $V_{FE}$, whichever of the two is the lesser, shall be obtained and maintained.

(c) It shall be possible without the use of exceptional piloting skill to prevent loss of altitude when wing flap retraction from any position is initiated during steady straight level flight at a speed equal to 1.1 $V_{s1}$ with simultaneous application of not more than maximum continuous power, with the landing gear extended, and with the airplane weight equal to the maximum sea level landing weight. (See also § 4b.323.)

§ 4b.132 *Directional and lateral control*—(a) *Directional control; general.* It shall be possible, while holding the wings approximately level, to execute reasonably sudden changes in heading in either direction without encountering dangerous characteristics. Heading changes up to 15° shall be demonstrated, except that the heading change at which the rudder pedal force is 180 pounds need not be exceeded the control shall be demonstrated at a speed equal to 1.4 $V_{s1}$, under the following conditions:

(1) The critical engine inoperative and its propeller in the minimum drag position,

(2) Power required for level flight at 1.4 $V_{s1}$, but not greater than maximum continuous power,

(3) Most unfavorable center of gravity position,

(4) Landing gear retracted,

(5) Wing flaps in the approach position,

(6) Maximum landing weight.

(b) *Directional control; four or more engines.* Airplanes with four or more engines shall comply with paragraph (a) of this section, except that:

(1) The two critical engines shall be inoperative, their propellers in the minimum drag position,

(2) The center of gravity shall be in the most forward position,

(3) The wing flaps shall be in the most favorable climb position.

(c) *Lateral control; general.* It shall be possible to execute 20° banked turns with and against the inoperative engine from steady flight at a speed equal to 1.4 $V_{s1}$ with:

(1) The critical engine inoperative and its propeller in the minimum drag position,

(2) Maximum continuous power on the operating engines,

(3) Most unfavorable center of gravity position,

(4) Landing gear retracted and extended,

(5) Wing flaps in the most favorable climb position,

(6) Maximum take-off weight.

(d) *Lateral control; four or more engines.* It shall be possible to execute 20° banked turns with and against the inoperative engines from steady flight at a speed equal to 1.4 $V_{s1}$ with maximum continuous power and with the airplane in the configuration prescribed by paragraph (b) of this section.

§ 4b.133 *Minimum control speed, $V_{MC}$.* (a) A minimum speed shall be determined under the conditions specified in this paragraph, so that when the critical engine is suddenly made inoperative at that speed it shall be possible to recover control of the airplane with the engine still inoperative, and maintain it in straight flight at that speed, either with zero yaw or, at the option of the applicant, with an angle of bank not in excess of 5°. Such speed shall not exceed 1.2 $V_{s1}$ with:

(1) Take-off or maximum available power on all engines,

(2) Rearmost center of gravity,

(3) Flaps in take-off position,

(4) Landing gear retracted,

(5) Cowl flaps in the position normally used during take-off,

(6) Maximum sea level take-off weight, or such lesser weight as may be necessary to demonstrate $V_{MC}$.

(7) The airplane trimmed for take-off,

(8) The propeller of the inoperative engine windmilling, except that a different position of the propeller shall be acceptable if the specific design of the propeller control makes it more logical to assume the different position,

(9) The airplane airborne and the ground effect negligible.

(b) In demonstrating the minimum speed of paragraph (a) of this section, the rudder force required to maintain control shall not exceed 180 pounds, and it shall not be necessary to throttle the remaining engines.

(c) During recovery of the maneuver of paragraph (a) of this section the airplane shall not assume any dangerous attitude, nor shall it require exceptional skill, strength, or alertness on the part of the pilot to prevent a change of heading in excess of 20° before recovery is complete.

NOTE: Interpretation No. 1 (17 F.R. 2112, Mar. 12, 1952), adopted by the Civil Aeronautics Board, Mar. 7, 1952, provides as follows:

(1) The Board interprets and construes subparagraph (8) of §4b.133 (a) as requiring the Administrator to accept for the purposes of §4b.133 a value for the one-engine-inoperative minimum control speed which has been established in accordance with the provisions of that section with the propeller of the inoperative engine feathered: *Provided*, That the airplane involved is equipped with an automatic feathering device acceptable to the Administrator under § 4b.10 for demonstrating compliance with the take-off path and climb requirement of §§ 4b.116 and 4b.120 (a) and (b).

### TRIM

§ 4b.140 *General.* The means used for trimming the airplane shall be such that after being trimmed and without further pressure upon, or movement of, either the primary control or its corresponding trim control by the pilot or the automatic pilot, the airplane shall comply with the trim requirements of §§ 4b.141 through 4b.144

§ 4b.141 *Lateral and directional trim.* The airplane shall maintain lateral and directional trim under the most adverse lateral displacement of the center of gravity within the relevant operating limitations, under all normally expected conditions of operation, including operation at any speed from 1.4 $V_{s1}$ to 90 percent of the maximum speed in level flight obtained with maximum continuous power.

§ 4b.142 *Longitudinal trim.* The airplane shall maintain longitudinal trim under the following conditions:

(a) During a climb with maximum continuous power at a speed not in excess of 1.4 $V_{s1}$ with the landing gear retracted and the wing flaps both retracted and in the take-off position,

(b) During a glide with power off at a speed not in excess of 1.4 $V_{s1}$ with the landing gear extended and the wing flaps both retracted and extended, with the forward center of gravity position approved for landing with the maximum landing weight, and with the most forward center of gravity position approved for landing regardless of weight,

(c) During level flight at any speed from 1.4 $V_{s1}$ to 90 percent of the maximum speed in level flight obtained with maximum continuous power with the landing gear and wing flaps retracted, and from 1.4 $V_{s1}$ to $V_{LE}$ with the landing gear extended.

§ 4b.143 *Longitudinal, directional, and lateral trim.* (a) The airplane shall maintain longitudinal, directional, and lateral trim at a speed equal to 1.4 $V_{s1}$ during climbing flight with the critical engine inoperative, with

(1) The remaining engine(s) operating at maximum continuous power,

(2) Landing gear retracted,

(3) Wing flaps retracted.

(b) In demonstrating compliance with the lateral trim requirement of paragraph (a) of this section, the angle of bank of the airplane shall not be in excess of 5 degrees.

§ 4b.144 *Trim for airplanes with four or more engines.* The airplane shall maintain trim in rectilinear flight at the climb speed, configuration, and power used in establishing the rates of climb in § 4b.121, with the most unfavorable center of gravity position, and at the weight at which the two-engine-inoperative climb is equal to at least 0.01 $V_{so}^2$ at an altitude of 5,000 feet.

## STABILITY

§ 4b.150 *General.* The airplane shall be longitudinally, directionally, and laterally stable in accordance with §§ 4b.151 through 4b.157. Suitable stability and control "feel" (static stability) shall be required in other conditions normally encountered in service if flight tests show such stability to be necessary for safe operation.

§ 4b.151 *Static longitudinal stability.* In the conditions outlined in §§ 4b.152 through 4b.155, the characteristics of the elevator control forces and friction shall comply with the following:

(a) A pull shall be required to obtain and maintain speeds below the specified trim speed, and a push shall be required to obtain and maintain speeds above the specified trim speed. This criterion shall apply at any speed which can be obtained without excessive control force, except that such speeds need not be greater than the appropriate operating limit speed or need not be less than the minimum speed in steady unstalled flight.

(b) The air speed shall return to within 10 percent of the original trim speed when the control force is slowly released from any speed within the limits defined in paragraph (a) of this section.

(c) The stable slope of stick force curve versus speed shall be such that any substantial change in speed is clearly perceptible to the pilot through a resulting change in stick force.

§ 4b.152 *Stability during landing.* The stick force curve shall have a stable slope, and the stick force shall not exceed 80 pounds at any speed between 1.1 $V_{s1}$ and 1.8 $V_{s1}$ with:

(a) Wing flaps in the landing position,

(b) The landing gear extended,

(c) Maximum landing weight,

(d) Throttles closed on all engines,

(e) The airplane trimmed at 1.4 $V_{s1}$ with throttles closed.

§ 4b.153 *Stability during approach.* The stick force curve shall have a stable slope at all speeds between 1.1 $V_{s1}$ and 1.8 $V_{s1}$ with:

(a) Wi[illegible] flaps in se[illegible]vel approach position,

(b) Landing gear retracted,

(c) Maximum landing weight,

(d) The airplane trimmed at 1.4 $V_{s1}$ and with power sufficient to maintain level flight at this speed.

§ 4b.154 *Stability during climb*. The stick force curve shall have a stable slope at all speeds between 85 and 115 percent of the speed at which the airplane is trimmed with:

(a) Wing flaps retracted,

(b) Landing gear retracted,

(c) Maximum take-off weight,

(d) 75 percent of maximum continuous power,

(e) The airplane trimmed at the best rate-of-climb speed, except that the speed need not be less than 1.4 $V_{s1}$.

§ 4b.155 *Stability during cruising*— (a) *Landing gear retracted*. Between 1.3 $V_{s1}$ and $V_{NE}$ the stick force curve shall have a stable slope at all speeds obtainable with a stick force not in excess of 50 pounds with:

(1) Wing flaps retracted,

(2) Maximum take-off weight,

(3) 75 percent of maximum continuous power,

(4) The airplane trimmed for level flight with 75 percent of the maximum continuous power.

(b) *Landing gear extended*. The stick force curve shall have a stable slope at all speeds between 1.3 $V_{s1}$ and the speed at which the airplane is trimmed, except that the range of speeds need not exceed that obtainable with a stick force of 50 pounds with:

(1) Wing flaps retracted,

(2) Maximum take-off weight,

(3) 75 percent maximum continuous power, or the power for level flight at the landing gear extended speed, $V_{LE}$ whichever is the lesser,

(4) The airplane trimmed for level flight with the power specified in subparagraph (3) of this paragraph.

§ 4b.156 *Dynamic longitudinal stability*. Any short period oscillation occurring between stalling speed and maximum permissible speed appropriate to the configuration of the airplane shall be heavily damped with the primary controls free and in a fixed position.

§ 4b.157 *Static directional and lateral stability*. (a) The static directional stability, as shown by the tendency to recover from a skid with rudder free, shall be positive with all landing gear and flap positions and symmetrical power conditions, at all speeds from 1.2 $V_{s1}$ up to the operating limit speed.

(b) The static lateral stability, as shown by the tendency to raise the low wing in a sideslip with the aileron controls free and with all landing gear and flap positions and symmetrical power conditions, shall:

(1) Be positive at the operating limit speed,

(2) Not be negative at a speed equal to 1.2 $V_{s1}$.

(c) In straight steady sideslips (unaccelerated forward slips) the aileron and rudder control movements and forces shall be substantially proportional to the angle of sideslip, and the factor of proportionality shall lie between limits found necessary for safe operation throughout the range of sideslip angles appropriate to the operation of the airplane. At greater angles up to that at which the full rudder control is employed or a rudder pedal force of 180 pounds is obtained, the rudder pedal forces shall not reverse, and increased rudder deflection shall produce increased angles of sideslip. Sufficient bank shall accompany sideslipping to indicate clearly any departure from steady unyawed flight, unless a yaw indicator is provided.

§ 4b.158 *Dynamic directional and lateral stability*. Any short period oscillation occurring between stalling speed and maximum permissible speed appropriate to the configuration of the airplane shall be heavily damped with th primary controls free and in a fixed position.

### STALLING CHARACTERISTICS

§ 4b.160 *Stalling; symmetrical power*. (a) Stalls shall be demonstrated with the airplane in straight flight and in banked turns at 30 degrees, both with power off and with power on. In the power-on conditions the power shall be that necessary to maintain level flight at a speed of 1.6 $V_{s1}$, where $V_{s1}$ corresponds with the stalling speed with flaps in the approach position, the landing gear retracted, and maximum landing weight.

(b) The stall demonstration shall be in the following configurations:

(1) Wing flaps and landing gear in any likely combination of positions,

(2) Representative weights within the range for which certification is sought,

(3) The center of gravity in the most adverse position for recovery.

(c) The stall demonstration shall be conducted as follows:

(1) With trim controls adjusted for straight flight at a speed of 1.4 $V_{s1}$, the speed shall be reduced by means of the elevator control until it is steady at slightly above stalling speed; after which the elevator control shall be applied at a rate such that the airplane

speed reduction does not exceed one mile per hour per second until the airplane is stalled or, if the airplane is not stalled, until the control reaches the stop.

(2) The airplane shall be considered stalled when, at an angle of attack measurably greater than that of maximum lift, the inherent flight characteristics give a clear indication to the pilot that the airplane is stalled

NOTE: A nose-down pitch or a roll which cannot be readily arrested are typical indications that the airplane is stalled. Other indications, such as marked loss of control effectiveness, abrupt change in control force or motion, characteristic buffeting, or a distinctive vibration of the pilot's controls, may be accepted if found in a particular care to be sufficiently clear.

(3) Recovery from the stall shall be effected by normal recovery techniques, starting as soon as the airplane is stalled.

(d) During stall demonstration it shall be possible to produce and to correct roll and yaw by unreversed use of the aileron and rudder controls up to the moment the airplane is stalled; there shall occur no abnormal nose-up pitching; and the longitudinal control force shall be positive up to and including the stall.

(e) In straight flight stalls the roll occurring between the stall and the completion of the recovery shall not exceed approximately 20 degrees.

(f) In turning flight stalls the action of the airplane following the stall shall not be so violent or extreme as to make it difficult with normal piloting skill to effect a prompt recovery and to regain control of the airplane

(g) In both the straight flight and the turning flight stall demonstrations it shall be possible promptly to prevent the airplane from stalling and to recover from the stall condition by normal use of the controls.

§ 4b.161 *Stalling; asymmetrical power.* (a) The airplane shall be safely recoverable without applying power to the inoperative engine when stalled with:

(1) The critical engine inoperative,

(3) Flaps and landing gear retracted,

(3) The remaining engines operating up to 75 percent of maximum continuous power, except that the power need not be greater than that at which the wings can be held level laterally with the use of maximum control travel.

(b) It shall be acceptable to throttle back the operating engines during the recovery from the stall.

§ 4b.162 *Stall warning.* Clear and distinctive stall warning shall be apparent to the pilot with sufficient margin to prevent inadvertent stalling of the airplane with flaps and landing gear in all normally used positions, both in straight and in turning flight. It shall be acceptable for the warning to be furnished either through the inherent aerodynamic qualities of the airplane or by a device which will give clearly distinguishable indications under all expected conditions of flight.

NOTE: A stall warning beginning at a speed 7 percent above the stalling speed is normally considered sufficient margin. Other margins may be acceptable depending upon the degree of clarity, duration, and distinctiveness of the warning and upon other characteristics of the airplane evidenced during the approach to the stall.

### Ground Handling Characteristics

§ 4b.170 *Longitudinal stability and control.* (a) There shall be no uncontrollable tendency for landplanes to nose over in any reasonably expected operating condition or when rebound occurs during landing or take-off.

(b) Wheel brakes shall operate smoothly and shall exhibit no undue tendency to induce nosing over.

(c) When a tail-wheel landing gear is used it shall be possible during the take-off ground run on concrete to maintain any attitude up to thrust line level at 80 percent of $V_{S1}$.

§ 4b.171 *Directional stability and control.* (a) There shall be no uncontrollable ground-looping tendency in 90° cross winds of velocity up to 0.2 $V_{SO}$ at any ground speed at which the airplane is expected to operate.

(b) All landplanes shall be demonstrated to be satisfactorily controllable with no exceptional degree of skill or alertness on the part of the pilot in power-off landings at normal landing speed during which brakes or engine power are not used to maintain a straight path.

(c) Means shall be provided for directional control of the airplane during taxying.

§ 4b.172 *Shock absorption.* The shock absorbing mechanism shall not produce damage to the structure when the airplane is taxied on the roughest ground which it is reasonable to expect the airplane to encounter in normal operation.

§ 4b.173 *Demonstrated cross wind.* There shall be established a cross component of wind velocity at which it has been demonstrated to be safe to take off or land.

### Water Handling Characteristics

§ 4b.180 *Water conditions.* The most adverse water conditions in which the seaplane has been demonstrated to be safe for take-off, taxying, and alighting shall be established:

§ 4b.181 *Wind conditions.* The following wind velocities shall be established:

(a) A lateral component of wind velocity not less than 0.2 $V_{SO}$ at and below which it has been demonstrated that the seaplane is safe for taking off and alighting under all water conditions in which the seaplane is likely to be operated;

(b) A wind velocity at and below which it has been demonstrated that the seaplane is safe in taxying in all directions, under all water conditions in which the seaplane is likely to be operated.

§ 4b.182 *Control and stability on the water.* (a) In taking off, taxying, and alighting, the seaplane shall not exhibit the following:

(1) Any dangerously uncontrollable porpoising, bouncing, or swinging tendency;

(2) Any submerging of auxiliary floats or sponsons, any immersion of wing tips, propeller blades, or other parts of the seaplane which are not designed to withstand the resulting water loads;

(3) Any spray forming which would impair the pilot's view, cause damage to the seaplane, or result in ingress of an undue quantity of water.

(b) Compliance with paragraph (a) of this section shall be shown under the following conditions:

(1) All water conditions from smooth to the most adverse condition established in accordance with § 4b.180;

(2) All wind and cross-wind velocities, water currents, and associated waves and swells which the seaplane is likely to encounter in operation on water;

(3) All speeds at which the seaplane is likely to be operated on the water;

(4) Sudden failure of the critical engine occurring at any time while the airplane is operated on water;

(5) All seaplane weights and center of gravity positions within the range of loading conditions for which certification is sought, relevant to each condition of operation.

(c) In the water conditions of paragraph (b) of this section and the corresponding wind conditions the seaplane shall be able to drift for 5 minutes with engines inoperative, aided if necessary by a sea anchor.

### Miscellaneous Flight Requirements

§ 4b.190 *Flutter and vibration.* (a) All parts of the airplane shall be demonstrated in flight to be free from flutter and excessive vibration under all speed and power conditions appropriate to the operation of the airplane up to at least the minimum value permitted for $V_D$ in §4b.210(b)(5). The maximum speeds so demonstrated shall be used in establishing the operating limitations of the airplane in accordance with § 4b.711

(b) There shall be no buffeting condition in normal flight severe enough to interfere with the control of the airplane, to cause excessive fatigue to the crew, or to cause structural damage.[2] (See also §4b.308.)

## SUBPART C—STRUCTURE

### General

§ 4b.200 *Loads.* Strength requirements of this subpart are specified in terms of limit and ultimate loads. Unless otherwise stated, the specified loads shall be considered as limit loads. In determining compliance with these requirements the following shall be applicable:

(a) The factor of safety shall be 1.5 unless otherwise specified.

(b) Unless otherwise provided, the specified air, ground, and water loads shall be placed in equilibrium with inertia forces, considering all items of mass in the airplane.

(c) All loads shall be distributed in a manner closely approximating or conservatively representing actual conditions.

(d) If deflections under load significantly change the distribution of external or internal loads, the redistribution shall be taken into account.

§ 4b.201 *Strength and deformation.* (a) The structure shall be capable of supporting limit loads

[2]It is not the intent of this requirement to discourage such stall warning buffeting as does not contradict these provisions.

without suffering detrimental permanent deformations.

(b) At all loads up to limit loads the deformation shall be such as not to interfere with safe operation of the airplane.

(c) The structure shall be capable of supporting ultimate loads without failure. It shall support the load for at least 3 seconds, unless proof of strength is demonstrated by dynamic tests simulating actual conditions of load application.

(d) 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 with static loads, the effects of such rate of application shall be considered.

§ 4b.202 *Proof of structure.* (a) Proof of compliance of the structure with the strength and deformation requirements of § 4b.201 shall be made for all critical loading conditions.

(b) Proof of compliance by means of structural analysis shall be acceptable only when the structure conforms to types for which experience has shown such methods to be reliable. In all other cases substantiating tests shall be required.

(c) In all cases certain portions of the structure shall be tested as specified in §4b.300.

### Flight Loads

§ 4b.210 *General.* Flight load requirements shall be complied with at critical altitudes within the range selected by the applicant, at all weights from the design minimum weight to the design maximum weight, the latter not being less than the design take-off weight, with any practicable distribution of disposable load within prescribed operating limitations stated in the Airplane Flight Manual (see § 4b.740). At all speeds in excess of those corresponding with a Mach number of 0.65, compressibility effects shall be taken into account.

(a) *Flight load factor.* The flight load factors specified in this subpart shall represent the component of acceleration in terms of the gravitational constant. The flight load factor shall be assumed to act normal to the longitudinal axis of the airplane, shall be equal in magnitude, and shall be opposite in direction to the airplane inertia load factor at the center of gravity.

(b) Design air speeds. The design air speeds shall be equivalent air speeds (EAS) and shall be chosen by the applicant, except that they shall not be less than the speeds defined in subparagraphs (1) through (5) of this paragraph. Where estimated values of the speeds $V_{SO}$ and $V_{s1}$ are used, such estimates shall be conservative.

(1) *Design flap speed, $V_F$.* The minimum values of the design flap speed shall be equal to 1.4 $V_{s1}$ or 1.8 $V_{SO}$, whichever is the greater, where $V_{s1}$ is the stalling speed with flaps retracted at the design landing weight, and $V_{SO}$ is the stalling speed with flaps in the landing position at the design landing weight. (See § 4b.212 (d) regarding automatic flap operation.)

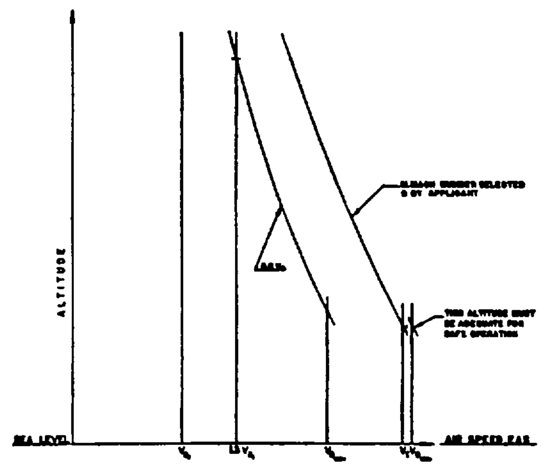



Figure 4b-1—Minimum design air speeds vs. altitude.

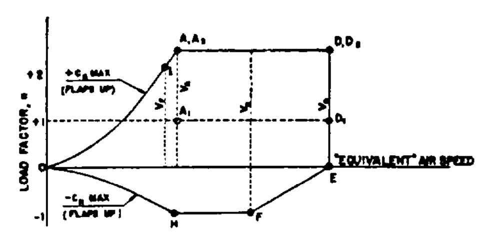



Figure 4b-2—Maneuvering envelope.

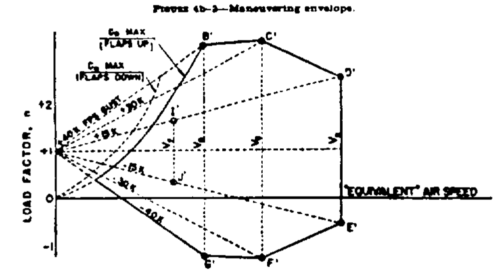



Figure 4b-3—Gust envelope.

(2) *Design maneuvering speed,* $V_A$. The design maneuvering speed $V_A$ shall be equal to $V_{s1}\sqrt{n}$ where $n$ is the limit maneuvering load factor used (see § 4b.211(a)) and $V_{s1}$ is the stalling speed with flaps retracted at the design take-off weight. (See fig. 4b-2.)

(3) *Design speed for maximum gust intensity*, $V_B$. $V_B$ shall be the speed at which the 40 f.p.s. gust line intersects the positive $C_{N_{max}}$ curve on the gust V-*n* envelope. (See § 4b.211(b) and fig. 4b-3.)

(4) Design cruising speed, $V_C$. The minimum design cruising speed $V_C$ shall be sufficiently greater than $V_B$, to provide for inadvertent speed increases likely to occur as a result of severe atmospheric turbulence. In the absence of a rational investigation substantiating the use of other values, $V_C$ shall not be less than $V_B$+50 (m. p. h.), except that it need not exceed the maximum speed in level flight at maximum continuous power for the corresponding altitude. At altitudes where $V_D$ is limited by Mach number, $V_C$ need not exceed 0.8 $V_D$, as shown in figure 4b-1, except that it shall not be less than 1.3 $V_{s1}$ with the flaps retracted at the maximum altitude for which certification is desired.

(5) *Design dive speed $V_D$*. The minimum design dive speed $V_D$ shall be sufficiently greater than $V_C$ to provide for safe recovery from inadvertent upsets occurring at $V_C$. In the absence of a rational investigation, the minimum value of $V_D$ shall not be less than 1.25 $V_C$ or $V_C$+70 (m.p.h.), whichever is the greater, in the altitude range between sea level and an altitude selected by the applicant. At higher altitudes it shall be acceptable to limit $V_D$ to a Mach number selected by the applicant. (See fig. 4b-1.)

§ 4b.211 *Flight envelopes*. The strength requirements shall be met at all combinations of air speed and load factor on and within the boundaries of the V-n diagrams of figures 4b-2 and 4b-3 which represent the maneuvering and gust envelopes. These envelopes shall also be used in determining the airplane structural operating limitations as specified in § 4b.710.

(a) *Maneuvering load factory*. (See fig. 4b-2.) The airplane shall be assumed to be subjected to symmetrical maneuvers resulting in the limit load factors prescribed in subparagraphs (1) and (2) of this paragraph, except where limited by maximum (static) lift coefficients. Pitching velocities appropriate to the corresponding pull-up and steady turn maneuvers shall be taken into account. Lower values of maneuvering load factor shall be acceptable only if it is shown that the airplane embodies features of design which make it impossible to exceed such values in flight.

(1) The positive maneuvering load factor *n* for any flight speed up to $V_D$ shall be selected by the applicant, except that it shall not be less than 2.5.

(2) The negative maneuvering load factor shall have a minimum value of -1.0 at all speeds up to $V_C$, and it shall vary linearly with speed from the value at $V_C$ to zero at $V_D$.

(b) *Gust load f. ctors*. The airplane shall be assumed to be subjected to symmetrical vertical gusts while in level flight. The resulting limit load factors shall correspond with the following conditions:

(1) Positive (up) and negative (down) gusts of 40 f.p.s. nominal intensity at a speed $V_B$ shall be applicable where the positive 40 f.p.s. gust line intersects the positive $C_{NMAX}$ curve. It this gust intensity produces load factors greater than those obtained in condition (2) of this paragraph, it shall be acceptable to modify it at altitudes above 20,000 ft. in such a manner as to produce a load factor not less than that obtained in condition (2) of this paragraph.

(2) Positive and negative gust of 30 f.p.s. shall be considered at $V_C$.

(3) Positive and negative gusts of 15 f.p.s. shall be considered at $V_D$.

(4) Gust load factors shall be assumed to vary linearly between the specified conditions as shown on the gust envelope of figure 4b-3.

(5) In the absence of a more rational analysis the gust load factors shall be computed by the following formula:

$$n=1+\frac{KUVa}{575(W/S)};$$

where

$$K=\tfrac{1}{2}\left(\frac{W}{S}\right)^{1/4} \text{ (for } W/S<16 \text{ p. s. f.), or}$$

$$K=1.33-\frac{2.67}{(W/S)^{3/4}} \text{ (for } W/S>16 \text{ p. s. f.),}$$

$U$=nominal gust velocity (f. p. s.). (Note that the "effective sharp-edged" gust equals $KU$.)

$V$=airplane speed (m. p. h.).

$W/S$=wing loading (p. s. f.).

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

§ 4b.212 *Effect of high lift devices*. When flaps or similar high lift devices intended for use at the relatively low air speeds of approach, landing, and take-off are installed, the airplane shall be assumed to be subjected to symmetrical maneuvers and gusts with the flaps in landing position at the design flap speed $V_F$ resulting in limit load factors within the range determined by the following conditions:

(a) Maneuvering to a positive limit load factor of 2.0,

(b) Positive and negative 15 fps nominal intensity gusts acting normal to the flight path in level flight,

(c) In designing flaps and supporting structure on tractor type airplanes, slipstream effects shall be taken into account as specified in § 4b.221. For other than tractor type airplanes a head-on gust of 25 feet per second with no alleviations acting along the flight path shall be considered.

(d) When automatic operation is provided, the airplane shall be designed for the speeds and the corresponding flap positions which the mechanism permits. (See § 4b.323.)

§ 4b.213 *Symmetrical flight condition*— (a) *Procedures of analysis*. In the analysis of symmetrical flight conditions at least those specified in paragraphs (b), (c), and (d) of this section shall be considered. The following procedure of analysis shall be applicable:

(1) A sufficient number of points on the maneuvering and gust envelopes shall be investigated to insure that the maximum load for each part of the airplane structure is obtained. It shall be acceptable to use a conservative combined envelope for this purpose.

(2) All significant forces acting on the airplane shall be placed in equilibrium in a rational or a conservative manner. The linear inertia forces shall be considered in equilibrium with wing and horizontal tail surface loads, while the angular (pitching) inertia forces shall be considered in equilibrium with wing and fuselage aerodynamic moments and horizontal tail surface loads.

(3) Where sudden displacement of a control is specified, the assumed rate of displacement need not exceed that which actually could be applied by the pilot.

(4) In determining elevator angles and chordwise load distribution in the maneuvering conditions of paragraphs (b) and (c) of this section in turns and pull-ups, account shall be taken of the effect of corresponding pitching velocities.

(b) *Maneuvering balanced conditions*. The maneuvering conditions A through I on the maneuvering envelope (fig. 4b-2) shall be investigated, assuming the airplane to be in equilibrium with zero pitching acceleration.

(c) *Maneuvering pitching conditions*. The following conditions on figure 4b-2 involving pitching acceleration shall be investigated:

(1) *$A_1$, Unchecked pull-up at speed $V_A$*. The airplane shall be assumed to be flying in steady level flight (point $A_1$ on fig. 4b-2) and the pitching control suddenly moved to obtain extreme positive pitching (nose up), except as limited by pilot effort, § 4b.220 (a).

(2) *$A_2$, Checked maneuvers at speed $V_A$*. (i) The airplane shall be assumed to be maneuvered to the positive maneuvering load factor by a checked maneuver from an initial condition of steady level flight (point $A_1$ on fig. 4b-2). The initial positive pitching portion of this maneuver may be considered to be covered by subparagraph (1) of this paragraph

(ii) A negative pitching acceleration (nose down) of at least the following value shall be assumed to be attained concurrently with the airplane maneuvering load factor (point $A_2$, on fig. 4b-2), unless it is shown that a lesser value could not be exceeded:

$$-\frac{30}{V_A} n\,(n - 1.5)\ \text{(radians/sec.}^2\text{)}$$

where $n$ is equal to the value of the positive maneuvering load factor as defined by point $A_2$ on figure 4b-2.

(3) *$D_1$ and $D_2$ checked maneuver at $V_D$*. The airplane shall be assumed to be subjected to a checked maneuver from steady level flight (point $D_1$ on fig. 4b-2) to the positive maneuvering load factor (point $D_2$ on fig. 4b-2) as follows:

(i) A positive pitching acceleration (nose up), equal to at least the following value, shall be assumed to be attained concurrently with the airplane load factor of unity, unless it is shown that lesser values could not be exceeded:

$$+\frac{45}{V_D} n\,(n - 1.5)\ \text{(radians/sec.}^2\text{)}$$

where $n$ is equal to the value of the positive maneuvering load factor as defined by point $D_2$ on figure 4b-2.

(ii) A negative pitching acceleration (nose down) equal to at least the following value shall be assumed to be attained concurrently with the airplane positive maneuvering load factor (point $D_2$ on fig. 4b-2), unless it is shown that lesser values could not be exceeded:

$$-\frac{30}{V_D} n\ (n - 1.5)\ \text{(radians/sec.}^2\text{)}$$

where $n$ is equal to the value of the positive maneuvering load factor as defined by point $D_2$, on figure 4b-2.

(d) *Gust condition*. The gust conditions B' through J' on figure 4b-3 shall be investigated. The following provisions shall apply:

(1) The air load increment due to a specified gust shall be added to the initial balancing tail load corresponding with steady level flight.

(2) It shall be acceptable to include the alleviating effect of wing down-wash and of the airplane's motion in response to the gust in computing the tail gust load increment.

(3) In lieu of a rational investigation of the airplane response it shall be acceptable to apply the gust factor K (see §4b.211 (b)) to the specified gust intensity for the horizontal tail.

§ 4b.214 *Rolling conditions*. The airplane shall be designed for rolling loads resulting from the conditions specified in paragraphs (a) and (b) of this section. Unbalanced aerodynamic moments about the center of gravity shall be reacted in a rational or a conservative manner considering the principal masses furnishing the reacting inertia forces.

(a) *Maneuvering*. The following conditions, aileron deflection, and speeds, except as the deflections may be limited by pilot effort (see § 4b.220 (a)), shall be considered in combination with an airplane load factor of zero and of two-thirds of the positive maneuvering factor used in the design of the airplane. In determining the required aileron deflections, the torsional flexibility of the wing shall be taken into account in accordance with § 4b.200 (d).

(1) Conditions corresponding with steady rolling velocity shall be investigated. In addition, conditions corresponding with maximum angular acceleration shall be investigated for airplanes having engines or other weight concentrations outboard of the fuselage. For the angular acceleration conditions, it shall be acceptable to assume zero rolling velocity in the absence of a rational time history investigation of the maneuver.

(2) At speed $V_A$ a sudden deflection of the aileron to the stop shall be assumed.

(3) At speed $V_C$ the aileron deflection shall be that required to produce a rate of roll not less than that obtained in condition (2) of this paragraph.

(4) At speed $V_D$ the aileron deflection shall be that required to produce a rate of roll not less than one-third of that in condition (2) of this paragraph.

(b) *Unsymmetrical gusts*. The condition of unsymmetrical gusts shall be considered by modifying the symmetrical flight conditions B' or C' of figure 4b-3, whichever produces the greater load factor it shall be assumed that 100 percent of the wing air load acts on one side of the airplane, and 80 percent acts on the other side.

§ 4b.215 *Yawing conditions*. The airplane shall be designed for loads resulting from the conditions specified in paragraphs (a) and (b) of this section. Unbalanced aerodynamic moments about the center of gravity shall be reacted in a rational or a conservative manner considering the principal masses furnishing the reacting inertia forces.

(a) *Maneuvering*. At all speeds from $V_{MC}$ to $V_A$ the following maneuvers shall be considered. In computing the tail loads it shall be acceptable to assume the yawing velocity to be zero.

(1) With the airplane in unaccelerated flight at zero yaw, it shall be assumed that the rudder control is suddenly displaced to the maximum deflection as limited by the control stops or by a 300 lb. rudder pedal force, whichever is critical

(2) With the rudder deflected as specified in subparagraph (1) of this paragraph it shall be assumed that the airplane yaws to the resulting sideslip angle.

(3) With the airplane yawed to the static sideslip angle corresponding with the rudder deflection specified in subparagraph (1) of this paragraph, it shall be assumed that the rudder is returned to neutral.

(b) *Lateral gusts*. The airplane shall be assumed to encounter gusts of 30 f. p. s. nominal intensity normal to the plane of symmetry while in unaccelerated flight at speed $V_C$. In the absence of a rational investigation of the airplane's response to a true gust, it shall be acceptable to compute the gust loading on the vertical tail surfaces by the following formula:

$$\overline{W} = \frac{KUV_c a}{575}$$

where:

$\overline{W}$ = average limit unit pressure (p. s. f.),

$K = 1.33 - \frac{4.5}{\left(\frac{W}{S_V}\right)^{3/4}}$; except that $K$ shall not be less than 1.0. A value of $K$ obtained by rational determination shall be acceptable.

$U$ = nominal gust intensity (f. p. s.),

$V_c$ = design cruising speed (m. p. h.),

$a$ = slope of lift curve of the vertical surface $C_L$ per radian corrected for aspect ratio,

$W$ = design take-off weight (lb.),

$S_V$ = vertical surface area (sq. ft.).

§ 4b.216 *Supplementary conditions.*—(a) *Engine torque effects.* Engine mounts and their supporting structures shall be designed for engine torque effects combined with basic flight conditions as described in subparagraphs (1) and (2) of this paragraph. The limit torque shall be obtained by multiplying the mean torque by a factor of 1.33 in the case of engines having 5 or more cylinders. For 4, 3, and 2-cylinder engines, the factors shall be 2, 3, and 4, respectively.

(1) The limit torque corresponding with take-off power and propeller speed shall act simultaneously with 75 percent of the limit loads from flight condition A (see fig 4b-2).

(2) The limit torque corresponding with maximum continuous power and propeller speed shall act simultaneously with the limit loads from flight condition A (see fig. 4b-2).

(b) *Side load on engine mount.* The limit load factor in a lateral direction for this condition shall be equal to the maximum obtained in the yawing conditions, but shall not be less than either 1.33 or one-third the limit load factor for flight condition A (see fig. 4b-2). Engine mounts and their supporting structure shall be designed for this condition which may be assumed independent of other flight conditions.

(c) *Pressurized cabin loads.* When pressurized compartments are provided for the occupants of the airplane, the following requirements shall be met. (See § 4b.373.)

(1) The airplane structure shall have sufficient strength to withstand the flight loads combined with pressure differential loads from zero up to the maximum relief valve setting. Account shall be taken of the external pressure distribution in flight

(2) If landings are to be permitted with the cabin pressurized, landing loads shall be combined with pressure differential loads from zero up to the maximum to be permitted during landing.

(3) The airplane structure shall have sufficient strength to withstand the pressure differential loads corresponding with the maximum relief valve setting multiplied by a factor of 1.33 to provide for such effects as fatigue and stress concentration. It shall be acceptable to omit all other loads in this case.

(4) Where a pressurized cabin is separated into two or more compartments by bulkheads or floor, the primary structure shall be designed for the effects of sudden release of pressure in any compartment having external doors or windows. This condition shall be investigated for the effects resulting from the failure of the largest opening in a compartment. Where intercompartment venting is provided, it shall be acceptable to take into account the effects of such venting.

### Control Surface and System Loads

§ 4b.220 *Control surface loads; general.* The control surfaces shall be designed for the limit loads resulting from the flight conditions prescribed in § 4b.213 through 4b.215 and the ground gust conditions prescribed in § 4b.22( taking into account the provisions of paragraphs (a) through (e) of this section.

(a) *Effect of pilot effort,* (1) In the control surface flight loading conditions the air loads on the movable surfaces and the corresponding deflections need not exceed those which could be obtained in flight by employing the maximum pilot control forces specified in fig. 4b-5, except that two-thirds of the maximum values specified for the aileron and elevator shall be acceptable when control surface hinge moments are based on reliable data. In applying this criterion, proper consideration shall be given to the effects of servo mechanisms, tabs, and automatic pilot systems in assisting the pilot.

(b) *Effect of trim tabs.* The effect of trim tabs on the main control surface design conditions need be taken into account only in cases where the surface loads are limited by pilot effort in accordance with the provisions of paragraph (a) of this section. In such cases the trim tabs shall be considered to be deflected in the direction which would assist the pilot, and the deflection shall be as follows:

(1) For elevator trim tabs the deflections shall be those required to trim the airplane at any point within the positive portion of the V-$n$ diagram (fig. 4b-2), except as limited by the stops.

(2) For ailerons and rudder trim tabs the deflections shall be those required to trim the

airplane in the critical unsymmetrical power and loading conditions, with appropriate allowance for rigging tolerances.

(c) *Unsymmetrical loads.* Horizontal tail surfaces and the supporting structure shall be designed for unsymmetrical loads arising from yawing and slipstream effects in combination with the prescribed flight conditions.

NOTE: In the absence of more rational data, the following assumptions may be made for airplanes which are conventional in regard to location of propellers, wings, tail surfaces, and fuselage shape: 100 percent of the maximum loading from the symmetrical flight conditions acting on the surface on one side of the plane of symmetry and 80 percent of this loading on the other side. Where the design is not conventional (e. g., where the horizontal tail surfaces have appreciable dihedral or are supported by the vertical tail surfaces), the surfaces and supporting structures may be designed for combined vertical and horizontal surface loads resulting from the prescribed maneuvers.

(d) *Outboard fins.* (1) When outboard fins are carried on the horizontal tail surface, the tail surfaces shall be designed for the maximum horizontal surface load in combination with the corresponding loads induced on the vertical surfaces by end plate effects. Such induced effect need not be combined with other vertical surface loads.

(2) To provide for unsymmetrical loading when outboard fins extend above and below the horizontal surface, the critical vertical surface loading (load per unit area) as determined by the provisions of this section shall also be applied as follows:

(i) 100 percent to the area of the vertical surfaces above (or below) the horizontal surface, and

(ii) 80 percent to the area below (or above) the horizontal surface.

(e) *Loads parallel to hinge line.* Control surfaces and supporting hinge brackets shall be designed for inertia loads acting parallel to the hinge line.

NOTE: In lieu of a more rational analysis the inertial loads may be assumed to be equal to KW, where:

K=24 for vertical surfaces,

K= 12 for horizontal surfaces,

W = weight of the movable surfaces.

§ 4b.221 *Wing flaps.* (a) Wing flaps, their operating mechanism, and supporting structure shall be designed for critical loads prescribed by § 4b.212 with the flaps extended to any position from fully retracted to the landing position.

(b) The effects of propeller slipstream corresponding with take-off power shall be taken into account at an airplane speed of not less than 1.4 $V_{s1}$, where $V_{s1}$ is the stalling speed with flaps as follows: (For automatic flaps see § 4b.212 (d).)

(1) Landing and approach settings at the design landing weight,

(2) Take-off and en route settings at the design take-off weight.

(c) It shall be acceptable to assume the airplane load factor to be equal to 1.0 for investigating the slipstream condition.

§ 4b.222 *Tabs.* The following shall apply to tabs and their installations:

(a) *Trimming tabs.* Trimming tabs shall be designed to withstand loads arising from all likely combinations of tab setting, primary control position, and airplane speed, obtainable without exceeding the flight load conditions prescribed for the airplane as a whole, when the effect of the tab is being opposed by pilot effort loads up to those specified in §4b.220 (a).

(b) *Balancing tabs.* Balancing tabs shall be designed for deflections consistent with the primary control surface loading conditions.

(c) *Servo tabs.* Servo tabs shall be designed for all deflections consistent with the primary control surface loading conditions achievable within the pilot maneuvering effort (see § 4b.220 (a)) with due regard to possible opposition from the trim tabs.

§ 4b.223 *Special devices.* The loading for special devices employing aerodynamic surfaces, such as slots and spoilers, shall be based on test data.

§ 4b.224 *Primary flight control systems.* Elevator, aileron, and rudder control systems and their supporting structures shall be designed for loads corresponding with 125 percent of the computed hinge moments of the movable control surface in the conditions prescribed in § 4b.220, subject to the following provisions:

(a) The system limit loads, except the loads resulting from ground gusts (§ 4b.226), need not exceed those which can be produced by the pilot or pilots and by automatic devices operating the controls. Acceptable maximum and minimum pilot loads for elevator, aileron, and rudder controls are shown in figure 4b-5. These pilot loads shall be assumed to act at the appropriate control grips or pads in a manner simulating flight conditions and to be reacted at the attachment of the control system to the control surface horn.

(b) The loads shall in any case be sufficient to provide a rugged system for service use, including considerations of jamming, ground gusts, taxying tail to wind, control inertia, and friction.

§ 4b.225 *Dual primary flight control systems.* (a) When dual controls are provided, the system shall be designed for the pilots operating in opposition, using individual pilot loads equal to 75 percent of those obtained in accordance with § 4b.224, except that the individual pilot loads shall not be less than the minimum loads specified in figure 4b-5.

(b) The control system shall be designed for the pilots acting in conjunction, using individual pilot loads equal to 75 percent of those obtained in accordance with § 4b.224.

§ 4b.226 *Ground gust conditions.* The following conditions intended to simulate the loadings on control surfaces due to ground gusts and when taxying downwind shall be investigated:

(a) The loads in the systems between the stops nearest the surfaces and the cockpit controls need not exceed those corresponding with the maxima of figure 4b-5 for each pilot alone, or with 75 percent of these maxima for each pilot when the pilots act in conjunction.

(b) The control system stops nearest the surfaces, the control system locks, and the portions of the systems, if any, between such stops and locks and the control surface horns shall be designed for limit hinge moments H obtained from the following formula:

$$H = KcSq,$$

where:

$H$ = limit hinge moment (ft. lbs.),
$c$ = mean chord of the control surface aft of the hinge line (ft.),
$S$ = area of the control surface aft of the hinge line (sq. ft.),
$q$ = dynamic pressure (p. s. f.) based on a design speed not less than $10\sqrt{W/S}+10$ (m. p. h.), except that the design speed need not exceed 60 m. p. h.,
$K$ = factor as specified in figure 4b-4.

§ 4b.227 *Secondary control systems.* Secondary controls such as wheel brake, spoiler, and tab controls, shall be designed for the loads based on the maximum which a pilot is likely to apply to the control in question. The values of figure 4b-6 are considered acceptable.

| Surface | K | Position of Controls |
|---|---|---|
| (a) Aileron | 0.75 | Control column locked or lashed in mid-position. |
| (b) Aileron | *±0.50 | Ailerons at full throw. |
| (c) {Elevator | *±0.75 | {(c) Elevator full down. |
| (d) { | | {(d) Elevator full up. |
| (e) {Rudder | 0.75 | {(e) Rudder in neutral. |
| (f) { | | {(f) Rudder at full throw. |

* A positive value of K indicates a moment tending to depress the surface, while a negative value of K indicates a moment tending to raise the surface.

**FIGURE 4b-4—Limit hinge moment factor for ground gusts**

**[Limit pilot loads (one pilot)]**

| Control | Maximum Load | Minimum Load |
|---|---|---|
| Aileron | | |
| Stick | 100 lbs. | 40 lbs. |
| Wheel * | 80 D in. lbs.** | 40 D in. lbs. |
| Elevator: | | |
| Stick | 250 lbs. | 100 lbs. |
| Wheel | 300 lbs. | 100 lbs. |
| Rudder | 300 lbs. | 130 lbs. |

* The critical portions of the aileron control system shall be designed for a single tangent force having a limit value equal to 1.25 times the couple force determined from these criteria.
** D = wheel diameter.

**FIGURE 4b-5—Pilot control force limits (primary controls).**

| Control | Limit pilot loads |
|---|---|
| Miscellaneous: *Crank wheel or lever. | $\frac{1+R}{3}$ x 50lbs., but not less than 50 lbs., nor more than 150 lbs. (R=radius). (Applicable to any angle within 20° of plane of control.) |
| Twist | 133 in. lbs. |
| Push-pull | To be chosen by applicant. |

* Limited to flap, tab, stabilizer, spoiler, and landing gear operating controls.

**FIGURE 4b-6—Pilot control force limits (secondary controls).**

## GROUND LOADS

§ 4b.230 *General.* The limit loads obtained in the conditions specified in §§ 4b.231 through 4b.236 shall be considered as external forces applied to the airplane structure and shall be placed in equilibrium by linear and angular inertia forces in a rational or conservative manner. In applying the specified conditions the provisions of paragraph (a) of this section shall be complied with. In addition, for the landing conditions of §§ 4b.231 through 4b.234 the airplane shall be assumed to be subjected to forces and descent velocities prescribed in paragraph (b) of this section. (The basic landing gear dimensional data are given in figure 4b-7.)

(a) *Center of gravity positions.* The critical center of gravity positions within the certification limits shall be selected so that the maximum design loads in each of the landing gear elements are obtained in the landing and the ground handling conditions.

(b) *Load factors, descent velocities, and design weights for landing conditions.* (1) In the landing conditions the limit vertical inertia load factors at the center of gravity of the airplane shall be chosen by the applicant, except that they shall not be less than the values which would be obtained when landing the airplane with the following limit descent velocities and weights:

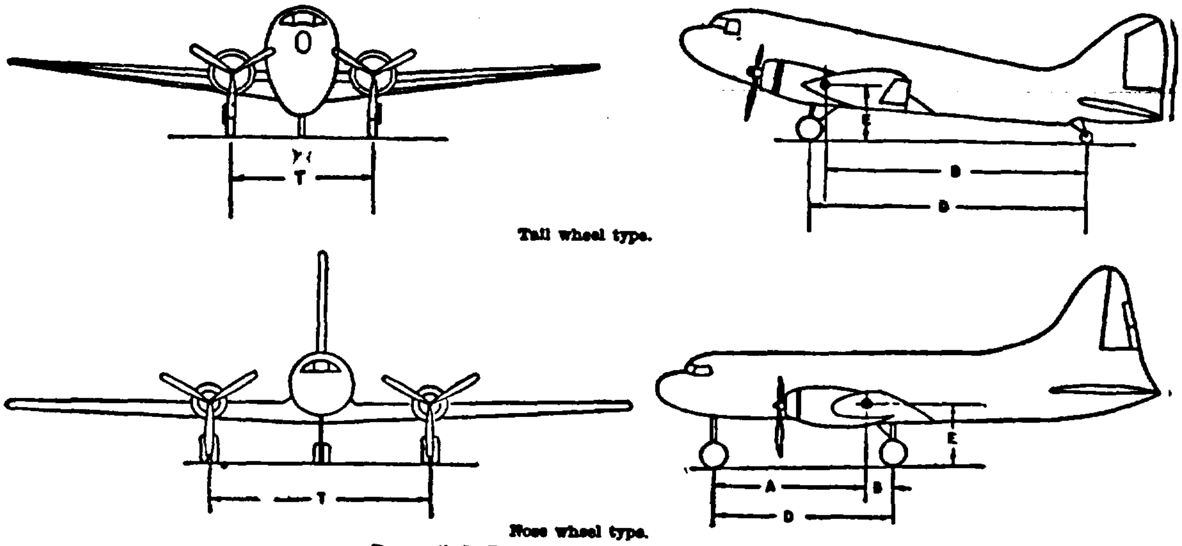



FIGURE 4b-7—Basic landing gear dimension data.

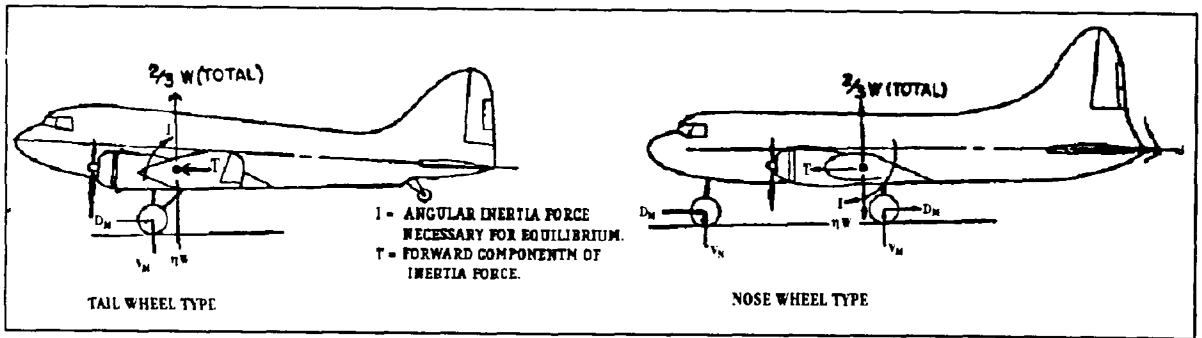



FIGURE 4b-8—Level landing

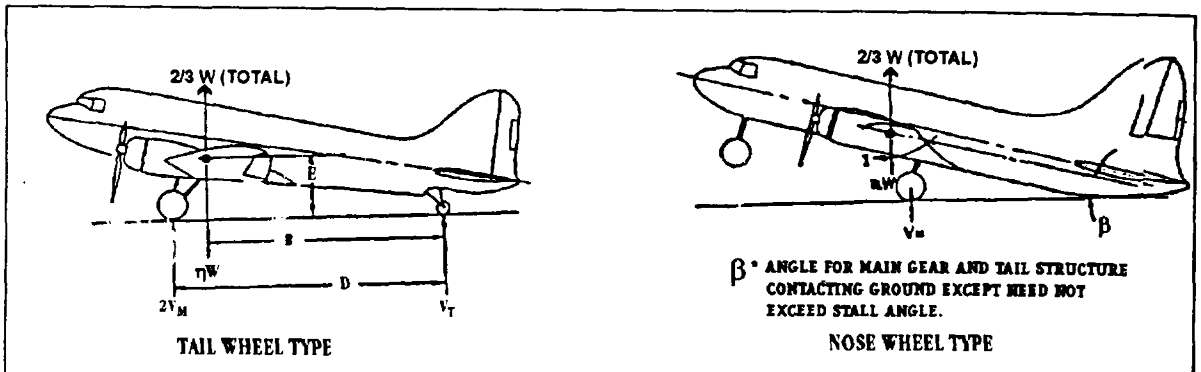



FIGURE 4b-9—Tail down landing

(i) 10 f.p.s. at the design landing weight, and

(ii) 6 f.p.s. at the design take-off weight.

(2) It shall be acceptable to assume a wing lift not exceeding two-thirds of the airplane weight to exist throughout the landing impact and to act through the center of gravity of the airplane.

(3) The provisions of subparagraphs (1) and (2) of this paragraph shall be predicated on conventional arrangements of main and nose gears, or main and tail gears, and on normal operating techniques. It shall be acceptable to modify the prescribed descent velocities if it is shown that the airplane embodies features of design which make it impossible to develop these velocities. (See § 4b.332 (a) for requirements on energy absorption tests which determine the minimum limit inertia load factors corresponding with the required limit descent velocities.)

§ 4b.231 *Level landing conditions*—(a) *General.* In the level attitude the airplane shall be assumed to contact the ground at a forward velocity component parallel to the ground equal to 1.2 $V_{SO}$ and shall be assumed to be subjected to the load factors prescribed in § 4b.230 (b) (1). The following three combinations of vertical and drag components shall be considered acting at the axle center line:

(1) *Condition of maximum wheel spin-up load.* Drag components simulating the forces required to accelerate the wheel rolling assembly up to the specified ground speed shall be combined with the vertical ground reactions existing at the instant of peak drag loads. A coefficient of friction between the tires and ground need not be assumed to be greater than 0.8. It shall be acceptable to apply this condition only to the landing gear and the directly affected attaching structure.

(2) *Condition of maximum wheel vertical load.* An aft acting drag component not less than 25 percent of the maximum vertical ground reaction shall be combined with the maximum ground reaction of § 4b.230 (b).

(3) *Condition of maximum spring-back load.* Forward-acting horizontal loads resulting from a rapid reduction of the spin-up drag loads shall be combined with the vertical ground reactions at the instant of the peak forward load. It shall be acceptable to apply this condition only to the landing gear and the directly affected structure.

(b) *Level landing; tail-wheel type.* The airplane horizontal reference line shall be assumed to be horizontal. The conditions specified in paragraph (a) of this section shall be investigated (See fig. [illegible].)

(c) *Level landing; nose-wheel type.* The following airplane attitudes shall be considered: (See fig. 4b-8.)

(1) Main wheels shall be assumed to contact the ground with the nose wheel just clear of the ground. The conditions specified in paragraph (a) of this section shall be investigated.

(2) Nose and main wheels shall be assumed to contact the ground simultaneously. Conditions in this attitude need not be investigated if this attitude cannot reasonably be attained at the specified descent and forward velocities. The conditions specified in paragraph (a) of this section shall be investigated, except that in conditions (a)(1) and (a)(3) it shall be acceptable to investigate the nose and the main gear separately neglecting the pitching moments due to wheel spin-up and spring-back loads, while in condition (a)(2) the pitching moment shall be assumed to be resisted by the nose gear.

§ 4b.232 *Tail-down landing conditions.* The following conditions shall be investigated for the load factors obtained in § 4b.230 (b)(1) with the vertical ground reactions applied to the landing gear axles.

(a) *Tail-wheel type.* The main and tail wheels shall be assumed to contact the ground simultaneously. (See fig. 4b-9.) Two conditions of ground reaction on the tail wheel shall be assumed to act in the following conditions:

(1) Vertical,

(2) Up and aft through the axle at 45° to the ground line.

(b) *Nose-wheel type.* The airplane shall be assumed to be at an attitude corresponding with either the stalling angle or the maximum angle permitting clearance with the ground by all parts of the airplane other than the main wheels, whichever is the lesser. (See fig. 4b-9.)

§ 4b.233 *One-wheel landing condition.* The main landing gear on one side of the airplane center line shall be assumed to contact the ground in the level attitude. (See fig. 4b-10.) The ground reactions on this side shall be the same as those obtained in § 4b.231 (a)(2). The unbalanced external loads shall be reacted by inertia of the airplane in a rational or conservative manner.

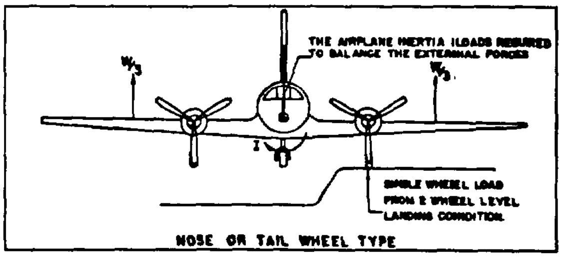



**FIGURE 4b-10—One wheel landing**

§ 4b.234 *Lateral drift landing condition.* (a) The airplane shall be assumed to be in the level attitude with only the main wheels contacting the ground. (See fig. 4b-11.)

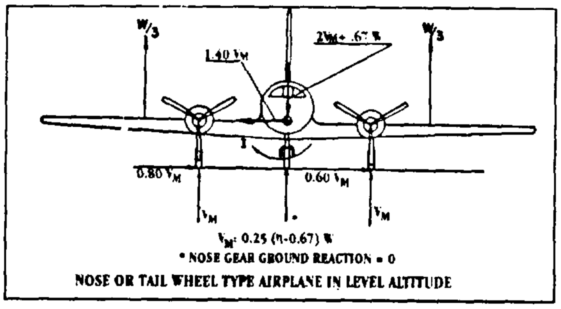



**FIGURE 4b-11—Lateral draft landing**

(b) Side loads of 0.8 of the vertical reaction (on one side) acting inward and 0.6 of the vertical reaction (on the other side) acting outward shall be combined with one-half of the maximum vertical ground reactions obtained in the level landing conditions. These loads shall be assumed to be applied at the ground contact point and to be resisted by the inertia of the airplane. It shall be acceptable to assume the drag loads to be zero.

§ 4b.235 *Ground handling conditions.* The landing gear and airplane structure shall be investigated for the conditions of this section with the airplane at the design take-off weight, unless otherwise prescribed. No wing lift shall be considered. It shall be acceptable to assume the shock absorbers and tires to be deflected to their static position.

(a) *Take-off run.* The landing gear and the airplane structure shall be assumed to be subjected to loads not less than those encountered under conditions described in § 4b.172.

(b) *Braked roll* (1) *Tail-wheel type.* The airplane shall be assumed to be in the level attitude with all load on the main wheels. The limit vertical load factor shall be 1.2 for the airplane at the design landing weight, and 1.0 for the airplane at the design take-off weight. A drag reaction equal to the vertical reaction multiplied by a coefficient of friction of 0.8 shall be combined with the vertical ground reaction and applied at the ground contact point. (See fig. 4b-12.)

(2) *Nose-wheel type.* The limit vertical load factor shall be 1.2 for the airplane at the design landing weight and 1.0 for the airplane at the design take-off weight. A drag reaction equal to the vertical reaction multiplied by a coefficient of friction of 0.8 shall be combined with the vertical reaction and applied at the ground contact point of each wheel having brakes. The following two airplane attitudes shall be considered: (See fig. 4b-12.)

(i) The airplane shall be assumed to be in the level attitude with all wheels contacting the ground and the loads distributed between the main and nose gear. Zero pitching acceleration shall be assumed.

(ii) The airplane shall be assumed to be in the level attitude with only the main gear contacting the ground and the pitching moment resisted by angular acceleration.

(c) *Turning.* The airplane in the static position shall be assumed to execute a steady turn by nose gear steering or by application of differential power such that the limit load factors applied at the center of gravity are 1.0 vertically and 0.5 laterally. (See fig. 4b-13.) The side ground reaction of each wheel shall be 0.5 of the vertical reaction.

(d) *Pivoting.* The airplane shall be assumed to pivot about one side of the main gear, the brakes on that side being locked. The limit vertical load factor shall be 1.0 and the coefficient of friction 0.8. The airplane shall be assumed to be in static equilibrium, the loads being applied at the ground contact points. (See fig. 4b-14.)

(e) *Nose-wheel yawing.* (1) A vertical load factor of 1.0 at the airplane center of gravity and a side component at the nose wheel ground contact equal to 0.8 of the vertical ground reaction at that point shall be assumed.

(2) The airplane shall be assumed to be in static equilibrium with the loads resulting from the application of the brakes on one side of the main gear. The vertical load factor at the center of gravity shall be 1.0. The forward acting load at the airplane center of gravity shall be 0.8 times the vertical load on one main gear. The side and vertical loads at the ground contact point on the nose gear shall be those required for static equilibrium. The side load factor at the airplane center of gravity shall be assumed to be zero.

(f) *Tail-wheel yawing.* (1) A vertical ground reaction equal to the static load on the tail wheel in combination with a side component of equal magnitude shall be assumed.

(2) When a swivel is provided the tail wheel shall be assumed to be swiveled 90° to the airplane longitudinal axis with the resultant load passing through the axle. When a lock, steering device or shimmy damper is provided, the tail wheel shall also be assumed to be in the trailing position with the side load acting at the ground contact point.

§ 4b.236 *Unsymmetrical loads on dual-wheel units.* In dual-wheel units 60 percent of the total ground reaction for the unit shall be applied to one wheel and 40 percent to the other To provide for the case of one flat tire, 60 percent of the load which would be assigned to the unit in the specified conditions shall be applied to either wheel, except that the vertical ground reaction shall not be less than the full static value.

### WATER LOADS

§ 4b.250 *General.* The structure of hull and float type seaplanes shall be designed for water loads developed during take-off 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. Unless a more rational analysis of the water loads is performed, the requirements of §§ 4b.251 through 4b.258 shall apply.

§ 4b.251 *Design weights and center of gravity positions*—(a) *Design weights*. The water load requirements shall be complied with at all operating weights up to the design landing weight except that for the take-off condition prescribed in § 4b.255 the design take-off weight shall be used.

(b) *Center of gravity positions*. The critical center of gravity positions within the limits for which certification is sought shall be considered to obtain maximum design loads for each part of the seaplane structure.

§ 4b.252 *Application of loads*. (a) The seaplane as a whole shall be assumed to be subjected to the loads corresponding with the load factors specified in § 4b.253, except as otherwise prescribed. In applying the loads resulting from the load factors prescribed in § 4b.253, it shall be permissible to distribute the loads over the hull bottom in order to avoid excessive local shear loads and bending moments at the location of water load application, using pressures not less than those prescribed in § 4b.256 (b).

(b) For twin float seaplanes, each float shall be treated as an equivalent hull on a fictitious seaplane having a weight equal to one-half the weight of the twin float seaplane.

(c) Except in the take-off condition of § 4b.255, the aerodynamic lift on the seaplane during the impact shall be assumed to be 2/3 of the weight of the seaplane.

§ 4b.253 *Hull and main float load factors*. Water reaction load factors shall be computed as follows:

**For the step landing case:**

$$n_W = \frac{C_1 V_{S_0}^2}{\tan^{2/3}\beta W^{1/3}};$$

**For the bow and stern landing cases:**

$$n_W = \frac{C_1 V_{S_0}^2}{\tan^{2/3}\beta W^{1/3}} \times \frac{K_1}{(1+r_x^2)^{2/3}};$$

**where:**

**$n_W$ = water reaction load factor (water reaction divided by the seaplane weight);**

**$C_1$ = empirical seaplane operations factor equal to 0.009, except that this factor shall not be less than that necessary to obtain the minimum value of step load factor of 2.33;**

$V_{SO}$ = seaplane stalling speed (mph) with landing flaps extended in the appropriate position and with no slipstream effect;

$\beta$ = angle of dead rise at the longitudinal station at which the load factor is being determined (see fig. 4-15a);

W = seaplane design landing weight in pounds;

$K_1$ = empirical hull station weighing factor. (See fig. 4b-15b.) For a twin float seaplane in recognition of the effect of flexibility of the attachment of the floats to the seaplane, it shall be acceptable to reduce the factor $K_1$ at the bow and stern to 0.8 of the value shown in figure 4b-15b. This reduction shall not apply to the float design but only to the design of the carry-through and seaplane structure;

$r_x$ = ratio of distance, measured parallel to hull reference axis, from the center of gravity of the seaplane to the hull longitudinal station at which the load factor is being computed to the radius of gyration in pitch or the seaplane the hull reference axis being a straight line in the plane of symmetry, tangential to the keel at the main step.

§ 4b.254 *Hull and main float landing conditions* (a) *Symmetrical step landing*. The limit water reaction load factor shall be in accordance with § 4b.253. The resultant water load shall be applied at the keel through the center of gravity perpendicularly to the keel line.

(b) *Symmetrical bow landing*. The limit water reaction load factor shall be in accordance with § 4b.253. The resultant water load shall be applied at the keel 1/5 of the longitudinal distance from the bow to the step, and shall be directed perpendicularly to the keel line.

(c) *Symmetrical stern landing*. The limit water reaction load factor shall be in accordance with § 4b.253. The resultant water load shall be applied at the keel at a point 85 percent of the longitudinal distance from the step to the stern post, and shall be directed perpendicularly to the keel line.

(d) *Unsymmetrical landing; hull type and single float seaplanes*. Unsymmetrical step, bow, and stern landing conditions shall be investigated. The loading for each condition shall consist of an upward component and a side component equal, respectively, to 0.75 and 0.25 tan $\beta$ times the resultant load in the corresponding symmetrical landing condition. (See paragraphs (a), (b), and (c) of this section.) The point of application and direction of the upward component of the load shall be the same as that in the symmetrical condition, and the point of application of the side component shall be at the same longitudinal station as the upward component but directed inward perpendicularly to the plane of symmetry at a point midway between the keel and chine lines.

(e) *Unsymmetrical funding; twin float seaplanes*. The unsymmetrical loading shall consist of an upward load at the step of each float of 0.75 and a side load of 0.25 tan $\beta$ at one float times the step landing load obtained in accordance with § 4b.253. The side load shall be directed inboard perpendicularly to the plane of symmetry midway between the keel and chine lines of the float at the same longitudinal station as the upward load.

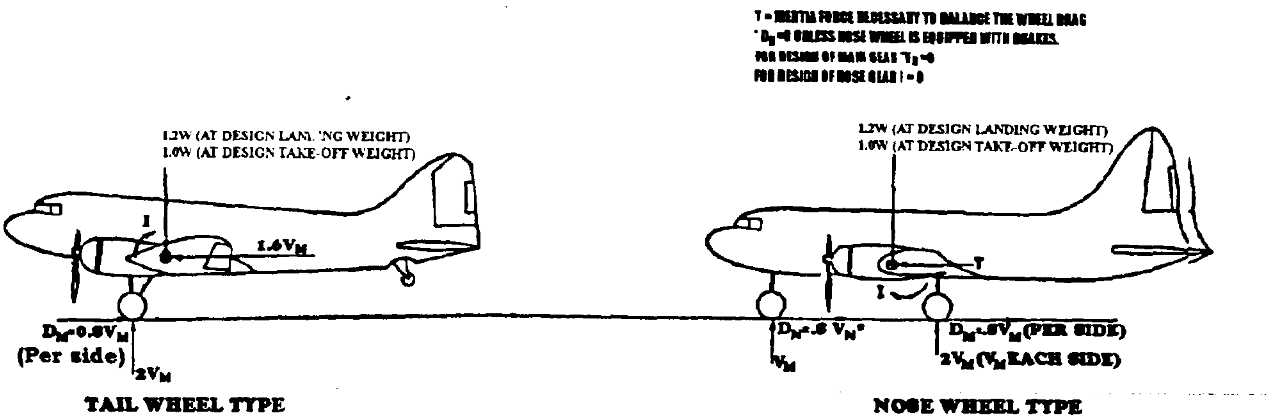



FIGURE 4b-12—Braked roll.

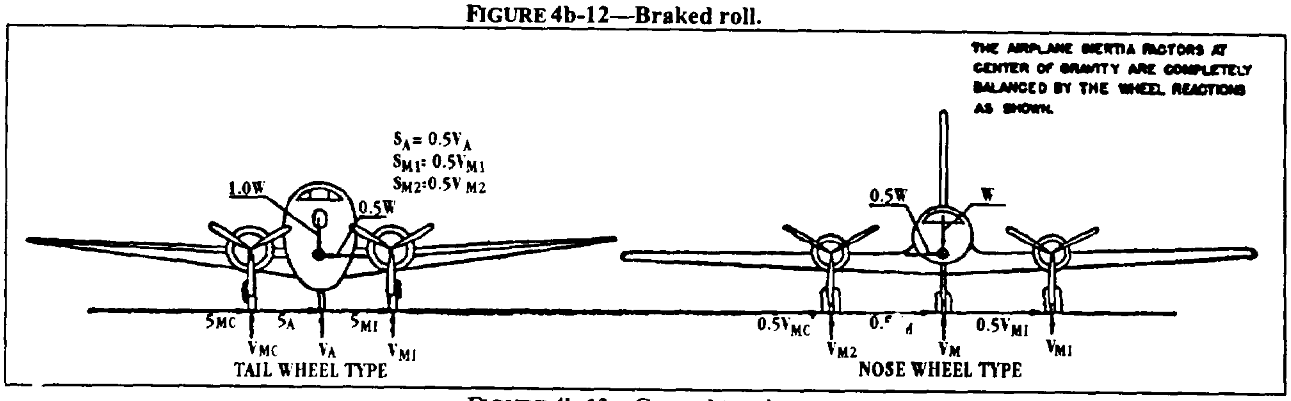



FIGURE 4b-13—Ground turning

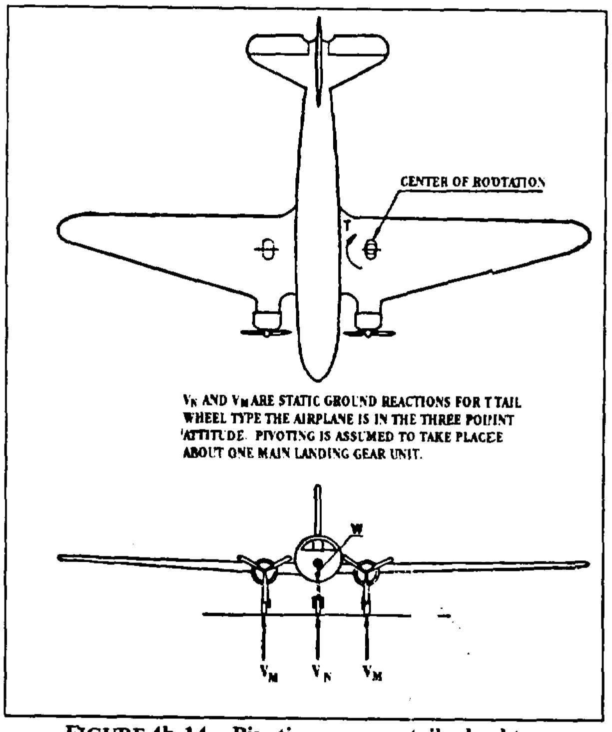



FIGURE 4b-14—Pivoting, nose or tail wheel type.

§ 4b.255 *Hull and main float take-off condition*. The provisions of this section shall apply to the design of the wing and its attachment to the hull or main float. The aerodynamic wing lift shall be assumed to be zero. A downward inertia load shall be applied and shall correspond with the following load factor:

$$n=\frac{C_{TO}\ V_{s_1}^2}{\tan^{2/3}\beta W^{1/3}};$$

where:

$n$= inertia load factor;
$C_{TO}$= empirical seaplane operations factor equal to 0.003;
$V_{s_1}$= seaplane stalling speed (mph) at the design take-off weight with the flaps extended in the appropriate take-off position;
$\beta$= angle of dead rise at the main step (degrees);
$W$= seaplane design take-off weight in pounds.

§ 4b.256 *Hull and main float bottom pressures*. The provisions of this section shall apply to the design of the hull and main float structure, including frames and bulkheads, stringers, and bottom plating. In the absence of more rational data, the pressures and distributions shall be as follows:

(a) *Local pressures*. The following pressure distributions are applicable for the design of the bottom plating and stringers and their attachments to the supporting structure. The area over which these pressures are applied shall be such as to simulate pressures occurring during high localized impacts on the hull or float, and need not extend over an area which would induce critical stresses in the frames or in the overall structure:

(1) *Unflared bottom*. The pressure at the keel (psi) shall be computed as follows:

$$P_k=C_2\frac{K_2\ V_{s_1}^2}{\tan\beta_k};$$

where:

$P_k$= pressure at the keel;
$C_2$= 0.0016;
$K_2$= hull station weighing factor (see fig. 4b-15b);
$V_{s_1}$=seaplane stalling speed (mph) at the design take-off weight with flaps extended in the appropriate take-off position;
$\beta_k$= angle of dead rise at keel (see fig. 4b-15a).

The pressure at the chine shall be 0.75 $P_K$, and the pressures between the keel and chine shall vary linearly. (See fig. 4b-15c.)

(2) *Flared bottom*. The pressure distribution for a flared bottom shall be that for an unflared bottom prescribed in subparagraph (1) of this paragraph, except that the pressure at the chine shall be computed as follows:

$$P_{ch}=C_3\frac{K_2\ V_{s_1}^2}{\tan\beta};$$

where:

$P_{ch}$= pressure at the chine;
$C_3$= 0.0012;
$K_2$= hull station weighing factor (see fig. 4b-15b);
$V_{s_1}$=seaplane stalling speed (mph) at the design take-off weight with flaps extended in the appropriate take-off position;
$\beta$= angle of dead rise at appropriate station.

The pressure at the beginning of the flare shall be the same as for an unflared bottom, and the pressure between the chine and the beginning of the flare shall vary linearly. (See fig. 4b-15c.)

(b) *Distributed pressures*. The following distributed pressures are applicable for the design of the frames, keel, and chine structure. These pressures shall be uniform and shall be applied simultaneously over the entire hull or main float bottom. The loads so obtained shall be carried into the sidewall structure of the hull proper, but need not be transmitted in a fore and aft direction as shear and bending loads.

(1) *Symmetrical*. The symmetrical pressures shall be computed as follows:

$$P=C_4\frac{K_2\ V_{s_0}^2}{\tan\beta};$$

where:

$P$=pressure;
$C_4$=0.078$C_1$ (for $C_1$ see § 4b.253);
$K_2$=hull station weighing factor (see fig. 4b-15b);
$V_{s_0}$=seaplane stalling speed (mph) with landing flaps extended in the appropriate position and with no slipstream effect;
$\beta$=angle of dead rise at appropriate station.

(2) *Unsymmetrical*. The unsymmetrical pressure distribution shall consist of the pressures prescribed in subparagraph (1) of this paragraph on one side of the hull or main float center line and one-half of that pressure on the other side of the hull or main float center line. (See fig. 4b-15c.)

§ 4b.257 *Auxiliary float loads*. Auxiliary floats, their attachments, and supporting structure shall be designed for the following conditions. In the cases specified in paragraphs (a), (b), (c), and (d) of this section it shall be acceptable to distribute the prescribed water loads over the float bottom to avoid excessive local loads, using bottom pressures not less than those prescribed in paragraph (f) of this section.

(a) *Step loading*. The resultant water load shall be applied in the plane of symmetry of the float at a point three-fourths of the distance from the bow to the step and shall be perpendicular to the keel. The resultant limit load shall be computed as follows, except that the value of L need not exceed three times the weight of the displaced water when the float is completely submerged:

$$L=\frac{C_1\ V_{s_0}^2\ W^{2/3}}{\tan^{2/3}\beta_s\ (1+r_y^2)^{2/3}};$$

where:

$L$ = limit load;

$C_1$ = 0.004;

$V_{s_0}$ = seaplane stalling speed (mph) with landing flaps extended in the appropriate position and with no slipstream effect;

$W$ = seaplane design landing weight in pounds;

$\beta_s$ = angle of dead rise at a station ¾ of the distance from the bow to the step, but need not be less than 15 degrees;

$r_y$ = ratio of the lateral distance between the center of gravity and the plane of symmetry of the float to the radius of gyration in roll.

(b) *Bow loading.* The resultant limit load shall be applied in the plane of symmetry of the float at a point one-fourth of the distance from the bow to the step and shall be perpendicular to the tangent to the keel line at that point. The magnitude of the resultant load shall be that specified in paragraph (a) of this section.

(c) *Unsymmetrical step loading.* The resultant water load shall consist of a component equal to 0.75 times the load specified in paragraph (a) of this section and a side component equal to 0.25 tan β times the load specified in paragraph (a) of this section. The side load shall be applied perpendicularly to the plane of symmetry of the float at a point midway between the keel and the chine.

(d) *Unsymmetrical bow loading.* The resultant water load shall consist of a component equal to 0.75 times the load specified in paragraph (b) of this section and a side component equal to 0.25 tan β times the load specified in paragraph (b) of this section. The side load shall be applied perpendicularly to the plane of symmetry at a point midway between the keel and the chine.

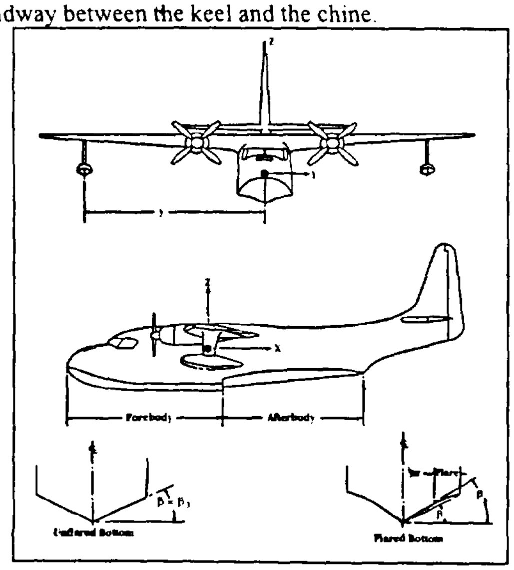



**Figure 4b-15a—Pictorial definition of angles, dimensions, and directions on a seaplane.**

(e) *Immersed float condition.* The resultant load shall be applied at the centroid of the cross section of the float at a point one-third of the distance from the bow to the step. The limit load components shall be as follows:

$$\text{vertical}=\rho g V$$

$$\text{aft}=C_x\frac{\rho}{2}V^{2/3}\ (KV_{s_0})^2$$

$$\text{side}=C_y\frac{\rho}{2}V^{2/3}\ (KV_{s_0})^2$$

where:

$\rho$ = mass density of water;

$V$ = volume of float;

$C_x$ = coefficient of drag force, equal to 0.10;

$C_y$ = coefficient of side force, equal to 0.08;

$K$ = 0.8, except that lower values shall be acceptable if it is shown that the floats are incapable of submerging at a speed of 0.8 $V_{s_0}$ in normal operations;

$V_{s_0}$ = seaplane stalling speed (mph) with landing flaps extended in the appropriate position and with no slipstream effect.

(f) *Float bottom pressures.* The float bottom pressures shall be established in accordance with § 4b.256 (a) and (b). The angle of dead rise to be used in determining the float bottom pressures shall be as defined in paragraph (a) of this section.

§ 4b.258 *Seawing loads.* Seawing design loads shall be based on applicable test data.

### EMERGENCY LANDING CONDITIONS

§ 4b.260 *General.* The following requirements deal with emergency conditions of landing on land or water in which the safety of the occupants shall be considered, although it is accepted that parts of the airplane may be damaged.

(a) The structure shall be designed to give every reasonable probability that all of the occupants, if they make proper use of the seats, belts, and other provisions made in the design (see § 4b.358), will escape serious injury in the event of a minor crash landing (with wheels up if the airplane is equipped with retractable landing gear) in which the occupants experience the following ultimate inertia forces relative to the surrounding structure:

(1) Upward 2.0g (Downward...4.5g)

(2) Forward 9.0g

(3) Sideward 1.5g

(b) The use of a lesser value of the downward inertia force specified in paragraph (a) of this section shall be acceptable if it is shown that the airplane structure can absorb the landing loads corresponding with the design landing weight and an ultimate descent velocity of 5 f. p. s. without exceeding the value chosen.

the bow to the step. The limit load components shall be as follows:

$$\text{vertical} = \rho g V$$

$$\text{aft} = C_x \frac{\rho}{2} V^{2/3} (KV_{s_0})^2$$

$$\text{side} = C_y \frac{\rho}{2} V^{2/3} (KV_{s_0})^2$$

where:

$\rho$ = mass density of water;
$V$ = volume of float;
$C_x$ = coefficient of drag force, equal to 0.10;
$C_y$ = coefficient of side force, equal to 0.08;
$K$ = 0.8, except that lower values shall be acceptable if it is shown that the floats are incapable of submerging at a speed of 0.8 $V_{s_0}$ in normal operations;
$V_{s_0}$ = seaplane stalling speed (mph) with landing flaps extended in the appropriate position and with no slipstream effect.

(f) *Float bottom pressures.* The float bottom pressures shall be established in accordance with § 4b.256 (a) and (b). The angle of dead rise to be used in determining the float bottom pressures shall be as defined in paragraph (a) of this section.

[Amdt. 4b–6, 17 F. R. 1092, Feb. 5, 1952]

### § 4b.258 Seawing loads.

Seawing design loads shall be based on applicable test data.

## Emergency Landing Conditions

### § 4b.260 General.

The following requirements deal with emergency conditions of landing on land or water in which the safety of the occupants shall be considered, although it is accepted that parts of the airplane may be damaged.

(a) The structure shall be designed to give every reasonable probability that all of the occupants, if they make proper use of the seats, belts, and other provisions made in the design (see § 4b.358), will escape serious injury in the event of a minor crash landing (with wheels up if the airplane is equipped with retractable landing gear) in which the occupants experience the following ultimate inertia forces relative to the surrounding structure:

(1) Upward ..... 2.0g (Downward.. 4.5g)
(2) Forward..... 9.0g
(3) Sideward.... 1.5g

(b) The use of a lesser value of the downward inertia force specified in paragraph (a) of this section shall be acceptable if it is shown that the airplane structure can absorb the landing loads corresponding with the design landing weight and an ultimate descent velocity of 5 f. p. s. without exceeding the value chosen.

(c) The inertia forces specified in paragraph (a) of this section shall be applied to all items of mass which would be apt to injure the passengers or crew if such items became loose in the event of a minor crash landing, and the supporting structure shall be designed to restrain these items.

[15 F. R. 3543, June 8, 1950, as amended by Amdt. 4b–6, 17 F. R. 1093, Feb. 5, 1952]

### § 4b.261 Structural ditching provisions.

(For structural strength considerations of ditching provisions see § 4b.361 (c).)

[Amdt. 4b–8, 18 F. R. 2214, Apr. 18, 1953]

## Fatigue Evaluation

### § 4b.270 Fatigue evaluation of flight structure.

The strength, detail design, and fabrication of those portions of the airplane's flight structure in which fatigue may be critical shall be evaluated in accordance with the provisions of either paragraph (a) or (b) of this section.

(a) *Fatigue strength.* The structure shall be shown by analysis and/or tests to be capable of withstanding the repeated loads of variable magnitude expected in service. The provisions of subparagraphs (1) through (3) of this paragraph shall apply.

(1) Evaluation of fatigue shall involve the following:

(i) Typical loading spectrum expected in service;

(ii) Identification of principal structural elements and detail design points, the fatigue failure of which could cause catastrophic failure of the aircraft; and

(iii) An analysis and/or repeated load tests of principal structural elements and detail design points, identified in subdivision (ii) of this subparagraph;

NOTE: Usually tests of principal structural elements include major fittings, samples of joints, spar cap strips, skin units, and other representative sections of the flight structure.

(2) It shall be acceptable to utilize the service history of airplanes of similar structural design, taking due account of



28

differences in operating conditions and procedures.

(3) When circumstances require substantiation of the pressure cabin by fatigue tests, the cabin or representative portions of it shall be cycle-pressure tested, utilizing the normal operating pressure together with the effects of external aerodynamic pressure combined with the flight loads. It shall be acceptable to represent the effects of flight loads by an increased cabin pressure, or to omit the flight loads if they are shown to have no significant effect upon fatigue.

(b) *Fail safe strength.* It shall be shown by analysis and/or tests that catastrophic failure or excessive structural deformation, which could adversely affect the flight characteristics of the airplane, are not probable after fatigue failure or obvious partial failure of a single principal structural element. After such failure, the remaining structure shall be capable of withstanding static loads corresponding with the flight loading condition specified in subparagraphs (1) through (4) of this paragraph. These loads shall be multiplied by a factor of 1.15 unless the dynamic effects of failure under static load are otherwise taken into consideration. In the case of a pressure cabin, the normal operating pressures combined with the expected external aerodynamic pressures shall be applied simultaneously with the flight loading conditions specified in this paragraph.

(1) An ultimate maneuver load factor of 2.0 at $V_C$.

(2) Gust loads as specified in §§ 4b.211 (b) and 4b.215(b), except that these gust loads shall be considered to be ultimate and the gust velocities shall be as follows:

(i) At speed $V_B$, 49 fps from sea level to 20,000 feet altitude, thereafter decreasing linearly to 28 fps at 50,000 feet altitude.

(ii) At speed $V_C$, 33 fps from sea level to 20,000 feet altitude, thereafter decreasing linearly to 16.5 fps at 50,000 feet altitude.

(iii) At speed $V_D$, 15 fps from sea level to 20,000 feet altitude, thereafter decreasing linearly to 6 fps at 50,000 feet altitude.

(3) Eighty percent of the limit loads resulting from the conditions specified in § 4b.220 (c). These loads shall be considered to be ultimate.

(4) Eighty percent of the limit maneuvering loads resulting from the conditions specified in § 4b.215 (a), except that the load need not exceed 100 percent of the critical load obtained in compliance with the provisions of § 4b.215 (a) using a pilot effort of 180 pounds. This load shall be considered to be ultimate.

[Amdt. 4b-3, 21 F.R. 992, Feb. 11, 1956, as amended by Amdt. 4b-6, 22 F.R. 5564, July 16, 1957; Amdt. 4b-8, 23 F.R. 2590, Apr. 19, 1958; Amdt. 4b-12, 27 F.R. 2991, Mar. 30, 1962]

### § 4b.270-1 Flight structure for fatigue evaluation (FAA interpretations which apply to § 4b.270).

The term "flight structure" as applied to fatigue evaluation is defined as those portions of the airplane's structure failure of which could result in catastrophic failure of the aircraft and includes the wings, fixed and movable control surfaces, fuselage, and their related primary attachments.

[Supp. 38, 23 F. R. 3031, May 7, 1958]

### § 4b.270-2 Fatigue evaluation, general (FAA policies which apply to § 4b.270).

The applicant should submit to the FAA a report outlining the procedures and the substantiating analyses and tests he proposes to follow in showing compliance with the fatigue evaluation requirements of § 4b.270. Typical procedures which may be used as guidance in the fatigue evaluation of the structures are discussed in Appendix H[1] to the Civil Aeronautics Manual 4b.

[Supp. 38, 23 F. R. 3031, May 7, 1958]

### § 4b.271 Fatigue evaluation of landing gear.

The strength, detail design, and fabrication of those portions of the landing gear and its attachment fittings in which fatigue may be critical shall be evaluated in accordance with the provisions of either paragraph (a) or (b) of this section.

(a) The fatigue strength of the structure shall be evaluated and, when indicated by such evaluation, inspection or other procedures shall be established to prevent catastrophic fatigue failure. The evaluation shall include the loading spectrum expected in service and the identification and analysis or repeated load testing of the principal structural elements and detail design points where catastrophic fatigue failure could occur.

[1] Not filed for publication in the FEDERAL REGISTER.



29

It shall be acceptable to utilize the service history of airplanes of similar structural design, taking due account of differences in operating conditions and procedures.

(b) It shall be shown by analysis or tests that catastrophic failure is not probable after fatigue failure or obvious partial failure of a single principal structural element. After such failure the remaining structure shall be capable of withstanding static loads corresponding with 80 percent of the limit loads resulting from the conditions prescribed in § 4b.230. These static loads shall be considered ultimate loads.

[Amdt. 4b-12, 27 F.R. 2991, Mar. 30, 1962]

## Subpart D—Design and Construction

### General

**§ 4b.300 Scope.**

The airplane shall not incorporate design features or details which experience has shown to be hazardous or unreliable. The suitability of all questionable design details or parts shall be established by tests.

**§ 4b.300-1 Turnbuckle safetying (FAA policies which apply to § 4b.300).**

The procedure outlined in § 4b.329-2 should be followed in safetying turnbuckles.

[Supp. 25, 20 F. R. 2278, Apr. 8, 1955]

**§ 4b.301 Materials.**

The suitability and durability of all materials used in the airplane structure shall be established on the basis of experience or tests. All materials used in the airplane structure shall conform to approved specifications which will insure their having the strength and other properties assumed in the design data.

**§ 4b.301-1 Acceptability of materials (FAA policies which apply to § 4b.301).**

(a) Materials conforming to established industry or military specifications or to Technical Standard Orders issued by the Administrator are acceptable for use on transport category airplanes. Where new or improved materials are used or where the materials are not covered by specifications sufficient information and data should be submitted to the Administrator to enable him to assess the suitability of the material. In all cases it is the responsibility of the applicant to demonstrate the adequacy of the materials employed.

[Supp. 25, 20 F. R. 2278, Apr. 8, 1955]

**§ 4b.302 Fabrication methods.**

The methods of fabrication employed in constructing the airplane structure shall be such as to produce a consistently sound structure. When a fabrication process such as gluing, spot welding, or heat treating requires close control to attain this objective, the process shall be performed in accordance with an approved process specification.

**§ 4b.303 Standard fastenings.**

All bolts, pins, screws, and rivets used in the structure shall be of an approved type. The use of an approved locking device or method is required for all such bolts, pins, and screws. Self-locking nuts shall not be used on bolts which are subject to rotation in operation.

**§ 4b.304 Protection.**

(a) All members of the structure shall be suitably protected against deterioration or loss of strength in service due to weathering, corrosion, abrasion, or other causes.

(b) Provision for ventilation and drainage of all parts of the structure shall be made where necessary for protection.

(c) In seaplanes, special precautions shall be taken against corrosion from salt water, particularly where parts made from different metals are in close proximity.

**§ 4b.305 Inspection provisions.**

Means shall be provided to permit the close examination of those parts of the airplane which require periodic inspection, adjustment for proper alignment and functioning, and lubrication of moving parts.

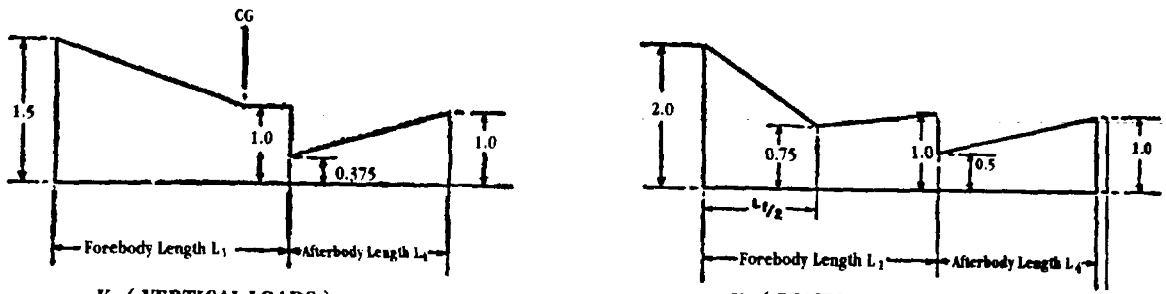
**§ 4b.306 Material strength properties and design values.**

(a) Material strength properties shall be based on a sufficient number of tests of material conforming to specifications to establish design values on a statistical basis.

(b) The design values shall be so chosen that the probability of any structure being understrength because of material variations is extremely remote. The effects of temperature on allowable stresses used for design in an essential component or structure shall be considered where thermal effects are significant under normal operating conditions.

(c) The inertia forces specified in paragraph (a) of this section shall be applied to all items of mass which would be apt to injure the passengers or crew if such items became loose in the event of a minor crash landing, and the supporting structure shall be designed to restrain these items.

§ 4b.261 *Structural ditching provisions.* (For structural strength considerations of ditching provisions see § 4b.361 (c).)




$K_1$ ( VERTICAL LOADS )    $K_2$ ( BOTTOM PRESSURES )

FIGURE 4b-15b—Hull station weighing factor.

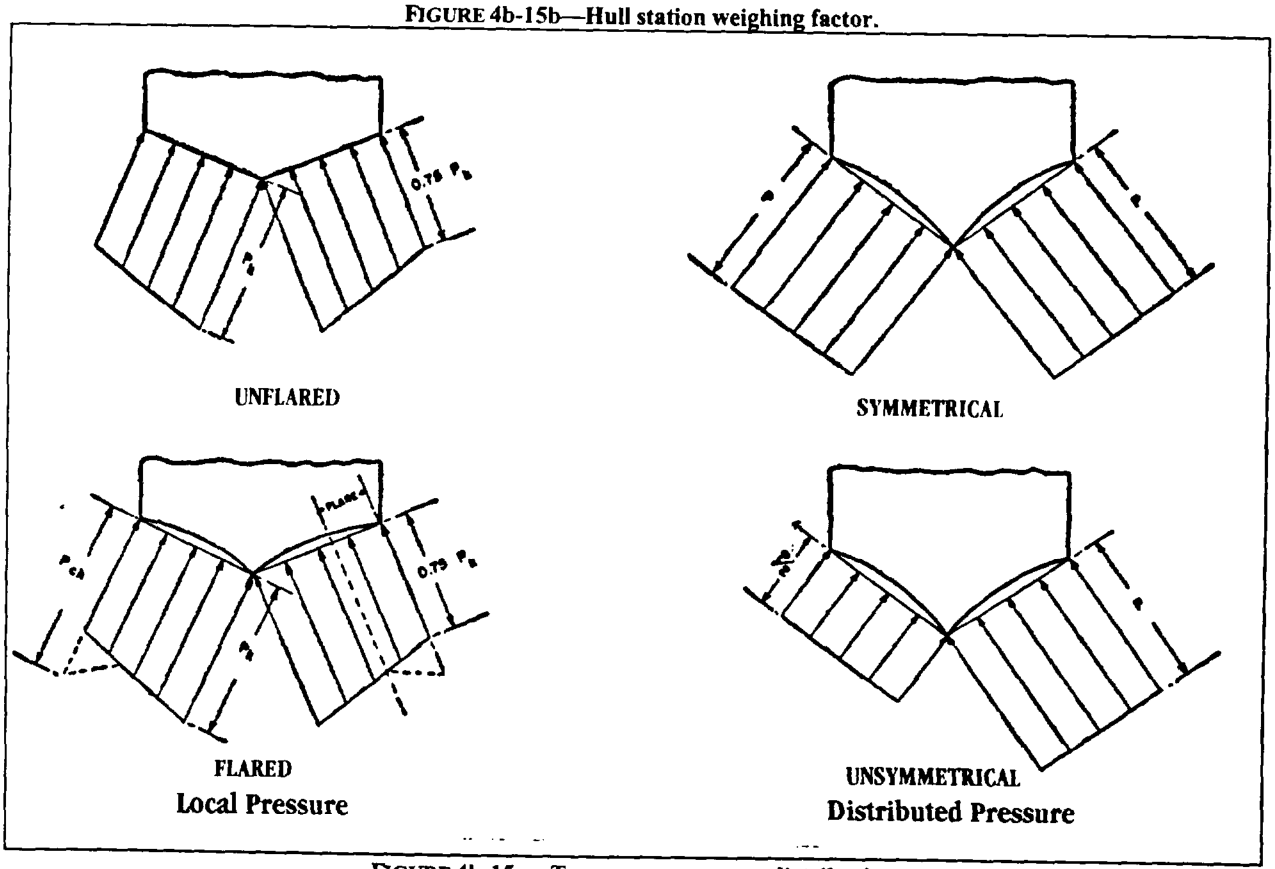



FIGURE 4b-15c—Transverse pressure distributions.

## SUBPART D—DESIGN AND CONSTRUCTION

### GENERAL

§ 4b.300 *Scope.* The airplane shall not incorporate design features or details which experience has shown to be hazardous or unreliable. The suitability of all questionable design details or parts shall be established by tests.

§ 4b.301 *Materials.* The suitability and durability of all materials used in the airplane structure shall be established on the basis of experience or tests. All materials used in the airplane structure shall conform to approved specifications which will insure their having the strength and other properties assumed in the design data.

§ 4b.302 *Fabrication methods.* The methods of fabrication employed in constructing the airplane structure shall be such as to produce a consistently sound structure. When a fabrication process such as gluing, spot welding, or heat treating requires close control to attain this objective, the process shall be performed in accordance with an approved process specification.

§ 4b.303 *Standard fastenings.* All bolts, pins, screws, and rivets used in the structure shall be of an approved type. The use of an approved locking device or method is required for all such bolts, pins, and screws. Self-locking nuts shall not be used on bolts which are subject to rotation in operation.

§ 4b.304 *Protection.* (a) All members of the structure shall be suitably protected against deterioration or loss of strength in service due to weathering, corrosion, abrasion, or other causes.

(b) Provision for ventilation and drainage of all parts of the structure shall be made where necessary for protection.

(c) In seaplanes, special precautions shall be taken against corrosion from salt water, particularly where parts made from different metals are in close proximity.

§ 4b.305 *Inspection provisions.* Means shall be provided to permit the close examination of those parts of the airplane which require periodic inspection, adjustment for proper alignment and functioning, and lubrication of moving parts.

§ 4b.306 *Material strength properties and design values.* (a) Material strength properties shall be based on a sufficient number of tests of material conforming to specifications to establish design values on a statistical basis.

(b) The design values shall be so chosen that the probability of any structure being understrength because of material variations is extremely remote.

(c) ANC-5, ANC-18, and ANC-23, Part II values shall be used unless shown to be inapplicable in a particular case.

NOTE: ANC-5, "Strength of Metal Aircraft Elements," ANC-18, "Design of Wood Aircraft Structures," and ANC-23, "Sandwich Construction for Aircraft," are published by the subcommittee on Air Force-Navy-Civil Aircraft Design Criteria and may be obtained from the superintendent of Documents, Government Printing Office, Washington 25, D.C.

(d) The strength, detail design, and fabrication of the structure shall be such as to minimize the probability of disastrous fatigue failure.

NOTE: Points of stress concentration are one of the main sources of fatigue failure.

§ 4b.307 *Special factors.* Where there is uncertainty concerning the actual strength of a particular part of the structure, or where the strength is likely to deteriorate in service prior to normal replacement of the part, or wher. the strength is subject to appreciable variability due to uncertainties in manufacturing processes and inspection methods, the factor of safety prescribed in § 4b.200 (a) shall be multiplied by a special factor of a value such as to make the probability of the part being understrength from these causes extremely remote. The following special factors shall be used:

(a) *Casting factors.* (1) Where only visual inspection of a casting is to be employed, the casting factor shall be 2.0, except that it need not exceed 1.25 with respect to bearing stresses.

(2) It shall be acceptable to reduce the factor of 2.0 specified in subparagraph (1) of this paragraph to a value of 1.25 if such a reduction is substantiated by testing at least three sample castings and if the sample castings as well as all production castings are visually and radiographically inspected in accordance with an approved inspection specification. During these tests the samples shall withstand the ultimate load multiplied by the factor of 1.25 and in addition shall comply with the corresponding limit load multiplied by a factor of 1.15.

(3) Casting factors other than those contained in subparagraphs (1) and (2) of this paragraph shall be acceptable if they are found to be appropriately related to teats and to inspection procedures.

(4) A casting factor need not be employed with respect to the bearing surface of a part if the bearing factor used (see paragraph (b) of this section) is of greater magnitude than the casting factor.

(b) *Bearing factors.* (1) Bearing factors shall be used of sufficient magnitude to provide for the effects of normal relative motion between parts and in joints with clearance (free fit) which are subject to pounding or vibration. (Bearing factor values for control surface and system joints are specified in § 4b.313 (a) and 4b.329 (b).)

(2) A bearing factor need not be employed on a part if another special factor prescribed in this section is of greater magnitude than the bearing factor.

(c) *Fitting factors.* (1) A fitting factor of at least 1.15 shall be used on all fittings the strength of which is not proven by limit and ultimate load tests in which the actual stress conditions are simulated in the fitting and the surrounding structure. This factor shall apply to all portions of the fitting, the means of attachment, and the bearing on the members joined.

(2) In the case of integral fittings the part shall be treated as a fitting up to the point where the section properties become typical of the member.

(3) The fitting factor need not be employed where a type of joint made in accordance with approved practices is based on comprehensive test data, e. g., continuous joints in metal plating welded joints, and scarf joints in wood.

(4) A fitting factor need not be employed with respect to the bearing surface of a part if the bearing factor used (see paragraph (b) of this section) is of greater magnitude than the fitting factor.

§ 4b.308 *Flutter, deformation, and vibration.* Compliance with the following provisions shall be shown by such calculations, resonance tests, or other tests as are found necessary by the Administrator.

(a) *Flutter prevention.* The airplane shall be designed to be free from flutter of wing and tail units, including all control and trim surfaces, and from divergence (i.e. unstable structural distortion due to aerodynamic loading), at all speeds up to 1.2 $V_D$. A smaller margin above $V_D$ shall be acceptable if the characteristics of the airplane (including the effects of compressibility) render a speed of 1.2 $V_D$ unlikely to be achieved, and if it is shown that a proper margin of damping exists at speed $V_D$. In the absence of more accurate data, the terminal velocity in a dive of 30 degrees to the horizontal shall be acceptable as the maximum speed likely to be achieved. If concentrated balance weights are used on control surfaces, their effectiveness and strength, including supporting structure, shall be substantiated.

(b) *Loss of control due to structural deformation.* The airplane shall be designed to be free from control reversal and from undue loss of longitudinal, lateral, and directional stability and control as a result of structural deformation, including that of the control surface covering, at all speeds up to the speed prescribed in paragraph (a) of this section for flutter prevention.

(c) *Vibration and buffeting.* The airplane shall be designed to withstand all vibration and buffeting which might occur in any likely operating conditions.

### Control Surfaces

§ 4b.310 *General.* The requirements of §§ 4b.311 through 4b.313 shall apply to the design of fixed and movable control surfaces.

§ 4b.311 *Proof of strength.* (a) Control surface limit load tests shall be conducted to prove compliance with limit load requirements.

(b) Control surface tests shall include the horn or fitting to which the control system is attached.

(c) Analyses or individual load tests shall be conducted to demonstrate compliance with the special factor requirements for control surface hinges. (See §§ 4b.307 and 4b.313 (a).)

§ 4b.312 *Installation.* (a) Movable tail surfaces shall be so installed that there is no interference between any two surfaces when one is held in its extreme position and all the others are operated through their full angular movement.

(b) When an adjustable stabilizer is used, stops shall be provided which will limit its travel, in the event of failure of the adjusting mechanism, to a range equal to the maximum required to trim the airplane in accordance with § 4b.140.

§ 4b.313 *Hinges.* (a) Control surface hinges, except ball and roller bearings, shall incorporate a special factor of not less than 6.67 with respect to the ultimate bearing strength of the softest material used as a bearing.

(b) For hinges incorporating ball or roller bearings, the approved rating of the bearing shall not be exceeded.

(c) Hinges shall provide sufficient strength and rigidity for loads parallel to the hinge line.

### Control Systems

§ 4b.320 *General.* All controls and control systems shall operate with ease, smoothness, and positiveness appropriate to their function. (See also §§ 4b.350 and 4b.353.)

§ 4b.321 *Two-control airplanes.* Two-control airplanes shall be capable of continuing safely in flight and landing in the event of failure of any one connecting element in the directional-lateral flight control system.

§ 4b.322 *Trim controls and systems.* (a) Trim controls shall be designed to safeguard against inadvertent or abrupt operation.

(b) Each trim control shall operate in the plane and with the sense of motion of the airplane. (See fig. 4b-16.)

(c) Means shall be provided adjacent to the trim control to indicate the direction of the control movement relative to the airplane motion.

(d) Means shall be provided to indicate the position of the trim device with respect to the range of adjustment. The indicating means shall be clearly visible.

(e) Trim devices shall be capable of continued normal operation in the event of failure of any one connecting or transmitting element of the primary flight control system.

(f) Trim tab controls shall be irreversible, unless the tab is appropriately balanced and shown to be free from flutter.

(g) Where an irreversible tab control system is employed, the portion from the tab to the attachment of the irreversible unit to the airplane structure shall consist of a rigid connection.

§ 4b.323 *Wing flap controls.* (a) The wing flap controls shall operate in a manner to permit the flight crew to place the flaps in all of the take-off, en route, approach, and landing positions established under § 4b.111 and to maintain these positions thereafter without further attention on the part of the crew, except for flap movement produced by an automatic flap positioning or load limiting device.

(b) The wing flap control shall be located and designed to render improbable its inadvertent operation.

(c) The rate of motion of the wing flap in response to the operation of the control and the characteristics of the automatic flap positioning or load limiting device shall be such as to obtain satisfactory flight and performance characteristics under steady or changing conditions of air speed, engine power, and airplane attitude.

(d) The wing flap control shall be designed to retract the flaps from the fully extended position during steady flight at maximum continuous engine power at all speeds below $V_F + 10$ (m.p.h.).

(e) Means shall be provided to indicate the take-off, en route, approach, and landing flap positions.

(f) If any extension of the flaps beyond the landing position is possible the flap control shall be clearly marked to identify such range of extension.

§ 4b.324 *Wing flap interconnection.* (a) The motion of wing flaps on opposite sides of the plane of symmetry shall be synchronized by a mechanical interconnection unless the airplane is demonstrated to have safe flight characteristics while the flaps are retracted on one side and extended on the other.

(b) Where a wing flap interconnection is used, it shall be designed to account for the applicable unsymmetrical loads, including those resulting from flight with the engines on one side of the plane of symmetry inoperative and the remaining engines at take-off power. For airplanes with flaps which are not subjected to slipstream conditions, the structure shall be designed for the loads imposed when the wing flaps on one side are carrying the most severe load occurring in the prescribed symmetrical conditions and those on the other side are carrying not more than 80 percent of that load.

§ 4b.325 *Control system stops.* (a) All control systems shall be provided with stops which positively limit the range of motion of the control surfaces.

(b) Control system stops shall be so located in the system that wear, slackness, or take-up adjustments will not affect adversely the control characteristics of the airplane because of a change in the range of surface travel.

(c) Control system stops shall be capable of withstanding the loads corresponding with the design conditions for the control system

§ 4b.326 *Control system locks.* Provision shall be made to prevent damage to the control surfaces (including tabs) and the control system which might result from gusts striking the airplane while it is on the ground or water (see also § 4b.226). If a device provided for this purpose, when engaged, prevents normal operation of the control surfaces by the pilot, it shall comply with the following provisions.

(a) The device shall either automatically disengage when the pilot operates the primary flight controls in a normal manner, or it shall limit the operation of the airplane in such a manner that the pilot receives unmistakable warning at the start of take-off.

(b) Means shall be provided to preclude the possibility of the device becoming inadvertently engaged in flight.

§ 4b.327 *Static tests.* Tests shall be conducted on control systems to show compliance with limit load requirements in accordance with the following provisions.

(a) The direction of the test loads shall be such as to produce the most severe loading in the control system.

(b) The tests shall include all fittings, pulleys, and brackets used in attaching the control system to the main structure.

(c) Analyses or individual load tests shall be conducted to demonstrate compliance with the special factor requirements for control system joints subjected to angular motion. (See §§ 4b.307 and 4b.329 (b).)

§ 4b.328 *Operation tests.* An operation test shall be conducted for each control system by operating the controls from the pilot compartment with the entire system loaded to correspond with 80 percent of the limit load specified for the control system. In this test there shall be no jamming, excessive friction, or excessive deflection.

§ 4b.329 *Control system details; general.* All details of control systems shall be designed and installed to prevent jamming, chafing, and interference from cargo, passengers, and loose objects. Precautionary means shall be provided in the cockpit to prevent the entry of foreign objects into places where they would jam the control systems. Provisions shall be made to prevent the slapping of cables or tubes against other parts of the airplane. The following detail requirements shall be applicable with respect to cable systems and joints.

(a) *Cable systems.* (1) Cables, cable fittings, turnbuckles, splices, and pulleys shall be of an approved type.

(2) Cables smaller than 1/8-inch diameter shall not be used in the aileron, elevator, or rudder systems.

(3) The design of cable systems shall be such that there will be no hazardous change in cable tension throughout the range of travel under operating conditions and temperature variations.

(4) Pulley types and sizes shall correspond with the cables used.

(5) All pulleys and sprockets shall be provided with closely fitted guards to prevent the cables and chains being displaced or fouled.

(6) Pulleys shall lie in the plane passing through the cable within such limits that the cable does not rub against the pulley flange.

(7) Fairleads shall be so installed that they do not cause a change in cable direction of more than 3°.

(8) Clevis pins (excluding those not subject to load or motion) retained only by cotter pins shall not be used in the control system.

(9) Turnbuckles attached to parts having angular motion shall be installed to prevent positively any binding throughout the range of travel.

(10) Provision for visual inspection shall be made at all fairleads, pulleys, terminals, and turnbuckles.

(b) *Joints.* (1) Control system joints subjected to angular motion in push-pull systems, excepting ball and roller bearing systems, shall incorporate a special factor of not less than 3.33 with respect to the ultimate bearing strength of the softest material used as a bearing.

(2) It shall be acceptable to reduce the factor specified in subparagraph (1) of this paragraph to a value of 2.0 for joints in cable control systems.

(3) The approved rating of ball and roller bearings shall not be exceeded.

### Landing Gear

§ 4b.330 *General.* The requirements of §§ 4b.331 through 4b.338 shall apply to the complete landing gear.

§ 4b.331 *Shock absorbers.* (a) The shock absorbing elements for the main, nose, and tail wheel units shall be substantiated by the tests specified in § 4b.332.

(b) The shock absorbing ability of the landing gear in taxying shall be demonstrated by the tests prescribed in § 4b.172.

§ 4b.332 *Landing gear tests.* The landing gear shall withstand the following tests.

(a) *Shock absorption tests.* (1) It shall be demonstrated by energy absorption tests that the limit load factors selected for design in accordance with § 4b.230 (b) for take-off and landing weights, respectively, will not be exceeded.

(2) In addition to the provisions of subparagraph (1) of this paragraph, a reserve of energy absorption shall be demonstrated by a test simulating an airplane descent velocity of 12 f.p.s. at design landing weight, assuming wing lift not greater than the airplane weight acting during the landing impact. In this test the landing gear shall not fail. (See paragraph (c) of this section.)

(b) *Limit drop tests.* (1) If compliance with the limit landing conditions specified in paragraph (a)(1) of this section is demonstrated by free drop tests, these shall be conducted on the complete airplane, or on units consisting of wheel, tire, and shock absorber in their proper relation. The free drop heights shall not be less than the following:

(i) 18.7 inches for the design landing weight conditions.

(ii) 6.7 inches for the design take-off weight conditions.

(2) If wing lift is simulated in free drop tests the landing gear shall be dropped with an effective mass equal to:

$$W_e = W\left(\frac{h+(1-L)d}{h+d}\right);$$

**where:**

**$W_e$ = the effective weight to be used in the drop test (lbs.),**

**$h$ = specified free drop height (inches),**

**$d$ = deflection under impact of the tire (at the approved inflation pressure) plus the vertical component of the axle travel relative to the drop mass (inches),**

**$W = W_M$ for main gear units (lbs.), equal to the static weight on the particular unit with the airplane in the level attitude (with the nose wheel clear in the case of nose wheel type airplanes),**

**$W = W_T$ for tail gear units (lbs.), equal to the static weight on the tail unit with the airplane in the tail-down attitude,**

**$W = W_N$ for nose wheel units (lbs.), equal to the vertical component of the static reaction which would exist at the nose wheel, assuming the mass of the airplane acting at the center of gravity and exerting a force of 1.0g downward and 0.25g forward,**

**$L$ = the ratio of the assumed wing lift to the airplane weight, not in excess of 0.667.**

(3) The attitude in which a landing gear unit is drop tested shall simulate the airplane landing condition critical for the unit.

(4) The value of $d$ used in the computation of $W_e$ in subparagraph (2) of this paragraph shall not exceed the value actually obtained in the drop test.

(c) *Reserve energy absorption drop tests.* (1) If compliance with the reserve energy absorption condition specified in paragraph (a)(2) of this section is demonstrated by free drop tests, the landing gear units shall be dropped from a free drop height of not less than 27 inches.

(2) If wing lift equal to the airplane weight is simulated, the units shall be dropped with an effective mass equal to:

$$W_e = W\left(\frac{b}{b+d}\right);$$

where the symbols and other details are the same as in paragraph (b) of this section.

§ 4b.333 *Limit load factor determination.* (a) In determining the airplane inertia limit load factor *n* from the free drop tests specified in § 4b.332, the following formula shall be used:

$$n = n_j \frac{W_e}{W} + L;$$

**where:**

**$n_j$=the load factor during impact developed on the mass used in the drop test (i. e., the acceleration $dv/dt$ in g's recorded in the drop test plus 1.0). (See § 4b.332 (b) (2) for explanation of $W_e$, $W$, and $L$).**

(b) The value of η determined in paragraph (a) of this section shall not be greater than the limit load factor used for the landing conditions. (See § 4b.230 (b)).

§ 4b.334 *Retracting mechanism*—(a) *General.* (1) The landing gear retracting mechanism, wheel well doors, and supporting structure shall be designed for the loads occurring in the flight conditions when the gear is in the retracted position, and for the combination of friction, inertia, brake torque, and air loads occurring during retraction and extension at any air speed up to 1.6 $V_{s1}$ (flaps in the approach position at design landing weight), and any load factor up to those specified in § 4b.212 for the flaps extended condition.

(2) The landing gear, the retracting mechanism, and the airplane structure including wheel well doors shall be designed to withstand the flight loads occurring with the landing gear in the extended position at any speed up to 0.67 $V_C$, unless other means are provided to decelerate the airplane in flight at this speed.

(3) Landing gear doors, their operating mechanism, and their supporting structure shall be designed for the conditions of air speed and load factor prescribed in subparagraphs (1) and (2) of this paragraph, and in addition they shall be designed for the yawing maneuvers prescribed for the airplane

(b) *Landing gear lock.* A positive means shall be provided for the purpose of maintaining the landing gear in the extended position.

(c) *Emergency operation.* Emergency means of extending the landing gear shall be provided, so that the landing gear can be extended in the event of any reasonably probable failure in the normal retraction system. In any case the emergency system shall provide for the failure of any single source of hydraulic, electric, or equivalent energy supply.

(d) *Operation test.* Proper functioning of the landing gear retracting mechanism shall be demonstrated by operation tests.

(e) *Position indicator and warning device.* (1) When a retractable landing gear is used, means shall be provided for indicating to the pilot when the gear is secured in the extended and in the retracted positions.

(2) In addition to the requirement of subparagraph (1) of this paragraph, landplanes shall be provided with an aural warning device which will function continuously when all throttles are closed if the gear is not fully extended and locked.

(3) If a manual shutoff for the warning device prescribed in subparagraph (2) of this paragraph is provided, it shall be installed so that reopening the throttles will reset the warning mechanism.

(f) *Control.* The location and operation of the landing gear retraction control shall be according to the provisions of § 4b.353.

§ 4b.335 *Wheels.* Main wheels and nose wheels shall be of an approved type. The following provisions shall apply.

(a) The maximum static load rating of each main wheel and nose wheel shall not be less than the corresponding static ground reaction under the design take-off weight of the airplane and the critical center of gravity position.

(b) The maximum limit load rating of each main wheel and nose wheel shall not be less than the maximum radial limit load determined in accordance with the applicable ground load requirements of this part (see §§ 4b.230 through 4b.236).

(c) The maximum kinetic energy capacity rating of each main wheel-brake assembly shall not be less than the kinetic energy absorption requirement determined as follows:

$$KE = \frac{0.0334 W V_{s_0}^{\,2}}{N};$$

**where:**

**$KE$=kinetic energy per wheel (ft. lb.);**
**$W$=design landing weight (lb.);**
**$V_{s_0}$=power-off stalling speed of the airplane (mph) at sea level at the design landing weight and in the landing configuration;**
**$N$=number of main wheels.**

**NOTE: The expression for kinetic energy assumes an equal distribution of braking between main wheels. In cases of unequal distribution the expression requires appropriate modification.**

(d) The minimum stalling speed rating of each main wheel-brake assembly i.e., the initial speed used in the dynamometer tests, shall not be greater than the Vso used in the determination of kinetic energy in accordance with paragraph (c) of this section.

NOTE: The provision of this paragraph is based upon the assumption that the testing procedures for wheel-brake assemblies involve a specified rate of deceleration, and, therefore, for the same amount of kinetic energy the rate of energy absorption (the power absorbing ability of the brake) varies inversely with the initial speed.

§ 4b.336 *Tires*. (a) Landing gear tires shall be of a proper fit on the rim of the wheel, and their approved rating shall be such that it is not exceeded under the following conditions:

(1) Airplane weight equal to the design take-off weight,

(2) Load on each main wheel tire equal to the corresponding static ground reaction at the critical center of gravity position.

(3) Load on nose wheel tires (to be compared with the dynamic rating established for such tires) equal to the reaction obtained at the nose wheel assuming the mass of the airplane concentrated at the most critical center of gravity and exerting a force of 1.0g downward and 0.31g forward, the reactions being distributed to the nose and main wheels by the principles of statics with the drag reaction at the ground applied only at those wheels which have brakes.

§ 4b.337 *Brakes*—(a) *General*. (1) The airplane shall be equipped with brakes of an approved type. The brake ratings shall be in accordance with § 4b.335 (c) and (d).

(2) The brake system shall be so designed and constructed that in the event of a single failure in any connection or transmitting element in the brake system (excluding the operating pedal or handle), or the lose of any single source of hydraulic or other brake operating energy supply, it shall be possible to bring the airplane to rest under conditions specified in § 4b.122 with a mean deceleration during the landing roll of at least 50 percent of that obtained in determining the landing distance as prescribed in that section.

(3) In applying the requirement of subparagraph (2) of this paragraph to hydraulic brakes, the brake drum, shoes, and actuators (or their equivalents) shall be considered as connecting or transmitting elements, unless it is shown that the leakage of hydraulic fluid resulting from failure of the sealing elements in these units would not reduce the braking effectiveness below that specified in subparagraph (2) of this paragraph.

(b) *Brake controls*. Brake controls shall not require excessive control forces in their operation.

(c) *Parking brake controls*. A parking brake control shall be provided and installed so that it can be set by the pilot and, without further attention, will maintain sufficient braking to prevent the airplane from rolling on a paved, level runway while take-off power on the critical engine is being applied.

§ 4b.338 *Skis*. Skis shall be of an approved type. The maximum limit load rating of each ski shall not be less than the maximum limit load determined in accordance with the applicable ground load requirements of this part. (See §§ 4b.230 through 4b.236.)

### HULLS AND FLOATS

§ 4b.340 *General*. The requirements of §§ 4b.341 and 4b.342 shall apply to the design of hulls and floats.

§ 4b.341 *Seaplane main floats*. Seaplane main floats shall be of an approved type and shall comply with the provisions of § 4b.250. In addition, the following shall apply.

(a) *Buoyancy*. Each seaplane main float shall have a buoyancy of 80 percent in excess of that required to support the maximum weight of the seaplane in fresh water.

(b) *Compartmentation*. Each seaplane main float shall contain not less than 5 watertight compartments. The compartments shall have approximately equal volumes.

§ 4b.342 *Boat hulls*. (a) The hulls of boat seaplanes and amphibians shall be divided into watertight compartments so that, with any two adjacent compartments flooded, the buoyancy of the hull and auxiliary floats (and wheel tires, if used) will provide a sufficient margin of positive stability to minimize capsizing in rough fresh water.

(b) For the purpose of communication between compartments, bulkheads with watertight doors shall be allowed.

exhaust system parts or exhaust gas impingement shall be constructed of fireproof material.

(e) The airplane shall be so designed and constructed that fire originating in the engine power or accessory sections cannot enter, either through openings or by burning through external skin, into any other zone of the nacelle where such fire would create additional hazards. If the airplane is provided with a retractable landing gear, this provision shall apply with the landing gear retracted. Fireproof materials shall be used for all nacelle skin areas which might be subjected to flame in the event of a fire originating in the engine power or accessory sections.

§ 4b.488 *Engine accessory section diaphragm.* Unless equivalent protection can be shown by other means, a diaphragm shall be provided on air-cooled engines to isolate the engine power section and all portions of the exhaust system from the engine accessory compartment. This diaphragm shall comply with the provisions of § 4b.486.

§ 4b.489 *Drainage and ventilation of fire zones.* (a) Provision shall be made for the rapid and complete drainage of all portions of designated fire zones in the event of failure or malfunctioning of components containing flammable fluids. The drainage provisions shall be so arranged that the discharged fluid will not cause an additional fire hazard.

(b) All designated fire zones shall be ventilated to prevent the accumulation of flammable vapors. Ventilation openings shall not be placed in locations which would permit the entrance of flammable fluids, vapors, or flame from other zones. The ventilation provisions shall be so arranged that the discharged vapors will not cause an additional fire hazard.

(c) Except with respect to the engine power section of the nacelle and the combustion heater ventilating air ducts, provision shall be made to permit the crew to shut off sources of forced ventilation in any fire zone, unless the extinguishing agent capacity and rate of discharge are based on maximum air flow through the zone.

§ 4b.490 *Protection of other airplane components against fire.* All airplane surfaces aft of the nacelles, in the region of one nacelle diameter on both sides of the nacelle center line, shall be constructed of fire-resistant material. This provision need not be applied to tail surfaces lying behind nacelles, unless the dimensional configuration of the aircraft is such that the tail surfaces could be affected readily by heat, flames, or sparks emanating from a designated fire zone or engine compartment of any nacelle.

## SUBPART F—EQUIPMENT

### General

§ 4b.600 *Scope.* The required basic equipment as prescribed in this subpart is the minimum which shall be installed in the airplane for certification. Such additional equipment as is necessary for a specific type of operation is prescribed in the operating rules of this subchapter.

§ 4b.601 *Functional and installational requirements.* Each item of equipment shall be:

(a) Of a type and design appropriate to perform its intended function,

(b) Labeled as to its identification, function, or operational limitations, or any combination of these, whichever is applicable,

(c) Installed in accordance with specified limitations of the equipment,

(d) Demonstrated to function properly in the airplane.

§ 4b.602 *Required basic equipment.* The equipment listed in §§ 4b.603 through 4b.605 shall be the required basic equipment. (See § 4b.600 )

§ 4b.603 *Flight and navigational instruments.* (See § 4b.612 for installation requirements.)

(a) Air-speed indicating system,

(b) Altimeter (sensitive),

(c) Clock (sweep-second),

(d) Free air temperature indicator,

(e) Gyroscopic bank and pitch indicator,

(f) Gyroscopic rate-of-turn indicator ( with bank indicator),

(g) Gyroscopic directional indicator,

(h) Magnetic direction indicator,

(i) Rate-of-climb indicator (vertical speed).

(j) Maximum allowable air-speed indicator if an air-speed limitation results from compressibility hazards. (See § 4b.710.)

§ 4b.604 *Powerplant instruments.* (See § 4b.613 for installation requirements.)

(a) Carburetor air temperature indicator for each engine,

(b) Coolant temperature indicator for each liquid-cooled engine,

(c) Cylinder head temperature indicator for each air-cooled engine,

(d) An individual fuel pressure indicator for each engine and either an independent warning device for each engine or a master warning device for all engines with means for isolating the individual warning circuit from the master warning device,

(e) Fuel flowmeter indicator or fuel mixture indicator for each engine not equipped with an automatic altitude mixture control,

(f) Fuel quantity indicator for each fuel tank,

(g) Manifold pressure indicator for each engine,

(h) An individual oil pressure indicator for each engine and either an independent warning device for each engine or a master warning device for all engines with means for isolating the individual warning circuit from the master warning device,

(i) Oil quantity indicator for each oil tank when a transfer or oil reserve supply system is used,

(j) Oil temperature indicator for each engine,

(k) Tachometer for each engine,

(l) Fire warning indicators (see § 4b.485),

(m) A device for each engine capable of indicating to the flight crew during flight any change in the power output, if the engine is equipped with an automatic propeller feathering system the operation of which is initiated by a power output measuring system or if the total engine cylinder displacement is 2,000 cubic inches or more.

(n) A means for each reversing propeller to indicate to the pilot when the propeller is in reverse pitch.

§ 4b.605 *Miscellaneous equipment.* (a) Approved seats for all occupants (see § 4b.358),

(b) Approved safety belts for all occupants (see § 4b.643),

(c) Master switch arrangement for electrical circuits other than ignition (see §§ 4b.623 and 4b.624),

(d) Source(s) of electrical energy (see 4b.620),

(e) Electrical protective devices (see § 4b.624),

(f) Radio communication system (two-way),

(g) Radio navigation system,

(h) Windshield wiper or equivalent for each pilot,

(i) Ignition switch for each and all engines (see § 4b.472),

(j) Approved portable fire extinguisher (see § 4b.641).

§ 4b.606 *Equipment, systems, and installations*—(a) *Functioning and reliability.* All equipment, systems, and installations the functioning of which is necessary in showing compliance with the regulations in this subchapter shall be designed and installed to insure that they will perform their intended functions reliably under all reasonably foreseeable operating conditions.

(b) *Hazards.* All equipment, systems, and installations shall be designed to safeguard against hazards to the airplane in the event of their malfunctioning or failure.

(c) *Power supply.* Where an installation the functioning of which is necessary in showing compliance with the regulations of this subchapter requires a power supply, such installation shall be considered an essential load on the power supply, and the power sources and the system shall be capable of supplying the following power loads in probable operating combinations and for probable durations:

(1) All loads connected to the system with the system functioning normally;

(2) All essential loads after failure of any one prime mover, power converter, or energy storage device;

(3) All essential loads after failure of any one engine on two- or three-engine airplanes, or after failure of any two engines on four-or-more-engine airplanes.