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Airplane Airworthiness; Transport Categories

General

Applicability and Definitions

4b.0 *Applicability of this part.* This part establishes standards with which compliance shall be demonstrated for the issuance of and changes to type certificates 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 This part, until superseded or rescinded, shall apply to all transport category airplanes for which applications for type certification in the transport category are made after the effective date of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 sec. 4b.18.)

(b) *General design.*

(1) *Standard atmosphere.* The standard atmosphere is an atmosphere [(see NACA Technical Note 3182)] 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 [—69.7° F.] is —0.003566° F./ft. and zero thereabove,

(v) The density ρ_0 at sea level under the above conditions is [0.002377] 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 standards. (See sec. 4b.451 (b).)

(3) *Airplane configuration.* Airplane configuration is a term referring to the position of the various elements affecting the aerodynamic 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 sec. 4b.114.)

(7) *Continuous maximum icing.* The maximum continuous intensity of atmospheric icing conditions is defined by the variables of the cloud liquid water content, the mean effective diameter of the cloud droplets, the ambient air temperature, and the inter-relationship of these three variables as shown in figure 4b–24a. The limiting icing envelope in terms of altitude and temperature is given in figure 4b–24b. The inter-relationship of cloud liquid water content with drop diameter and altitude is determined from figures 4b–24a and 4b–24b. The cloud liquid water content for continuous maximum icing conditions of a horizontal extent other than twenty miles is determined by the value of liquid water content of figure 4b–24a multiplied by the appropriate factor from figure 4b–24c. (See sec. 4b.640.)

(8) ***Intermittent maximum icing.*** The intermittent maximum intensity of atmospheric icing conditions is defined by the variables of the cloud liquid water content, the mean effective diameter of the cloud droplets, the ambient air temperature, and the inter-relationship of these three variables as shown in figure 4b–25a. The limiting icing envelope in terms of altitude and temperature is given in figure 4b–25b. The inter-relationship of cloud liquid water content with drop diameter and altitude is determined from figures 4b–25a and 4b–25b. The cloud liquid water content for intermittent maximum icing conditions of a horizontal extent other than three miles is determined by the value of cloud liquid water content of figure 4b–25a multiplied by the appropriate factor in figure 4b–25c. (See sec. 4b.640.)

NOTE: There is some indication that the upper altitude limit might extend to 30,000 feet pressure altitude, and the lower limit of ambient temperature may be as low as −40° F. Because of this, the portions in this region of figures 4b–25a and 4b–25b are shown by dashed lines.

(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 sec. 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 sec. 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 sec. 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 sec. 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 sec. 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 sec. 4b.210.)

(7) ***Design landing weight.*** The design landing weight is the maximum airplane weight used in structural design for landing conditions at the maximum velocity of descent. (See sec. 4b.230 (b).)

(8) ***Design unit weight.*** The design unit weight is a representative weight used to show compliance with the structural design requirements.

(i) Gasoline 6 pounds per U. S. gallon.

(ii) Lubricating oil 7.5 pounds per U. S. gallon.

(iii) Crew and passengers 170 pounds per person.

(d) ***Speeds.***

(1) IAS: Indicated airspeed is equal to the pitot static airspeed indicator reading as installed in the airplane without correction for airspeed indicator system errors but including the sea level standard adiabatic compressible flow correction. (This latter correction is included in the calibration of the airspeed instrument dials.) (See secs. 4b.612 (a) and 4b.710.)

(2) CAS: Calibrated airspeed is equal to the airspeed indicator reading corrected for position and instrument error. (As a result of the sea level adiabatic compressible flow correction to the airspeed instrument dial, CAS is equal to the true airspeed TAS in standard atmosphere at sea level.)

(3) EAS: Equivalent airspeed is equal to the airspeed indicator reading corrected for position error, instrument error, and for adiabatic compressible flow for the particular altitude. (EAS is equal to CAS at sea level in standard atmosphere.)

(4) TAS: True airspeed of the airplane relative to undisturbed air. ($TAS = EAS(\rho_0/\rho^{1/2}$.)

(5) V_A: The design maneuvering speed. (See sec. 4b.210 (b) (2).)

(6) V_B: The design speed for maximum gust intensity. (See sec. 4b.210 (b) (3).)

(7) V_C: The design cruising speed. (See sec. 4b.210 (b) (4).)

(8) V_D: The design diving speed. (See sec. 4b.210 (b) (5).)

(9) V_{DE}: The demonstrated flight diving speed. (See sec. 4b.190.)

(10) V_F: The design flap speed for flight loading conditions with wing flaps in the landing position. (See sec. 4b.210 (b) (1).)

(11) V_{FE}: The flap extended speed is a maximum speed with wing flaps in a prescribed extended position. (See sec. 4b.714.)

(12) V_{LE}: The landing gear extended speed is the maximum speed at which the airplane can be flown safely with the landing gear extended. (See sec. 4b.716.)

(13) V_{LO}: The landing gear operating speed is a maximum speed at which the landing gear can be raised or lowered safely. (See sec. 4b.715.)

(14) V_{MC}: The minimum control speed with the critical engine inoperative. (See sec. 4b.133.)

(15) V_{NE}: The never-exceed speed. (See sec. 4b.711.)

(16) V_{NO}: The normal operating limit speed. (See sec. 4b.712.)

(17) V_{S_0}: The stalling speed or the minimum steady flight speed with wing flaps in the landing position. (See secs. 4b.112 (a) and 4b.160.)

(18) V_{S_1}: The stalling speed or the minimum steady flight speed obtained in a specified configuration. (See sec. 4b.112 (b).)

(19) V_1: The critical-engine-failure speed. (See sec. 4b.114.)

(20) V_2: The take-off safety speed. (See sec. 4b.114 (b).)

(21) M: Mach number is the ratio of true airspeed to the speed of sound.

(e) *Structural.*

(1) *Limit load.* A limit load is the maximum load anticipated in normal conditions of operation. (See sec. 4b.200.)

(2) *Ultimate load.* An ultimate load is a limit load multiplied by the appropriate factor of safety. (See sec. 4b.200.)

(3) *Factor of safety.* The factor of safety is a design factor used to provide for the possibility of loads greater than those anticipated in normal conditions of operation and for uncertainties in design. (See sec. 4b.200 (a).)

(4) *Load factor.* The load factor is the ratio of a specified load to the total weight of the airplane; the specified load may be expressed in terms of any of the following: aerodynamic forces, inertia forces, or ground or water reactions.

(5) *Limit load factor.* The limit load factor is the load factor corresponding with limit loads.

(6) *Ultimate load factor.* The ultimate load factor is the load factor corresponding with ultimate loads.

(7) *Checked pitching maneuver.* A checked pitching maneuver is one in which the pitching control is suddenly displaced in one direction and then suddenly moved in the opposite direction, the deflections and timing being such as to avoid exceeding the limit maneuvering load factor.

(8) *Design wing area.* The design wing area is the area enclosed by the wing outline (including wing flaps in the retracted position and ailerons, but excluding fillets or fairings) on a surface containing the wing chords. The outline is assumed to be extended through the nacelles and fuselage to the plane of symmetry in any reasonable manner.

(9) *Balancing tail load.* A balancing tail load is that load necessary to place the airplane in equilibrium with zero pitch acceleration.

(10) *Fitting.* A fitting is a part or terminal used to join one structural member to another. (See sec. 4b.307 (c).)

(f) [*Powerplant installation.*] [1]

(1) *Brake horsepower.* Brake horsepower is the power delivered at the propeller shaft of the engine.

[(2) *Take-off power or thrust.*

[(i) Take-off power for reciprocating engines is the brake horsepower developed under standard sea level conditions and under the maximum conditions of crankshaft rotational speed and engine manifold pressure approved for the normal take-off, and limited in use to a maximum continuous period as indicated in the approved engine specification.

[(ii) Take-off power for turbine engines is the brake horsepower developed under static conditions at specified altitudes and atmospheric temperatures and under the maximum

[1] For engine airworthiness requirements see Part 13 of this subchapter; for propeller airworthiness requirements see Part 14 of this subchapter.

conditions of rotor shaft rotational speed and gas temperature approved for the normal take-off, and limited in use to a maximum continous period as indicated in the approved engine specification.

[(iii) Take-off thrust for turbine engines is the jet thrust developed under static conditions at specified altitudes and atmospheric temperatures and under the maximum conditions of rotor shaft rotational speed and gas temperature approved for the normal take-off, and limited in use to a maximum continuous period as indicated in the approved engine specification.

[(3) *Maximum continuous power or thrust.*

[(i) Maximum continous power for reciprocating engines is the brake horsepower developed in standard atmosphere at a specified altitude and under the maximum conditions of crankshaft rotational speed and engine manifold pressure, and approved for use during periods of unrestricted duration.

[(ii) Maximum continuous power for turbine engines is the brake horsepower developed at specified altitudes, atmospheric temperatures, and flight speeds and under the maximum conditions of rotor shaft rotational speed and gas temperature, and approved for use during periods of unrestricted duration.

[(iii) Maximum continuous thrust for turbine engines is the jet thrust developed at specified altitudes, atmospheric temperatures, and flight speeds and under the maximum conditions of rotor shaft rotational speed and gas temperature, and approved for use during periods of unrestricted duration.

[(4) *Gas temperature.* Gas temperature for turbine engines is the temperature of the gas stream obtained as indicated in the approved engine specification.]

[(5)] *Manifold pressure.* Manifold pressure is the absolute pressure measured at the appropriate point in the induction system, usually in inches of mercury.

[(6)] *Critical altitude.* The critical altitude is the maximum altitude at which in standard atmosphere it is possible to maintain, at a specified rotational speed, a specified power or a specified manifold pressure. Unless otherwise stated, the critical altitude is the maximum altitude at which it is possible to maintain, at the maximum continuous rotational speed, one of the following:

(i) The maximum continuous power, in the case of engines for which this power rating is the same at sea level and at the rated altitude.

(ii) The maximum continuous rated manifold pressure, in the case of engines the maximum continuous power of which is governed by a constant manifold pressure.

[(7)] *Pitch setting.* Pitch setting is the propeller blade setting determined by the blade angle measured in a manner, and at a radius, specified in the instruction manual for the propeller.

[(8)] *Feathered pitch.* Feathered pitch is the pitch setting which in flight, with the engines stopped, gives approximately the minimum drag and corresponds with a windmilling torque of approximately zero.

[(9)] *Reverse pitch.* Reverse pitch is the propeller pitch setting for any blade angle used beyond zero pitch (e. g., the negative angle used for reverse thrust).

(g) *Fire protection.*

(1) *Fireproof.* Fireproof material means a material which will withstand heat at least as well as steel in dimensions appropriate for the purpose for which it is to be used. When applied to material and parts used to confine fires in designated fire zones, fireproof means that the material or part will perform this function under the most severe conditions of fire and duration likely to occur in such zones.

(2) *Fire-resistant.* When applied to sheet or structural members, fire-resistant material means a material which will withstand heat at least as well as aluminum alloy in dimensions appropriate for the purpose for which it is to be used. When applied to fluid-carrying lines, other flammable fluid system components, wiring, air ducts, fittings, and powerplant controls, this term refers to a line and fitting assembly, component, wiring or duct, or controls, which will perform the intended functions under the heat and other conditions likely to occur at the particular location.

(3) *Flame-resistant.* Flame-resistant material means material which will not support combustion to the point of propagating, beyond

safe limits, a flame after the removal of the ignition source.

(4) *Flash-resistant.* Flash-resistant material means material which will not burn violently when ignited.

(5) *Flammable.* Flammable pertains to those fluids or gases which will ignite readily or explode.

(h) *Miscellaneous.*

(1) *Supplemental breathing equipment.* Supplemental breathing equipment is equipment designed to supply the supplementary oxygen required to protect against anoxia at altitudes where the partial pressure of oxygen in ambient air is reduced. (See sec. 4b.651.)

(2) *Protective breathing equipment.* Protective breathing equipment is equipment designed to prevent the breathing of noxious gases which might be present as contaminants in the air within the airplane in emergency situations. (See sec. 4b.651.)

Certification

4b.10 *Eligibility for type certificates.* An airplane shall be eligible for type certification under the provisions of this part if it complies with the airworthiness provisions established by this part or if the Administrator finds that the provision or provisions not complied with are compensated for by factors which provide an equivalent level of safety: *Provided,* That the Administrator finds no feature or characteristic of the airplane which renders it unsafe for the transport category.

4b.10–1 *Approval of reverse thrust propellers (CAA policies which apply to sec. 4b.10).* A reverse thrust propeller is a design feature which is not fully covered in the Civil Air Regulations. When an airplane incorporates a reverse thrust propeller installation, it will be approved in accordance with the policies set forth in section 4b.402–1, provided it has no feature or characteristic which renders its use unsafe in transport category airplanes.

(20 F. R. 2277, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.10–2 *Approval of automatic propeller feathering installations (CAA policies which apply to sec. 4b.10).* An automatic propeller feathering device is a design feature not specifically covered in the Civil Air Regulations. When an airplane incorporates an automatic feathering device, it will be acceptable under the provisions of section 4b.10 as providing an equivalent level of safety in showing compliance with sections 4b.115, 4b.116, 4b.120, and 4b.133 if it complies with policies prescribed in sections 4b.115–2, 4b.116–1, 4b.120–1, 4b.401–1, and 4b.700–1, and if there are no features or characteristics which make it unsafe for use on transport aircraft.

(19 F. R. 1817, Apr. 2, 1954, effective Apr. 2, 1954.)

4b.10–3 *Minimum quantity of anti-detonant fluid required (CAA policies which apply to sec. 4b.10).* The use of anti-detonant fluid in limited quantities as a supplemental fluid for takeoff power operations is a feature not specifically covered in the Civil Air Regulations. A system incorporating anti-detonant fluid will be acceptable under the provisions of section 4b.10 as providing a satisfactory level of safety from the standpoint of the quantity of fluid available if it complies with the policies contained in sections 4b.420–1 and 4b.718–1.

4b.11 *Designation of applicable regulations.* The provisions of this section shall apply to all airplane types certificated under this part irrespective of the date of application for type certificate.

(a) Unless otherwise established by the Board, the airplane shall comply with the provisions of this part together with all amendments thereto effective on the date of application for type certificate, except that compliance with later amendments may be elected or required pursuant to paragraphs (c), (d), and (e) of this section.

(b) If the interval between the date of application for type certificate and the issuance of the corresponding type certificate exceeds five years, a new application for type certificate shall be required, except that for applications pending on May 1, 1954, such five-year period shall commence on that date. At the option of the applicant, a new application may be filed prior to the expiration of the five-year period. In either instance the applicable regulations shall be those effective on the date of the new application in accordance with paragraph (a) of this section.

(c) During the interval between filing the application and the issuance of a type certificate, the applicant may elect to show compliance

with any amendment of this part which becomes effective during that interval, in which case all other amendments found by the Administrator to be directly related shall be complied with.

(d) Except as otherwise provided by the Board, or by the Administrator pursuant to section 1.24 of this subchapter, a change to the type certificate (see sec. 4b.13 (b)) may be accomplished, at the option of the holder of the type certificate, either in accordance with the regulations incorporated by reference in the type certificate pursuant to section 4b.13 (c), or in accordance with subsequent amendments to such regulations in effect on the date of application for approval of the change, subject to the following provisions:

(1) When the applicant elects to show compliance with an amendment to the regulations in effect on the date of application for approval of a change, he shall show compliance with all amendments which the Administrator finds are directly related to the particular amendment selected by the applicant.

(2) When the change consists of a new design or a substantially complete redesign of a component, equipment installation, or system installation of the airplane, and the Administrator finds that the regulations incorporated by reference in the type certificate pursuant to section 4b.13 (c) do not provide complete standards with respect to such change, he shall require compliance with such provisions of the regulations in effect on the date of application for approval of the change as he finds will provide a level of safety equal to that established by the regulations incorporated by reference at the time of issuance of the type certificate.

NOTE: Examples of new or redesigned components and installations which might require compliance with regulations in effect on the date of application for approval, are: New powerplant installation which is likely to introduce additional fire or operational hazards unless additional protective measures are incorporated; the installation of an auto-pilot, a pressurization system, or a new electric power system.

(e) If changes listed in subparagraphs (1) through (3) of this paragraph are made, the airplane shall be considered as a new type, in which case a new application for type certificate shall be required and the regulations together with all amendments thereto effective on the date of the new application shall be made applicable in accordance with paragraphs (a), (b), (c), and (d) of this section.

(1) A change in the number of engines;

(2) A change to engines employing different principles of operation or propulsion;

(3) A change in design, configuration, power, or weight which the Administrator finds is so extensive as to require a substantially complete investigation of compliance with the regulations.

4b.12 *Recording of applicable regulations.* The Administrator, upon the issuance of a type certificate, shall record the applicable regulations with which compliance was demonstrated. Thereafter, the Administrator shall record the applicable regulations for each change in the type certificate which is accomplished in accordance with regulations other than those recorded at the time of issuance of the type certificate. (See sec. 4b.11.)

4b.13 *Type certificate.*

(a) An applicant shall be issued a type certificate when he demonstrates the eligibility of the airplane by complying with the requirements of this part in addition to the applicable requirements in Part 1 of this subchapter.

(b) The type certificate shall be deemed to include the type design (see sec. 4b.14 (b)), the operating limitations for the airplane (see sec. 4b.700), and any other conditions or limitations prescribed by the regulations in this subchapter.

(c) The applicable provisions of this part recorded by the Administrator in accordance with section 4b.12 shall be considered as incorporated in the type certificate as though set forth in full.

4b.14 *Data required.*

(a) The applicant for a type certificate shall submit to the Administrator such descriptive data, test reports, and computations as are necessary to demonstrate that the airplane complies with the requirements of this part.

(b) The descriptive data required in paragraph (a) of this section shall be known as the type design and shall consist of such drawings and specifications as are necessary to disclose the configuration of the airplane and all the design features covered in the requirements of this part, such information on dimensions, materials, and processes as is necessary to

define the structural strength of the airplane, and such other data as are necessary to permit by comparison the determination of the airworthiness of subsequent airplanes of the same type.

4b.15 *Inspections and tests.* Inspections and tests shall include all those found necessary by the Administrator to insure that the airplane complies with the applicable airworthiness requirements and conforms to the following:

(a) All materials and products are in accordance with the specifications in the type design.

(b) All parts of the airplane are constructed in accordance with the drawings in the type design.

(c) All manufacturing processes, construction, and assembly are as specified in the type design.

4b.16 *Flight tests.* After proof of compliance with the structural requirements contained in this part, and upon completion of all necessary inspections and testing on the ground, and proof of the conformity of the airplane with the type design, and upon receipt from the applicant of a report of flight tests performed by him, the following shall be conducted:

(a) Such official flight tests as the Administrator finds necessary to determine compliance with the requirements of this part.

(b) After the conclusion of flight tests specified in paragraph (a) of this section, such additional flight tests as the Administrator finds necessary to ascertain whether there is reasonable assurance that the airplane, its components, and equipment are reliable and function properly. The extent of such additional flight tests shall depend upon the complexity of the airplane, the number and nature of new design features, and the record of previous tests and experience for the particular airplane type, its components, and equipment. If practicable, these flight tests shall be conducted on the same airplane used in the flight tests specified in paragraph (a) of this section.

4b.16–1 *Applicant's flight test report (CAA policies which apply to sec. 4b.16).* The applicant should submit a report signed by his test pilot containing the results of flight tests which were conducted by him. It should certify that the airplane has been flown at least in all maneuvers necessary for proof of compliance with the flight requirements and it is his belief that the airplane will conform therewith. In the case of very large airplanes, this procedure may be modified as deemed necessary by the Administrator.

(19 F. R. 4446, July 20, 1954, effective Sept. 1, 1954.)

4b.16–2 *Preflight test planning (CAA policies which apply to sec. 4b.16 (a)).*

(a) *Proposed official flight test program.* Before the airplane is presented for official type certification tests, the applicant should submit to the CAA a proposed flight test program which will indicate at least the following:

(1) The area, defined by the several selections described in section 4b.100–2, which is to be covered by the terms of the type certification.

(2) All proposed tests; the order in which they are to be conducted; the purpose of each test; and for each the airplane weight, c. g., position flap setting, power to be drawn, and, where appropriate, the altitude, the trim speed(s) and the speed(s) or speed range to be investigated. Appendix B presents a list of most of the flight and operation tests generally required for the type certification program together with information relative to the airplane configuration, test procedure, and special instrumentation for each test.

(3) Since most transport airplanes undergo many changes during their life span it is well to consider this fact in setting up a flight test program. Such changes as installation of different propellers, higher powered engines, etc., can often be predicted in advance.

(4) It is often desirable to simulate operation with higher power for the determination of flying qualities and other tests, thus simplifying the problem of approving the airplane when the power change becomes effective. Data of this nature obtained during CAA flight tests may often reduce further testing during the life of the airplane.

(5) When an airplane has been type certificated in the transport category and a change is made affecting performance and/or flying qualities, the following procedure is suggested:

(i) The effect of the change on each of the flight tests in the general flight program should be noted.

(ii) Those tests which are materially influenced by the change should be listed.

(iii) A test program should be prepared embodying such of these tests as are felt to be critical or representative. This program should be forwarded to the CAA with the reasons for selecting the pertinent items. Appendix C shows representative flight programs for various types of changes and may be helpful in the preparation of the programs.

(iv) A description should be submitted of the method(s) which the applicant purposes to use in order to reduce the observed data to standard conditions.

(v) A statement should be submitted of any intention on the part of the applicant to resort to calculation in lieu of, or for the purpose of generalizing test data, together with a description of the data upon which these calculations are to be based and the methods to be used therein.

(6) Since it will require time for the CAA to determine the adequacy of this entire program, it is strongly recommended that it be submitted as early as practicable, otherwise the commencement of the testing may be delayed.

(b) *Order of testing.* The Civil Air Regulations are so worded that the results of some flight tests have a definite bearing on the conduct of other tests. For this reason careful attention should be given to the order of testing. The exact order of testing will be determined only by considering the particular airplane and test program involved. Appendix E shows a general arrangement that may be of assistance to those applicants who are not familiar with the CAA flight test procedures. Tests which are particularly important in the early stages of the program are:

(1) *Airspeed calibration.* All tests involving airspeed depend upon the calibration.

(2) *Stall speed measurement.* Most of the performance tests and flying qualities are related to the stall speed.

(3) *Minimum control speed for takeoff.* The takeoff safety speed depends upon this item.

(4) *Engine cooling.* All en route climb speeds and cowl flap settings are related to this test.

(c) *Test groupings.*

(1) *Weight and c. g.* In addition to the regulatory relation of one test to another, efficient testing requres that consideration be given to the accomplishment of as many tests on a single flight as can be accommodated successfully. The tests shown in Appendix E have been grouped under various weight and center of gravity conditions in order to facilitate the development of a flight test program.

(2) *Special instrumentation.* Similarly, consideration should be given to grouping of tests that involve special instrumentation. Examples of these are takeoff and landing tests which usually require ground equipment to record horizontal distance, height, and time. Ground calibration of the airspeed indicating system can be accomplished at the same time. The CAA possesses certain instruments which may be used for obtaining test data, such as trailing airspeed bombs, sensitive altimeters, stop watches, carbon monoxide indicators, etc., as well as photographic equipment for measuring takeoff and flight landing paths. It is therefore recommended that the matter of instrumentation be discussed with the CAA before any decision is made with regard to the detailed flight test program. A list containing those tests requiring special instrumentation is shown in Appendix F.

(3) *Data reduction.* If the overall elapsed time for the certification program is to be kept to a minimum, tests requiring considerable data reduction should be conducted as early in the program as possible. Most performance data, particularly landing and takeoff data, fall in this category.

(19 F. R. 4446, July 20, 1954, effective Sept. 1, 1954.)

4b.16–3 *Additional flight tests (CAA policies which apply to sec. 4b.16 (b)).*

(a) *General.*

(1) At the option of the applicant, the flight tests specified in Civil Aeronautics Manual 1.77–4 for the ferry flight of a four-engine airplane with one engine inoperative may be conducted during the flight tests for type certification. Routine CAR tests as prescribed in sections 4b.100 through 4b.743 will be conducted (in accordance with existing procedures) to determine performance, flying qualities, power plant characteristics, etc.

(2) The official functional and reliability tests will be that portion of the tests conducted under the immediate supervision of the Type

Certification Board,[1] as prescribed in (c) through (h) of this section, to show compliance with sections 4b.100 through 4b.743.

(3) Supplementary experience consisting of other flight tests and experience with an airplane (of the same) type will be taken into consideration in establishing the extent of the official portions of the tests. This supplementary experience may be obtained by the manufacturer, military services, airlines, etc.

(4) Simulated tests consisting of tests on the ground or in an airplane of (like) components and equipment under conditions simulating those likely to be obtained in service will also be taken into consideration in establishing the extent of the official portion of the tests.

(b) *Functional and reliability tests.* In order to satisfactorily accomplish the objectives of section 4b.16 (b) concerning additional flight tests and the extent thereof, the Administrator deems it necessary that:

(1) A comprehensive and systematic check be made in flight of the operation of all components to determine whether they "function properly," i. e., perform their intended function without introducing safety hazards.

(2) Sufficient testing and supplementary experience under actual, or a combination of simulated and actual experience, be obtained and evaluated to give reasonable assurance that the airplane is "reliable," i. e., should continue to function properly in service. (In order to obtain wider experience, manufacturers are encouraged to cooperate with airlines or other responsible operators in operating experimental airplanes of the same type under service conditions.)

(3) Appropriate corrective action be taken when the need therefor is determined under (b) (1) and (b) (2) of this section. (The CAA is concerned only to the extent that the airplane can be operated safely under suitable inspection and maintenance procedures, but is not concerned with maintenance costs.)

(c) *Test program.* The Type Certification Board for each project will decide upon a proposed official test program at the time of the preflight meeting of the Board (prior to the routine CAR flight tests) and coordinate this with the airplane manufacturer. At the conclusion of the routine CAR tests, the T. C. Board will meet again to review the experience gained in those tests, changes made in the design and any additional supplementary experience, and to revise the proposed test program accordingly.

(d) *Planning and execution of test program.* The following points should be considered:

(1) The test program should be sufficiently well planned to enable its execution in an efficient manner without overlooking important items. It is not intended that the "paper work" be overemphasized to the detriment of the practical results, and it should be reduced to a minimum for small simple airplanes. The T. C. Board will review the design features and equipment with respect to the general objectives, and prepare a list showing:

(i) Components and systems to be checked in (d) (4) of this section,

(ii) A brief description of the operations to be performed, where these are not obvious (referencing any necessary operating instructions),

(iii) Special checks or likely critical conditions,

(iv) Estimated flight time required.

(2) Allowance may be made for the functional tests already required by the routine CAR tests. Allowance may also be made for simulated testing of new features and equipment; however, the flight test program should be planned to determine the adequacy of the simulated tests (e. g., to determine whether the actual environmental conditions of temperature,[2] vibration, etc. are covered by the simulated tests) when these may be critical, and to determine whether the installation and connected systems are satisfactory. The T. C. Board will then make a consolidated estimate of the total flight time required, allowing for overlapping, and adjust this in accordance with the "Test time" outlined in (e) of this section.

(3) The program will be arranged to permit the Flight Test Inspector in charge to become thoroughly familiar with the flying qualities of

[1] A Type Certification Board is set up by the CAA field offices on aech new type aircraft project.

[2] This does not imply that flight tests must be conducted under the most severe outside air temperatures likely to be encountered in service. It should normally be possible to determine the effects of extreme outside temperatures on local temperatures by extrapolation or by suitable correction factors.

the airplane, particularly those not specifically covered in the routine CAR tests.

(4) All components of the airplane should be intensively operated and studied under all operating conditions expected in service and obtainable within the time and geographic limitations of the tests. Intensive operation means repeated operation of components in various sequences and combinations likely to occur in service. Particular attention should be given to potential sources of crew error, overtaxing of crew ability and the emergency procedures that would be required in the event of malfunction of any component. This intensive type of testing should be conducted in all cases, but the length of time for which it is continued will depend upon the simulated and supplementary experience available for the particular type, as outlined in "Test time" in (e) of this section.

(5) Ground inspections should be made at appropriate intervals during the test program to determine whether there are any failures or incipient failures in any of the components which might be a hazard to safe flight.

(6) When design changes are made during the course of the test, or when the official test airplane differs from those on which supplementary experience is obtained, or from modified versions of the same basic airplane type, the revised or modified items should be rechecked in accordance with the above procedure, but every effort should be made to include such items in the program in such a way as to avoid unduly extending the overall test time. To this end, the Administrator may accept, in lieu of additional flight tests:

(i) Special tests of the original and revised components in which the conditions causing failure are intensified and

(ii) Simulated tests of differing components.

(e) *Test time.* It is highly desirable that functioning and reliability test programs be administered uniformly so that the program and flight time for a given project would be approximately the same regardless of which T. C. Board administered the project. This is difficult to achieve without establishing fixed arbitrary test times which would obviously be contrary to the intent of section 4b.16 (b). The following procedure which permits considerable flexibility is, therefore, established for the guidance of T. C. Boards.

(1) When supplementary experience is not taken into account and the airplane is conventional in regard to complexity and design features, the functioning and reliability test programs should be 150 hours. This time may be reduced to allow for simulated testing (see (d) (2) of this section), and for supplementary experience (see (e) (2) of this section). However it may be necessary to increase the 150 hours, if difficulties are encountered in earlier flights, or for radically new design features or in extreme cases of complexity. An example of extreme complexity would be an airplane intended for operation at 40,000 ft. altitude, with automatic dive recovery flaps, turbos, variable jet exhaust, two speed cooling fans, retractable wind screens, automatic control of engine cooling, turbos, intercoolers, jet exhausts, etc. The test program for such an airplane might require as much as 300 hours if no supplementary experience were available.

(2) When satisfactory supplementary experience is available and taken into account, the following allowances should be used as a guide and applied with judgment in reducing the official flight test time. However, in any case, the official program should provide sufficient time to accomplish the objective of (b) (1) of this section in accordance with the items listed in (d) (3) and (d) (4) of this section.

(i) *For intensive experience.* When the allowance is based on the total time of any one airplane in airline crew training and similar intensive operations, two hours of such operation may be considered equivalent to one hour of official testing.

(ii) *For miscellaneous experience.* When the allowance is based on the total time of any one airplane, five hours of such experience may be considered equivalent to one hour of official testing.

(iii) *Reduction for supplementary experience.* Whenever a reduction of official test time is desired on the basis of supplementary experience, such experience should be adequately recorded and submitted to the T. C. Board as described in (f) of this section.

(f) *Reports and records.*

(1) A log should be kept of all flight tests, and accurate and complete records kept of the inspections made and of all defects, difficulties, and unusual characteristics and sources of crew error discovered during the tests, and of the recommendations made and action taken. Items for which design changes may be required will be reported to the manufacturer and the appropriate CAA engineering division.

(2) If supplementary experience is to be taken into account, similar records of such experience should be kept and submitted to the T. C. Board, together with a list of the differences between the airplane on which the experience was obtained and the official test airplane. When supplementary experience is obtained on a large fleet of airplanes (for example, military operations) of the same or a comparable type (see (d) (6) of this section), these records may consist of statistical summaries in lieu of complete records for each individual airplane.

(3) At the conclusion of the official tests, a summary report should be prepared by the T. C. Board and forwarded to Washington for inclusion in the Type Inspection Report.

(g) *Administration.* The CAA Flight Test Inspector in charge will act as coordinator of all flight activities of the T. C. Board during the official program and the agent or an alternate designated by him will participate in all flights. He will collaborate with the manufacturers' pilots in all these activities, particularly in regard to flight plans and procedures. The manufacturers' pilots should be in command of all flights, but CAA pilots will fly the airplane at least sufficiently to accomplish item (d) (3) of this section.

(1) Other CAA personnel (e. g., representatives of other divisions and specialists) will participate in the flight tests when deemed necessary by the T. C. Board to accomplish the purposes of the tests.

(2) When supplementary experience is obtained in airline operations, a CAA Flight Operations and Airworthiness Agent will be assigned to follow the operations, review the operator's records, and supplement these by reports to the T. C. Board.

(h) *Test airplane.* To facilitate completion of the type certification procedure one airplane may be used for the official functioning and reliability tests while another airplane (or airplanes) is used for the routine CAR tests. In such cases the test time on at least one airplane should be sufficient to accomplish the objective of (b) (2) of this section.

(i) *Modified types.* The procedure outlined in (h) applies to new type designs. When a design employs components identical to those used in previous designs, credit may be given for the supplementary experience available for such components. When a design is modified (for example, several versions of the same basic type with different engines, propellers, etc.), the modified features and components should be treated in accordance with (d) (6) of this section.

(19 F. R. 4447, July 20, 1954, effective Sept. 1, 1954, amended 20 F. R. 6677, Sept. 10, 1955, effective Sept. 30, 1955.)

4b.16–4 *Flight tests (CAA policies which apply to sec. 4b.16).* The policies outlined in section 4b.402–1 (c) and section 4b.402–1 (l) (3) will apply.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.17 *Airworthiness, experimental, and production certificates.* (For requirements with regard to these certificates see Part 1 of this subchapter.)

4b.18 *Approval of materials, parts, processes, and appliances.*

(a) Materials, parts, processes, and appliances shall be approved upon a basis and in a manner found necessary by the Administrator to implement the pertinent provisions of the regulations in this subchapter. The Administrator may adopt and publish such specifications as he finds necessary to administer this regulation, and shall incorporate therein such portions of the aviation industry, Federal, and military specifications respecting such materials, parts, processes, and appliances as he finds appropriate.

NOTE: The provisions of this paragraph are intended to allow approval of materials, parts, processes, and appliances under the system of Technical Standard Orders, or in conjunction with type certification procedures for an airplane, or by any other form of approval by the Administrator.

(b) Any material, part, process, or appliance shall be deemed to have met the requirements for approval when it meets the pertinent specifications adopted by the Administrator, and the manufacturer so certifies in a manner prescribed by the Administrator.

4b.18–1 *Approval of aircraft materials, parts, processes and appliances (CAA rules which apply to sec. 4b.18).* Aircraft materials, parts, processes and appliances made the subject of Technical Standard Orders shall be approved upon the basis and in the manner prescribed in Part 514 [3] of the Regulations of the Administrator, "Technical Standard Orders—C Series—Aircraft Components."

(17 F. R. 10101, Nov. 7, 1952, effective Dec. 1, 1952.)

4b.18–2 *Application of Technical Standard Orders—C Series (CAA policies which apply to sec. 4b.18).*

(a) *Purpose of Technical Standard Orders,* Technical Standard Orders are a means by which the Administrator adopts and publishes the specifications for which authority is provided in section 4b.18 (a) of this chapter.

(b) *Applicability of Technical Standard Order Requirements.*

(1) The applicability of and effective dates for TSO'd items are set forth in each TSO.

(2) Each Technical Standard Order sets forth the conditions under which materials, parts, processes and appliances approved by the Administrator prior to establishment of an applicable TSO, may continue to be used in aircraft.

(3) The establishment of a Technical Standard Order for any product does not preclude the possibility of establishing the acceptability of a similar product as part of an aircraft, engine or propeller, under the type certification or modification procedures, if there is established a level of safety equivalent to that provided in the Civil Air Regulations as implemented by the appropriate Technical Standard Order and the product is identified as a part of the airplane, engine or propeller.

(c) *Administration of the Technical Standard Order (TSO) System.* The principles which apply in administering the Technical Standard Orders system are as follows:

(1) Technical Standard Orders will reference performance provisions of recognized government specifications; or established industry specifications which have been found acceptable by the CAA. If no satisfactory specification exists, the Orders will include criteria prepared by the Administrator. In preparing criteria of this type, the Administrator will give consideration to recommendations made by the industry.

(2) Minimum performance requirements established by the Civil Aeronautics Administration and published in Technical Standard Orders will serve as a means by which component equipment and materials intended for use in certificated aircraft will be accepted.

(3) TSO's set forth the minimum requirements for safety. Every effort will be made by the CAA to keep the requirements at the minimum levels of safety, and TSO's will not be used to set forth "desirable" standards.

(4) It will be the responsibility of the person submitting a statement of conformance to the CAA, certifying that his product meets the requirements of the TSO, to conduct the necessary tests demonstrating compliance therewith. This person will be held responsible for maintaining quality control adequate to assure that products which he guarantees to meet the requirements of a TSO do, in fact, meet these standards. The CAA will not formally approve such products as meeting the requirements of TSO's nor exercise direct inspection control over them. The statement of conformance with the provisions of a Technical Standard Order normally will be accepted by the CAA as sufficient indication that the applicable requirements have been fulfilled.

Any TSO'd item which is modified must continue to comply with the requirements of the TSO, and the person authorizing the modification will be responsible for such compliance.

(d) *Numbering of Technical Standard Orders.* Each Technical Standard Order will be assigned a designation consisting of the letters, "TSO," a series code letter "C", indicating aircraft materials, parts, processes, or appliances and a serial number to be assigned in sequence for each of the TSO's issued in the "C" series, e. g.,

[3] Part 514 is available only through the Federal Register where it appeared on October 12, 1951, 16 FR 10403. Copies of individual TSO's contained therein are available upon application to the Aviation Information Staff, Civil Aeronautics Administration, Department of Commerce, Washington 25, D. C.

TSO–C–1, "Smoke Detectors." Revisions are indicated by the addition of letters a, b, c, etc., *after the number.*

4b.19 *Changes in type design.* (For requirements with regard to changes in type design and the designation of applicable regulations therefor, see sec. 4b.11 (d) and (e), and Part 1 of this subchapter.)

Flight

General

4b.100 *Proof of compliance.*

(a) Compliance with the requirements prescribed in this subpart shall be established by flight or other tests conducted upon an airplane of the type for which a certificate of airworthiness is sought or by calculations based on such tests, provided that the results obtained by calculations are equivalent in accuracy to the results of direct testing.

(b) Compliance with each requirement shall be established at all appropriate combinations of airplane weight and center of gravity position within the range of loading conditions for which certification is sought by systematic investigation of all these combinations, except where compliance can be inferred reasonably from those combinations which are investigated.

(c) The controllability, stability, trim, and stalling characteristics of the airplane shall be established at all altitudes up to the maximum anticipated operating altitude.

(d) The applicant shall provide a person holding an appropriate pilot certificate to make the flight tests, but a designated representative of the Administrator shall pilot the airplane when it is found necessary for the determination of compliance with the airworthiness requirements.

(e) Official type tests shall be discontinued until corrective measures have been taken by the applicant when either:

(1) The applicant's test pilot is unable or unwilling to conduct any of the required flight tests, or

(2) It is found that requirements which have not been met are so substantial as to render additional test data meaningless or are of such a nature as to make further testing unduly hazardous.

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(f) Adequate provision shall be made for emergency egress and for the use of parachutes by members of the crew during the flight tests.

(g) The applicant shall submit to the Administrator's representative a report covering all computations and tests required in connection with calibration of instruments used for test purposes and correction of test results to standard atmospheric conditions. The Administrator's representative shall conduct any flight tests which he finds necessary to check the calibration and correction report.

(17 F. R. 10101, Nov. 7, 1952, effective Dec. 1, 1952.)

4b.100–1 *Procedure for demonstrating compliance with the flight requirements (CAA policies which apply to sec. 4b.100 (a)).*

(a) *Responsibility.* The burden of showing or implementing compliance with the requirements for an airworthiness or a type certificate rests with the applicant. The applicant should at his own expense and risk, conduct such official flight tests as determined by the CAA to demonstrate compliance with the minimum requirements. During the type inspection the applicant should make available the airplane for that purpose as well as all of the personnel and equipment necessary to obtain the required data.

(b) *Tolerances permitted for flight tests.*

(1) *General.* The tolerances in (b) (2) of this section are the allowable deviation from specified flight conditions for a particular test. They are not allowable tolerances on specific requirements, nor are they to be considered as allowable inaccuracy of measurement or of the method of determination. As an example, when demonstrating stability with specified trim speed of 1.4 V_{s_1}, the trim speed may be 1.4 $V_{s_1} \pm 3$ m. p. h. or 3 percent; however, no positive tolerance is permitted when demonstrating the minimum prescribed trim speed of 1.4 V_{s_1}.

(i) Where variation in the parameter on which a tolerance is allowed will have an appreciable effect on the test, the result should be corrected to the standard value of the parameter; otherwise, no correction is necessary. The applicant may adhere to closer tolerances if he so desires.

(ii) The following list indicates the cases in which correction for tolerances should be made:

Test	Weight	C. G.	Air speed	Power	Wind
Airspeed calibration					
Stall speeds	X				
All climbs	X			X	
Landings	X		X		X
Takeoff	X		X	X	X
Accelerate	X		X	X	X
Decelerate	X		X		X
Stability and control.					
Minimum control speed.				X	

(2) *Individual tolerances.* The following are general tolerances from specified values permitted during CAA testing. These tolerances apply unless, for a particular test, other tolerances are set forth in the testing procedure. These tolerances are plus or minus variations unless otherwise noted in the particular test:

Item	*Tolerance*
Weight	+5%−10%
Critical items affected by weight	+5%−1%
C. G.	7% total travel
Air speed	3 m. p. h. or ±3% whichever is greater
Power	5%
Wind (takeoff and landing tests)	As low as possible but not to exceed approximately 12% V_{s_1} or 12 m. p. h. whichever is lower, along the runway—measured at a height of 6 feet above the runway surface.

(c) *Type Inspection Report.*

(1) All information and data obtained as a result of the type inspection investigation and tests should be reported in Form ACA 283–4b, Type Inspection Report.

(2) Upon completion of the type inspection, the applicant should prepare the information necessary to show compliance with the requirements. This material together with the Airplane Flight Manual required by section 4b.740 should be completed as promptly as possible and forwarded to the CAA.

(19 F. R. 4448, July 20, 1954, effective Sept. 1, 1954.)

4b.100–2 *Selection of weight, altitudes, speeds and wing flap positions (CAA policies which apply to sec. 4b.100 (b)).* Before starting official flight tests, certain data should be obtained by the applicant in order that the options prescribed in (a) through (e) of this section can be executed:

(a) *The selection of the range of weight and altitude to be covered by the flight testing required for certification.* This selection should be based upon the extent to which the applicant for certification is concerned with the operating limitations which will be imposed upon the airplane. If the applicant is not concerned with this point, he may elect to conduct only the flight tests required to demonstrate compliance with the minimum performance requirements contained in section 4b.110 together with those required to demonstrate compliance with the flying qualities and other requirements specified in sections 4b.130 through 4b.190. If it is practicable to limit the operation of the airplane by a scheduled air carrier to sea level airports containing runways of ample length and to terrain altitude not in excess of 4,000 feet, this procedure appears satisfactory. It should be noted that this case could apply to a seaplane in scheduled operation. If the applicant wishes to provide for the greatest possible flexibility in the matter of compliance with the operating limitations contained in section 40.70 of this subchapter, considerably more performance tests will be necessary. It may be entirely practicable, for example, for operation over routes involving appreciable differences in the altitude of airports, to take advantage of the improvement in performance which is possible by means of reducing the weight at which the airplane is operated. It may also be desirable to alter the various flap settings in order to improve the climbing performance at a given weight. In cases such as these, it will be necessary to determine by flight testing and calculation, the effect of weight, altitude, and flap setting, throughout the range of each for which it is desired to provide, upon the takeoff, landing, and climbing performance and to include this information in the CAA Approved Airplane Flight Manual. This selection will be left to the applicant since, even though he may find it difficult to anticipate the uses to

which the airplane may subsequently be put, he is nevertheless in better position to forecast this than anyone else.

(b) *The selection of the weight range to be covered by the terms of the certification.* This selection is closely related to (a) of this section and should be based upon essentially the same considerations. The simplest possible selection of weights is a single maximum weight to be used both for takeoff and landing and as a basis for the operating limitations. The next simplest choice would appear to be a maximum takeoff weight and a maximum landing weight differing from takeoff weight. This choice requires the installation of fuel jettisoning equipment (when the takeoff weight exceeds the landing weight by more than 5 percent) of sufficient capacity to reduce the weight of the airplane from the maximum takeoff weight to the maximum landing weight in compliance with section 4b.437. The operating limitations may then be based upon the assumption that these two weights exist through each flight. The most flexible possible arrangement in the matter of weights is provided by selecting a range of weights for takeoff and a range for landing, and determining the performance as functions of these weights so that, in showing compliance with the operating limitations, any weight within these ranges may be selected to fit the requirements of a particular route. This selection should be left with the applicant.

(c) *The selection of the range of attitude to be covered by the terms of the certification.* This selection is also closely related to (a) of this section and is analogous in its nature to (a) of this section. The simplest possible selection is that indicated by the minimum performance requirements contained in section 4b.110, namely, sea level for the purposes of the determination of the takeoff and landing distances and certain of the rates of climb at 5,000 feet for the purpose of determining the en route rates of climb. The selection providing the greatest possible flexibility is the one in which these items of performance are determined for a range of altitude great enough to cover all anticipated routes over which the airplane may be operated.

(d) *The selection of the wing flap positions desired for certification.* Policies outlined in section 4b.111–1 will apply to this selection.

(e) *The selection of the critical speed*[4] *to be used in the determination of the takeoff distance.* Policies outlined in section 4b.113–2 will apply to this selection.

(19 F. R. 4449, July 20, 1954, effective Sept. 1, 1954.)

Discussion of Policies Relating to Flying Qualities in Section 4b.100–3

The relation between flying qualities (controllability, stability, trim, stalling characteristics) and safety involves the level of skill and the degree of attention required on the part of the pilot to fly the airplane. It is theoretically possible to design an airplane which cannot be flown by a single pilot because, for example, he may not have enough strength, or alternatively a sufficiently delicate touch, to operate the controls or there may be so many necessary operations that he cannot perform all of them within the required time. The flight tests pertaining to flying qualities are specified in sections 4b.130 through 4b.133, sections 4b.140 through 4b.144, sections 4b.150 through 4b.158, sections 4b.160 through 4b.162 and sections 4b.170 and 4b.171. These requirements cover the more important characteristics and loading conditions which have been agreed to be critical or representative of flight regimes. If the airplane passes the tests no investigation of other loading conditions will ordinarily be required.

4b.100–3 *Flying qualities (CAA policies which apply to sec. 4b.100 (c)).*

(a) It should be possible to operate the airplane safely at all anticipated altitudes without requiring exceptional attention and skill by the pilot or appropriate crew members.

(b) If there is less than 2 m. p. h. difference

[4] The practical effect of the selection of this speed is that it permits the applicant to define in the type certificate the limits of airplane weight and airport altitude within which the airplane may be operated by a scheduled air carrier in compliance with Part 40 of this subchapter.

in the forward and rearward c. g. stalling speeds, all flying qualities may be based upon the forward c. g. stalling speeds. Otherwise, the stalling speed appropriate to the c. g. position should be used.

(c) If there is reason to believe that any of the flying qualities would be affected by altitude, they should be investigated for the most adverse altitude condition expected in normal operation.

4b.101 *Weight limitations.* The maximum and minimum weights at which the airplane will be suitable for operation shall be established as follows:

(a) Maximum weights shall not exceed any of the following:

(1) The weight selected by the applicant;

(2) The design weight for which the structure has been proven;

(3) The maximum weight at which compliance with all of the applicable flight requirements has been demonstrated.

(b) It shall be acceptable to establish maximum weights for each altitude and for each practicably separable operating condition (e. g., take-off, en route, landing).

(c) Minimum weights shall not be less than any of the following:

(1) The minimum weight selected by the applicant;

(2) The design minimum weight for which the structure has been proven;

(3) The minimum weight at which compliance with all of the applicable flight requirements has been demonstrated.

4b.102 *Center of gravity limitations.* Center of gravity limits shall be established as the most forward position permissible and the most aft position permissible for each practicably separable operating condition in accordance with section 4b.101 (b). Limits of the center of gravity range shall not exceed any of the following:

(a) The extremes selected by the applicant;

(b) The extremes for which the structure has been proven;

(c) The extremes at which compliance with all of the applicable flight requirements has been demonstrated.

4b.103 *Additional limitations on weight distribution.* If a weight and center of gravity combination is permissible only within certain load distribution limits (e. g., spanwise) which could be exceeded inadvertently, such limits shall be established together with the corresponding weight and center of gravity combinations, and shall not exceed any of the following:

(a) The limits selected by the applicant;

(b) The limits for which the structure has been proven;

(c) The limits for which compliance with all the applicable flight requirements has been demonstrated.

4b.104 *Empty weight.*

(a) The empty weight and the corresponding center of gravity position shall be determined by weighing the airplane. This weight shall exclude the weight of the crew and payload, but shall include the weight of all fixed ballast, unusable fuel supply (see sec. 4b.416), undrainable oil, and total quantity of hydraulic fluid.

(b) The condition of the airplane at the time of weighing shall be one which can be easily repeated and easily defined, particularly as regards the contents of the fuel and oil tanks, and the items of equipment installed.

4b.105 *Use of ballast.* It shall be acceptable to use removable ballast to enable the airplane to comply with the flight requirements. (See secs. 4b.738 and 4b.741 (c).)

(19 F. R. 4449, July 20, 1954, effective Sept. 1, 1954.)

4b.105–1 *Use of ballast during flight tests (CAA policies which apply to sec. 4b.105).* Ballast should be carried during the flight tests whenever it is necessary to simulate pay load. Consideration should be given to the vertical as well as horizontal location of the ballast in cases where it may have an appreciable effect on the performance or flying qualities of the airplane. The strength of the supporting structures should be adequate to preclude their failure as a result of the flight loads that may be imposed during the tests.

(19 F. R. 4449, July 20, 1954, effective Sept. 1, 1954.)

Performance

4b.110 *General.*

(a) With respect to all airplanes type certificated on or after February 12, 1951, the

performance prescribed in this subpart shall be determined, and compliance shall be shown, for standard atmospheric conditions and still air, except that the performance as affected by engine power, instead of being based on dry air, shall be based on 80 percent relative humidity.

(b) Each set of performance data required for a particular flight condition shall be determined with the powerplant accessories absorbing the normal amount of power appropriate to that flight condition. (See also sec. 4b.117.)

4b.110–1 *Engine power corrections (CAA policies which apply to sec. 4b.110).*

(a) *Engine power corrections for vapor pressure.* The following standard vapor pressures versus altitude have been established for the purpose of correcting airplane performance data in accordance with section 4b.110:

Altitude (Feet)	*Vapor Pressure* (in. hg.)
0	0.400
2000	.307
4000	.237
6000	.179
8000	.133
10000	.096
12000	.069
14000	.049
16000	.035
18000	.025
20000	.016
25000	.005

(b) *Engine power corrections for cylinder head temperatures.* Official flight tests should be discontinued whenever engine limitations are exceeded. This procedure automatically makes corrections of this type unnecessary.

(c) *Engine power corrections for fuel flow.* Official flight tests should not be conducted when the metering characteristics of the carburetor are outside the range of acceptable tolerances. This procedure automatically makes corrections for fuel-air mixture ratio in performance evaluation unnecessary.

(19 F. R. 1817, Apr. 2, 1954, effective Apr. 2, 1954.)

4b.110–2 *Engine power calibration (CAA policies which apply to sec. 4b.110).* The performance of an airplane established in accordance with the requirements of sections 4b.110 through 4b.125 and shown in the performance section of the Airplane Flight Manual should be reproducible by any airplane of a similar model having engines that deliver no more than 100 percent certificated rated power. This means that the power used to drive all accessories, other than those necessary to the functioning of the engine, should be deducted from the certificated rated or installed engine power, whichever is less. To assist in meeting these objectives, the engine power of all new type airplanes as defined by section 4b.11 (e) should be calibrated in accordance with paragraphs (a) through (c) of this section.

(a) *Corrections to the calibrated power for engines producing power above the certificated ratings.* The applicant should provide engine power output data obtained from dynamometer tests, or the equivalent thereof, for all engines that are installed in the airplane which will be used in the power calibration flight tests. The data should be sufficiently complete to allow a direct comparison with the approved certificated ratings of the engines.

If the dynamometer calibration data for any engine selected for the inflight power calibration in accordance with the provisions of paragraph (b) of this section indicate that the power (based on standard atmospheric conditions for the engine) is higher than the certificated rating for the engine model, the calibrated power curve established as a result of flight tests in paragraphs (b) and (c) of this section should be corrected by applying the following power reduction: 100 percent of the power increment between the dynamometer calibration and the certificated engine rating at sea level, and 47 percent of the sea level power increment applied at an altitude of 20,000 feet with a lineal variation between these two points throughout the operating altitude range of the airplane. If the calibrated power curve established as a result of the flight tests represents an average power for more than one engine, it should be corrected by applying a power reduction equivalent to the average power difference between the dynamometer and the rated power for all engines used in the flight calibration tests. The application of other correction methods and values that will adjust the power data on the basis of the cer-

tificated rating of the engine throughout the operating altitude range of the airplane are acceptable if they can be substantiated.

(b) *Selection of engines for power calibration in flight.* With the exception of the critical inoperative engine, the number of engines which will be used as a basis for power calibration is left to the option of the applicant. However, the procedure specified in this paragraph should be followed to determine which engine(s) should be selected for establishing the basic calibrated power curve.

(1) The installed power of all engines should be compared in flight by means of calibrated torquemeters or other equivalent methods. If a calibrated power curve is to be established on the basis that all engine driven accessories will be in operation during flight, the comparison should be made under full accessory load conditions. If a separate calibrated power curve is to be established for application to those test configurations where certain accessories will not be in operation, the power of all engines may be compared when these accessories are in the appropriate idling or off position. In this case it will be necessary to provide data, indicating accessory load requirements for those flight configurations and the particular engine(s) from which the power is obtained.

(2) For two-engine aircraft it is only necessary to calibrate the engine which produces the lesser power determined by comparing the results of the torquemeter indications in accordance with subparagraph (1) of this paragraph for the most critical accessory load condition and taking into consideration the appropriate power reduction when the engine dynamometer test output is above the rated power for the engine. All performance data scheduled in the Airplane Flight Manual should be based on the calibrated power curve established for this engine. If the applicant desires to calibrate the power of both engines, only the all-engine-operating performance data should be based on a curve representing the average power for the two engines.

(3) When the applicant desires to calibrate the power of one engine for aircraft having more than two engines, the engine selected should be that which delivers the lowest power, determined by comparing the results similarly as in the case of the two-engine aircraft in subparagraph (2) of this paragraph. All performance data scheduled in the Airplane Flight Manual should be based on the calibrated power curve established for this engine. If the applicant desires to calibrate the power of two engines, the calibrated power curve should be based on values representing an average of the two engines delivering the lowest power.

(4) The procedure in subparagraph (3) of this paragraph should be followed if the applicant desires to calibrate the power of more than two engines, however, the Airplane Flight Manual performance data should be based upon an average calibrated power curve which has been derived from not more than the actual number of engines in operation corresponding to the test configuration for which performance is established. This procedure is not necessary, for example, in the case where the average power curve for two and three engines is substantially equal. However, the third engine may be calibrated to obtain additional data which will permit a more accurate fairing of the calibrated power curve.

(5) If the results of the flight tests indicate that the power of any engine selected in accordance with the provisions of this paragraph exceeds rated power after the application of the dynamometer correction specified in paragraph (a) of this section, the calibrated power curve for application to performance testing should be based upon not more than certificated rated power of the engine with the power to drive the accessories deducted.

(c) *Flight test procedure for calibrating engine power.* The engine calibration flight tests should be conducted in accordance with the provisions specified in this paragraph.

(1) The critical altitudes of the engine should be established for takeoff power and maximum continuous power providing these critical altitudes lie below the highest operating altitude desired for certification. Critical altitudes need not be determined above the maximum operating altitude of the airplane.

(2) For engine installations specifically designed to indicate power by means of torquemeters, the engine power calibration tests as well as all performance tests which are

affected by power should be obtained with calibrated torquemeters.

(3) All engine adjustments such as ignition timing, valve clearances, air-fuel ratios, fuel flow rates, antidetonant injection flow rates, etc. should be maintained within approved limits for the engine. If any permanent changes are made to the engine or powerplant installation during the type certification tests, and such changes result in an engine power output less than that established in the calibrated power data, then all performance data should be corrected to this lower power.

(4) The engine power calibration tests should be conducted in an atmosphere which is free of any visible moisture.

(5) The engine power calibration tests should be conducted in the configurations that follow:

(i) *Takeoff power.*

Weight—maximum takeoff.
C. G. position—optional.
Wing flaps—takeoff position.
Landing gear—retracted.
Operating engine(s)—takeoff r. p. m. and manifold pressure or full throttle, mixture setting at normal position for takeoff power, carburetor air heat control at cold and cowl flaps in takeoff position (see sec. 4b.118–1 (d) (1)).
Critical inoperative engine—throttle closed on highest powered engine, propeller windmilling in takeoff pitch (may be feathered if automatic feathering device is installed), mixture setting at idle cut-off and cowl flaps in takeoff position (see sec. 4b.118–1 (d) (1)).

(ii) *Maximum continuous power.*

Weight—maximum takeoff.
C. G. position—optional.
Wing flaps—en route position.
Landing gear—retracted.
Operating engine(s)—maximum continuous r. p. m. and manifold pressure or full throttle, mixture setting at normal position, carburetor air heat control at cold and cowl flaps at CAA hot day cooling position.
Critical inoperative engine—throttle closed on highest powered engine, propeller feathered and cowl flaps in minimum drag position.

(6) *Test procedure and required data.* The engine power calibration tests should be conducted in a climbing attitude at the takeoff safety speed, V_2, with the use of takeoff power and at the en route climb speed with the use of maximum continuous power. The climbs should be started at the lowest practicable altitude and cover the altitude range desired for certification. During these tests the engine(s) should be operated within the approved limits for r. p. m., manifold pressures, temperatures, etc. The following data should be recorded at reasonable time intervals for each power condition:

Pressure altitude.
Ambient air temperature.
Humidity.
Indicated air speed.
Engine(s), r. p. m. and manifold pressure.
Torque pressure.
Cylinder head temperatures.
Carburetor air temperature.
Fuel flow rate.
Antidetonant injection flow rate.

In addition a record should be made of the following items:

Fuel grade.
Wing flap position.
Landing gear position.
Cowl flap position.
Mixture setting.
Blower setting.
Accessory power loads and distribution.

(d) *Engine power checks.* A suitable means should be established by which engine power may be compared after overhauls with the original calibrated power data obtained as a result of the type certification tests.

(21 F. R. 8417, Nov. 3, 1956, effective Nov. 30, 1956.)

4b.111 *Wing flap positions.*

(a) The wing flap positions denoted respectively as the take-off, en route, approach, and landing positions shall be selected by the applicant. (See also sec. 4b.323.)

(b) It shall be acceptable to make the flap positions variable with weight and altitude.

4b.111-1 *Selection of the wing flap positions (CAA policies which apply to sec. 4b.111).*

(a) In the selection of the wing flap positions desired for certification, the flap position indicator should show flap up, takeoff, en route, approach, and landing positions. Various items of performance are required to be determined at each of these flap positions. Section 4b.120 (d) requires that the stalling speed with the flap in the "approach" position should not exceed 110 percent of the stalling speed with the flap in the "landing" position. No plans for flight testing should be made until these positions are selected unless the applicant wishes to investigate systematically the effect of flap position upon each of several of the items of performance which should be determined at the nominal position to be selected.

(b) The selection of multiple sets of wing flap positions is permitted in order to obtain optimum performance at various airports. However, it is recommended that the approval of multiple flap position settings for any one airplane be limited to two or at the most three.[5]

(c) A reasonable number of takeoff flap settings in excess of three may be approved for operation under Civil Air Regulations, Parts 40, 41, 42, and 43 of this subchapter if a dispatch procedure is established to provide pertinent operating limitations for the particular takeoff involved.

(19 F. R. 4449, July 20, 1954, effective Sept. 1, 1954.)

4b.112 *Stalling speeds.*

(a) The speed, V_{s_0}, shall denote the calibrated stalling speed, or the minimum steady flight speed at which the airplane is controllable, in miles per hour, with:

(1) Engines idling, throttles closed (or not more than sufficient power for zero thrust at a speed not greater than 110 percent of the stalling speed);

(2) Propeller pitch controls in the position normally used for take-off;

(3) Landing gear extended;

(4) Wing flaps in the landing position;

(5) Cowl flaps closed;

(6) Center of gravity in the most unfavorable position within the allowable landing range;

(7) The weight of the airplane equal to the weight in connection with which V_{s_0} is being used as a factor to determine a required performance.

(b) The speed, V_{s_1}, shall denote the calibrated stalling speed, or the minimum steady flight speed at which the airplane is controllable, in miles per hour, with:

(1) Engines idling, throttles closed (or not more than sufficient power for zero thrust at a speed not greater than 110 percent of the stalling speed);

(2) Propeller pitch controls in the position normally used for take-off, the airplane in all other respects (flaps, landing gear, etc.) in the particular condition existing in the particular test in connection with which V_{s_1} is being used;

(3) The weight of the airplane equal to the weight in connection with which V_{s_1} is being used as a factor to determine a required performance.

(c) The stall speeds defined in this section shall be the minimum speeds obtained in flight tests conducted in accordance with the procedure of subparagraphs (1) and (2) of this paragraph.

(1) With the airplane trimmed for straight flight at a speed of 1.4 V_{s_1} and from a speed sufficiently above the stalling speed to assure steady conditions, the elevator control shall be applied at a rate such that the airplane speed reduction does not exceed one mile per hour per second.

(2) During the test prescribed in subparagraph (1) of this paragraph, the flight characteristics provisions of section 4b.160 shall be complied with.

4b.112-1 *Procedure for determining stalling speeds (CAA policies which apply to sec. 4b.112 (c)).*

(a) Since all performance requirements are based upon some function of the stalling speeds, accurate measuring methods and careful piloting technique should be employed during the tests required for determination of these speeds. The essential items to be considered

[5] The reason for recommending a limited number of flap settings is due to the increasing complexity of T-category operation with the increasing number of variables such as power ratings, takeoff flap settings and associated climb speeds, temperature accountability, etc., which are contained in the Airplane Flight Manual. Each additional set of flap positions approved increases the complexity with which the performance information in the Airplane Flight Manual can be evaluated to provide the proper level of safety, particularly in the takeoff flight stage.

when conducting tests to determine the stalling speeds are as follows:

(1) The airspeed system should have the same characteristics as outlined in section 4b.612–1 (a) (2). Preferably, an independent test airspeed system should be employed in measuring the stalling speeds such as a shielded or swivel impact pressure sensing head used in conjunction with a trailing static bomb. The airspeed system lag should be a minimum with the impact and static systems dynamically balanced to minimize the error associated with changing ambient pressure. With the above described airspeed system, the applicant may elect to use the minimum airspeed obtained during the maneuver, or may determine and apply the lag correction associated with changing airspeed (deceleration) to the minimum values obtained above. If the latter option is elected, the applicant should determine the correct lag factors to be applied under varying dV/dt conditions. If the airspeed system is *not* dynamically balanced, adequate corrections should be made.

(2) A satisfactory method of determining the correct lag associated with changing airspeed to be applied for balanced systems only in (1) is to simulate the airspeed variations associated with stall tests, utilizing the airspeed system installed in the aircraft. For this purpose an additional airspeed instrument having a known calibration should be inserted in the airspeed system adjacent to the pressure source, and a velocity-time history of instantaneous values for true and lagging total pressures be obtained by photo-recorder. It is necessary that a steady deceleration rate appropriate to that used during actual flight tests be maintained sufficiently long to allow the system lag to stabilize. The simulated velocity-time history should be appropriately corrected to the conditions existing in the actual stall flight tests.

(3) If the stalling speed tests are to be conducted with the propellers delivering zero thrust, some dependable method such as a propeller slipstream rake by means of which zero thrust condition can be ascertained should be available in flight. The general practice of establishing zero thrust r. p. m. by calculation is also acceptable. For the turbo-propeller and turbo-jet powered aircraft of conventional design, the stall speed can be determined with flight idle power, in lieu of zero thrust, if it can be shown that this power does not materially affect the stall speed. If the stall speed is materially affected by the above power, corrections should be made to zero thrust conditions. Analytical corrections will be acceptable if satisfactory accounting is made for the effects of propeller efficiency, slipstream, altitude, and other pertinent variables. The stall speed should be determined below an altitude of 10,000 feet, where practicable, to minimize the altitude effect on flight idle power.

(4) An accurate method for determining the fuel load should be established for the purpose of ascertaining the airplane's gross weight and c. g. position at the time of each stall.

(5) Test instrumentation should consist of the usual sensitive indicators, especially sensitive tachometers, in order to be able to maintain r. p. m. which results in zero thrust. The time history during the stall should be recorded photographically, and should include those data indicated in paragraph (e) (4) of this section.

(b) The test methods required in the options that follow (see also fig. 1) are for the purpose of determining accurately the stalling speed used to calculate the pertinent performance climb requirements. The airplane loading during these tests will depend upon the c. g.-weight range desired for approval, and whether the climb requirements are based on stalling speeds obtained with a fixed, or variable, c. g. position as indicated in subparagraphs (1) and (2) of this paragraph. In any case, the stalling speeds should be based on tests conducted for the most critical c. g.-weight combination, within the allowable tolerance specified in section 4b.100–1.

(1) *Climb requirement based on stalling speed at the most forward c. g. position desired for certification.* Under this option, the applicant should measure stalling speeds at the maximum forward c. g. position for certification and at the maximum landing weight. However, in some cases where the forward c. g. limit is variable with weight, this would require that stalling speed tests be conducted at a weight and c. g. position outside of the

approved structural limit. In lieu of this, and if the applicant so desires, he may measure the stalling speeds at the maximum forward c. g. position for maximum landing weight and also at the maximum forward c. g. position desired for certification and its associated weight.

It is only necessary to conduct stall speed tests for one or two loading conditions, as indicated above, if the weight range from maximum takeoff to minimum landing weight, and the variations in c. g. positions are within the allowable tolerances specified in section 4b.100–1 (b) (2) with respect to both maximum takeoff and minimum landing weights. (See fig. 1, option 1, case A.) In cases where a large variation of weight exists, it may be necessary to make an additional check of the stalling speed at the most forward c. g. position corresponding to maximum takeoff weight. (See fig. 1, option 1, case B.)

(2) *Climb requirement based on stalling speed varying with c. g. position.* If this option is elected, the applicant should conduct a sufficient number of tests to adequately establish the variation of stalling speed with center of gravity position. In any case, the stalling speed should be measured at the maximum forward c. g. position desired for certification and at the most rearward c. g. position desired for the purpose of varying the climb requirement with c. g. position. In the event that the above configurations do not encompass the maximum takeoff weight considering the allowable tolerances, stalling speed test should also be conducted at the maximum takeoff weight and its appropriate c. g.

(c) The deceleration rate actually utilized in each test may be obtained from the velocity-time history provided by photo-recorder data. For the purpose of determining the above deceleration rate, dV/dt should be based on the average slope of the velocity-time history, from a speed 10 percent above the minimum speed obtained with the test airspeed system, down to the minimum speed. (This method should not be used in calculating the appropriate lag corrections indicated in sec. 4b.112–1 (a) (1) and (2).)

(d) *Configurations.* The stalling speed should be demonstrated in the configuration shown in subparagraphs (1) and (2).

(1) *Configurations for demonstrating stalling speed* V_{S_0} *section 4b.112 (a).*

Weight—maximum landing or maximum weight at required c. g. position.
C. G. position—as required in paragraph (b) of this section.
Wing flaps—landing position.
Landing gear—extended.
Engines—idling or not more than sufficient power for zero thrust at a speed not greater than 110 percent of the stall speed.
Propeller controls—normal takeoff pitch.
Cowl flaps—closed.
Trim speed—1.4 V_{S_0}.

(2) *Configuration for demonstrating stalling speeds* V_{S_1}, *section 4b.112 (b).*

Weight—maximum landing or maximum weight at required c. g. position.
C. G. position—as required in (b) of this section.
Wing flaps—en route, takeoff and approach positions.
Landing gear—retracted.
Engines—idling or not more than sufficient power for zero thrust at a speed not greater than 110 percent of the stall speed.
Propeller controls—normal takeoff pitch.
Cowl flaps—closed.
Trim speed—1.4 V_{S_1}.

(e) *Test procedure and required data.*

(1) A sufficient number of representative stalls should be conducted for each airplane configuration and for each c. g. location as required in paragraphs (b) and (d) of this section in order to provide for accurate determination of the stall speeds at a dV/dt equals 1 mph/sec. The minimum number of stalls required will depend on the range of flap angles and other variable factors (such as variable c. g. position in determining the minimum climb requirement) which are proposed by the applicant. In cases where the flap positions have not been predetermined, it is permissible to conduct tests using four or more equally spaced flap angles. Based upon four equally spaced flap settings, an acceptable minimum number of representative stalls for each flap angle should be four. The minimum number of stalls at each flap angle should be increased if a lesser number of flap settings is proposed.

For other configurations and variables a lesser number of stalls should be acceptable once a basic stall speed versus flap angle curve has been determined. Not more than zero propeller thrust should be used, as determined in in paragraph (a) (3) of this section.

(2) The stalling speed tests should be conducted in accordance with the procedure outlined in section 4b.112 (c).

(3) Since the trim speed (1.4 V_{s_1}) and the speed at which zero thrust r. p. m. is set (not more than 1.1 V_{s_1}) are a function of the stall speed, a practice run should be made in order to determine the approximate stalling speed.

(4) The following data should be recorded photographically for each stall:

Vertical acceleration.	Air speed.
Angle of attack.	Altimeter.
Elevator angle.	R. P. M.

(5) In addition to the photorecorder record, the following data should be recorded for each stall:

Torque pressure.	Ambient air temperature.
C. G. position.	Wing flap position.
R. P. M. for zero thrust at 1.1 V_s.	Landing gear position.
Time.	IAS at stall warning.
Weight.	Nature of stall warning.

(6) In subparagraph (4), the following data may be omitted if the exception clause of section 4b.160 (c) (2) is applicable, or if during the demonstration of stall characteristics no marginal conditions existed and the elevator control was utilized to the full extent of its rearward (up elevator) travel. Under these circumstances the procedure used for stalling the aircraft to determine stall speeds, and recovery therefrom, should duplicate that used during the stall characteristics demonstration.

Elevator angle.
Angle of attack.
Vertical acceleration.

(22 F. R. 5791, July 20, 1957, effective Aug. 15, 1957.)

4b.113 *Take-off; general.*

(a) The take-off data in sections 4b.114 to 4b.116, inclusive, shall be determined under the following conditions:

(1) At all weights and altitudes selected by the applicant;

(2) With a constant take-off flap position for the particular weight and altitude;

(3) With the operating engines not exceeding their approved limitations at the particular altitude.

(b) All take-off data, when corrected, shall assume a level take-off surface, and shall be determined on a smooth, dry, hard-surfaced runway, in such a manner that reproduction of the performance does not require exceptional skill or alertness on the part of the pilot. (For temperature accountability data see sec. 4b.117. For wind and runway gradient corrections see appropriate operating rules of this subchapter.)

4b.113–1 *Downwind takeoff (CAA policies which apply to sec. 4b.113).* Downwind takeoff data may be approved on the following basis to provide for situations where geographic locations and terrain indicate they are desirable:

(a) *Performance.* In determining the required distances for takeoff in downwind the data should be substantiated by actual flight tests. The general methods and procedures would be comparable to those for substantiating takeoff distances in no wind. The flight tests should be conducted in tailwind components up to 150 percent of the maximum velocity for which approval is desired except that the performance tests may be simulated in zero wind as outlined below:

(1) The accelerate portions of the "takeoff" and "accelerate-stop" should be demonstrated at speeds corresponding to the zero wind plus 150 percent of the tailwind component for which approval is desired. The calculated distances for entry in the Airplane Flight Manual should also be based on 1.5 times the tailwind component, see (3).

(2) The decelerate portion of the "accelerate-stop" should be demonstrated by stopping from a speed corresponding to V_1 plus 1.5 times the tailwind velocity for which certification is desired.

(3) In determining the takeoff distances for the Airplane Flight Manual performance

data, 150 percent of the effect of the reported tailwind component should be taken into account. (See sec. 4b.740–1 (d) (2) (x).)

This may in some cases, permit calculating the required distances without further tests providing sufficiently high speed takeoffs and decelerations were made in the original type tests. However, except in the circumstances outlined in (d), actual takeoffs should be made under the conditions outlined in (b) to check the flight and ground handling characteristics.

(b) *Controllability.* Takeoffs should be made in steady downwind velocities equal to 1.5 times the maximum velocity for which approval is granted to check the controllability at the higher ground speeds with correspondingly reduced aerodynamic control forces, dynamic balance of landing gear, nose gear shimmy or vibration, etc.

(c) *Brakes.* At present it is believed that for calculated accelerate-stop distances based on actual airplane deceleration tests, the existing brake capacity requirements are sufficient to cover accelerate-stops in downwind velocities of 10 m. p. h. measured at 50′ height. However, in wind velocities above 10 m. p. h. and in unusual cases or special types of operation additional tests or substantiation of the adequacy of the brakes may be necessary, and a revision to the braking system may be required.

(d) *Tolerances.*

(1) With regard to performance tests outlined in (a), approval may be given for calculated takeoff distances for reported tailwind velocities up to 10 m. p. h. measured at 50′ height without camera tests additional to those required for approval of the no wind data.

(2) With regard to controllability tests outlined in (b), approval may be given for reported downwind velocities up to 10 m. p. h. measured at 50′ height without additional flight tests.

(19 F. R. 1817, Apr. 2, 1954, effective Apr. 2, 1954, amended 20 F. R. 2277, Apr. 8, 1955, effective Apr. 30, 1955.)

Discussion of Policies Relating to Determination of the Takeoff Field Length in Section 4b.113–2

The flight path specified in section 4b.113–2 (a) necessarily involves consideration of the level of skill of the pilot who happens to be flying the airplane at the time. The conditions under which this flight path is established provides for a reasonable level of skill by requiring certain minimum speeds which should be attained, as well as a sequence and timing in which it is assumed various configuration adjustments are made to the airplane, each of which have a measurable effect upon the resulting dimensions. The takeoff field length involves the determination of the distances traversed by the airplane for two alternative sequences of events. In the first case the airplane is accelerated to the critical engine failure speed, V_1 (see sec. 4b.114), at which speed all engines are made inoperative and the airplane decelerated to rest. In the second sequence of events the airplane is again accelerated to the same speed, but at that speed the critical engine only is made inoperative and the takeoff continued under certain specified conditions. The distance required to accelerate to the critical-engine-failure speed, V_1, is thus common to both sequences.

4b.113–2 *Determination of the takeoff field length (CAA policies which apply to sec. 4b.113).*

(a) The dimensions of a takeoff flight path should be such that, if the takeoff runway has a length equal to the greater of two possible dimensions of that flight path, an engine failure may occur at any point along the runway and the airplane be able either to stop within the length of the runway or to continue and clear all obstructions to flight until a safe landing is made.

(b) In the tests required by sections 4b.113 through 4b.116, generally one set of data at one altitude should be sufficient to determine take-

off distances for altitudes from sea level to 8,000 feet. If a greater range of airport altitudes is desired, the test should be conducted at two or more altitudes.

(19 F. R. 4451, July 20, 1954, effective Sept. 1, 1954.)

4b.114 *Take-off speeds.*

(a) The critical-engine-failure speed V_1, in terms of calibrated air speed, shall be selected by the applicant, but it shall not be less than the minimum speed at which the controllability is demonstrated during the take-off run to be adequate to permit proceeding safely with the take-off, using normal piloting skill, when the critical engine is suddenly made inoperative.

(b) The minimum take-off safety speed V_2, in terms of calibrated air speed, shall be selected by the applicant so as to permit the rate of climb required in section 4b.120 (a) and (b), but it shall not be less than:

(1) 1.2 V_{S1} for two-engine propeller-driven airplanes and for airplanes without propellers which have no provisions for obtaining a significant reduction in stalling speed with power on (one engine inoperative).

(2) 1.15 V_{S1} for propeller-driven airplanes having more than two engines and for airplanes without propellers which have provisions for obtaining a significant reduction in stalling speed with power on (one engine inoperative).

(3) 1.10 times the minimum control speed V_{MC} established under section 4b.133.

(c) If engine failure is assumed to occur at or after the attainment of V_2, the demonstration in which the take-off run is continued to include the take-off climb, as provided in paragraph (a) of this section, shall not be required.

Discussion of Policies Relating to Selection of the Takeoff Speeds in Section 4b.114–1

Section 4b.114 (a) specifies a speed at which the engine is assumed to fail and which may be lower than the speed at which flight is possible. The operating requirements of section 40.72 of this chapter limit the takeoff operation of the airplane to a weight such that in the event of engine failure at the critical-engine-failure speed, (V_1), the airplane can be brought to rest within the length of the runway or the takeoff continued and a height of 50 feet attained at the end of the runway. It follows that for any airplane at a particular weight there is an optimum value for this critical-engine-failure speed which results in the minimum required runway length and further, this optimum condition is obtained when the two alternative distances are equal. In the case of an airplane having a comparatively high wing loading but low power loading, and particularly in the case of airplanes with four or more engines, this optimum may be appreciably below the speed at which flight is possible.

The V_2 speed specified in section 4b.114 (b) is a minimum speed at which it is considered safe to attempt to complete the takeoff with one engine inoperative. The limitation upon the takeoff safety speed, (V_2), based upon stalling speed, involves the power-off stalling speed with 20 percent and 15 percent margins as reasonable minimums to insure against inadvertent stalling of the airplane.

[For propeller-driven airplanes the] difference between the two margins, based upon the number of engines installed in the airplane, is due to the fact that the application of power ordinarily reduces the stalling speed appreciably. In the case of the two-engine [propeller-driven] airplane, at least half of this reduction is eliminated by the failure of an engine. In the case of a four-engine [propeller-driven] airplane, certainly less than half and probably closer to one-quarter only of the difference is eliminated by the failure of an engine. The difference in the required factors, therefore, provides approximately the same margin over the actual stalling speed under the power conditions which are obtained after the loss of an engine no matter what the number of engines

(in excess of one) may be. [Unlike the propeller-driven airplane, the turbine engine airplane does not show any appreciable difference between the power-on and power-off stalling speeds. This is due to the absence of the propeller which ordinarily induces a slipstream with the application of power causing the wing to retain its lift to a speed lower than the power-off stalling speed.] The applicant's selection of the two speeds specified will influence the nature of the testing required in establishing the takeoff flight path.

4b.114–1 *Selection of the takeoff speeds (CAA policies which apply to sec. 4b.114).*

(a) It should be possible to continue the takeoff acceleration after the failure of an engine at the speed, V_1, until a minimum safe flying speed has been attained. This condition should be demonstrated by test in order to determine that it can be safely accomplished. Throttling an opposite engine should not be permitted during the demonstration.

(b) It should not be necessary to demonstrate a takeoff that is continued after engine failure in the case where the applicant chooses to make the critical engine failure speed not less than the takeoff safety speed. If V_1 is less than V_2, the tests should include an actual takeoff during which the critical engine is made inoperative at the minimum V_1 speed and the takeoff continued after the speed V_2 is attained.

(c) The minimum takeoff safety speed should be at least 10 percent in excess of the minimum speed at which the airplane can be safely controlled when the critical engine is suddenly made inoperative under takeoff conditions in flight. (See sec. 4b.133.)

(19 F. R. 4451, July 20, 1954, effective Sept. 1, 1954.)

4b.115 *Accelerate-stop distance.*

(a) The accelerate-stop distance shall be the sum of the following:

(1) The distance required to accelerate the airplane from a standing start to the speed V_1,

(2) Assuming the critical engine to fail at the speed V_1, the distance required to bring the airplane to a full stop from the point corresponding with the speed V_1.

(b) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the accelerate-stop distance, provided that such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected under normal conditions of operation, and that exceptional skill is not required to control the airplane.

(c) The landing gear shall remain extended throughout the accelerate-stop distance.

Discussion of Policies Relating to the Determination of the Accelerate-Stop Distance in Section 4b.115–1

In establishing an accelerate and stop distance it is obvious that when the throttles are suddenly closed, a finite time will elapse before the propellers and the rotating parts of the engine are decelerated from the takeoff r. p. m. to an idling r. p. m. During this period the propellers continue to exert thrust, until a certain zero thrust r. p. m. is reached as a result of the deceleration. For this reason the speed of the airplane continues to increase beyond that speed which exists at the moment the throttles are closed before it begins to decrease again. The period of time covered by the deceleration of the engine r. p. m. is also a very critical period for the application of brakes since there usually results a change in trim of the airplane which may necessarily require certain adjustments in the position of the controls.

4b.115–1 *Determination of the accelerate-stop distance (CAA policies which apply to sec. 4b.115).*

(a) In order to establish a representative dimension for the distance that would be required in the event of an actual failure of an engine during takeoff and the election of the pilot to stay on the ground, a sufficient number of runs should be conducted starting from rest and ending at rest to determine the transition

distance for piecing together the acceleration and deceleration portion of the runs. In determining this distance, the wing flaps should be in the takeoff position at least until the engines have been made inoperative, but they may thereafter be altered to aid the deceleration if it is demonstrated by the applicant that this may be done with reasonable ease and safety. The accelerate-stop tests should be demonstrated in accordance with the following provisions: These tests are predicated on the assumption that the airplane is not equipped with reverse pitch or automatic feathering propellers.[6]

(1) Accelerate and stop runs should be conducted at two weights and at one altitude, and one deceleration run to demonstrate braking capacity and deceleration characteristics associated with the maximum altitude at which it is desired to certificate the airplane. Altitude conditions should be simulated by adjusting power and air speed. At least one representative run should be made for each of three engine failure speeds at each weight. If more than one flap setting is to be used for takeoff, additional tests should be conducted to cover the flap range. (See sec. 4b.118–1 (d) (2).)

(2) If tests are not made at the maximum airport altitude, one landing or deceleration run should be made at an optional altitude for the purpose of demonstrating braking capacity and deceleration characteristics at maximum airport altitude and corresponding takeoff gross weight with the airplane at this maximum takeoff weight. The true ground speed at the start of the deceleration should correspond to that speed which would be experienced at the maximum airport altitude and weight. Discretion should be used in this test to assure remaining within safe structural and operational limits of the airplane.

(3) The accelerations may be made during takeoffs and the decelerations during landings at the takeoff configuration, providing a minimum of one acceleration and stop run is conducted at the maximum takeoff weight to determine the transition distance.

(4) Instrumentation should include means to record the airplane path relative to the runway against time in a manner to determine the horizontal distance-time history and a means should be provided to measure the wind velocity and direction, pressure altitude, engine r. p. m., manifold and/or torque pressure.

(i) The wind velocity should be measured adjacent to the runway at the height of 6 feet above the runway surface for test purposes. If wind effect on runway lengths is shown in the Airplane Flight Manual (see sec. 4b.740–1 (d) (2) (x)), the manual data should be based on reported wind velocities for a 50-foot tower height. Figure 2 should be used to calculate the wind velocity at the 50-foot height from the wind velocity measured at the 6-foot height.

(5) A special tolerance of not greater than ± 2 percent of the maximum takeoff weight is allowed for the accelerate-stop distance tests.

(b) *Configuration.* The accelerate-stop tests should be conducted in the configuration that follows:

Weight—maximum takeoff and one lower.
C. G. position—most forward. (Most aft for reverse thrust decelerations.)
Wing flaps—takeoff position.
Landing gear—extended.
Operating engines—during acceleration, all engines operating at full takeoff power and r. p. m.; cowl flaps set in takeoff position (see sec. 4b.118–1 (d) (1)).
Inoperative engines—during deceleration, throttles closed; propellers windmilling in takeoff pitch (except for failed engine with automatic feathering, see sec. 4b.115–2); cowl flaps set in takeoff position (see sec. 4b.118–1 (d) (1)).

(c) *Test procedure and required data.*

(1) The airplane should be accelerated from full stop to each of three speeds up to V_1, the highest value of which should correspond to at least the maximum value desired for certification. The throttles should be closed at this speed and the airplane brought to a complete stop with the inoperative propellers windmilling (except when an auto-feathering device is installed).

(2) The airplane path relative to the runway should be recorded against time in a manner to determine the horizontal distance—time history.

[6] See section 4b.115–2 for policies covering automatic feathering propellers.

(3) The following data should be recorded:
Pressure altitude.
Ambient air temperature.
Airplane gross weight.
R. P. M. (obtained during acceleration and deceleration).
Manifold pressure.
Torque pressure.
Carburetor air temperature.
Mixture setting.
Cowl flap position.
Wing flap position.
Time, distance, and airspeed at engine cut.
Slope of field.
Direction of run.

(4) In addition, humidity, wind direction, and wind velocity should be recorded adjacent to the runway at a height of 6 feet above the runway surface.

(19 F. R. 4451, July 20, 1954, effective Sept. 1, 1954.)

4b.115–2 *Approval of automatic propeller feathering installations for use in establishing accelerate-stop distance (CAA policies which apply to sec. 4b.115).* The accelerate-stop distance should be determined with the automatic propeller feathering installation feathering the propeller of the critical engine and with the other throttles closed at the instant of attainment of V_1. (See secs. 4b.10–2, 4b.401–1, 4b.700–1, and Civil Air Regulations Part 4b Interpretation No. 1.)

(19 F. R. 1817, Apr. 2, 1954, effective Apr. 2, 1954.)

4b.115–3 *Reverse thrust used in accelerate-stop distance (CAA policies which apply to sec. 4b.115).* The policies outlined in section 4b.402–1 (k) will apply.

(20 F. R. 2277, Apr. 8,19 55, effective Apr. 30, 1955.)

4b.115–4 *Accelerate-stop distance with an antiskid device installed (CAA policies which apply to sec. 4b.115).* The policies outlined in section 4b.337–4 will apply.

(21 F. R. 2558, Apr. 19, 1956, effective May 15, 1956.)

4b.116 *Take-off path.* The take-off path shall be considered to consist of the following five consecutive elements:

(a) The distance required to accelerate the airplane to the speed V_2, assuming the critical engine to fail at the speed V_1.

(b) The horizontal distance traversed and the height attained by the airplane in the time required to retract the landing gear when operating at the speed V_2 with:

(1) The critical engine inoperative, its propeller:

(i) Windmilling with the propeller control in a position normally used during take-off until (if applicable) its rotation has been stopped (see paragraph (c) (1) of this section),

(ii) If applicable, stopped for the remainder of the gear retraction time.

(2) The landing gear extended.

(c) If applicable, the horizontal distance traversed and the height attained by the airplane in the time elapsed from the end of element (b) until the rotation of the inoperative propeller has been stopped when:

(1) The operation of stopping the propeller is initiated not earlier than the instant the airplane has attained a total height of 50 feet above the take-off surface,

(2) The airplane speed is equal to V_2,

(3) The landing gear is retracted,

(4) The inoperative propeller is windmilling with the propeller control in a position normally used during take-off.

(d) The horizontal distance traversed and the height attained by the airplane in the time elapsed from the end of element (c) until the time limit on the use of take-off power is reached, while operating at the speed V_2, with:

(1) The inoperative propeller stopped,

(2) The landing gear retracted.

(e) The slope of the flight path followed by the airplane in the configuration of element (d), but drawing not more than maximum continuous power on the operating engine(s).

4b.116–1 *Approval of automatic propeller feathering installations for use in establishing the takeoff path (CAA policies which apply to sec. 4b.116).* The takeoff path may be modified by permitting a feathered propeller instead of windmilling after the necessary time interval has elapsed from the instant of engine failure to complete feathering of the propeller. If it can be shown that the net work produced by the feathering propeller from the instant of engine failure to completion of feathering under all types of engine failure is positive using a datum based on feathered propeller drag, then it is

permissible to assume that the propeller of the failed engine is in the feathered drag condition from the instant of attainment of the takeoff climb speed V_2. (See secs. 4b.10–2, 4b.401–1, and 4b.700–1.)

(19 F. R. 1818, Apr. 2, 1954, effective Apr. 2, 1954.)

Discussion of Policies Relating to the Determination of the Takeoff Path in Section 4b.116–2

The takeoff path elements in section 4b.116 are intended to reflect, as closely as possible, the probable order in which a pilot would make changes to the airplane configuration in the actual case of an engine failure. They are conservative in their nature in an effort to simplify the testing required to establish the flight path. For example, it is assumed that the pilot will initiate gear retraction at the takeoff safety speed, V_2, immediately after the wheels leave the ground but that climbing performance does not increase during the retraction period over that with the gear fully extended. In the case of non-automatic propeller feathering systems it is assumed that the pilot would not initiate propeller feathering, if an engine fails during the ground run, prior to attaining a height of 50 feet, and further that the climb performance of the airplane remains the same as with the propeller wind-milling until the propeller feathering cycle is completed. However, in the case of an airplane with a slow retracting gear, propeller feathering may be started at the 50-foot height prior to the completion of the gear retraction as noted in section 4b.116 (c). It is also assumed that the cowl flaps on the inoperative engine will be closed when the airplane enters the third takeoff climb segment with the gear retracted and propeller feathered.

4b.116–2. *Determination of the takeoff path (CAA policies which apply to sec. 4b.116).*

(a) The recommended procedure for obtaining the takeoff path is to determine the ground and climb portions separately and piece the corrected data together. The takeoff flight path should be demonstrated in accordance with the following provisions:

(1) Three accelerations should be made during which the airplane is accelerated from a complete stop using all engines to speeds bracketing speed V_1 at which speed the critical engine fuel mixture is cut and the acceleration continued to speed V_2 with the inoperative engine propeller windmilling[7] in the takeoff pitch setting. If V_1 is less than V_2, a takeoff should be made on one of the above runs when the critical engine is failed at the lowest V_1 speed.

(2) The takeoff flap setting should be maintained throughout the takeoff flight path. If more than one flap setting is to be used for takeoff, additional tests should be included to cover the flap range (see sec. 4b.118–1(d)(2)).

(3) See section 4b.115–1 (a) (4) for instrumentation requirements.

(4) A special tolerance of not greater than ±2 percent of the maximum takeoff weight is allowable for the ground portion of the accelerate distance.

(*b*) *General test program.*

(1) *Accelerate to takeoff safety speed,* V_2 *section 4b.116 (a).*

(i) *Configuration.* These tests should be conducted in the configuration that follows:

Weight—maximum takeoff and one lower.
C. G. position—most forward.
Wing flaps—takeoff position.
Landing gear—extended.
Operating engine(s)—takeoff r. p. m. and manifold pressure, cowl flaps in takeoff position (see sec. 4b.118–1 (d) (1)).
Critical inoperative engine—fuel mixture cut on engine most critical performancewise (see sec. 4b.118–1 (e) (2)), propeller windmilling in

[7] When a satisfactory fully automatic propeller feathering device is installed on the airplane, advantage of such a device may be used in showing compliance with this section. See section 4b.116–1 for policies covering automatic propeller feathering systems.

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takeoff pitch (feathered if automatic feathering device is installed) and cowl flaps in takeoff position (see sec. 4b.118–1 (d) (1)).

(ii) *Test procedure and required data.* The airplane should be accelerated from a complete stop to the V_1 speed with all engines operating. The critical engine fuel mixture should be cut at the V_1 speed and the acceleration should be continued until V_2 speed is reached with the propeller of the inoperative engine windmilling in the takeoff pitch. The airplane's path relative to the runway should be recorded against time in a manner to determine the horizontal distance-time history. In addition the following data should be recorded:

Pressure altitude.
Ambient air temperature.
Airplane gross weight.
R. P. M.
Manifold pressure.
Torque pressure.
Mixture setting.
Cowl flap position.
Wing flap position.
Time, distance, and speed at engine, cut.
Time, distance, and speed when V_2 is reached.
Slope of field.
Direction of run.

In addition, humidity, wind direction, and wind velocity should be recorded adjacent to the runway at a height of 6 feet above the runway surface.

(2) *Initial takeoff flight path segment test, section 4b.116 (b).*

(i) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff and one lower.
C. G. position—optional (see sec. 4b.118–1 (c) (2)).
Wing flaps—takeoff position.
Landing gear—extended.
Operating engine(s)—takeoff r. p. m. and manifold pressure or full throttle, mixture setting for takeoff, carburetor air heat control at cold and cowl flaps in takeoff position (see sec. 4b.118–1 (d) (1)). Critical inoperative engine—throttle closed on engine most critical performance-wise (see sec. 4b.118–1 (e) (2)), propeller windmilling in takeoff pitch, (feathered if automatic feathering device is installed [see sec. 4b.120–1]), mixture setting at idle cut-off and cowl flaps in takeoff position (see sec. 4b.118–1 (d) (1)).

(ii) *Test procedure and required data.* The airplane should be climbed at the takeoff safety speed, V_2. See section 4b.118–1 for test procedure and required data in connection with climb tests.

(3) *Second takeoff flight path climb segment test, section 4b.116 (c).*

(i) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff and one lower.
C. G. position—optional (see sec. 4b.118–1 (c) (2)).
Wing flaps—takeoff position.
Landing gear—retracted.
Operating engine(s)—takeoff r. p. m. and manifold pressure or full throttle, mixture setting for takeoff, carburetor air heat control at cold and cowl flaps in takeoff position (see sec. 4b.118–1 (d) (1)). Critical inoperative engine—throttle closed on engine most critical performance-wise (see sec. 4b.118–1 (e) (2)), propeller windmilling in takeoff pitch, (feathered if automatic feathering device is installed [see sec. 4b.120–1]), mixture setting at idle cut-off and cowl flaps in takeoff position (see sec. 4b.118–1 (d) (1)).

(ii) *Test procedure and required data.* The airplane should be climbed at the takeoff safety speed, V_2. See section 4b.118–1 for test procedure and required data in connection with climb test.

(4) *Third takeoff flight path climb segment test, section 4b.116 (d).*

(i) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff and one lower.

C. G. position—optional (see sec. 4b.118–1 (c) (2)).
Wing flaps—takeoff position.
Landing gear—retracted.
Operating engine(s)—takeoff r. p. m. and manifold pressure or full throttle, mixture setting for takeoff, carburetor air heat control at cold and cowl flaps in takeoff position (see sec. 4b.118–1 (d) (1)). Critical inoperative engine—throttle closed on engine most critical performance-wise (see sec. 4b.118–1 (e) (2)), propeller feathered and cowl flaps in minimum drag position.

(ii) *Test procedure and required data.* The airplane should be climbed at the takeoff safety speed, V_2. See section 4b.118–1 for test procedure and required data in connection with climb tests.

(5) *Fourth takeoff flight path climb segment test, section 4b.116 (e).*

(i) *Configuration.* This configuration should be the same as for the third takeoff flight path climb segment except that maximum continuous power is used on the operating engine(s).

(ii) *Test procedure and required data.* The airplane should be climbed at the takeoff safety speed, V_2. See section 4b.118–1 for test procedure and required data in connection with climb tests.

(19 F. R. 4446, July 20, 1954, effective Sept. 1, 1954; amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957.)

4b.117 *Temperature accountability.* Operating correction factors for take-off weight and take-off distance shall be determined to account for temperatures above and below standard, and when approved by the Administrator they shall be included in the Airplane Flight Manual. These factors shall be obtained as follows:

(a) For any specific airplane type, the average full temperature accountability shall be computed for the range of weights of the airplane, altitudes above sea level, and ambient temperatures required by the expected operating conditions. Account shall be taken of the temperature effect on both the aerodynamic characteristics of the airplane and on the engine power. The full temperature accountability shall be expressed per degree of temperature in terms of a weight correction, a take-off distance correction, and a change, if any, in the critical-engine-failure speed V_1.

(b) The operating correction factors for the airplane weight and take-off distance shall be at least one-half of the full accountability values. The value of V_1 shall be further corrected by the average amount necessary to assure that the airplane can stop within the runway length at the ambient temperature, except that the corrected value of V_1 shall not be less than a minimum at which the airplane can be controlled with the critical engine inoperative.

4b.118 *Climb; general.* Compliance shall be shown with the climb requirements of sections 4b.119 through 4b.121.

Discussion of Policies Relating to Test Procedures for the Determination of Climb Performance in Section 4b.118–1

Sections 4b.119 through 4b.121 specify the airplane configurations which are considered to be representative for those operating conditions certain to be encountered in the use of the airplane. With the exception of section 4b.121, the requirements specify rates of climb which are believed to be the minimum that will guarantee the ability of the airplane to perform any necessary maneuver safely considering the possibility of an engine failure and other contingencies.

The required rates of climb specified in sections 4b.119 through 4b.120, where appropriate, are related to the stall speed squared since it has been assumed that the degree of danger associated with an emergency landing would be dependent upon the kinetic energy of the airplane. Equivalent safety dictates that excess power expressed in terms of rate of climb should be proportioned to the stall speed squared. For example, the one-engine-inoperative en route climb requirement defines a minimum rate of climb which is ac-

ceptable as evidence of the ability of the airplane to maintain altitude in case of an engine failure during cruising flight. The altitude, in standard atmospheric conditions, at which this rate of climb exists under the conditions specified becomes the basis of the operating rule specified in section 40.74 of this subchapter. Essentially similar reasoning has been used in determining climb criteria for the configurations in (a) through (c) of this section.

(a) *Climb: all engines operating, section 4b.119.*

(1) *Cruising configuration, section 4b.119 (a).* The factors which cause performance deterioration during cruising flight, such as inadequate cooling, high air temperatures, inefficient carburetion, etc., affect the airplane by reducing its available angle of climb. The climb requirement specified for this configuration will result in an approximate constant angle of climb regardless of the air speed and it is intended to insure that some climb performance will be available regardless of those conditions that may be encountered during the operation which impair performance.

(2) *Landing configuration, section 4b.119 (b).* This airplane configuration is ordinarily used in the final stages of an approach for landing, and the purpose of the specified required rate of climb is to assure that the descent may be readily arrested and that the airplane will be able to "go around" for another attempt at landing in the event conditions beyond the control of the pilot make this action necessary.

(b) *One-engine-inoperative climb, section 4b.120.*

(1) *Flaps in takeoff position: landing gear extended, section 4b.120 (a).* This requirement is specified to insure that the airplane will have a positive rate of climb during the initial stage of the takeoff for the configuration which is assumed to exist in this element.

(2) *Flaps in the takeoff position; landing gear retracted, section 4b.120 (b).* This airplane configuration is intended to be representative of the conditions which might be expected to occur in the event of an engine failure at about the time the airplane leaves the ground during takeoff. The rate of climb specified is believed to be a reasonable minimum which will insure the ability of the airplane to continue the takeoff under such circumstances. Because this segment is the more critical, it was not believed necessary to specify minimum climb requirements for the cleaner configuration which is assumed to be representative of the third or fourth takeoff flight path climb segments. However the conduct of climb tests for the latter two configurations is necessary for the determination of the takeoff path required in section 4b.116.

(3) *Flaps in en route position, section 4b.120 (c).* See the second paragraph under "Discussion of policies relating to test procedures for the determination of climb performance in section 4b.118–1."

(4) *Flaps in approach position, section 4b.120 (d).* This airplane configuration is intended to represent conditions under which a pilot would attempt to "go around" after an approach in which the engine became inoperative and section 4b.120 (d) is intended to insure that the airplane will have the performance necessary to accomplish this maneuver.

(c) *Two-engine-inoperative climb, section 4b.121.* The probability of two engines failing in a single flight is considered remote and therefore it is not believed reasonable to specify a climb requirement which would have to be met for this configuration. Climb tests should be demonstrated in this configuration for the purpose of obtaining the data necessary to be shown in the Airplane Flight Manual.

4b.118–1 *Test procedures for the determination of climb performance (CAA policies which apply to sec. 4b.118).* The test conditions and methods in (a) through (i) of this section assume that the flight test data do not exhibit excessive scatter in points and that if such scatter makes the accuracy of the climb slopes questionable, additional tests and/or the applicants' previous flight test data for the particular configuration involved should be available. The following methods are also based upon consistent flight test data that can be properly correlated, and the use of previous acceptable test and correction methods. All new tests and correction methods will be judged upon their own merits. Polar curve or other equivalent methods are acceptable. The number of climb tests recommended for each case in (a) and (b) of this section represents a minimum, and in certain instances it is possible that more tests may be necessary.

(a) *For all takeoff path segments, landing and approach climb.* If it is desired to show that the required climb is met at the highest altitude and heaviest weight to be certified, a constant rate of climb curve with altitude should be acceptable. One good climb should be satisfactory if it is 50 ft./min., or more, in excess of the required climb at the highest altitude for which certification is desired. Three climbs (at same altitude) should be made if the R/C is less than 50 ft./min. in excess of the required climb. (No climb variation with weight or altitude.)

If it is desired to determine the rate of climb vs. altitude curve:

(1) For a sea level engine, or the critical altitude above the maximum altitude of certification (no breaks in the curve) where the altitude range is not in excess of 8,000 feet, two good climbs at each weight over the altitude range if weight spread is in excess of 10 percent but not less than 4 climbs if only one weight is used. If the altitude range is in excess of 8,000 feet, three climbs at each weight over the altitude range (6 climbs if weight range is in excess of 10 percent) should be conducted.

(2) For installations where a critical altitude is within the altitude range (one break in the curve) two climbs on one slope of the curve should be conducted at each weight and at least one climb on the other slope (6 climbs for a weight spread of 10 percent or more). If the altitude range is in excess of 8,000 feet, consideration should be given to the need for a fourth climb at each weight.

(3) For installations where two breaks in the R/C curve occur within the certification range, four climbs at each weight should be made.

(b) *For all engine en route, one-engine-inoperative en route and two-engines-inoperative en route climbs.* The regulations specify that these climbs should be determined at all altitudes of expected use and weight of certification. For each weight at least the following climbs should be conducted:

Altitude Range	SL–8,000	SL–17,000	SL–25,000
No breaks in curve (one slope)	[1] 2	[1] 3	4
One break (2 slopes)	[1] 3	4	4
Two breaks (3 slopes)	------	4	4–5
Three breaks (4 slopes)	------	5	5

[1] But not less than 4 if only one weight is used.

When an airplane is approved for more than one landing flap position, the climb requirements for the cruising and en route configurations should be based upon the stall speed with the maximum sea level landing flap position for which the airplane is eligible.

Where several climb points are available at the same test conditions the average point should be determined by averaging all consistent points not using the obviously erratic points (either high or low).

(c) *Weight and c. g. position.*

(1) The climb tests should be conducted at maximum takeoff weight for takeoff climbs and at maximum landing weight for landing climbs. Climbs should also be made at an optional lower weight for both the takeoff and landing configuration.

(2) Climbs may be made at any c. g. position except where the applicant elects to vary the stalling speed with c. g. position in which case the most critical c. g. position should be used. (See sec. 4b.112–1 (b).)

(d) *Airplane configuration.*

(1) The cowl flaps should be set in the required position prior to conducting climb tests. The position of the cowl flaps for the takeoff segments should comply with the provisions of the takeoff cooling tests of section 4b.453.

(2) If more than one wing flap setting is to be used for takeoff or landing, additional tests should be included to cover the flap range (see sec. 4b.111–1 (b)).

(e) *Engine power.*

(1) The power should be stabilized prior to conducting the climb tests. The climbs should be made at constant power or at constant throttle setting. Unless limited by engine temperature, tests should be run for at least 3 minutes at takeoff power. If limited by temperature, short duration tests of approximately 1 minute duration should be acceptable provided the stabilized climbing speed is attained by accelerating from a lower speed. Where maximum continuous power is required, climb tests should be of 5 minutes duration or not necessarily more than climbs of 2,000 feet but in any case not less than 3 minutes. If climb tests are conducted for short durations, such as takeoff climbs which are limited by an engine rating of two minutes for takeoff power, consideration should be given to the necessity of conducting an adequate number of tests in order to obtain results which are representative of the actual performance.

(2) For the one-engine-inoperative climb tests, it may be assumed that the critical inoperative engine, performancewise, is the higher powered outboard engine unless there is evidence to indicate that another engine is more critical.

(3) For all climb tests, the powerplant equipment and accessories appropriate to the specific configuration being tested should be in operation. During each test, a record should be made of such accessories in operation and of the particular engine from which power is being absorbed.

(f) The climb speeds are to be selected by the applicant, but should be consistent with the performance and cooling requirements involved. The airspeed should be stabilized prior to conducting the climb tests.

(g) The airplane's wings should be maintained in a level attitude during all takeoff climb tests with one engine inoperative.

(h) All climbs should be conducted in free air (without ground effect).

(i) In addition to the following items, the data necessary to establish the weight and c. g. position during the climb tests should be recorded.

Pressure altitude recorded at 15 second intervals.
Humidity recorded at 15 second intervals.
Air speed recorded at 15 second intervals.
R. P. M.
Manifold pressure.
Torque pressure.
Carburetor air temperature.
Mixture setting.
Throttle setting.
Cowl flap position.
Wing flap position.
Landing gear position.

(19 F. R. 4452, July 20, 1954, effective Sept. 1, 1954.)

4b.119 *Climb; all engines operating.*

(a) *Cruising configuration.* In the cruising configuration the steady rate of climb in feet per minute at 5,000 feet shall not be less than 8 V_{s_0}. In addition the steady rate of climb shall be determined at any altitude at which the airplane is expected to operate and at any weight within the range of weights to be specified in the airworthiness certificate. The cruising configuration shall be with:

(1) Landing gear fully retracted,

(2) Wing flaps in the most favorable position,

(3) Cowl flaps (or other means of controlling the engine cooling) in the position which provides adequate cooling in the hot-day condition,

(4) Center of gravity in the most unfavorable position,

(5) All engines operating within the maximum continuous power limitations,

(6) Maximum take-off weight.

(b) *Landing configuration.* In the landing configuration the steady rate of climb in feet per minute shall not be less than 0.07 $V_{s_0}^2$ at any altitude within the range for which landing weight is to be specified in the certificate, with:

(1) Landing gear extended,

(2) Wing flaps in the landing position (see secs. 4b.111 and 4b.323),

(3) Cowl flaps in the position normally used in an approach to a landing,

(4) Center of gravity in the most unfavorable position permitted for landing,

(5) All engines operating at the take-off power available at such altitude,

(6) The weight equal to maximum landing weight for that altitude,

(7) A climb speed not in excess of $1.4\,V_{s_0}$.

4b.119–1 *Determination of all engine climb (CAA policies which apply to sec. 4b.119).*

(a) *Cruising configuration test, section 4b.119 (a).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff and one lower.

C. G. position—optional (see sec. 4b.118–1 (c) (2)).

Wing flaps—optional.

Landing gear—retracted.

Engines—maximum continuous r. p. m. and manifold pressure or full throttle, mixture setting in normal position, carburetor air heat control cold and cowl flaps in CAA hot day cooling position.

(2) *Test procedure and required data.* See section 4b.118–1 for test procedure and required data in connection with climb tests.

(b) *Landing configuration test, section 4b.119 (b).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing and one lower.

C. G. position—optional (see sec. 4b.118–1 (c) (2)).

Wing flaps—landing position.

Landing gear—extended.

Engines—takeoff power and manifold pressure or full throttle mixture setting in normal position, carburetor air heat control cold and cowl flaps in approach position.

(2) *Test procedures and required data.* See section 4b.118–1 for test procedure and required data in connection with climb tests.

(19 F. R. 4453, July 20, 1954, effective Sept. 1, 1954.)

4b.120 *One-engine-inoperative climb.*

(a) *Flaps in take-off position; landing gear extended.* The steady rate of climb without ground effect shall not be less than 50 ft/min. at any altitude within the range for which take-off weight is to be specified in the certificate, with:

(1) Wing flaps in the take-off position (see secs. 4b.111 and 4b.323),

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

(3) Center of gravity in the most unfavorable position permitted for take-off,

(4) The critical engine inoperative, its propeller windmilling with the propeller control in a position normally used during take-off,

(5) All other engines operating at the take-off power available at such altitude,

(6) The speed equal to the minimum take-off safety speed V: (see sec. 4b.114 (b)),

(7) The weight equal to maximum take-off weight for that altitude,

(8) Landing gear extended.

(b) *Flaps in take-off position; landing gear retracted.* With the landing gear retracted the steady rate of climb in feet per minute shall not be less than $0.035\,V_{s_1}^2$ with all other conditions as described in paragraph (a) of this section.

(c) *Flaps in en route position.* The steady rate of climb in feet per minute at any altitude at which the airplane is expected to operate, at any weight within the range of weights to be specified in the airworthiness certificate, shall be determined and shall, at a standard altitude of 5,000 feet and at the maximum take-off weight, be at least

$$\left(0.06-\frac{0.08}{N}\right)V_{s_0}^2,$$

where N is the number of engines installed, with:

(1) The landing gear retracted,

(2) Wing flaps in the most favorable position,

(3) Cowl flaps or other means of controlling the engine cooling air supply in the position which provides adequate cooling in the hot-day condition,

(4) Center of gravity in the most unfavorable position,

(5) The critical engine inoperative, its propeller stopped,

(6) All remaining engines operating at the maximum continuous power available at the altitude.

(d) *Flaps in approach position.* The steady rate of climb in feet per minute shall not be less than 0.04 $V_{s_0}^2$ at any altitude within the range for which landing weight is to be specified in the certificate, with:

(1) The landing gear retracted,

(2) Wing flaps set in position such that V_{s_1} does not exceed 1.10 V_{s_0},

(3) Cowl flaps in the position normally used during an approach to a landing,

(4) Center of gravity in the most unfavorable position permitted for landing,

(5) The critical engine inoperative, its propeller stopped,

(6) All remaining engines operating at the take-off power available at such altitude,

(7) The weight equal to the maximum landing weight for that altitude,

(8) A climb speed not in excess of 1.5 V_{s_1}.

4b.120–1 *Approval of automatic propeller feathering installations for use in establishing flaps in takeoff position climb (CAA policies which apply to sec. 4b.120 (a) and (b)).* The propeller of the inoperative engine may be in the feathered condition during either or both of the landing gear extended or retracted conditions if:

(a) The propeller would be completely feathered at the beginning of these segments of the takeoff flight path, or

(b) It can be shown that the network produced by the feathering propeller during the segment is positive using a datum based on feathered propeller drag. (See secs. 4b.10–2, 4b.401–1, and 4b.700–1.)

(19 F. R. 1818, Apr. 2, 1954, effective Apr. 2, 1954.)

4b.120–2 *Determination of one engine inoperative climb (CAA policies which apply to sec. 4b.120).*

(a) *Flaps in takeoff position; landing gear extended, section 4b.120 (a).* Policies outlined in section 4b.116–2 (b) (2) will apply.

(b) *Flaps in takeoff position; landing gear retracted, section 4b.120 (b).* Policies outlined in section 4b.116–2 (b) (3) will apply.

(c) *Flaps in en route position, section 4b.120 (c).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff and one lower.

C. G. position—optional (see sec. 4b.118–1 (c) (2)).

Wing flaps—optional.

Landing gear—retracted.

Operating engine(s)—maximum continuous r. p. m. and manifold pressure or full throttle, mixture setting at normal position, carburetor air heat control at cold and cowl flaps in CAA hot day cooling position.

Critical inoperative engine — throttle closed on engine most critical performancewise (see sec. 4b.118–1 (e) (2)), propeller feathered and cowl flaps in minimum drag position.

(2) *Test procedure and required data.* The airplane should be climbed at the en route climb speed. See section 4b.118–1 for test procedure and required data in connection with climb tests.

(d) *Flaps in approach position, section 4b.120 (d).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing and one lower.

C. G. position—optional (see sec. 4b.118–1 (c) (2)).

Wing flaps—approach position (V_{s_1} must not exceed 1.10 V_{s_0}).

Landing gear—retracted.

Operating engine(s)—takeoff r. p. m. and manifold pressure or full throttle, mixture setting at normal position, carburetor air heat control at cold and cowl flaps in approach position.

Critical inoperative engine — throttle closed on engine most critical performancewise (see sec. 4b.118–1 (e) (2)),

propeller feathered and cowl flaps position optional.

(2) *Test procedure and required data.* The airplane should be climbed at the approach climb speed. See section 4b.118–1 for test procedure and required data in connection with climb tests.

(19 F. R. 4453, July 20, 1954, effective Sept. 1, 1954.)

4b.121 *Two-engine-inoperative climb.* For airplanes with four or more engines, the steady rate of climb at any altitude at which the airplane is expected to operate, and at any weight within the range of weights to be specified in the Airplane Flight Manual, shall be determined with:

(a) The landing gear retracted,

(b) Wing flaps in the most favorable position,

(c) Cowl flaps or other means of controlling the engine cooling air supply in the position which will provide adequate cooling in the hot-day condition,

(d) Center of gravity in the most unfavorable position,

(e) The two critical engines on one side of the airplane inoperative and their propellers stopped,

(f) All remaining engines operating at the maximum continuous power available at that altitude.

4b.121–1 *Determination of two engine inoperative climb (CAA policies which apply to sec. 4b.121).*

(a) *Configuration.* This test should be conducted in the configuration that follows:

Weight—two optional weights.

C. G. position—optional (see sec. 4b.118–1 (c) (2)).

Wing flaps—optional.

Landing gear—retracted.

Operating engines—maximum continuous r. p. m and manifold pressure or full throttle, mixture setting at normal position, carburetor air heat control at cold and cowl flaps in CAA hot day cooling position.

Critical inoperative engines—throttles closed on outboard engine most critical performancewise (see sec. 4b.118–1 (e) (2)), and on adjacent engine, propellers feathered and cowl flaps in minimum drag position.

(b) *Test procedure and required data.* See section 4b.118–1 for test procedure and required data in connection with climb tests.

(19 F. R. 4454, July 20, 1954, effective Sept. 1, 1954.)

4b.122 *Determination of the landing distance; general.* The horizontal distance required to land and to come to a complete stop (to a speed of approximately 3 m. p. h. for seaplanes or float planes) from a point at a height of 50 feet above the landing surface shall be determined for a range of weights and altitudes selected by the applicant. In making this determination the following conditions shall apply:

(a) A steady gliding approach shall have been maintained down to the 50-foot altitude with a calibrated aid speed of not less than 1.3 V_{S_0}.

(b) The nose of the airplane shall not be depressed, nor the forward thrust increased by application of power after reaching the 50-foot altitude.

(c) At all times during and immediately prior to the landing, the flaps shall be in the landing position, except that after the airplane is on the landing surface and the calibrated air speed has been reduced to not more than 0.9 V_{S_0} the flap position may be changed.

(d) The landing shall be made in such manner that there is no excessive vertical acceleration, no tendency to bounce, nose over, ground loop, porpoise, or water loop, and in such manner that its reproduction shall not require any exceptional degree of skill on the part of the pilot, or exceptionally favorable conditions.

4b.122–1 *Downwind landings (CAA policies which apply to sec. 4b.122).* Downwind landing data will be approved on the following basis to provide for situations where geographic locations and terrain indicate they are desirable, as well as for use with ILS:

(a) *Performance.* In determining the required distances for landing downwind, the data should be substantiated by actual flight tests. The general methods and procedures should be comparable to those for substantiating landing distances in no wind. The flight tests should be conducted in tailwind velocities up to the maximum velocity for which approval is desired except that the performance tests may be simulated in zero wind as outlined below:

(1) Landings should be demonstrated by approaching and contacting at speeds corresponding to the zero wind speed plus 150 percent of the tailwind velocity for which approval is desired.

(2) In determining the downwind landing distances for the Airplane Flight Manual data, 150 percent of the effect of the reported tailwind velocity should be taken into account. (See sec. 4b.740–1 (d) (2) (x).) This may in some cases, permit calculating the required distances without further tests providing sufficiently high speed landings and decelerations were made in the original type tests. However, except in the cases outlined in (d), actual landings should be made under the conditions described in (b) to check the flight and ground handling characteristics.

(b) *Controllability.* Landings should be made in steady downwind velocities equal to 1.5 times the maximum velocity for which approval is desired to check the controllability at the higher ground speed with correspondingly reduced aerodynamic control forces, dynamic balance of landing gear, nose gear shimmy or vibration, etc. Also actual approaches should be demonstrated under the above wind conditions at an approach angle corresponding to the maximum ILS beam angle (3° 18′) to determine the minimum altitude on the glide path from which the airplane can be readily flared for landing.

(c) *Brakes.* At present it is believed that for calculated landing distance based on actual airplane deceleration tests, the existing brake capacity requirements are sufficient to cover landings in downwind velocities of 10 m. p. h. measured at 50′. However, in wind velocities above 10 m. p. h. and in unusual cases or special types of operation, additional tests or substantiation of the adequacy of the brakes may be necessary and a revision to the braking system may be required. In determining the landing distances under paragraph (a) of this section, normal braking as outlined in section 4b.123 "Landplanes" should not be exceeded.

(d) *Tolerances.*

(1) With regard to performance tests outlined in section 4b.122–1 (a), approval will be given for calculated landing distances for reported tailwind velocities up to 10 m. p. h. measured at 50 feet height without camera tests additional to those required for approval of the no wind data.

(2) With regard to controllability tests outlined in section 4b.122–1 (b), approval will be given for reported downwind velocities up to 10 m. p. h. measured at 50 feet without additional flight tests.

(19 F. R. 1818, Apr. 2, 1954, effective Apr. 2, 1954, amended by 20 F. R. 2277, Apr. 8, 1955, effective Apr. 30, 1955.)

Discussion of Policies Relating to Determination of the Landing Distances in Section 4b.122–2

The purpose of the requirement specified in section 4b.122 is to determine a distance from a point 50 feet above the takeoff surface to land and bring the airplane to rest. This procedure is representative of the actual operating technique and may serve as the basis for the specification of a landing runway length within which a pilot of average skill may reasonably be expected to be able to land the airplane safely under the most adverse weather or other operating conditions likely to be encountered in the actual operation.

The minimum approach speed of 1.3 V_{s_0} specified in section 4b.122 (a) is intended to provide a reasonable margin above the stalling speed. The "steady gliding approach" is an approach at essentially constant indicated air speed for a sufficient length of time prior to reaching the 50-foot point to simulate a continuous approach at this speed.

Sections 4b.122 (b), (c), and (d) are concerned primarily with preventing airplane contact with the runway surface at a very high speed in order to take advantage of the greater deceleration provided by most wheel brake installations

than is available from the drag of the airplane while still airborne. Flight Engineering Report No. 1, "Investigation of the Landing Distance Required by CAR 04.7503 for a Typical Airplane," covers an investigation undertaken to determine the effect of various factors which were considered in drafting section 4b.122 and indicates the critical dependence of the landing distance here defined upon the contact speed. The purposes of section 4b.122 (d) would be defeated if a distance is obtained by making contact at high speed which would require an exceptional degree of skill on the part of the pilot, or to base, a distance upon exceptionally favorable conditions such as wind or the nature of the surface of the runway.

4b.122–2 *Determination of the landing distances (CAA policies which apply to sec. 4b.122).*

(a) When a particular airplane cannot comply with that part of section 4b.122 (d) regarding exceptional degree of skill on the part of the pilot in landing from the 50-foot height with power off, compliance with the regulation should be shown by applying sufficient power during the approach to permit satisfactory landing.

(b) In the tests required by sections 4b.123 through 4b.124 generally one set of data at one altitude should be sufficient to determine the landing distances for altitudes from sea level to 8,000 feet. If a greater range of airport altitudes is desired, the tests should be conducted at two or more altitudes.

(19 F. R. 4454, July 20, 1954, effective Sept. 1, 1954.)

4b.122–3 *Reverse thrust used in determination of landing distance (CAA policies which apply to sec. 4b.122).* The policies outlined in section 4b.402–1 (l) will apply.

(20 F. R. 2277, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.122–4 *Determination of the landing distance with an antiskid device installed (CAA policies which apply to sec. 4b.122).* The policies outlined in section 4b.337–4 will apply.

(21 F. R. 2258, Apr. 19, 1956, effective May 15, 1956.)

4b.123 *Landplanes.* The landing distance referred to in section 4b.122 shall be determined on a dry, hard-surfaced runway in accordance with the following:

(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 skill 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.123–1 *Excessive wear of brakes or tires (CAA interpretation which applies to sec. 4b.123* (b)). "Excessive wear" is interpreted as skidding of a tire or excessive heating of the brakes which requires replacement during a series of five official test landings.

(19 F. R. 4454, July 20, 1954, effective Sept. 1, 1954.)

4b.123–2 *Determination of the landing distance (landplanes) (CAA policies which apply to sec. 4b.123).*

(a) The landing tests should be demonstrated in accordance with the following provisions:

(1) Landings should be made over an imaginary 50-foot obstacle at the maximum landing weight and at a lower weight at one altitude.

(2) During the landing demonstrations, the glide path should be established by the pilot as set forth in section 4b.122. The forward thrust should not be increased beyond the 50-foot obstacle. The ground roll should lie as close to a rectilinear path as possible including the airplane stop point. During each demonstration landing, the airplane should be brought to a complete stop.

(3) *Instrumentation.*

(i) Instrumentation should include a means to record the airplane's glide path relative to the ground and the ground roll against time in a manner to determine the horizontal and vertical distance-time histories.

(ii) A means should be provided to measure the wind velocity and direction, pressure altitude, and ambient air temperature. The wind measurement should be made at the height of 6 feet above the runway surface. If wind effect on runway lengths is shown in the Airplane Flight Manual (see sec. 4b.740–1 (d) (2) (x)), the manual data should be based on reported wind velocities for a 50-foot tower height. Figure 2 should be used to calculate the wind velocity at the 50-foot height from the wind velocity measured at 6 feet above the runway surface.

(iii) The ground roll distance from contact to full stop should be established by observers if it is difficult to establish the exact contact point by graphical means.

(4) A special tolerance of not greater than ±2 percent of the maximum landing weight is allowable for the landing distance tests.

(b) *Configuration.* The landing tests should be demonstrated in the configuration that follows:

Weight—maximum landing and one lower.
C. G. position—most forward for braked landings.
Wing flaps—landing position.
Landing gear—extended.

(c) *Test procedure and required data.*

(1) Three landings should be conducted at each weight with the airplane stabilized in a glide at a calibrated air speed of not less than 1.3 V_{s_0} approximately 1,000 feet (longitudinally) prior to reaching an altitude of 50 feet. Forward thrust should not be increased beyond the 50-foot obstacle; braking should not exceed manufacturer's approved maximum brake pressure and should be applied in such a manner as not to produce excessive wear of brakes and tires as evidenced by five measured landings. If more than one flap setting is to be used for landing, additional tests should be conducted to cover the flap range. (See sec. 4b.118–1 (d) (2).)

(2) The airplane path relative to the runway should be recorded against time in a manner to determine the horizontal and vertical distance–time history. In addition, the following data should be recorded:

Pressure altitude.
Ambient air temperature.
Airplane gross weight.
R. P. M.
Manifold pressure.
Torque pressure.
Carburetor air temperature.
Mixture setting.
Cowl flap position.
Wing flap position.
Slope of field.
Direction of landing run.

(3) [Wind direction, and wind velocity should be recorded adjacent to the runway at a height of 6 feet.]

(19 F. R. 4454, July 20, 1954, effective Sept. 1, 1954; amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957.)

4b.123–3 *Reverse thrust used in landing distance—landplanes (CAA policies which apply to sec. 4b.123 (c)).* The policies outlined in section 4b.402–1 (l) will apply.

(20 F. R. 2277, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.123–4 *Procedure in determination of landing distance with an antiskid device installed (CAA policies which apply to sec. 4b.123).* The policies outlined in section 4b.337–4 will apply.

(21 F. R. 2558, Apr. 19, 1956, effective May 15, 1956.)

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

4b.124–1 *Determination of the landing distance (seaplanes) (CAA policies which apply to sec. 4b.124).* Policies outlined in sections 4b.122–2 and 4b.123–2 will apply.

(19 F. R. 4454, July 20, 1954, effective Sept. 1, 1954.)

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

4b.125–1 *Determination of the landing distances (skiplanes) (CAA policies which apply to sec. 4b.125).* Policies outlined in sections 4b.122–2 and 4b.123–2 will apply.

(19 F. R. 4454, July 20, 1954, effective Sept. 1, 1954.)

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.130–1 *Procedure for demonstrating controllability qualities (CAA policies which apply to sec. 4b.130).* The general controllability and maneuverability qualities of the airplane should be observed and noted throughout the flight test program. The amount of force required to be exerted on the controls in conducting such maneuvers specified in section 4b.130 should also be noted.

(19 F. R. 4454, July 20, 1954, effective Sept. 1, 1954.)

4b.131 *Longitudinal control.*

(a) It shall be possible at all speeds between 1.4 V_{s_1} and V_{s_1} to pitch the nose downward so that a prompt recovery to a speed equal to 1.4 V_{s_1} can be made with the following combinations of configuration:

(1) The airplane trimmed at 1.4 V_{s_1},

(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_{s_1}, the flaps shall be extended as rapidly as possible while maintaining the airspeed 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_{s_1}, 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_{s_1}, take-off power shall be applied quickly while maintaining the same airspeed.

(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_{s_1}, airspeeds within the range of 1.1 V_{s_1} to 1.7 V_{s_1} 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_{s_1} 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 sec. 4b.323.)

Discussion of Policies Relating to Procedure for Demonstrating Longitudinal Control in Section 4b.131–1

Section 4b.131 (b) requires changes to be made in flap position and/or power which are likely to be encountered during an approach when it becomes necessary to go around for another attempt at landing. Its purpose is to insure that any of these changes are possible assuming that the pilot finds it necessary to devote at least one hand to the initiation of the desired operation without being overpowered by the primary airplane controls. It aims at a design such that no excessive change in trim results from the application or removal of power or the extension or retraction of wing flaps. Compliance with its terms also requires that the relation of control force to speed be such that reasonable changes in speed may be made without encountering very high control forces.

Section 4b.131 (c) is concerned with the eventuality of going around during an approach for landing in which event it is obviously desirable to be able to retract the wing flaps quickly and automatically at such a rate that there will be no loss of altitude if power is applied simultaneously with the initiation of flap retraction. The design feature involved in this requirement is the rate of flap retraction.

4b.131–1 *Procedure for demonstrating longitudinal control (CAA policies which apply to sec. 4b.131).* The flight tests specified in (a) through (h) of this section should be made in demonstrating compliance with section 4b.131. These tests may be conducted at an optional altitude (see sec. 4b.100–3 (c)). Where applicable, the following conditions should be maintained on the engines: propellers in low pitch, throttles—closed except as noted; cowl flaps—appropriate for the flight condition.

(a) *Longitudinal control recovery to 1.4* V_{s_1}, *section 4b.131 (a).* The test specified by this requirement should be demonstrated with power off and also with maximum continuous power.

(1) *Configuration.* This test should be conducted in the configuration that follows:

(i) Maximum takeoff weight, flaps and landing gear retracted, c. g. position—most aft.

(ii) Maximum landing weight, flaps extended in the maximum landing position; landing gear extended, c. g. position—most aft.

(The flap extended portion of this test may be combined with tests under (g) of this section.)

(2) *Test procedure and required data.* The airplane should be trimmed at a speed of 1.4 V_{s_1}; the nose should be pitched downward starting from any speed between 1.4 V_{s_1} and V_{s_1}. The rate of increase in airspeed should be satisfactory for prompt acceleration to a speed of 1.4 V_{s_1}. The following data should be recorded:

Weight.
C. G. position.
Wing flap position.
Landing gear position.
Engines, r. p. m. and manifold pressure.
Pressure altitude.
Ambient air temperature.
Trim speed at 1.4 V_{s_1}.
Lowest speed from which pitch is satisfactory.
Altitude lost to regain speed of 1.4 V_{s_1}.

(b) *Longitudinal control, flap extension, section 4b.131 (b) (1).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing.
C. G. position—most forward and most aft.
Wing flaps—retracted.
Landing gear—extended.
Engines—power off.

(2) *Test procedure and required data.* The airplane should be trimmed at a speed of 1.4 V_{s_1}; the flaps should be extended to the maximum landing position as rapidly as possible. During this maneuver, it should be possible to control the airplane with one hand for a reasonable time without the necessity of changing the trim control. The following data should be recorded:

Weight.
C. G. position.
Wing flap position.
Landing gear position.
Engines, r. p. m. and manifold pressure.
Pressure altitude.
Ambient air temperature.
Trim speed at 1.4 V_{s_1}.

(c) *Longitudinal control, flap retraction, section 4b.131 (b) (2).*

(1) *Configuration.* This test should be constructed in the configuration that follows:

Weight—maximum landing.
C. G. position—most forward and most aft.
Wing flaps—maximum landing position.
Landing gear—extended.
Engines—power off.

(2) *Test procedures and required data.* The airplane should be trimmed at a speed of 1.4 V_{s_1}; the flaps should be retracted as rapidly as possible. During this maneuver, it should be possible to control the airplane with one hand for a reasonable time without the necessity of changing the trim control. The same data as

are specified in (b) (2) of this section should be recorded.

(d) *Longitudinal control, flap retraction, section 4b.131 (b) (3).*

The maneuver shown in section 4b.131–1 (c) (2) should be repeated with takeoff power on all engines.

(e) *Longitudinal control, power application, section 4b.131 (b) (4).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing.
C. G. position—most forward and most aft.
Wing flaps—retracted.
Landing gear—extended.
Engines—power off.

(2) *Test procedure and required data.* The airplane should be trimmed at a speed of 1.4 V_{s_1}; takeoff power should be applied quickly without changing the airspeed. During this maneuver, it should be possible to control the airplane with one hand for a reasonable time without the necessity of changing the trim control. The same data as are specified in (b) (2) of this section should be recorded.

(f) *Longitudinal control, power application, section 4b.131 (b) (5).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing.
C. G. position—most forward and most aft.
Wing flaps—maximum landing position.
Landing gear—extended.
Engines—power off.

(2) *Test procedure and required data.* The airplane should be trimmed at a speed of 1.4 V_{s_1}; takeoff power should be applied quickly without changing the airspeed. During this maneuver, it should be possible to control the airplane with one hand for a reasonable time without the necessity of changing the trim control. The same data as are specified in (b) (2) of this section should be recorded.

(g) *Longitudinal control, air speed variation, section 4b.131 (b) (6).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing.
C. G. position—most forward.
Wing flaps—maximum landing position.
Landing gear—extended.
Engines—power off.

(2) *Test procedure and required data.* The airplane should be trimmed at a speed of 1.4 V_{s_1} and it should be possible to control the airplane with one hand for a reasonable time without the necessity of changing the trim control when:

(i) The speed is reduced to 1.1 V_{s_1},
(ii) The speed is increased to 1.7 V_{s_1} or to the placard flap speed.

In addition to the data specified in (b) (2) of this section, the recorded data should also include the airspeeds at 1.1 V_{s_1} and 1.7 V_{s_1} (or V_{FE} whichever is the lesser).

(h) *Longitudinal control, flap retraction and power application, section 4b.131 (c).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing.
C. G. position—most forward and most aft.
Wing flaps—maximum landing position.
Landing gear—extended.
Engines—power noted.

(2) *Test procedure and required data.* The airplane should be maintained in a steady horizontal flight at a speed of 1.1 V_{s_1}; the flaps should be retracted from the maximum landing position with simultaneous application of not more than maximum continuous power. During this maneuver, it should be possible to prevent a loss of altitude without the use of exceptional piloting skill. The following data should be recorded:

Weight.
C. G. position.
Wing flap position.
Landing gear position.
Engines, r. p. m. and manifold pressure before and after tests.
Pressure altitude.
Ambient air temperature.
Airspeed at 1.1 V_{s_1}.

(19 F. R. 4454, July 20, 1954, effective Sept. 1, 1954.)

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_{s_1}, 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_{s_1}, 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_{s_1} 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_{s_1} with maximum continuous power and with the airplane in the configuration prescribed by paragraph (b) of this section.

4b.132–1 *Procedure for demonstrating directional and lateral control (CAA policies which apply to sec. 4b.132).*

(a) When conducting directional and lateral control tests, the airplane should contain appropriate instrumentation in order to obtain the following data:

(1) *Sections 4b.132 (a) and 4b.132 (b).* Instrumentation to indicate airplane heading angle and rudder force.

(2) *Sections 4b.132 (c) and 4b.132 (d).* Instrumentation to measure bank angle.

(b) *General test program.*

(1) *Directional control; general, section 4b.132 (a).*

(i) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing.
C. G. position—most aft.
Wing flaps—approach position.
Landing gear—retracted.
Cowl flaps—appropriate for flight condition.
Operating engine(s)—power to maintain level flight at 1.4 V_{s_1} but more than maximum continuous power.
Critical inoperative engine—propeller feathered on engine most critical for controllability.

(ii) *Test procedure and required data.* The airplane should be trimmed as indicated above at any optional altitude (see sec. 4b.100–3 (c)). Reasonable sudden changes in heading to the left and right, using ailerons to maintain approximate level flight, should be made demonstrating a change of 15°, or the angle at which a dangerous condition is encountered, or at which 180 lbs. rudder force is required. The airplane should be satisfactorily controllable during this maneuver. The following data should be recorded:

Weight.
C. G. position.
Wing flap position.
Landing gear position.
Operating engine(s), r. p. m. and manifold pressure.
Position of critical inoperative engine and its propeller.
Pressure altitude.
Ambient air temperature.

Trim speed at 1.4 V_{s_1}.
Rudder force at maximum deflection.

(2) *Directional control; four or more engines, section 4b.132 (b).*

(i) *Configuration.* This test should be conducted in the configuration that follows:
Weight—maximum landing.
C. G. position—most forward.
Wing flaps—climb position.
Landing gear—retracted.
Operating engines—power required for level flight at 1.4 V_{s_1} but not more than maximum continuous power.
Critical inoperative engines—propellers feathered on outboard engine most critical for controllability and on adjacent engine.

(ii) *Test procedure and required data.* The test procedure shown in (b) (1) (ii) of this section should be repeated with two critical engines inoperative. In addition to the data specified in (b) (1) (ii) of this section, the position of the critical inoperative engines and the propeller configuration should also be recorded.

(3) *Lateral control; general, section 4b.132 (c).*

(i) *Configuration.* This test should be conducted in the configuration that follows:
Weight—maximum takeoff.
C. G. position—most aft.
Wing flaps—climb position.
Landing gear—retracted and extended.
Operating engine(s)—maximum continuous power.
Critical inoperative engine—throttle closed on engine most critical for controllability, propeller feathered.

(ii) *Test procedure and required data.* Banked turns of 20° should be demonstrated with and against the inoperative engine from a steady climb at 1.4 V_{s_1}. The following data should be recorded:
Weight.
C. G. position.
Wing flap position.
Landing gear position.
Engine(s), r. p. m. and manifold pressure.
Position of critical inoperative engine and its propeller.
Pressure altitude.
Ambient air temperature.

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Trim speed at 1.4 V_{s_1}.
Rudder force at maximum deflection.
Aileron force at maximum deflection.

(4) *Lateral control; four or more engines, section 4b.132 (d).*

(i) *Configuration.* This test should be conducted in the configuration that follows:
Weight—maximum landing.
C. G. position—most forward.
Wing flaps—climb position.
Landing gear—retracted.
Operating engines—power required for level flight at 1.4 V_{s_1} but not more than maximum continuous power.
Critical inoperative engines—propellers feathered on outboard engine most critical for controllability and on adjacent engine.

(ii) *Test procedure and required data.* Banked turns of 20° should be demonstrated with and against inoperative engines from steady flight at 1.4 V_{s_1}. The same data as are specified in (b) (3) (ii) of this section should be recorded.

(19 F. R. 4455, July 20, 1954, effective Sept. 1, 1954.)

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_{s_1} 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 section 4b.133 (a) as requiring the Administrator to accept for the purposes of section 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 section 4b.10 for demonstrating compliance with the take-off path and climb requirement of sections 4b.116 and 4b.120 (a) and (b).

4b.133–1 *Determination of the minimum control speed,* V_{MC} (*CAA policies which apply to sec. 4b.133*).

(a) When demonstrating the minimum control speed, the applicant may choose one of three basic methods dependent on the inherent characteristics of the airplane or a combination of the methods is acceptable provided that the combination chosen does not allow the aircraft to exceed any of the limiting factors specified in section 4b.133. These methods are:

(1) With wings level and 180 lbs. rudder force, or full rudder travel causing airplane to deviate from a constant heading, or airplane stall.

(2) With the wing on the engine operating side lowered 5° and 180 lbs. rudder force, or full rudder travel causing airplane to deviate from a constant heading, or airplane stall.

(3) At 0° yaw and full rudder travel causing airplane to deviate from zero degree yaw, or 180 lbs. rudder force, or airplane stall.

(b) When it has been found that the aircraft is limited by the 180 lbs. rudder force in any of the methods in (a) of this section, a plot of force vs. airspeed should be made through a suitable range of speeds to substantiate the speed chosen as V_{MC}.

(c) Generally speaking, in aircraft equipped with right-hand rotation propellers, the left-hand outboard engine is the most critical when inoperative from the standpoint of control. This condition should be substantiated, however, by a comparative test with both the right and then the left outboard engines inoperative, measuring the force necessary to hold the airplane within the limits as specified in section 4b.133 at or slightly above the minimum control speed. When conducting this test it is imperative to hold all remaining factors equal so that a true comparison may be accomplished.

(d) All testing should be accomplished at the appropriate weights and powers for the range of approval desired. The minimum control speed should be determined for each takeoff flap position selected for approval if the takeoff flap is made variable with altitude.

(e) Civil Air Regulation Part 4b, Interpretation No. 1, interprets section 4b.133 (a) (8) as requiring the establishment of one engine inoperative minimum control speed with the propeller of the inoperative engine feathered providing that the airplane is equipped with an automatic feathering device acceptable to the Administrator under section 4b.10 for demonstration of compliance with the takeoff path and climb requirements of sections 4b.116 and 4b.120 (a) and (b). In such cases where the applicant chooses to demonstrate V_{MC} with the propeller feathered, the value of V_{MC} with the propeller windmilling should also be obtained and included in the Airplane Flight Manual.

(f) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff. (If stall occurs prior to reaching V_{MC}, applicant may choose to demonstrate a lower V_{MC} at a reduced weight.)

C. G.—most aft.

Wing flaps—takeoff position.

Landing gear—retracted.

Operating engine(s)—takeoff r. p. m. and manifold pressure or full throttle, cowl flaps in takeoff position.

Inoperative engine—throttle closed, propeller windmilling or any other logical position, cowl flaps in takeoff position.

(g) *Test procedure and required data.* After establishing the critical inoperative engine and the choice of method for demonstration, the tests for establishing the minimum control speed may be conducted. Using the configuration specified in section 4b.133, all engines should be adjusted for takeoff power and a series of engine cuts made by moving the mixture control of the critical engine in idle cut-off position at consecutively lower airspeeds until one of the limiting factors specified in section 4b.133 is experienced. When the minimum control speed is determined, a minimum of five demonstrations should be made to provide adequate proof that the chosen value meets the requirement. The following data should be recorded:

Pressure altitude.
Ambient air temperature.
Indicated air speed.
Engines, r. p. m. and manifold pressure.
Torque pressure.
Carburetor air temperature.
Rudder force.
Bank angle.
Gyro direction indicator.
Yaw—if method is chosen where loss of airplane's ability to maintain 0° yaw is limiting factor specified in (a) (3) of this section.

(19 F. R. 4456, July 20, 1954, effective Sept. 1, 1954.)

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 sections 4b.141 through 4b.144.

4b.140–1 *General trim qualities (CAA policies which apply to sec. 4b.140).* It should be possible to trim the airplane completely for any flight condition which is reasonable to assume will be maintained steadily for any appreciable time. Compliance for unsymmetrical power should be demonstrated with "wings level" or "zero yaw" when a yawmeter is installed as a part of the required equipment.

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_{S_1} to V_{NO} or to M_{NO}, whichever is the lesser.

4b.141–1. *Procedure for demonstrating lateral and directional trim (CAA policies which apply to sec. 4b.141).*

(a) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff and maximum landing.
C. G. position—most forward and most aft with greatest lateral variation in useful load. Asymmetrical fuel loading should be considered.
Wing flaps—retracted and maximum landing position.
Landing gear—retracted and extended.
Engines—power required for level flight.
Cowl flaps—appropriate for flight condition.

(b) *Test procedure and required data.* It should be possible to maintain hands-off lateral and directional trim [when demonstrating compliance with section 4b.141]. The following data should be recorded:

Weight.
C. G. position.
Wing flap position.
Landing gear position.
Engines, r. p. m. and manifold pressure.
Pressure altitude.
Ambient air temperature.
Trim speed at 1.4 V_{S_1}.
(Additional lateral and directional trim should be demonstrated in other configurations in conjunction with tests in sec. 4b.150.)

(Amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957.)

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_{S_1} 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_{S_1} 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_{S_1} to V_{NO} or to M_{NO}, whichever is the lesser, with the landing gear and wing flaps retracted, and from 1.4 V_{S_1}, to V_{LE} with the landing gear extended.

4b.142–1 *Procedure for demonstrating longitudinal trim (CAA policies which apply to sec. 4b.142).*

(a) *Longitudinal trim during climb, section 4b.142 (a).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—most forward.
Wing flaps—retracted and takeoff position.
Landing gear—retracted.
Engines—maximum continuous power.
Cowl flaps—optional.

(2) *Test procedure and required data.* It should be possible to maintain hands-off longitudinal trim at a speed not in excess of 1.4 V_{S_1} with the wing flaps retracted and in the takeoff position. The same data specified in section 4b.141–1 (b) should be recorded.

(b) *Longitudinal trim during glide, section 4b.142 (b).*

(1) *Configuration.* This test should be conducted in the configurations that follow:

Weight—maximum landing.
C. G. position—most forward for maximum landing weight.
Wing flaps—retracted and maximum landing position.
Landing gear—extended.
Engines—power off, propellers windmilling.

(2) *Test procedure and required data.* It should be possible to maintain hands-off longitudinal trim at a speed not in excess of 1.4 V_{S_1} with the wing flaps retracted and extended. This test should be repeated with the most forward c. g. position for landing regardless of weight. The same data specified in section 4b.141–1 (c) should be recorded.

[“(c) *Longitudinal trim during level flight, section 4b.142 (c).*

[(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—most forward and most aft.
Wing flaps—retracted.
Landing gear—retracted and extended.
Engines—power required for level flight.
Cowl flaps—appropriate for flight condition.

[(2) *Test procedure and required data.* It should be possible to maintain hands-off longitudinal trim when demonstrating compliance with section 4b.142 (c).”]

(19 F. R. 4456, July 20, 1954, effective Sept. 1, 1954; amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957.)

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_{S_1} 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.143–1 *Procedure for demonstrating longitudinal, directional, and lateral trim (CAA policies which apply to sec. 4b.143).*

(a) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—most forward.
Wing flaps—retracted.
Landing gear—retracted.
Cowl flaps—appropriate for flight condition
Operating engine(s)—maximum continuous power.

Critical inoperative engine—throttle closed on engine most critical for trim, propeller feathered.

(b) *Test procedure and required data.* It should be possible to maintain hands-off longitudinal, directional, and lateral trim during climb at a speed of 1.4 V_{s_1}. In addition to the data specified in section 4b.141–1 (b), the position of the critical inoperative engine and its corresponding propeller should be recorded.

(19 F. R. 4457, July 20, 1954, effective Sept. 1, 1954.)

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 section 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 $V_{s_0}^2$ at an altitude of 5,000 feet.

4b.144–1 *Procedure for demonstrating trim for airplanes with four or more engines (CAA policies which apply to sec. 4b.144).*

(a) *Configuration.* This test should be conducted in the configuration that follows:

Weight—at which climb is equal to at least .01 $V_{s_0}^2$ at an altitude of 5,000 feet.
C. G. position—most forward.
Wing flaps—optional.
Landing gear—retracted.
Cowl flaps—appropriate for flight condition.
Operating engines—maximum continuous power.
Inoperative engines—throttles closed on outboard engine most critical for trim and on adjacent engine, propellers feathered.

(b) *Test procedure and required data.* It should be possible to maintain hands-off longitudinal, lateral, and directional trim at the same airspeed used in demonstrating the two-engine-inoperative climb (see sec. 4b. 121). The following data should be recorded:

Weight.
C. G. position.
Wing flap position.
Landing gear position.
Operating engines, r. p. m., manifold pressure and cowl flap position.
Position of critical inoperative engines and their propellers.
Pressure altitude.
Ambient air temperature.
Climb speed.

(19 F. R. 4457, July 20, 1954, effective Sept. 1, 1954.)

Stability

4b.150 *General.* The airplane shall be longitudinally, directionally, and laterally stable in accordance with sections 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.

Discussion of Policies Relating to the General Stability Qualities in Section 4b.150–1

Stability is closely related to trim in that if stability is absent, trimming is impossible. It should be noted that in sections 4b.151 through 4b.158 a great deal more attention is devoted to longitudinal stability than to the lateral stability because the longitudinal stability as affected by elevator control is intimately involved in the establishment of center of gravity limits, while the lateral characteristics ordinarily have negligible effect upon these limits. It should also be noted that, concerning longitudinal stability, the static stability is a function of positivity of return force as displayed at the pilot's controls, whereas the dynamic stability is specified in terms of the behavior which the airplane should exhibit when certain specific things are done with the elevator control. It has been attempted in this manual to cover those specific flight regimes in which stability is considered essential. It is believed that these are

critical in the sense that if the required stability is obtained in these conditions it will probably also be obtained in any other flight condition likely to be encountered with the airplane.

4b.150–1 *General stability requirements (CAA policies which apply to sec. 4b.150).* If an airplane design is encountered in which critical stability conditions may exist other than those prescribed in sections 4b.151 through 4b.157 they should be investigated.

(19 F. R. 4457, July 20, 1954, effective Sept. 1, 1954.)

4b.151 *Static longitudinal stability.* In the conditions outlined in sections 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.

Discussion of Policies Relating to Procedure for Demonstrating Static Longitudinal Stability in Section 4b.151–1

Static stability is specified in terms of control forces because it is believed necessary and desirable to provide "feel" of the airplane for the pilot through this medium. Thus it may be seen that elimination of friction from the control system is an important factor which should be considered in connection with static stability. The elevator control force requirements prescribed in section 4b.151 will safeguard against inadvertent stalls or inadvertent elevator control operation at excessive speeds, providing easy handling qualities during instrument flight, and will generally hold to a minimum the amount of attention and skill required of a pilot during landings, takeoffs, and the other normal operating conditions.

4b.151–1 *Procedure for demonstrating static longitudinal stability (CAA policies which apply to sec. 4b.151).*

(a) Once the airplane has been trimmed, it should tend to maintain the trim speed so that a conscious effort is required by the pilot to depart from that speed. A forward pressure on the control column should be necessary to increase the airspeed and the reverse for a decrease in the airspeed. These forces should be such that departures in speed in either direction from the trim speed would require control column pressure that increases approximately proportionately as the speed departs from the trim speed.

(b) It should be possible to make such changes in speed as may be required to perform a maneuver without the necessity of readjusting the trim in order to relieve very high control forces which would otherwise be necessary. Figure 3 has been prepared to indicate what should be required in the way of static longitudinal stability qualities.

(c) When conducting the stability tests specified in sections 4b.152 through 4b.155, the elevator control force required to hold a given stabilized airspeed should be measured at airspeeds within the range specified by the requirements to define the curve of elevator control force versus airspeed. The elevator control force should be measured at intervals of 20 m. p. h. in the region where the force indicates definite stability, and at 10 m. p. h. intervals when any change in stability becomes apparent.

An elevator control force indicator should be installed in the airplane in order to obtain this data. During these tests the airplane should return to an airspeed within 10 percent of the original trim speed when the control is released slowly from speeds above and below the trim speed.

(19 F. R. 4457, July 20, 1954, effective Sept. 1, 1954.)

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_{S_1} and 1.8 V_{S_1} 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_{S_1} with throttles closed.

4b.152–1 *Procedure for demonstrating stability during landing (CAA policies which apply to sec. 4b.152).*

(a) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing.
C. G. position—most forward and/or most forward at maximum landing weight and most aft.
Wing flaps—maximum landing position.
Landing gear—extended.
Engines—power off, propellers windmilling.
Cowl flaps—appropriate for flight condition.

(b) *Test procedure and required data.* The airplane should be trimmed at a speed of 1.4 V_{S_1} at any optional altitude (see sec. 4b.100–3 (c)). Static longitudinal stability should be demonstrated at speeds from just above the stall to 1.8 V_{S_1} (or placard speed). The elevator control force necessary to maintain each speed should be recorded at approximate even increments of velocity within the above speed range. The speed range representing the maximum friction band from which the airplane will not return to the trim speed should be recorded. For aircraft having an increase in stable elevator control force gradient with forward c. g. travel, only the maximum force need be checked at forward c. g. Lateral and directional trim should also be checked (see sec. 4b.141–1). The following data should be recorded:

Weight.
C. G. position.
Wing flap position.
Landing gear position.
Engines, r. p. m. and manifold pressure.
Pressure altitude.
Ambient air temperature.
Trim speed.
Elevator control force.

(19 F. R. 4458, July 20, 1954, effective Sept. 1, 1954.)

4b.153 *Stability during approach.* The stick force curve shall have a stable slope at all speeds between 1.1 V_{S_1} and 1.8 V_{S_1} with:

(a) Wing flaps in sea level approach position,

(b) Landing gear retracted,

(c) Maximum landing weight,

(d) The airplane trimmed at 1.4 V_{S_1} and with power sufficient to maintain level flight at this speed.

4b.153–1 *Procedure for demonstrating stability during approach (CAA policies which apply to sec. 4b.153).*

(a) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum landing.
C. G. position—most aft.
Wing flaps—approach position.
Landing gear—retracted.
Engines—power required for level flight at 1.4 V_{S_1}.
Cowl flaps—approach position.

(b) *Test procedure and required data.* The same procedures and data as outlined in section 4b.152–1 (b) should be followed in demonstrating stability for the approach configuration.

(19 F. R. 4458, July 20, 1954, effective Sept. 1, 1954.)

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 for reciprocating-engine-powered airplanes; and maximum power thrust selected by the applicant as an operating limitation for use during climb (see sec. 4b.718) for turbine-engine-powered airplanes,

(e) The airplane trimmed at the best rate-of-climb speed, except that the speed need not be less than 1.4 V_{S_1}.

4b.154–1 *Procedure for demonstrating stability during climb (CAA policies which apply to sec. 4b.154).*

(a) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—most aft.
Wing flaps—retracted.
Landing gear—retracted.
Engines—[the power specified in section 4b.154 (d).]
Cowl flaps—appropriate for flight condition.

(b) *Test procedure and required data.* The airplane should be trimmed at the best rate of climb speed except that this speed need not be less than 1.4 V_{S_1}. Static longitudinal stability should be demonstrated at speeds from just above the stall to the speed at which the control force becomes excessive but not to exceed V_{NE}. The curve of elevator control force vs. speed should have a stable slope between 85 percent and 115 percent of the trim speed and no reversal of elevator control force should occur throughout the speed range tested. Further test procedures and data to be recorded should be the same as are specified in section 4b.152–1 (b).

(19 F. R. 4458, July 20, 1954, effective Sept. 1, 1954; amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957).

4b.155 *Stability during cruising.*

(a) *Landing gear retracted.* Between 1.3 V_{S_1} 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, or the maximum cruising power selected by the applicant as an operating limitation (see sec. 4b.718), whichever is the greater, except that the power need not exceed that required at V_{NO},

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

(b) *Landing gear extended.* The stick force curve shall have a stable slope at all speeds between 1.3 V_{S_1} 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 of maximum continuous power, or the maximum cruising power selected by the applicant as an operating limitation, whichever is the greater, except that the power need not exceed that required for level flight at V_{LE},

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

4b.155–1 *Procedure for demonstrating stability during cruising (CAA policies which apply to sec. 4b.155).*

(a) *Cruising, landing gear retracted, section 4b.155 (a).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—most aft.
Wing flaps—retracted.
Landing gear—retracted.
Engines—[the power specified in section 4b.155 (b) (3).]
Cowl flaps—optional.

(2) *Test procedure and required data.* The airplane should be trimmed at the speed for level flight with [the power specified in section 4b.155 (b) (3).] Static longitudinal stability should be demonstrated at speeds from just above the stall to the speed at which the control forces become excessive (50 lbs.), but not to exceed V_{NE}. Further test procedure and data to be recorded should be the same as are specified in section 4b.152–1 (b).

(b) *Cruising, landing gear extended, section 4b.155 (b).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—most aft.
Wing flaps—retracted.
Landing gear—extended.

Engines—[the power specified in section 4b.155 (b) (3).]

Cowl flaps—appropriate for flight condition.

(2) *Test procedure and required data.* The airplane should be trimmed at the speed for level flight with [the power specified in section 4b.155 (b) (3).] Static longitudinal stability should be demonstrated at speeds from just above the stall to the speed at which the control forces become excessive (50 lbs.), but not to exceed V_{LE}. Further test procedures and data to be recorded should be the same as are specified in section 4b.152–1 (b).

(19 F. R. 4458, July 20, 1954, effective Sept. 1, 1954; amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957.)

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.156–1 *Procedure for demonstrating dynamic longitudinal stability (CAA policies which apply to sec. 4b.156).* Damping of accelerations and movement of the control should be noted when:

(a) The control column is quickly offset and immediately released and

(b) The control column is quickly offset and immediately returned to the trim position and held in this position.

(19 F. R. 4458, July 20, 1954, effective Sept. 1, 1954.)

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_{S_1} 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_{S_1}.

(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.157–1 *Procedure for demonstrating static directional and lateral stability (CAA policies which apply to sec. 4b.157).*

(a) No real motion of the airplane involving roll is possible without yaw also being involved, and vice versa. In showing compliance with section 4b.157 the rolling and yawing stability should be investigated separately.

(b) Directional stability [should] be investigated by starting from steady flight in the required configuration and deflecting the rudder at a fairly rapid rate by the amount required to maintain a steady skid with the airplane yawed approximately 20° (as read on the directional gyro) while the wings are maintained level by use of the ailerons, and the speed held constant by means of the elevator control. When the steady condition has been established, the rudder should be released and, if the airplane is directionally stable, it should cease to skid; i. e., the yaw should decrease to approximately zero and, if also laterally stable the aileron deflection and force required to hold the wings level should also approach zero. The test should be conducted by executing skids both to the right and left, recording in each case the time required from the release of the rudder controls and the number of oscillations, if any, involved to recover to steady level flight.

(c) Lateral stability should be investigated by starting from steady flight in the required configuration and banking the airplane approximately 20° (as read on the gyro horizon) by means of the ailerons, while maintaining the original heading by means of the rudder, and

the original speed by means of the longitudinal trimming device. When the steady slipping condition has been established, the aileron control should be released. If the airplane is laterally stable, it should cease to slip; i. e., the wing should return to an approximately level attitude, and the rudder deflection and pedal force required to maintain the heading should approach zero. The test should be conducted by executing slips from both to right and left, and in each case the time required from the release of the aileron control and the number of oscillations, if any, involved to recover to steady level flight should be recorded.

(d) In addition to the directional and lateral stability tests, section 4b.157 (c) contains provisions which should be used to test the airplane for rudder overbalance.

(e) *Static directional stability test, section 4b.157 (a) and (c).* *CAUTION*: Prior to conducting this test and that in (f), complete agreement should be reached between the applicant and the CAA Flight Test Inspector to insure that the severity of control application will not result in loads exceeding the design limitations.

(1) *Configuration.* This test should be conducted in the configurations that follow:

Maximum takeoff weight with wing flaps retracted.

Maximum landing weight with wing flaps extended.

C. G. position—most aft.

Wing flaps—retracted and maximum landing position.

Landing gear—retracted and extended.

(2) *Test procedure and required data.* The following tests should be conducted at the altitude deemed most critical for the combination of power and aerodynamic damping effect:

(i) The airplane should be yawed slowly to the left and right using ailerons to hold wings level, and, when controls are released slowly, the tendency of airplane to recover from the skid should be noted.

(ii) The qualitative proportionality of rudder and aileron deflection and force during steady straight sideslips should be noted.

(iii) Damping of yawing and movement of control should be noted when the rudder is quickly offset and immediately released and when the rudder is quickly offset and immediately returned and held in the trim position.

(3) The tests in (e) (2) of this section should be conducted in the following configurations:

(i) Flaps in landing position and gear extended, at 1.2 V_{s_1}, power off, and 75 percent maximum continuous power.

(ii) The flaps and gear retracted at 1.2 V_{s_1}, and V_c with 75 percent maximum continuous power.

(iii) Flaps and gear retracted at 1.2 V_{s_1}, with power off.

(4) The following data should be recorded for the tests specified in (e) (2) and (e) (3) of this section:

Weight.

C. G. position.

Wing flap position.

Landing gear position.

Engines, r. p. m. and manifold pressure.

Pressure altitude.

Ambient air temperature.

Air speed at V_{FE}, 1.2 V_{s_1} and V_c.

Rudder force at maximum deflection.

(f) *Static lateral stability test, section 4b.157 (b).*

(1) *Configuration.* This test should be conducted in the configurations that follow:

Maximum takeoff weight with flaps retracted.

Maximum landing weight with flaps extended.

C. G. position—most aft.

Wing flaps—retracted and maximum landing position.

Landing gear—retracted and extended.

(2) *Test procedure and required data.* The following tests should be conducted in the configurations specified in (e) (3) and at the altitude deemed most critical for the combination of power and aerodynamic damping effect.

(i) Starting from steady straight flight the airplane should be banked 20° while a constant heading is held; the aileron control should then be released. The stability as evidenced by the tendency to raise the low wing should be positive at high speed and should not be negative at 1.2 V_{s_1}.

(ii) Damping of rolling motion and movement of controls should be noted when the aileron is quickly offset and immediately

released and also when the aileron is quickly offset and immediately returned and held in the trim position.

(iii) The same data as are specified in (e) (4) should be recorded at air speeds of 1.2 V_{S_1} and V_c.

(19 F. R. 4458, July 20, 1954, effective Sept. 1, 1954; amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957.)

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 the primary controls free and in a fixed position.**

4b.158–1 *Procedure for demonstrating dynamic directional and lateral stability (CAA policies which apply to sec. 4b.158).* Damping of yawing and movement of the control should be noted during the test procedure in section 4b.157–1 (e) (2) (iii).

(19 F. R. 4459, July 20, 1954, effective Sept. 1, 1954.)

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_{S_1}, where V_{S_1} 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_{S_1}, 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, except that for airplanes demonstrating unmistakable inherent aerodynamic warning associated with the stall in all required configurations, the speed need not be reduced below a value which provides an adequate stall warning margin as defined in section 4b.162.

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 case to be sufficiently clear. Types of inherent aerodynamic warning considercd acceptable included characteristics such as buffeting, small amplitude pitch or roll oscillations, distinctive shaking of the pilots' control, etc.

(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.

Discussion of Policies Relating to Procedure for Demonstrating Stall Tests, Symmetrical Power in Section 4b.160–1

Flight tests have shown that the point of maximum lift in the time-history data may be obtained with sufficient accuracy from an accelerometer mounted perpendicular to the wing MAC axis if excessive angles-of-attack are not obtained. Mounting an accelerometer in this manner, however, gives acceleration along the normal force vector and not along the lift vector. This results in acceleration readings which are affected by longitudinal acceleration. Nevertheless, if a deceleration rate of not greater than 1 m. p. h./sec. $\left(\frac{1\times1.467}{32.2}=.05g\right)$ is maintained in the stall maneuver, the effect of longitudinal acceleration will be negligible.

Indicated acceleration is affected by the angle which the vertical axis of the accelerometer makes with a perpendicular to the earth's surface. Thus, for very high stall angles an accelerometer mounted perpendicular to the MAC will indicate a decrease in load factor merely due to rotation of the instrument. Since it is theoretically desirable to obtain acceleration along the lift vector (perpendicular to the flight path), and since tests have shown that the flight path during the stall maneuver is approximately level regardless of configuration down to the stall, it seems obvious that mounting the accelerometer so that its vertical axis is offset from a line perpendicular to the wing MAC by an angle equal to the angle-of-attack for C_L max. will reduce error due to improper orientation of the accelerometer axis. At angle-of-attack for C_L max., $L=\eta W$ if angle-of-attack for C_L max. was properly chosen; the error in lift either side of L_{max}, will be off by the cosine of the angular difference between the actual angle-of-attack and the angle at which the accelerometer was set. Calculations show that any reasonable angular error in setting the accelerometer will not significantly affect the shape or location of the lift curve peak.

In regard to measurement of angle-of-attack, determination of true angle-of-attack would require calibration of the indicator for each of several configurations. However, compliance with the regulation does not require knowledge of true angle-of-attack but only assurance that true angle-of-attack is increasing steadily as the maximum lift is exceeded. Since calibration of known angle-of-attack devices shows that the difference between true angle and indicated angle is proportional to C_L, then knowledge of variation of indicated angle-of-attack during the stall maneuver will be sufficient.

4b.160–1 *Procedure for demonstrating stall tests, symmetrical power (CAA policies which apply to sec. 4b.160 (c) (2)).*

(a) The angle-of-attack during the stall maneuver should be increased at least to the point where the following two conditions are satisfied:

(1) Attainment of an angle-of-attack measurably greater than that for maximum lift.

(2) Clear indication to the pilot through the inherent flight characteristics that the airplane is stalled.

(b) The following procedure may be used to demonstrate that these two conditions are fulfilled:

(1) A photopanel or equivalent method of obtaining continuous records of the following variables at not greater than ¼ second intervals should be provided: indicated angle-of-attack, swivel static and shielded total pressure head or equivalent, pressure altitude, pitch and bank angle, normal acceleration, elevator position and force, aileron and rudder position.

(2) If it is evident that longitudinal stick force is always positive, that is, no reversal exists down to the stall, then time history of this item should not be required.

(3) In order to insure that an accurate recording of the indicated angle-of-attack is obtained, the sensing device should be located in a region where tuft surveys show that the streamlines undergo no radical change in direction up to the maximum angle contemplated. Regions well forward of the wing leading edge are desirable to keep the angular difference between true angle and indicated angle as small as possible.

(4) Means for indicating the stall-warning point and the point at which the pilot is informed by the inherent flight characteristics that the airplane is stalled should be provided. This may consist of a light on the photopanel operable by a switch mounted on the control wheel. In order to insure that the camera records the light image a time delay device may need to be incorporated in the light circuit in cases where camera speed is low.

(c) *Configuration.* Stalls should be conducted in the configurations noted in the following listings and with cowl flaps appropriate for the flight condition. Power-off stalls should be conducted with the engines idling and propellers in low pitch. For power-on conditions, stalls should be conducted with that power necessary to maintain level flight at a speed of 1.6 V_{S_1} with flaps in the approach position, landing gear retracted and maximum landing weight.

(1) Stalls—straight flight:

Gross weight	C. G.	Power	Flap	Gear
Max. Land	Most Fwd	Off	Retr	Retr.[8]
Do	do	do	T. O	Do.[8]
Do	do	do	Appr	Do.[8]
Do	do	do	Land	Ext.[8]
Do	do	On	Appr	Do.[9]
Do	do	do	Land	Do.[9]
Do	Most Aft	Off	Appr	Do.[9]
Do	do	do	Land	Do.[9]
Do	do	On	Appr	Retr.
Do	do	do	do	Ext.
Do	do	do	Land	Retr.
Do	do	do	do	Ext.
Max. T. O	do	Off	Retr	Ext.[9]
Do	do	do	T. O	Do.[9]
Do	do	On	Retr	Do.[9]
Do	do	do	T. O	Do.[9]

[8] May be demonstrated during stalling speed tests. See section 4b.112.

[9] Use extended, unless, due to direction of C. G. shift with gear, retracted gear is more critical. If retracted is more critical use retracted position for these stalls.

(2) Stalls—30° banked turns:

Gross weight	C. G.	Power	Flap	Gear	Direction
Max. T. O	Most Aft	Off	Retr	Retr	To right
Do	do	do	do	do	To left
Do	do	On	do	do	To right
Do	do	do	do	do	To left
Max. Land	do	Off	Land	Extend	To right
Do	do	do	do	do	To left
Do	do	On	do	do	Do.
Do	do	do	do	do	To right

(d) *Test procedure and required data.* The stall tests may be conducted at any optional altitude (see sec. 4b.100–3 (d)). The flight test procedure should be conducted in accordance with section 4b.160 (c) (1). The pilot should be provided with a yawmeter or equivalent means for maintaining the angle of yaw as near zero as possible. The operation of the photopanel recording system, previously described in (b) (1) of this section, should be started at least 20 m. p. h. above the stall speed and allowed to operate continuously until the stall recovery is completed. The pilot's indication of stall warning and the actual occurrence of the stall should be obtained. In addition to the data obtained on the photopanel shown in (b) (1) of this section, the following information should also be recorded:

Weight.
C. G. position.
Ambient air temperature.
Wing flap position.
Landing gear position.
Engines, r. p. m. and manifold pressure.

(e) *Data analysis.* Time histories should be panel of the photopanel instruments. The stalling warning point (see sec. 4b.162–1) and the point at which "the inherent flight characteristics give a clear indication that the airplane is stalled" should be noted on the plots.

(1) Inspection of the plots will then show if the following two conditions are fulfilled:

(i) The indicated angle-of-attack increases steadily to a value measurably beyond that for maximum lift, and

(ii) The stall is evident to the pilot prior to initiation of recovery.

(2) Consideration should be given to the following points in the time-history analysis:

(i) The direction in which the elevator is moving, i. e., any nose down pitch or decrease in load factor not induced by inadvertent elevator motion,

(ii) Rudder and aileron movement with respect to uncontrollable roll,

(iii) The effect of lag in the airspeed system,

(iv) Rate of airspeed change,

(v) Effect of pitching velocity or rolling velocity on indicated angle-of-attack. If possible, angle-of-attack time history should be drawn through points where pitching or rolling velocity are small. If corrections are unavoidable, the angular correction is simply $\tan^{-1}$ pd/V where p is the rolling or pitching velocity, V is the true airspeed, and d is the distance from the pitch or rolling axis, as the case may be, to the sensing device. It should be noted that this correction is applicable to either true or indicated angle-of-attack.

(vi) The indicated acceleration is a function of the angle the vertical axis of the accelerometer makes with the perpendicular to the earth's surface. Therefore, bank angle will seriously affect the maximum lift point. For example, a bank of 45° without loss of lift will result in a drop in indicated acceleration from 1.00 to .707. As a result acceleration data obtained in the region of $C_{L\,max.}$ should be disregarded or corrected for bank angle when the bank angle exceeds nine or ten degrees.

(19 F. R. 4459, July 20, 1954, effective Sept. 1, 1954.)

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,

(2) 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.161–1 *Procedure for demonstrating stall tests, asymmetrical power (CAA policies which apply to sec. 4b.161).*

(a) During this test the airplane should not become uncontrollable or lose an excessive amount of altitude when so stalled.

(b) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—most aft.
Wing flaps—retracted.
Landing gear—retracted.
Operating engine(s)—power up to 75 percent maximum continuous power, cowl flaps optional.
Critical inoperative engine—propeller optional, feathered or windmilling, cowl flaps appropriate for flight condition.
Trim speed—1.4 V_{s_1}.

(c) *Test procedure and required data.* This test may be conducted at any optional altitude (see sec. 4b.100–3 (c)). See section 4b.160 (c) regarding test procedure.

(1) The speed of the airplane should be reduced from the trim condition with the wings held level until the first of the following occurs:

(i) Full rudder or aileron deflection.
(ii) 180 lbs. rudder force.
(iii) Stall is reached.

(2) If full rudder or aileron deflection, or the 180 lbs. rudder force occurs first, the power should be reduced and the test repeated until sufficient control is available to complete the stall. The power may be reduced on the operating engine(s) before reapplying power on the operating engine or engines for the purpose of regaining level flight. The following data should be recorded at that point:

Pressure altitude.
Ambient air temperature.
Indicated air speed.
Engines, r. p. m. and manifold pressure.
Torque pressure.
Carburetor air temperature.
Rudder force (if desirable).

(3) If stall is reached first, the same data should be recorded.

(19 F. R. 4460, July 20, 1954, effective Sept. 1, 1954.)

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.

Discussion of Policies Relating to Stall Warning in Section 4b.162–1

Occurrence of stall warning at some specific speed margin above the stalling speed is no longer required. It has been found that certain other characteristics may exist which make an airplane less susceptible to inadvertent stalling than one in which a specific speed margin has been provided between the occurrence of stall warning and the actual stall.

4b.162–1 *Stall warning (CAA policies which apply to sec. 4b.162).*

(a) The adequacy of stall warning should depend on the relative ease with which an airplane might be inadvertently stalled following the occurrence of stall warning. For example, if unmistakable warning occurs only 2 percent above the stall speed but undue pilot effort is required to reduce the airspeed to the stall, the speed margin of 2 percent may be adequate. On the other hand, if conscious effort is required to avoid stalling the airplane, a positive type of warning initiated at a relatively high speed above the stall may be required.

(b) Suggested suitable stall warnings are, buffeting which may be defined as general shaking or vibration of the airplane or elevator shake of sufficient magnitude to be unmistakable; or a stall warning instrument such as a stick shaker. A visual stall warning device which requires the attention of the crew within the cockpit is not considered acceptable by itself.

(19 F. R. 4460, July 20, 1954, effective Sept. 1, 1954.)

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 takeoff ground run on concrete to maintain any attitude up to thrust line level at 80 percent of Vs_1.

4b.170–1 *Procedure for demonstrating longitudinal stability and control on the ground (CAA policies which apply to sec. 4b.170).* Taxiing tests at velocities up to 70 percent of the stalling speed should be conducted on smooth and rough ground which may likely be encountered under normal operating conditions. Particular attention should be paid to the following:

(a) *Taxiing over rough ground.* There is some evidence to indicate that critical loads can be built up in taxiing over rough ground, even when the shock-absorbing system is entirely satisfactory with respect to capacity for landing purposes.

(b) *Brakes.* Their adequacy when maneuvering on the ground and their tendency to cause nosing-over should be investigated. Any bad tendency will normally be exaggerated when taxiing in a strong side or tail wind.

(19 F. R. 4460, July 20, 1954, effective Sept. 1, 1954.)

4b.170–2 *Longitudinal stability and control with reverse thrust (CAA policies which apply to sec. 4b.170).* The policies outlined in section 4b.402–1 (a), (d), and (e) will apply.

(20 F. R. 2277, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.170–3 *Longitudinal stability and control with an antiskid device installed (CAA policies which apply to sec. 4b.170).* The policies outlined in section 4b.337–4 will apply.

(21 F. R. 2558, Apr. 19, 1956, effective May 15, 1956.)

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_{s_0} 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.171–1 *Procedure for demonstrating directional stability and control on the ground (CAA policies which apply to sec. 4b.171).*

(a) Compliance with the requirement of section 4b.171 (a) may be demonstrated during tests for the establishment of the cross wind component velocity in accordance with section 4b.173.

(b) Compliance with the requirement of section 4b.171 (b) may be demonstrated during power-off landings in other tests.

(c) Compliance with the requirement of section 4b.171 (c) may be demonstrated during taxiing prior to takeoff or after landing from other flight tests.

(19 F. R. 4460, July 20, 1954, effective Sept. 1, 1954.)

4b.171–2 *Directional stability and control with reverse thrust (CAA policies which apply to sec. 4b.171).* The policies outlined in section 4b.402–1 (a), (d), and (e) will apply.

(20 F. R. 2277, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.171–3 *Directional stability and control with an antiskid device installed (CAA policies which apply to sec. 4b.171).* The policies outlined in section 4b.337–4 will apply.

(21 F. R. 2558, Apr. 19, 1956, effective May 15, 1956.)

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.172–1 *Shock absorbing mechanism tests (CAA policies which apply to sec. 4b.172).* The shock absorbing mechanism should be checked for satisfactory operation while taxiing, taking off and landing during other tests in the type certification program.

(19 F. R. 4460 July 20, 1954, effective Sept. 1, 1954.)

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.

4b.173–1 *Crosswind demonstration (CAA policies which apply to sec. 4b.173).*

(a) A crosswind component of not less than 0.2 V_{s_0} should be established during type tests. Consequently, two results are possible:

(1) A crosswind component may be established at a value which is not marginal with the airplane's handling characteristics. This value should be included in the Operating Procedures section of the Airplane Flight Manual. The operation of the aircraft in crosswinds greater than the value specified is not necessarily a hazard. Thus operation in crosswinds of a greater value is entirely within the discretion of the operator.

(2) A critical crosswind component may be established at a value which is considered the maximum up to which it is safe to operate the airplane on the ground, including takeoffs and landings. This value should be shown in the Operating Limitations section of the Airplane Flight Manual. Operation of the airplane in crosswinds above the maximum safe value is considered hazardous and the operator should do so only on the same emergency basis that a pilot would be justified in exceeding any of the operating limitations such as air speed, engine r. p. m., c. g. limitations, etc.

(3) An operator may of course restrict the operation of his airplane to crosswind components of any value equal to or less than that established during the type certification tests.

(b) *Configuration.* This test should be conducted in the configurations that follow:

Weight—maximum takeoff and landing.

C. G. position—most aft.

Flaps—takeoff and maximum landing positions.

(c) *Test procedure and required data.* At least three takeoffs and landings should be made in crosswind components of 0.2 V_{s_0} mph (or greater at applicant's option) to demonstrate satisfactory controllability and handling characteristics. The magnitude and direction of

the crosswind should be established by the use of appropriate meteorological instruments.

(19 F. R. 4460, July 20, 1954, effective Sept. 1, 1954.)

4b.173–2 *Ground handling characteristics with reverse thrust (CAA policies which apply to sec. 4b.173).* The policies outlined in section 4b.402–1 (a) and (d) will apply.

(20 F. R. 2278, Apr. 8, 1955, effective Apr. 30, 1955.)

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.180–1 *Water handling qualities (CAA policies which apply to sec. 4b.180).* Policies outlined in section 4b.182–2 will apply.

(19 F. R. 4461, July 20, 1954, effective Sept. 1, 1954.)

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

(a) A lateral component of wind velocity not less than 0.2 V_{S_0} 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.181–1 *Crosswind demonstration (CAA policies which apply to sec. 4b.181).* Policies outlined in section 4b.173–1 will apply.

(19 F. R. 4461, July 20, 1954, effective Sept. 1, 1954.)

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 section 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.

4b.182–1 *Procedure for demonstrating control and stability on the water (CAA policies which apply to sec. 4b.182).*

(a) In order to check water stability, taxiing tests should be made in a crosswind determined in accordance with section 4b.181.

(b) Porpoising tendencies should be investigated and reported for extreme loading conditions.

(c) The ability to maneuver up to and while on the step should be investigated and the results reported.

(d) Compliance with the spray requirements may be substantiated while taxiing, taking off, and landing during other tests in the type certification program.

(e) If water rudders are provided, their effectiveness should be checked.

(f) Water taxiing ability should be investigated by actually taxiing the seaplane with appropriate use of power.

(19 F. R. 4461, July 20, 1954, effective Sept. 1, 1954.)

4b.182–2 *Control and stability on the water with reverse thrust (CAA policies which apply*

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to sec. 4b.182). The policies outlined in section 4b.402–1 (a), (d), (f), and (h) will apply.

(20 F. R. 2278, Apr. 8, 1955, effective Apr. 30, 1955.)

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 section 4b.210 (b) (5). The maximum speeds so demonstrated shall be used in establishing the operating limitations of the airplane in accordance with section 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.[3] (See also sec. 4b.308.)

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

4b.190–1 *Determination of flutter and vibration qualities during dive (CAA policies which apply to sec. 4b.190).*

(a) The airplane should be observed for flutter and vibration tendencies during other tests in the type certification program. In case the design speed is limited at altitude by Mach number, the dive should be conducted at a combination of pressure altitude and equivalent airspeed to permit attaining the desired maximum Mach number and dynamic pressure simultaneously. Stability and control qualities should be noted during the dive.

(b) *Configuration.* This test should be conducted in the configurations that follow:

(1) *Maximum takeoff weight.*
- C. G. position—most aft.
- Wing flaps—retracted and takeoff position.
- Landing gear—retracted.
- Engines—power as desired.
- Cooling controls—optional.
- Pneumatic boots—inoperative.

(2) *Maximum landing weight.*
- C. G. position—most rearward.
- Wing flaps—approach and landing positions.
- Landing gear—extended.
- Engines—power as desired.
- Cooling controls—optional.
- Pneumatic boots—inoperative.

(c) *Test procedure and required data.* The speed of the airplane should be slowly increased, from a steady flight high speed condition, until the maximum calibrated design dive speed for maximum takeoff weight is attained. The power and trim may be adjusted during the dive. The dive should be entered at a sufficiently high altitude to insure safe recovery. In case the design speed is limited at altitude by Mach number, the airplane should be dived at constant Mach number (maximum design or highest desired by the applicant—but in no case less than that specified in section 4b.210 (b) (5)) until the maximum equivalent design dive speed is attained. The test should be repeated at maximum landing weight with flaps and gear extended diving to the maximum design flap speed or speeds. *CAUTION:* Throughout these tests any control displacements should be executed gently.

(1) The following data should be recorded for each test:
- Pressure altitude.
- Ambient air temperature.
- Indicated air speed.
- Machmeter reading (if applicable).
- Engines, r. p. m. and manifold pressure.
- Wing flap position.
- Landing gear position.
- Weight.
- C. G. position.

(19 F. R. 4461, July 20, 1954, effective Sept. 1, 1954.)

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 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 section 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 section 4b.300.

(d) Proof of compliance of the structure with the fatigue evaluation requirements of section 4b.270 shall be made.

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 maximum weight appropriate to each particular flight condition, with any practicable distribution of disposable load within prescribed operating limitations stated in the Airplane Flight Manual. (See sec. 4b.740.)] At all speeds in excess of those corresponding with a Mach number of 0.65, compressibility effects shall be taken into account at all speeds.

(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_{S_0} and V_{S_1} are used, such estimates shall be conservative.

(1) *Design flap speed,* V_F. The minimum value of the design flap speed shall be equal to 1.4 V_{S_1} or 1.8 V_{S_0}, whichever is the greater, where V_{S_1} is the stalling speed with flaps retracted at the design landing weight, and V_{S_0} is the stalling speed with flaps in the landing position at the design landing weight. (See sec. 4b.212 (d) regarding automatic flap operation.)

(2) *Design maneuvering speed,* V_A. The design maneuvering speed V_A shall be equal to $V_{S_1}\sqrt{n}$ where n is the limit maneuvering load factor used (see sec. 4b.211 (a)) and V_{S_1} 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 either the speed determined by the intersection of the line representing the maximum positive lift $C_{N_{max}}$ and the line representing the rough air gust velocity on the gust V-n diagram or $(\sqrt{n_g})\ V_{S_1}$, whichever is the lesser; where n_g is the positive airplane gust load factor due to gust at speed V_C in accordance with section 4b.211 (b) (2) at the particular weight under consideration and V_{S_1} is the stalling speed with flaps retracted at the particular weight under consideration. V_B need not be greater than V_C.

(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, it shall be acceptable to limit V_C to a Mach number selected by the applicant.

(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.)

(c) ***Design fuel loads.*** The disposable load combinations shall include all fuel loads in the

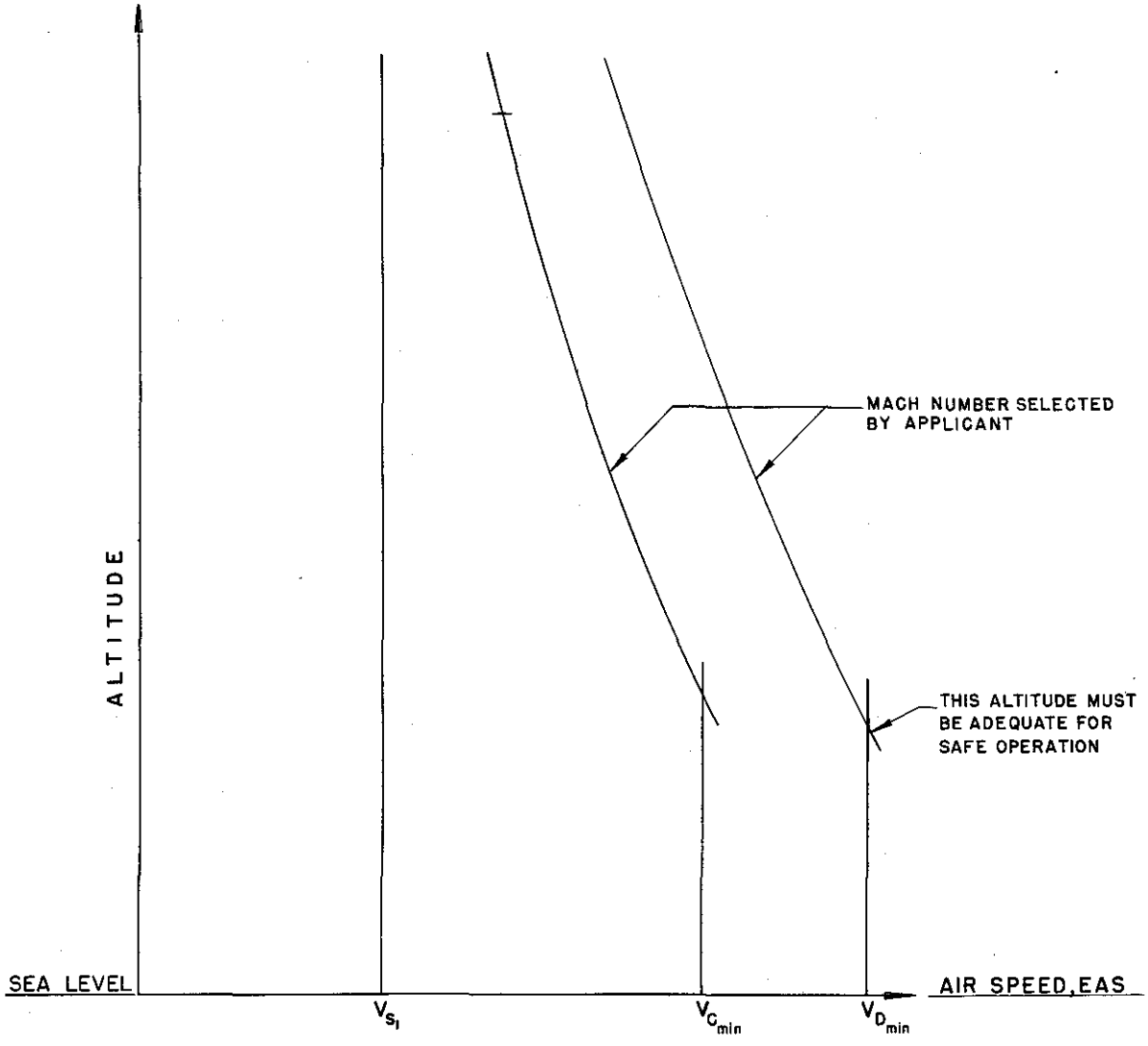


Figure 4b–1.—Minimum design air speeds vs. altitude.

range from zero fuel to the maximum fuel load selected by the applicant. It shall be permissible for the applicant to select a structural reserve fuel condition not exceeding 45 minutes of fuel under operating conditions defined in section 4b.437 (c). If a structural reserve fuel condition is selected, it shall be used as the minimum fuel weight condition for showing compliance with the flight load requirements as prescribed in this subpart, in which case, the provisions of subparagraphs (1) through (3) of this paragraph shall apply.

(1) The structure shall be designed for a condition of zero fuel at limit loads corresponding with:

(i) A maneuver load factor of +2.25, and

(ii) Gust intensities equal to 85 percent of the values prescribed in section 4b.211 (b).

(2) Fatigue evaluation of the structure shall take into account any increase in operating stresses resulting from the design condition of subparagraph (1) of this paragraph (see sec. 4b.270).

(3) The flutter, deformation, and vibration requirements shall also be met with zero fuel (see sec. 4b.308).

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 section 4b.710.

(a) *Maneuvering load factors.* (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

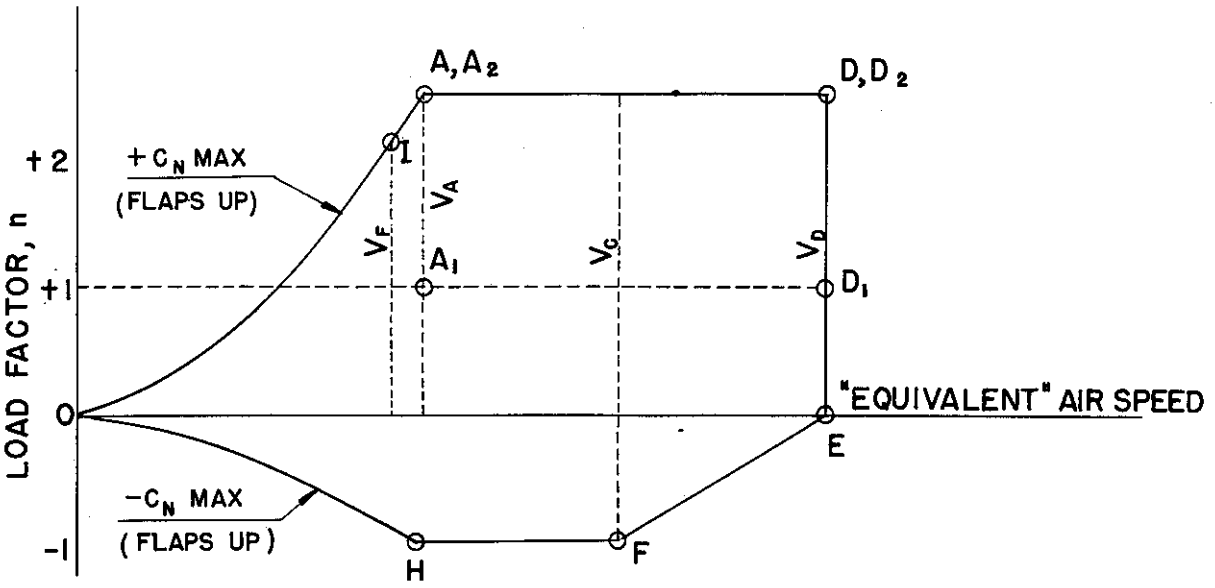


Figure 4b–2.—Maneuvering envelope.

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 factors.* 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 conditions prescribed in subparagraphs (1) through (5) of this paragraph. The shape of the gust shall be assumed to be:

$$U=\frac{U_{de}}{2}\left(1-\text{Cos}\,\frac{2\pi s}{25C}\right);$$

where:

s=distance penetrated into gust (ft.);
C=mean geometric chord of wing (ft.);
U_{de}=derived gust velocity referred to in subparagraphs (1) through (3) of this paragraph (fps).

(1) Positive (up) and negative (down) rough air gusts of 66 fps at the speed V_B shall be considered at altitudes between sea level and 20,000 feet. At altitudes above 20,000 feet, it shall be acceptable to reduce the gust velocity linearly from 66 fps at 20,000 feet to 38 fps at 50,000 feet.

(2) Positive and negative gusts of 50 fps at the speed V_C shall be considered at altitudes between sea level and 20,000 feet. At altitudes above 20,000 feet, it shall be acceptable to reduce the gust velocity linearly from 50 fps at 20,000 feet to 25 fps at 50,000 feet.

(3) Positive and negative gusts of 25 fps at the speed V_D shall be considered at altitudes between sea level and 20,000 feet. At altitudes above 20,000 feet, it shall be acceptable to reduce the gust velocity linearly from 25 fps at 20,000 feet to 12.5 fps at 50,000 feet.

(4) Gust load factors shall be assumed to vary linearly between the specified conditions B′ through G′, 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 in accordance with the following formula:

$$n=1+\frac{K_g U_{de} V a}{498\,(W/S)};$$

where:

$K_g=\frac{.88\mu_g}{5.3+\mu_g}$= gust alleviation factor;

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

U_{de}=derived gust velocities referred to in subparagraphs (1) through (3) of this paragraph (fps);
p=density of air (slugs/cu.ft.);
W/S=wing loading (psf);
$\bar{C}$=mean geometric chord (ft.);

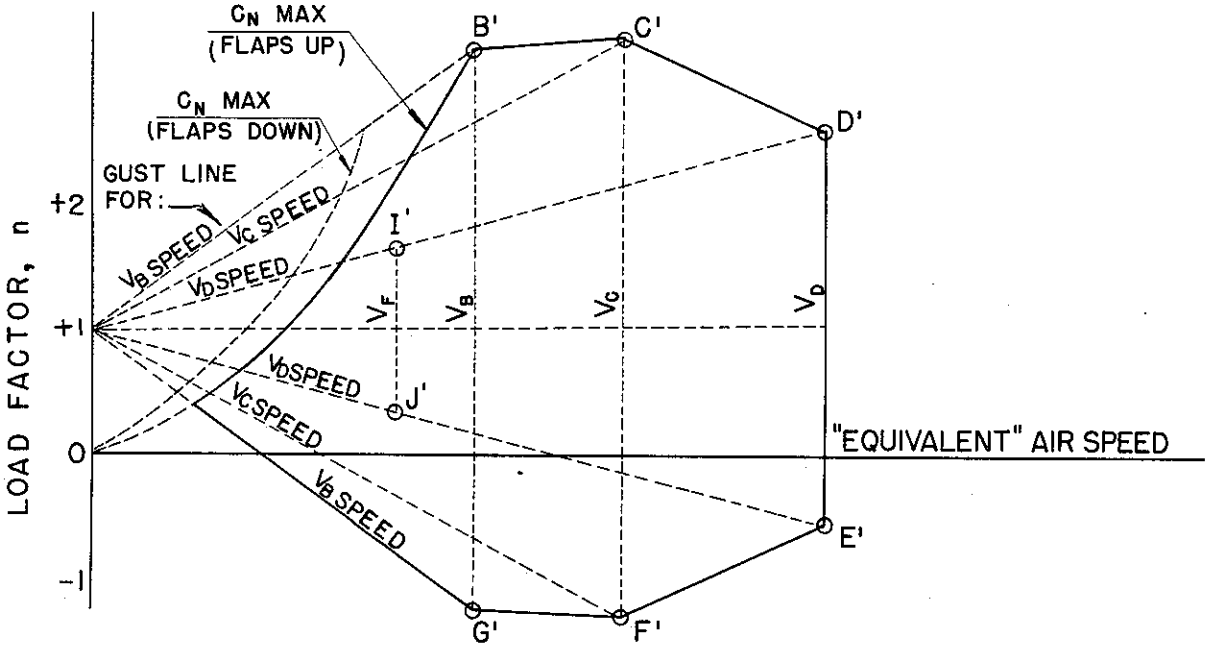


Figure 4b–3.—Gust envelope.

g=acceleration due to gravity (ft/sec.^{2});
V=airplane equivalent speed (knots);
a=slope of the airplane normal force coefficient curve C_{NA} per radian if the gust loads are applied to the wings and horizontal tail surfaces simultaneously by a rational method. It shall be acceptacle 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.*

(a) 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:

(1) Maneuvering to a positive limit load factor of 2.0.

(2) Positive and negative 25 fps derived gusts acting normal to the flight path in level flight,

(b) When flaps or similar high lift devices are intended for use in en route conditions (e. g., as speed brakes) the airplane shall be assumed to be subjected to symmetrical maneuvers and gusts, with flaps in the appropriate position at [speeds up to the] V_{FE} speed established in accordance with section 4b.714 (c), resulting in limit load factors, within the range determined by the following conditions:

(1) Maneuvering to a positive limit load factor of 2.5,

(2) Positive and negative derived gusts as prescribed in section 4b.211 (b) acting normal to the flight path in level flight.

(c) In designing flaps and supporting structure on tractor type airplanes, slip-stream effects shall be taken into account as specified in section 4b.221. For other than tractor type airplanes, a head-on gust equivalent to the intensity prescribed in section 4b.221 (b) (3) with no alleviations acting along the flight path shall be considered.

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

4b.213 *Symmetrical flight conditions.*

(a) *Procedure 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 pullups, 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, section 4b.220 (a).

(2) A_2, *Checked maneuver 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 conditions.* 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_g (see sec. 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 sec. 4b220 (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 section 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 derived gusts normal to the plane of symmetry while in unaccelerated flight. The derived gusts and airplane speeds corresponding with conditions B' through J' on figure 4b–3 as determined by sections 4b.211 (b) and 4b.212 (a) (2) or section 4b.212 (b) (2) shall be investigated. The shape of the gust shall be as specified in section 4b.211 (b). In the absence of a rational investigation of the airplane's response to a gust, it shall be acceptable to compute the gust loading on the vertical tail surfaces by the following formula:

$$L_t = \frac{K_{g_t} U_{de} V_{a_t} S_t}{498};$$

where:

L_t = vertical tail load (lbs.);

$K_{g_t} = \frac{.88\mu_{g_t}}{5.3+\mu_{g_t}}$ = gust alleviation factor;

$\mu_{g_t} = \frac{2W}{\rho \bar{C}_t g a_t S_t}\left(\frac{K}{l_t}\right)^2$ = lateral mass ratio;

U_{de} = derived gust velocity (fps);

ρ = air density (slugs/cu. ft.);

W = airplane weight (lbs.);

S_t = area of vertical tail (ft.^{2});

$\bar{C}_t$ = mean geometric chord of vertical surface (ft.);

a_t = lift curve slope of vertical tail (per radian);

K = radius of gyration in yaw (ft.);

l_t = distance from airplane c. g. to lift center of vertical surface (ft.);

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

V = airplane equivalent speed (knots).

4b.216 *Supplementary flight 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) through (3) 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).

(3) For turbine propeller installations, in addition to the conditions specified in subparagraphs (1) and (2) of this paragraph, the limit torque corresponding with take-off power and propeller speed multiplied by a factor of 2.0 shall be considered to act simultaneously with lg level flight loads.

[(4) For turbine engine installations, the limit torque load imposed by sudden engine stoppage due to malfunction or structural failure (e. g., compressor jam-up) shall be considered in the design of the engine mounts and supporting structure.]

(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 sec. 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. Stress concentration and fatigue effects shall be accounted for in the design of pressure cabins (see sec. 4b.270).

(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. 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.

(d) The [airplane] shall be designed for unsymmetrical loads resulting from failure of one engine.

(e) ***Gyroscopic loads.*** The structure supporting the engines shall be designed for gyroscopic loads associated with the conditions specified in sections 4b.213 through 4b.215 with the engines operating at maximum continuous rpm.

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 sections 4b.213 through 4b.215 and the ground gust conditions prescribed in section 4b.226, 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 aileron 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 effects 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 inertia 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 section 4b.212 (a) 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_{S_1}, where V_{S_1} is the stalling speed with flaps as follows: (For automatic flaps see sec. 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 section 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 sec. 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 section 4b.220, subject to the following provisions:

(a) The system limit loads, except the loads resulting from ground gusts (sec. 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 sysem 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 section 4b.224, except that the individual pilot loads shall not be less than the minmum 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 section 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 control system between the stops nearest the surfaces and the cockpit controls shall be designed for loads corresponding with the limit hinge moments H of paragraph (b) of this section, except that these loads 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.),

E = 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) Elevator	*±0.75	(d) Elevator full up.
(e) Rudder	0.75	(e) Rudder in neutral.
(f) Rudder	0.75	(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 tangential 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.	$\frac{1+R}{3}\times 50$ lbs., 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 sections 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 sections 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 in the attitude and subject to the drag loads associated with the particular landing condition, and with the following limit descent velocities and weights:

(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 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 sec. 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 forward velocity components parallel to the

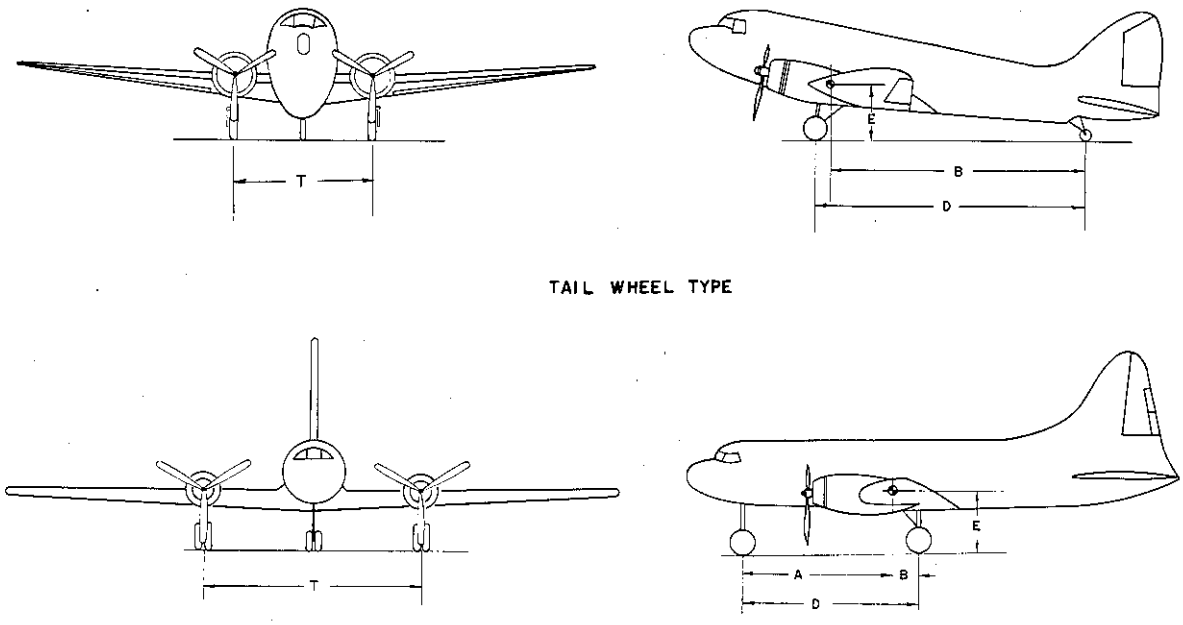


Figure 4b–7.—Basic landing gear dimension data.

ground ranging from V_{L_1} to 1.25 V_{L_2} and shall be assumed to be subjected to the load factors prescribed in section 4b.230 (b) (1) where V_{L_1} is equal to V_{S_0} (TAS) at the appropriate landing weight and in standard sea level conditions and where V_{L_2} is equal to V_{S_0} (TAS) at the appropriate landing weight and altitudes in a hot day temperature of 41° F. above standard. When approval of landings downwind exceeding 10 mph is sought, the effect of increased contact speeds shall be investigated. 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, directly affected attaching structure, and large mass items; i. e., external fuel tanks, nacelles, etc.

(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 section 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, directly affected attaching structure, and large mass items; i. e., external fuel tanks, nacelles, etc.

(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. 4b–8.)

(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 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.* In the conditions of paragraphs (a) and (b) of this section the airplane shall be assumed to contact the ground at forward velocity components parallel to the ground, ranging from V_{L_1} to V_{L_2}, where V_{L_1} and V_{L_2} are as indicated in section 4b.231 (a). The load factors prescribed in section 4b.230 (b) (1) shall apply. The combination of vertical and drag components specified in sections 4b.231 (a) (1) and 4b.231 (a) (3) shall be considered acting at the main wheel axle centerline.

(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 directions:

(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 section 4b.231 (a) (2). The unbalanced external loads

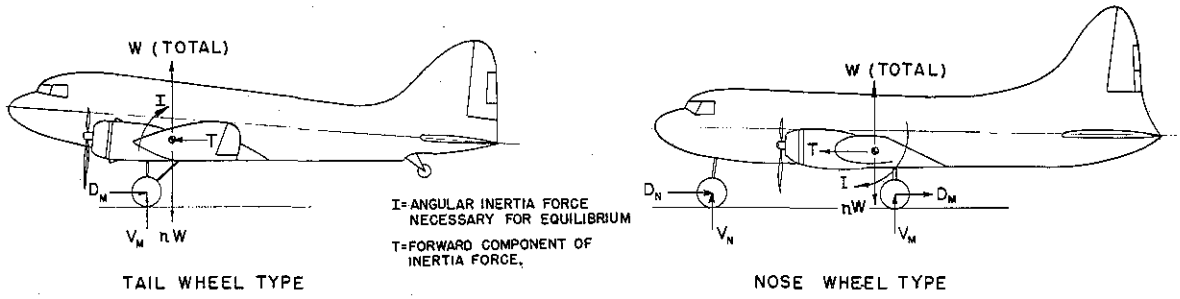


Figure 4b–8.—Level landing.

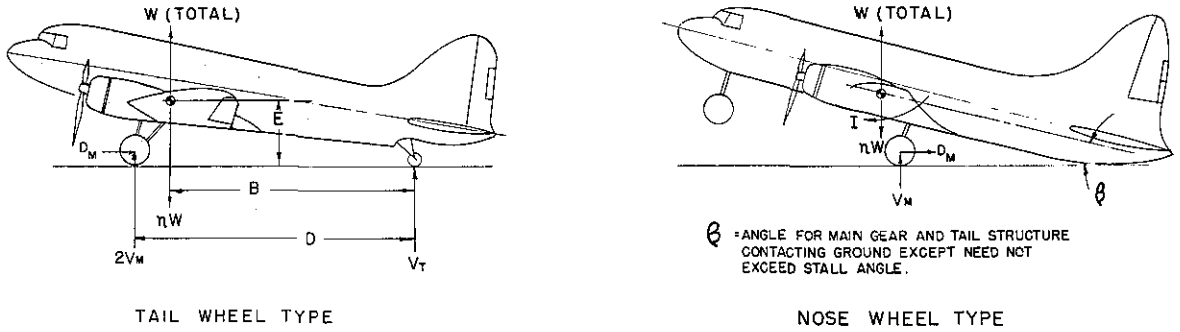


Figure 4b–9.—Tail down landing.

shall be reacted by inertia of the airplane in a rational or conservative manner.

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.)

(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 ienrtia of the airplane. It shall be acceptable to assume the drag loads to be zero.

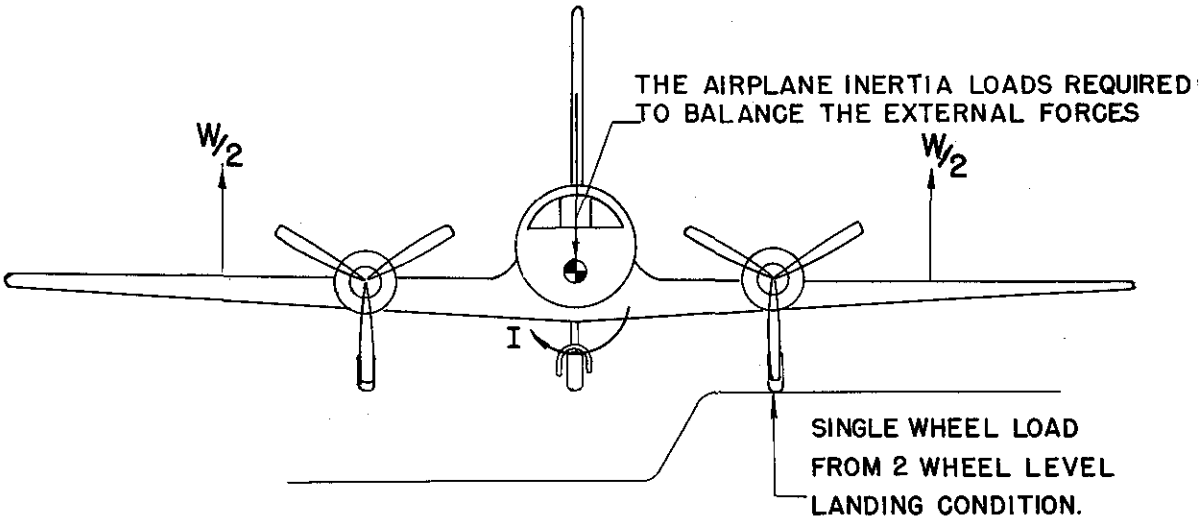
4b.234a *Rebound landing conditions.* The landing gear and its supporting structure shall be investigated for the loads occurring during rebound of the airplane from the landing surface. With the landing gear fully extended and not in contact with the ground, a load factor of 20.0 shall act on the unsprung weights of the landing gear. This load factor shall act in the direction of motion of the unsprung weights as they reach their limiting positions in extending with relation to the sprung portions of the landing gear.

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. [In the conditions of paragraph (b) (1) and (2), it shall be acceptable to use a drag reaction lower than prescribed therein if it is substantiated that an effective drag force of 0.8 times the vertical reaction cannot be attained under any likely loading condition.]

(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 section 4b.172.

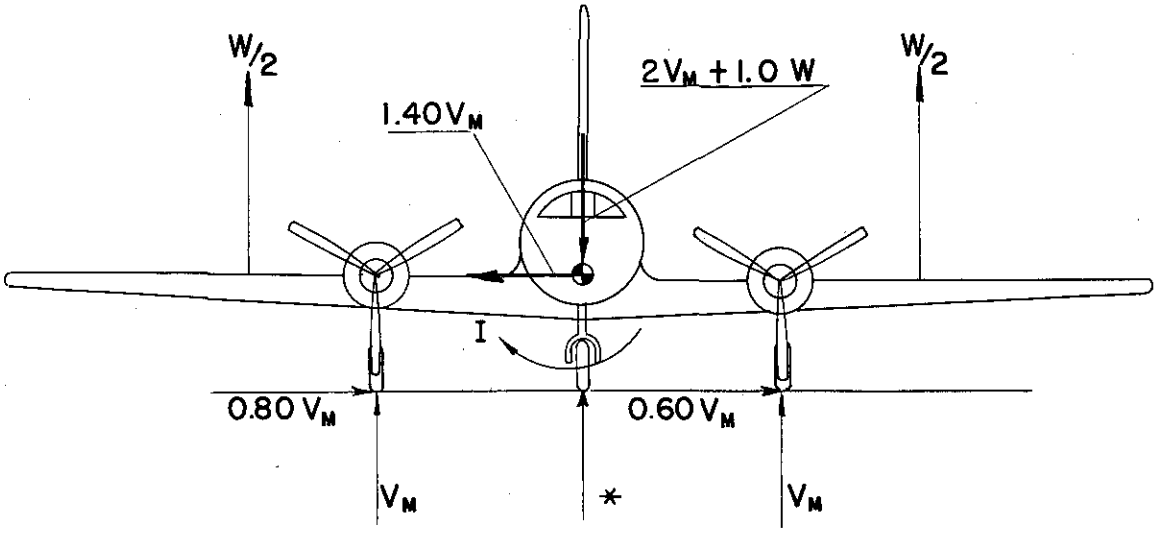
(b) *Braked roll.*

(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



NOSE OR TAIL WHEEL TYPE

Figure 4b–10.—One wheel landing.



[V_M=ONE-HALF THE MAXIMUM VERTICAL GROUND REACTION OBTAINED AT EACH MAIN GEAR IN THE LEVEL LANDING CONDITIONS.]

* NOSE GEAR GROUND REACTION =0

NOSE OR TAIL WHEEL TYPE AIRPLANE IN LEVEL ALTITUDE

Figure 4b–11.—Lateral drift landing.

with the vertical ground reaction and applied at the ground contact point. (See fig. 4b–12.)

(2) *Nose-wheel type.* The limit vertical 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 friction of 0.8 shall be combined with the vertical reaction and applied at the ground contact point of each

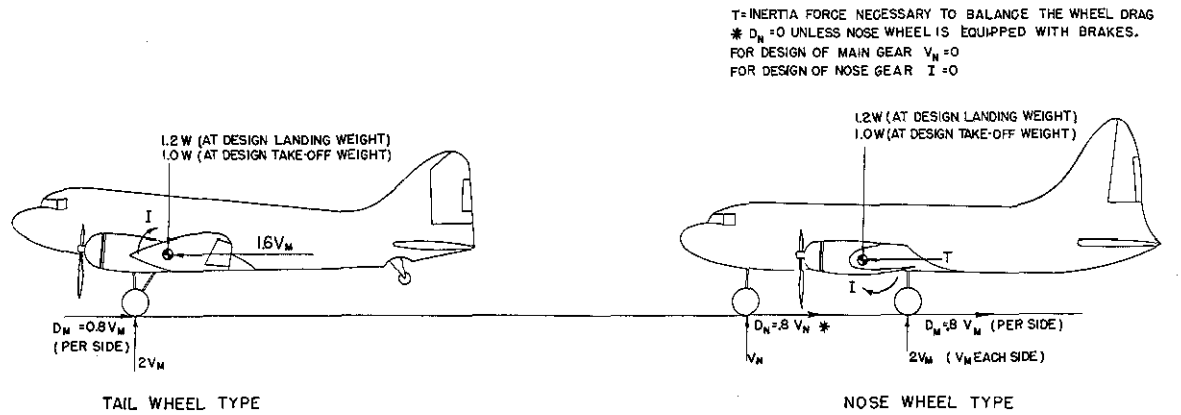


Figure 4b–12.—Braked roll.

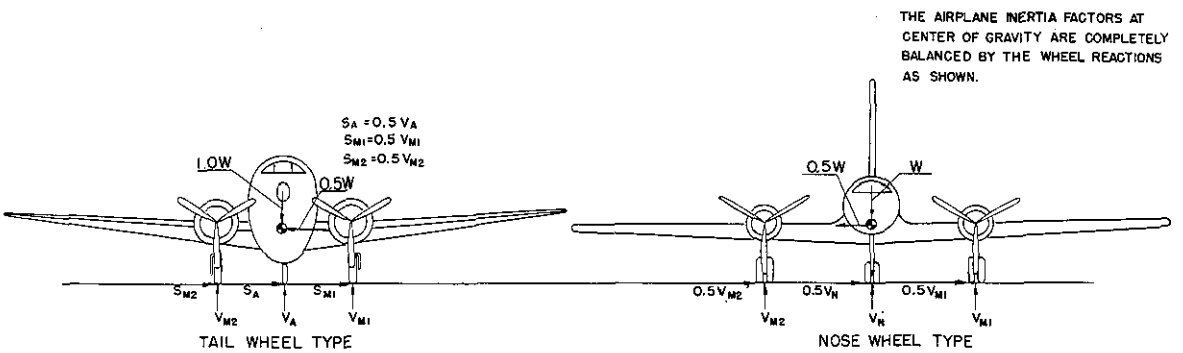


Figure 4b–13.—Ground turning.

wheel having brakes. The following two airplane attitudes shall be considered: (See fig. 4b–12.)

(i) The airplane shall be assumed to be in 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.

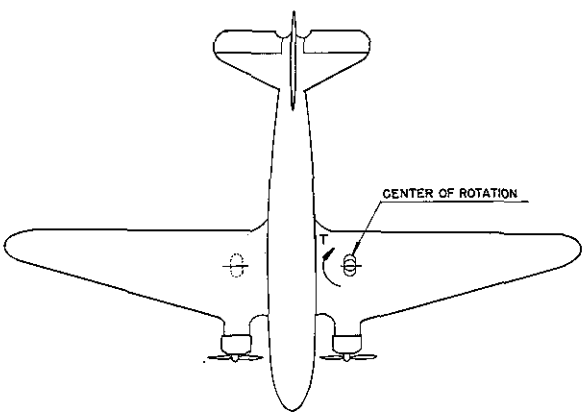
(d) *Pivoting.* The airplane shall be assumed to pivot about one side of the main gear, the brakes on that side being locked. The limit vertical load factor shall be 1.0 and the coefficient of friction 0.8. The airplane shall be assumed to be in static equilibrium, the loads being applied at the ground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

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V_N AND V_M ARE STATIC GROUND REACTIONS. FOR TAIL WHEEL TYPE THE AIRPLANE IS IN THE THREE POINT ATTITUDE. PIVOTING IS ASSUMED TO TAKE PLACE ABOUT ONE MAIN LANDING GEAR UNIT.

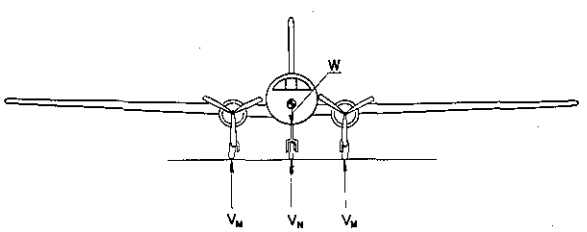


Figure 4b–14.—Pivoting, nose or tail wheel type.

(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.

(g) *Reversed braking.* The airplane shall be in a three point static ground attitude. Horizontal reactions parallel to the ground and directed forward shall be applied at the ground contact point of each wheel equipped with brakes. The limit loads shall be equal either to 0.55 times the vertical load at each wheel or to the load developed by 1.2 times the nominal maximum static brake torque, whichever is the lesser. For nose-wheel types, the pitching moment shall be balanced by rotational inertia. For tail-wheel types, the resultant of the ground reactions shall pass through the center of gravity of the airplane.

(h) *Towing loads.* Towing loads shall be those specified in figure 4b–26, considering each condition separately. These loads shall be applied at the towing fittings and shall act parallel to the ground. A vertical load factor equal to 1.0 shall be considered acting at the center of gravity. The shock struts and tires shall be in their static positions. The towing load, F_{TOW}, shall be defined as equal to $.3W_T$ for W_T less than 30,000 pounds, equal to $\frac{6W_T+450{,}000}{70}$ for W_T between 30,000 and 100,000 pounds and equal to $.15W_T$ for W_T over 100,000 pounds, where W_T is the design maximum take-off weight. For towing points not on the landing gear but located near the plane of symmetry of the airplane, the drag and side tow load components specified for the auxiliary gear shall apply. For tow points located outboard of the main gear, the drag and side tow load components specified for the main gear shall apply. In cases where the specified angle of swivel cannot be obtained, the maximum obtainable angle shall be used.

[4b.236 *Unsymmetrical loads on multiple-wheel units.*

[(a) *General.* Multiple-wheel landing gear units shall be assumed to be subjected to the limit ground loads prescribed in this subpart in accordance with the provisions of paragraphs (b) and (c) of this section.

[(b) *Distribution of limit loads to wheels; all tires inflated.* The distribution of the limit loads among the wheels of the landing gears shall be established for all landing, taxying, and ground handling conditions, taking into account the effects of the factors enumerated in subparagraphs (1) through (6) of this paragraph.

[(1) Number of wheels and their physical arrangement. In the case of truck type landing gear units, the effects of any see-saw motion of the truck during the landing impact shall be considered in determining the maximum design loads for the fore and aft wheel pairs.

[(2) Differentials in tire diameters resulting from a combination of manufacturing tolerances, tire growth, and tire wear. It shall be

acceptable to assume a maximum tire-diameter differential equal to ⅔ of the worst combination of diameter variations which is obtained when taking into account manufacturing tolerances, tire growth, and tire wear.

[(3) Unequal tire inflation pressure, assuming the maximum variation to be ±5 percent of the nominal tire inflation pressure.

[(4) A runway crown of zero and a runway crown having a convex upward shape which may be approximated by a slope of 1½ percent with the horizontal. Runway crown effects shall be considered with the nose gear unit on either slope of the crown.

[(5) Airplane attitude.

[(6) Structural deflections.

[(c) *Deflated tires.* The effect of deflated tires on the structure shall be considered with respect to the loading conditions specified in subparagraphs (1), (2), and (3) of this paragraph taking into account the physical arrangement of the gear components. Consideration shall be given to the deflation of any one tire for all multiple wheel landing gear units and, in addition, to the deflation of any 2 critical tires for landing gear units employing 4 or more wheels per unit. The ground reactions shall be applied to the wheels with inflated tires.

[(1) *Landing conditions.* For one deflated tire and for 2 deflated tires; the applied load to each gear unit shall be assumed to be 60 percent and 50 percent, respectively, of the limit load applied to each gear for each of the prescribed landing conditions except that, for the drift landing condition of section 4b.234, 100 percent of the vertical load shall be applied.

[(2) *Taxying and ground handling conditions.* For one deflated tire and for 2 deflated tires, the applied side and/or drag load factor at the center of gravity shall be the most critical value up to 50 percent and 40 percent, respectively, of the limit side and/or drag load factors corresponding with the most severe condition resulting from consideration of the prescribed taxying and ground handling conditions except that, for the braked roll conditions of section 4b.235 (b) (1) and (2) (ii), the drag loads on each inflated tire shall not be less than those at each tire for the symmetrical load distribution with no deflated tires. Pivoting need not be considered.

[(3) *Towing conditions.* For one deflated tire and for 2 deflated tires, the towing load, F_{TOW}, shall be 60 percent and 50 percent, respectively, of the load prescribed.

[NOTE: In determining the total load on a gear unit with respect to the provisions of paragraphs (b) and (c) of this section, the transverse shift in the load centroid, due to unsymmetrical load distribution on the wheels, is normally neglected.]

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 sections 4b.251 through 4b.258 shall apply.

4b.250–1 *Water loads—Alternate standards (CAA policies which apply to sec. 4b.250).* ANC–3 provides a level of safety equivalent to, and may be applied in lieu of section 4b.250.

(17 F. R. 10102, Nov. 7, 1952, effective Oct. 31, 1952.)

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 section 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 section 4b.253, except as otherwise prescribed. In applying the loads resulting from the load factors prescribed in section 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 section 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 section 4b.255, the aerodynamic lift on the seaplane during the impact shall be assumed to be ⅔ 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_{s_0} = seaplane stalling speed (mph) with landing flaps extended in the appropriate position and with no slipstream effect;

β = angle of dead rise at the longitudinal station at which the load factor is being determined (see fig. 4b–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 of 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 section 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 section 4b.253. The resultant water load shall be applied at the keel ⅕ 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 section 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 β 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 landing; 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 β at one float times the step landing load obtained in accordance with section 4b.253. The side load shall be directed inboard perpendicularly to

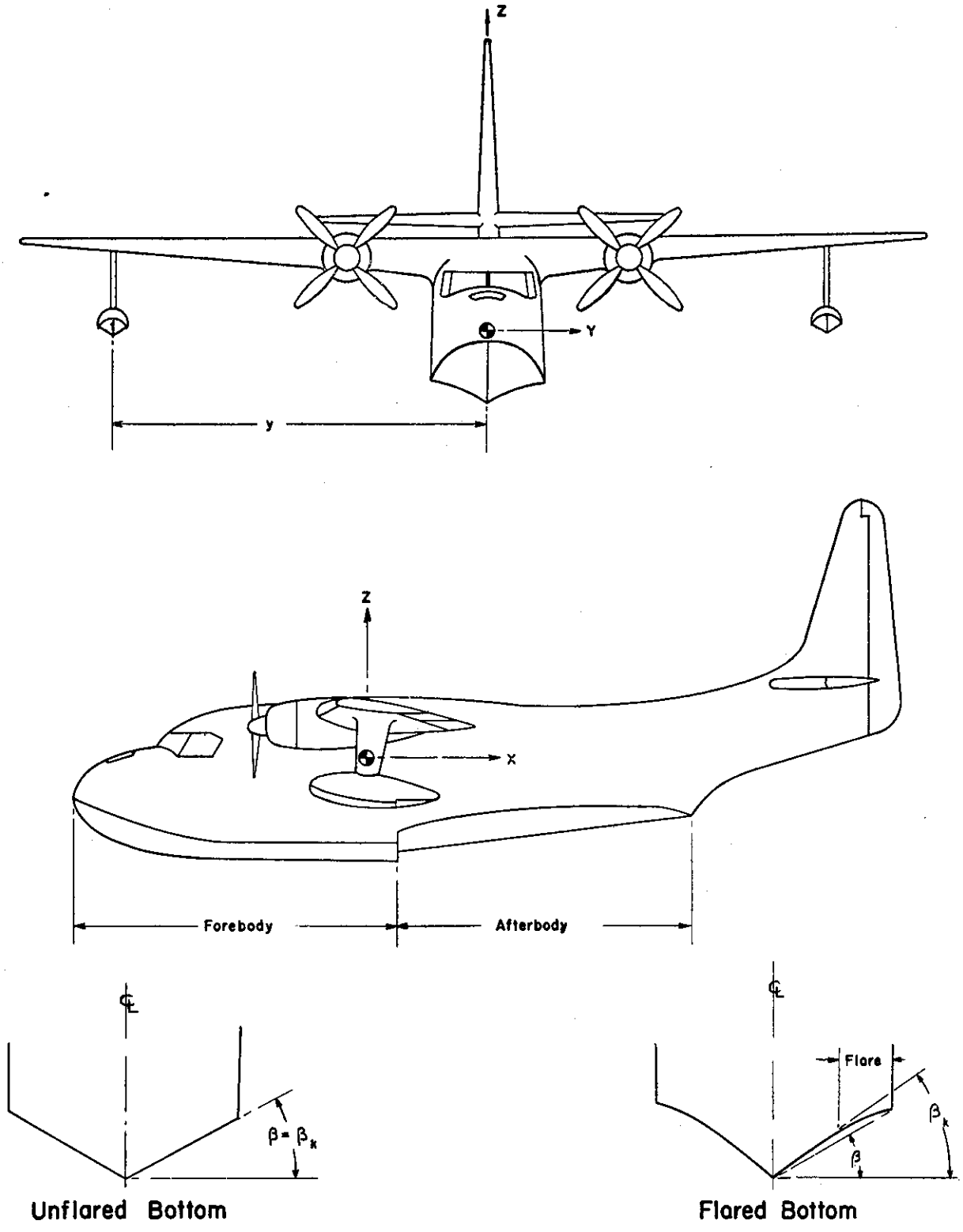


Figure 4b–15a.—Pictorial definition of angles, dimensions, and directions on a seaplane.

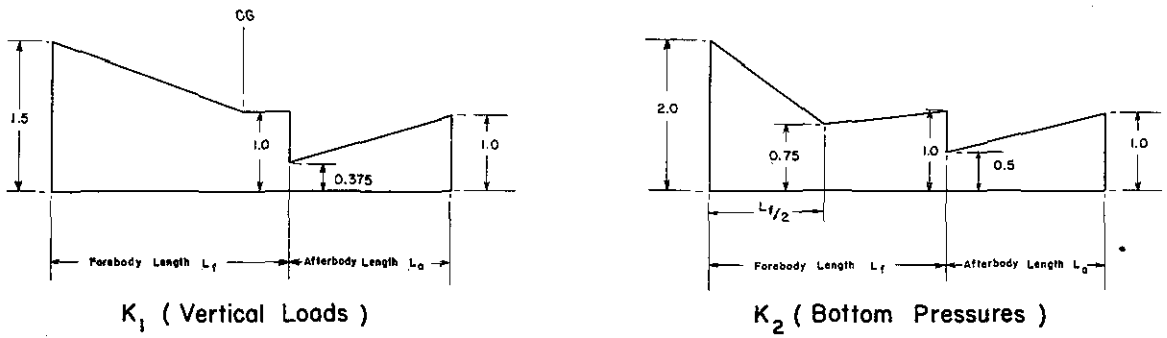


Figure 4b–15b.—Hull station weighing factor.

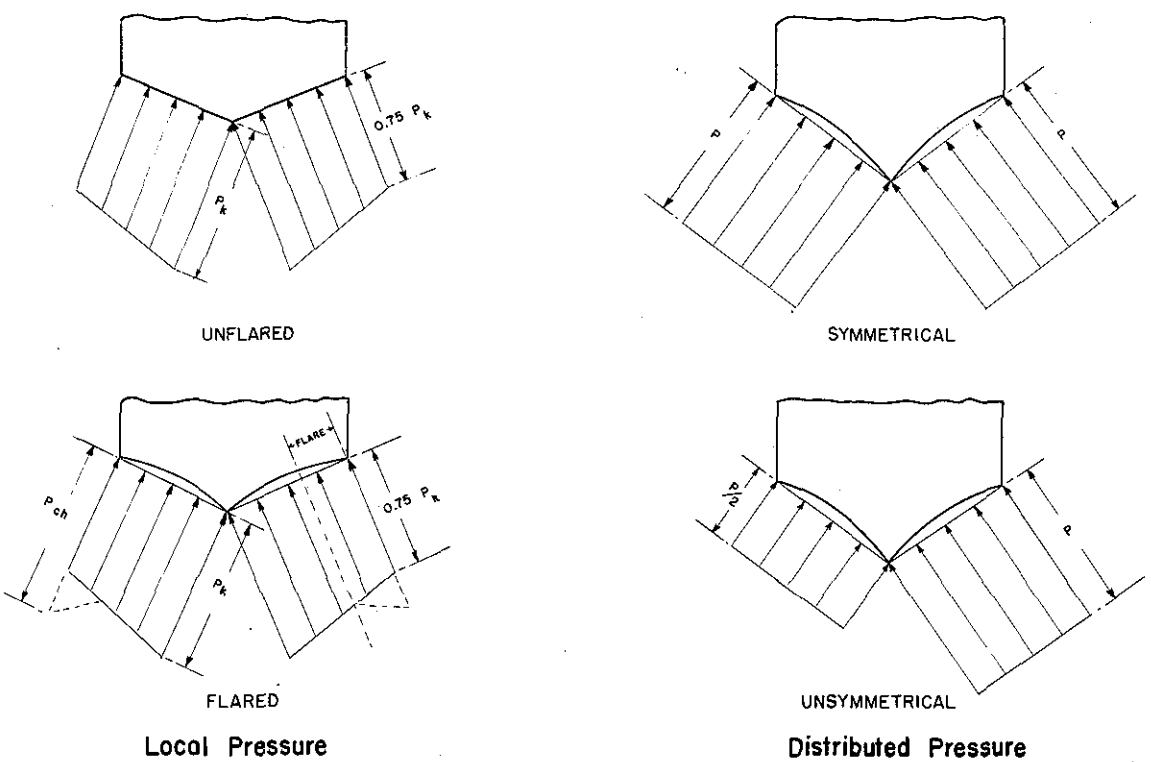


Figure 4b–15c.—Transverse pressure distributions.

the plane of symmetry midway between the keel and chine lines of the float at the same longitudinal station as the upward load.

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;

β=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;
β_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 takeoff position;
β = 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 = 0.078C_1 (for C_1 see sec. 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;
β = 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 perpendic-

ular 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:

$$L=\frac{C_5 V_{s_0}^2 W^{2/3}}{\tan^{2/3}\beta_s (1+r_y^2)^{2/3}};$$

where:

L=limit load

C_5=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;

β_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.

(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:

ρ=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 section 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 sec. 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.

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

Fatigue Evaluation

4b.270 *General.* 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 prncipal 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 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) and (2) 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 section 4b.211 (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.

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 (CAA policies which apply to sec. 4b.300).* The procedure outlined in section 4b.329–2 should be followed in safetying turnbuckles.

(20 F. R. 2278, Apr. 8, 1955, effective Apr. 30, 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 (CAA policies which apply to sec. 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.

(20 F. R. 2278, Apr. 8, 1955, effective Apr. 30, 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 *Inspections 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) 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. (See also sec. 4b.270.)

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

4b.306–1 *Material strength properties (CAA policies which apply to sec. 4b.306 (c)).*

(a) In the case of structures where the applied loads are eventually distributed through a single member within an assembly, the failure of which would result in the loss of the structural integrity of the component involved, the guaranteed minimum design mechanical properties ("A" values) listed in ANC–5 [8] should be used for design.

(b) Redundant structures wherein failure of individual elements would result in the applied load being safely distributed to other load-carrying members, may be designed on the basis of the "90 percent probability" ("B" values).

(c) When strength testing is employed to establish design allowables, such as in the case of sheet-stiffener compression tests, the test results should be reduced through use of a materials correction factor to values which would be met by material having the design allowable material properties for the part under consideration. The ANC–5 Bulletin outlines methods of accomplishing this reduction but these are by no means considered as the only methods available.

(d) Use of design values greater than the guaranteed minimums is permissible in applications where only guaranteed minimum values are normally permitted provided that the higher values are substantiated by "premium selection" of the material. These increased design allowables will be acceptable providing that a specimen or specimens of each individual item are tested prior to its use, to assure that the strength properties of the particular item will equal or exceed the properties to be used in design. Such quality control should aslo be exercised for the manufacture of spare parts.

(20 F. R. 2278, Apr. 8, 1955, effective Apr. 30, 1955.)

[8] The ANC–5 Bulletin "Strength of Metal Aircraft Elements" specifies "A" and "B" values for allowable design properties. The "A" values are those which the material producer has indicated to be the minimum he expects for the given material. The only values considered guaranteed values are the tensile ultimate and tensile yield "A" values which have been published by the material producer for the grain direction accepted for commercial guarantees. The "B" values represent design properties which the materials producers have indicated will be met or exceeded by 90 percent of the material supplied by them. More detailed information on the derivation of related design mechanical properties can be obtained by referring to section 3.111 "Design Mechanical Properties" of the ANC–5 Bulletin.

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 where the strength is subject to appreciable variability due to uncertainties in manufacturing processes and inspection methods, the factor of safety prescribed in section 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 tests 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 sections 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 sections 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 secs. 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 section 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. The elements of the flight control system shall incorporate design features or shall be distinctively and permanently marked to minimize the possibility of incorrect assembly which could result in malfunctioning of the control system. Tab control systems shall be such that disconnection or failure of any element at speeds up to V_C cannot jeopardize the safety of flight. (See also secs. 4b.308, 4b.350, and 4b.353.) [An adjustable stabilizer shall incorporate means to permit, after the occurrence of any reasonably probable single failure of the actuating system, such adjustment as would be necessary for continued safety of the flight.]

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 section 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. When a mechanical interconnection is employed means shall be provided to insure against hazardous unsymmetrical operation of the wing flaps after any reasonably possible single failure of the flap actuating system.

4b.324-1 *Procedure for demonstrating wing flaps that are not interconnected (CAA policies which apply to sec. 4b.324 (a)).* If the wing flaps are not mechanically interconnected, tests should be conducted to simulate flap malfunctioning (to the extent of the flaps being retracted on one side and extended on the other) during takeoffs, approaches, and landings to demonstrate that the airplane is safe under these conditions.

(19 F. R. 4461, July 20, 1954, effective Sept. 1, 1954.)

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 sec. 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 secs. 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 ⅛-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.

4b.329–1 *Installation of turnbuckles (CAA policies which apply to sec. 4b.329 (a)).* Fork ends of turnbuckles should not be attached directly to control surface horns or to bellcrank arms unless a positive means (such as the use of shackles, links, universal joints, spacer bushings, ball bearings, etc.) is used to prevent binding of turnbuckles relative to the horns or bellcrank arms or unless it can be shown that turnbuckles have adequate strength assuming one end fixed to the horn or arm and the design cable loads pulling off the other end at 5° to the turnbuckle axis. There should be no interference between the horns or bellcrank arms and the fork ends of turnbuckles throughout the range of motion of the control surfaces.

(20 F. R. 2278, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.329–2 *Safetying of turnbuckles (CAA policies which apply to sec. 4b.329).* Section 4b.300 requires in part that there be no design features or details which experience has shown to be hazardous or unreliable. Experience has shown that the reliability of turnbuckles should be insured by safetying with wire as shown in Figure 5. After safetying the turnbuckle, no more than three threads should be exposed on either side of the turnbuckle barrel and the ends of each safety wire should be securely fastened by at least four wraps. A turnbuckle safetying guide is given in table 1.

TABLE 1. TURNBUCKLE SAFETYING GUIDE

Cable size	Minimum Breaking Strength, Pounds				Type of wrap	Diameter of safety wire	Material (Annealed Condition)
	MIL–C–1511 Steel (Carbon) Flexible, Preformed		MIL–C–5424 Steel (Corrosion-Resisting) Flexible, Preformed				
	7 x 7	7 x 19	7 x 7	7 x 19			
Inch						*Inch*	
1/16	480		480		Single	0. 040	Copper, brass, galvanized or tinned steel, soft iron, or monel.
3/32	920		920		Single	. 040	Copper, brass, galvanized or tinned steel, soft iron, or monel.
1/8		2000		1760	Single	. 040	Stainless steel.
1/8		2000		1760	Double	. 040	Copper, brass, galvanized or tinned steel, soft iron, or monel.
5/32 and greater		2800		2400	Double	. 040	Galvanized or tinned steel, soft iron, stainless steel, or monel.
5/32 and greater		2800		2400	Double	. 051	Copper, brass.

NOTES

1. The swaged and unswaged turnbuckle assemblies are covered by AN Standard Drawings.
2. Certain of the AN Std. swaged terminal parts specify a safety wire hole size of .047 in. This hole may be reamed sufficiently to accomodate the .040 and .051 diameter wires.
3. The double wrap procedure given in Navy Specification PO–42A, Amendment No. 1, or the safetying procedure described by Air Force-Navy Aeronautical Design Standard AND 10482, may be used in lieu of the method shown in Figure 5.

(20 F. R. 2278, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.329–3 *Approval of control system components (CAA policies which apply to sec. 4b.329 (a))*. The Administrator does not issue specific approvals as such for cables, cable fittings, turnbuckles, splices, pulleys, etc., for general use on aircraft. Approval is limited to its use as part of a specific airplane design. Conformance with established industry or military specifications or adequate substantiation of the manufacturer's own design, are the procedures utilized in complying with the "approved type" requirement.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.329–4 *Cable terminals (CAA policies which apply to sec. 4b.329 (a))*. The selection of cable terminal locations and their proximities should minimize the possibility of interferences with structure, fairleads, other terminals, etc., and the possibility of pairing wrong cables during maintenance or overhaul.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.329–5 *Bellcrank and idler installation (CAA policies which apply to sec. 4b.329 (b))*. The design of such items as bellcrank arms, tab drums, idlers, etc., should minimize the possibility of inadvertent installation in the reversed direction, or, as an alternative, to preclude the possibility of jamming or interference that might result from such reversed installation.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.329–6 *Ball and roller bearings (CAA policies which apply to sec. 4b.329 (b) (3))*. The "approved ratings" of ball and roller bearings referred to are the ratings establishedin ANC–5, "Strength of Metal Aircraft Elements".

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

Landing Gear

4b.330 *General.* The requirements of sections 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 section 4b.332.

(b) The shock absorbing ability of the landing gear in taxying shall be demonstrated by the tests prescribed in section 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 section 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 1.0.

(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:

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

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

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in section 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 sec. 4b.332 (b) (2) for explanation of W_e, W, and L).

(b) The value of n determined in paragraph (a) of this section shall not be greater than the limit load factor used for the landing conditions. (See sec. 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_{s_1} (flaps in the approach position at design landing weight), and any load factor up to those specified in section 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 section 4b.353.

4b.334–1 *Procedure for testing landing gear retracting system (CAA policies which apply to sec. 4b.334).*

(a) *General, section 4b.334 (a).* The ability to extend and retract the landing gear at a speed of at least 1.6 V_{s_1} should be demonstrated. If no other satisfactory means of decelerating the airplane are provided (such as dive brakes or other high drag devices), the ability of the landing gear retracting mechanism and wheel well doors to withstand the flight loads should be demonstrated under the following conditions:

Power required for level flight.

Airspeed, at least 0.67 V_C.

Landing gear extended.

(b) *Emergency operation, section 4b.334 (c).* Extending the landing gear by use of the emergency system for demonstrating compliance with the requirement of this section may be accomplished during other tests in the flight program.

(c) *Operation test, section 4b.334 (d).* The time required to retract the landing gear at speed V_2 (see sec. 4b.116 (b)) should be demonstrated in flight under the following conditions:

Weight—optional.

C. G. position—optional.
Operating engine(s)—takeoff power.
Critical inoperative engine—propeller windmilling on engine most critical from the gear retraction standpoint.

It is also desirable to obtain the time required to extend the landing gear for purposes of information.

(19 F. R. 4961, July 20, 1954, effective Sept. 1, 1954.)

4b.334–2 *Landing gear position indicator switches (CAA interpretations which apply to sec. 4b.334 (e)).* The phrase "means shall be provided for indicating to the pilot" includes a landing gear position indicator as well as the switches necessary to actuate such indicator. The switches must be so located and coupled to the landing gear mechanical system as to preclude the possibility of an erroneous indication of "down and locked" if the landing gear is not in a fully extended position, or "up and locked" if the landing gear is not in the completely retracted position. Location of the switches so that they are operated by the actual landing gear locking latch or device is an acceptable method of compliance with the requirements of this section.

(21 F. R. 2747, Apr. 28, 1956, effective May 25, 1956.)

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 secs. 4b.230 through 4b.236).

(c) [The brake kinetic energy capacity rating of each main wheel-brake assembly shall not be less than the kinetic energy absorption requirement determined in accordance with this paragraph. The brake kinetic energy absorption requirements shall be based on a rational analysis of the sequence of events which are expected to occur during operational landings at maximum landing weight. This analysis shall include conservative values of airplane speed at which the brakes are applied, braking coefficient of friction between tires and runway, aerodynamic drag, propeller drag or powerplant forward thrust, and if more critical, the most adverse single engine or propeller malfunction. In lieu of a rational analysis it shall be acceptable to establish the kinetic energy absorption requirements for each main wheel brake assembly by the following "formula:"]

$$KE=\frac{0.0334WV_{s_0}^2}{N};$$

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 V_{s_0} 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.* Landing gear tires shall be of a proper fit on the rim of the wheel, and of load ratings which are not exceeded under the following conditions:

(a) Main wheel tires: Equal static loads on all main wheel tires corresponding with the most critical combination of maximum take-off weight and center of gravity position.

(b) Nose wheel tires: Equal loads on all nose wheel tires corresponding with the following conditions:

(1) The static ground reaction per tire corresponding with the most critical combination of take-off weight and center of gravity

position. This load shall correspond with the static rating of the tire.

(2) The dynamic ground reaction per tire at maximum landing weight, assuming the mass of the airplane concentrated at the most critical location of the center of gravity for this weight 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 a 0.31g drag reaction at the ground applied at those wheels which have brakes. This load shall correspond with the dynamic rating of the tire.

(3) The dynamic ground reaction per tire at design take-off weight, assuming the mass of the airplane concentrated at the most critical location of the center of gravity for this weight and exerting a force of 1.0g downward and 0.20g forward, the reactions being distributed to the nose and main wheels by the principles of statics with a 0.20g drag reaction at the ground applied at those wheels which have brakes. This load shall correspond with the dynamic rating of the tire.

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 section 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 connecting or transmitting element in the brake system (excluding the operating pedal or handle), or the loss 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 section 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.

[(d) *Anti-skid devices.* If anti-skid devices are installed, the devices and associated systems shall be such that no single probable malfunction will result in a hazardous loss of braking ability or directional control of the airplane.]

Discussion of Policies Relating to Brake Tests in Section 4b.337–1

The requirements of section 4b.337 are based upon the fact that compliance with the operating rules of section 40.70 of this subchapter will require great dependence upon the presence and proper functioning of brakes unless the runways involved are unusually long.

The nature and extent of the tests to show compliance with section 4b.337 (a) will necessarily depend upon a great many things such as the general arrangement of the landing gear, the design of the brake system, the extent to which the capacity of the brakes is used in establishing the landing distance required by section 4b.122, the amount of available performance data for the brakes, etc. The simplest possible procedure appears to be to determine the average deceleration during a landing ground roll without the use of brakes and then establish the landing distance required by section 4b.122 by using the brakes to the extent necessary to double the mean deceleration so established. It appears likely, however, that this procedure would result in excessive landing distance and might seriously limit the use of the airplane in operation.

4b.337–1 *Brake tests (CAA policies which apply to sec. 4b.337).* If it is desired by the applicant to make the maximum possible use of the brakes in establishing the landing distance, and if also the contribution of the brakes to the total deceleration is relatively large, the brake system should be designed to permit the application of slightly less than half the braking deceleration developed under the conditions specified in this section. The following dual system is recommended: Dual wheel elements (drums or disc units), transmitting elements, power sources, master cylinders, etc., connected to a single pedal on each rudder pedal, such that the failure of any single one of these would leave half the total braking capacity symmetrically disposed about the plane of symmetry of the airplane. With such a system it should be possible to show compliance with section 4b.337 (a) by means of calculation based upon the test data necessary to establish the landing distance plus the brake data calculated by the aircraft manufacturer.

If the system is designed so that under the conditions here specified appreciably less than half the total braking capacity remains or if the remaining capacity is asymmetrically disposed, tests should be conducted to determine that half the mean deceleration may in fact be developed and/or that the airplane may be safely controlled directionally while doing so.

(a) [Rescinded.]

(b) *Brake controls, section 4b.337 (b).* General brake control force and operation should be noted throughout the flight test program to determine that they are satisfactory.

(c) *Parking brake controls, section 4b.337 (c).* During engine run-up prior to takeoff for other tests, the parking brake control should be set, and without further attention, a demonstration should be made to determine that sufficient braking is maintained to prevent the airplane from rolling on a paved runway while takeoff power is applied on the most critical engine.

(19 F. R. 4461, July 20, 1954, effective Sept. 1, 1954; amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957.)

4b.337–2 *Brake systems. (CAA policies which apply to sec. 4b.337.)* In order to obtain a minimum landing distance under section 4b.122 and at the same time meet the deceleration requirement of section 4b.337 (a) (2) in event of failure of the normal brake system, it is a common practice to provide an alternate brake system. When hydraulic (or pneumatic) brakes are used in the normal brake system, this alternate means usually consists of a duplicate hydraulic or pneumatic brake system and is commonly referred to as the "emergency brake system." The following items should be considered in the design of such systems:

(a) *Relationship between normal and emergency brake systems.* The systems for actuating the normal brake and the emergency brake should be so separated that a failure in, or the leakage of fluid from, one system will not render the other system inoperative. A hydraulic brake assembly may be common to both the normal and emergency brake systems if it is shown that the leakage of hydraulic fluid resulting from failure of the sealing elements in the brake assembly would not reduce the braking effectiveness below that specified in section 4b.337 (a) (2).

(b) *Brake control valves.* In the normal brake system of all aircraft, the brake control valves should be of a type such that the pilots may exercise variable control of the pressure to the brakes. The foregoing provision need not necessarily apply to the emergency brake systems although obviously such a provision would be desirable. Flight tests should be conducted to determine that the normal and emergency brake systems fulfill the requirements of section 4b.170 (a) and (b).

In the normal brake systems of tail wheel type aircraft or of nose wheel type aircraft equipped with nonsteerable nose wheels, provisions should be made for independently controlling the brakes on either side of the main landing gear in order that directional control of the aircraft can be maintained. (See sec. 4b.171 (c).) In the emergency brake systems of tail wheel type aircraft and in the normal and emergency brake systems of nose wheel type aircraft, it is desirable that independent control of the brakes on either side of the landing gear be provided although such control is optional.

(19 F. R. 4461, July 20, 1954, effective Sept. 1, 1954.)

4b.337–3 *Replacement or modified brakes (CAA policies which apply to sec. 4b.337).*

(a) *General.* Replacement or modified brake installations may be approved on the basis of dynamometer tests together with functional flight tests in lieu of measured accelerate-stop and landing distance flight tests if the decelerate performance based on dynamometer data is shown to be equal to or better than the original airplane flight test decelerate performance. Dynamometer tests which simulate actual airplane decelerate-distance tests may incorporate variable kinetic energy absorption rates simulating flight test deceleration conditions, and may include an energy allowance for the aerodynamic drag of the airplane which occurs during the deceleration portion of the accelerate-stop and landing runs. However, if any improvement in decelerate performance over that shown in the original Airplane Flight Manual is desired, then this policy is inapplicable and complete airplane flight tests will be required.

(1) The procedures of (c) through (g) may be used for substantiating replacement or modified brake installations and may be applied to approved brakes of any manufacturer. The replacement brake does not have to be manufactured by the maker of the original brake.

(2) Brakes which have been approved under TSO or preceding approval standards (whichever is pertinent) may be approved as a replacement brake on an existing airplane type upon the presentation of test reports and other pertinent computations showing:

(i) That, insofar as deceleration performance is concerned, the replacement or modified brakes are equal to or better than the original brake installation on the basis of dynamometer tests contained in this section, and

(ii) That, the replacement or modified brakes when installed on the airplane, comply with the ground handling requirements of section 4b.170.

(b) *Brake modifications.* Modifications to a previously approved wheel-brake installation involving changes to component parts which will involve variations in kinetic energy absorption characteristics should be subjected to the dynamometer tests contained in (b) (1) in addition to the dynamometer tests specified in (e) and (f) for the accelerate-stop and landing conditions and should also include a check of operating and ground handling characteristics. Typical modifications which vary the kinetic energy absorption characteristics are as follows: changes of brake lining material, changes in brake discs or brake drum material, reductions in friction surface plan dimensions (area), etc.

(1) The minimum reliability standards for brakes referenced in TSO–C26 and contained in Specification AS227A should be used as a guide for modified brakes. However, section 5.4.3 of AS227A may be applied as follows for evaluating such modifications:

(i) Thirty tests simulating the stopping of an airplane at 100 percent kinetic energy.[9]

(ii) One test simulating the stopping of an airplane at 125 percent kinetic energy.[9]

(c) *Determination of kinetic energy requirements.*

(1) In the case of replacement brakes (that is, those brakes incorporating major design differences from those originally tested on the airplane) the kinetic energy (KE) to be absorbed on the dynamometer in compliance with provision (a) (2) of this section should be determined in accordance with the following formula:

$$KE_{dyn} = KE_{wv} - \tfrac{1}{2}\, KE_{ad}$$

where:

KE_{wv} = the maximum kinetic energy as determined from the most critical combination of weight and speed (in terms of ground speed). In determining the maximum speed, the effects of tailwind, altitude and flap setting should be taken into account.

KE_{ad} = the kinetic energy absorbed by aerodynamic drag of the airplane during the deceleration portion of the accelerate-stop and landing runs. This kinetic energy should be determined from available test data of the airplane or by other reliable calculations based on the basic parameters for the type of airplane involved.

(2) In the case of brakes modified as described in paragraph (b) the kinetic energy to be

[9] The modifier of the brake should substantiate the fact that the original brake approval tests and the tests specified in (i) and (ii) were conducted under similar conditions and that the modified brake assembly is at least the equal to that previously approved as an equipment item insofar as energy absorption and stopping time are concerned.

absorbed on the dynamometer should be determined in accordance with the following formula:

$$KE_{dyn}=KE_{wv}-KE_{ad}$$

(i) This formula should not apply to modifications of a replacement brake which has been approved in accordance with (1) of this paragraph. Such modifications of a replacement brake should meet the same dynamometer requirements as the replacement brake did when originally installed.

(d) *Dynamometer test method.*

(1) There should be no artificial cooling of the brakes during dynamometer tests. Ventilating air flowing normal to the tire tread is permissible.

(2) For wheel-brake installations where dual or duplex brakes are used, the dynamometer tests should be conducted on an entire wheel-brake unit.

(3) Brake lining should not be run-in to a degree which would be greater than the run-in for new lining when installed on an airplane prior to being put in regular airline service.

(4) Due to wing-lift acting on the airplane, the dynamometer tests should account for tire rolling friction due to the differential in braking effect resulting from the varying rolling radius of the tire on the runway as compared to the constant tire radius at constant tire deflection which occurs throughout the entire dynamometer run.

(5) The dynamometer mass should be corrected so that the selected inertia equivalent (I.E.) will result in a correct or conservative kinetic energy test value.

(6) During dynamometer testing a variable brake pressure, which does not exceed that pressure which is available from the airplane brake system intended for use with the replacement brake, should be used in duplicating as nearly as practicable the original airplane torque-speed and velocity-time flight test data corrected for aerodynamic drag and tire rolling friction.

(e) *Accelerate-stop distance test.* This condition is normally the most critical from a kinetic energy standpoint. The original flight test accelerate-stop deceleration camera data obtained during the type certification tests of the airplane should be obtained and corrected for aerodynamic drag and tire rolling friction.

(1) Continuous records of dynamometer torque-speed or velocity-time data for at least three of the runs, when absorbing the required kinetic energy for the critical combination of takeoff weight and V_1 speed, should duplicate, as nearly as practical, the original airplane brake deceleration data. These dynamometer records should be converted to corrected and faired velocity versus distance values and be plotted and superimposed on the curve for the original airplane velocity-distance data, and

(2) The average of the above three corrected dynamometer velocity-distance curves should be superimposed on the curve for the original airplane velocity-distance data.

(3) The curves plotted in (1) and (2) of this paragraph should compare favorably with the original corrected flight data over the entire speed range and should indicate that, from any given speed, the airplane stopping distance would be equal to or less than the distance resulting from the original brake installation at the required kinetic energy level corresponding to the actual accelerate-stop conditions which prevailed during the airplane type certification tests.

(4) If, in compliance with (1) of this paragraph, velocity-time data are submitted in lieu of torque-speed data, then sufficient spot-check calculations of the velocity-time data should be made to insure an accuracy comparable to the accuracy of torque-speed data. Inasmuch as torque-speed data are useful for airplane modification and design purposes, it is desirable that comparable and complete torque-speed data be included in the data submitted.

(5) Dynamometer time history recordings of brake pressure, torque, speed, and calculations for aerodynamic drag, tire rolling friction, and dynamometer mass correction, and all pertinent airplane data, should be submitted, together with an analysis showing the detailed calculations and charts necessary to establish the speed-distance relationship and comparison with the original airplane deceleration test data.

(f) *Landing distance test.* In order to substantiate landing distances, at least three dynamometer runs, using the critical combinations of landing weight and contact speed, should be conducted on the same brake unit.

Landing distance data, compiled in accordance with the method described in (e) for accelerate-stop evaluation, should be submitted. The landing distance data, which are comparable to those of (e) for the accelerate-stop data, should compare favorably with the corrected airplane flight test results obtained with the original brakes in order to substantiate the adequacy of the replacement brakes, insofar as landing distances are concerned.

(g) *Aircraft functional tests.* The brakes should be tested on the airplane to determine their functional characteristics as indicated in (a) (2). Functioning characteristics should be observed during taxi and engine run-up conditions and at least three normal takeoffs and landings, at the maximum landing weight, should be conducted. During these tests, the brakes should be checked for any undesirable characteristics such as "grabbing," "fading," etc., and should at least be visually inspected, without dismantling, at the completion of the test in order to determine any evidence of malfunction or failure. If no malfunctioning has occurred, this visual inspection is adequate, but if malfunctioning does occur, a thorough inspection should be conducted. If any characteristics arise which indicate that stopping distances would exceed the original values in the CAA Approved Airplane Flight Manual, then the Administrator may require actual camera recorded airplane deceleration tests or any other tests deemed necessary to establish the adequacy of the brakes.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.337–4 *Antiskid devices and installations (CAA policies which apply to sec. 4b.337).*

(a) *Eligibility.* Antiskid devices meeting the airworthiness portions of Military Specification MIL–B–8075 (ASG) and any amendments [10] thereto, are acceptable for installation on civil aircraft. Requests for deviations from these specifications should be submitted to the CAA Regional Office, Aircraft Engineering Division. The installation of the antiskid device should comply with the requirements specified in paragraph (b) of this section. The antiskid device and its installation will be approved for use on civil aircraft when the tests specified in paragraph (c) of this section have been satisfactorily demonstrated.

(b) *Installation.*

(1) *Data required.* An engineering evaluation of the antiskid installation as installed on the airplane, including all necessary components, should be conducted. This analysis and complete descriptive data should be submitted to the CAA. The data should include hydraulic and electric schematic diagrams of the installation, assembly drawings of antiskid system units, test results or stress analysis substantiating structural strength of attachments and modification of the axle or other structural members, installation drawings, recommended instructions pertaining to installation, maintenance and operation and analysis of flight test data and results. Schematic drawings should refer to all units in the normal and emergency brake systems. The engineering evaluation should also assure that the antiskid system does not cause undesirable and adverse yaw characteristics.

(i) Engineering evaluation should account for a bounce condition wherein the wheels may leave the runway after the brakes have been applied, for a condition wherein the wheels stay on the runway but the oleos are extended (if the system utilizes landing gear oleo compression in its operation), and for a condition in which the wheels of one main gear may not be in contact with the runway for a considerable time while the wheels of the other main gear are firmly on the runway. If the antiskid installation incorporates the "landing with brake pedals depressed" feature, then this type of operation should also be considered.

(ii) It should be shown that the brake cycling frequency imposed by the antiskid installation will not result in excessive loads on the landing gear because of proximity to resonant landing gear frequencies.

(2) *Systems.* The entire brake system (including both the basic brake system and the antiskid system) should conform to section 4b.337. The single failure criterion of section 4b.337 should be extended to include the antiskid system.

(i) In the event of a probable malfunction within the antiskid system which would result in loss of the antiskid feature in one

[10] Proposed amendments may be obtained from the Civil Aeronautics Administration, Washington 25, D. C.

or more brake units, those brake units affected should automatically revert to normal braking.

(ii) An indicating means should be provided to warn the pilot or copilot in the event of antiskid malfunction. For simple mechanical type antiskid installations wherein any single probable malfunction is considered remote and which will render only one braked wheel inoperative insofar as antiskid operation is concerned, the indicating means need not be located in the cockpit.

(iii) A means should be provided so that the pilot or copilot can readily deactivate the antiskid system. For simple mechanical type antiskid installations wherein any single probable malfunction is considered remote and which will render only one braked wheel inoperative insofar as antiskid operation is concerned, the deactivating means need not be located in the cockpit.

(iv) Antiskid installations should not cause surge pressures in the brake hydraulic system which would be detrimental to either the normal or emergency brake system and components.

(v) The antiskid equipment should insure satisfactory operation on slippery runways as well as on dry hard surfaced runways without additional antiskid adjustments.

(c) *Tests and analyses.*

(1) When an antiskid system is included as original equipment on an airplane, it is not required that field length data,[11] with antiskid inoperative, be determined.

(2) Tests and analyses for the approval of an antiskid system to be used with a previously approved brake installation, without consideration for reduction of runway distances, should be conducted in accordance with this paragraph. When equivalent alternate procedures are developed and approved, they may be used in lieu of the method specified in this paragraph. If credit for shorter field lengths is requested on the basis of an antiskid installation, then complete flight tests should be conducted in accordance with sections 4b.115, 4b.122, 4b.123, 4b.170 and 4b.171.

(3) When an antiskid system is installed, the braking performance and airplane stopping distances should be at least equivalent to those obtained during the accelerate-stop and landing type certification tests. The tests to be conducted are based on the high speed condition as being critical, both for airplane braking as controlled by the antiskid system, and for the functional integrity of an acceptable antiskid device. However, should it become necessary for a particular type of installation, these tests may be modified as warranted.

(i) Conduct at least one accelerate-stop test at each of the following speeds: 80, 90, and 100 percent of the highest V_1 speed for which the airplane is certificated.[12] The maximum landing weight, or the lowest weight above maximum landing weight necessary to keep the airplane from leaving the runway at the highest V_1 speed, should be used in the above three tests. When appropriate, the decelerate portions of the accelerate-stop tests may be demonstrated by landings with wing flaps in takeoff position in lieu of accelerating the airplane to V_1 speed on the runway. (See also sec. 4b.115–1.)

(ii) Conduct at least one landing deceleration test at each of the following weights: maximum landing weight, an intermediate landing weight and normal minimum landing weight.[13] All landings should be made from the highest corresponding contact speeds used in determining CAA Approved Airplane Flight Manual field lengths.

(4) Conduct controllability tests in accordance with sections 4b.170 and 4b.171 (except for the emergency braking condition) after the occurrence of any single malfunction within the antiskid system (excluding the device and those components which were determined to be satisfactory based on laboratory tests). Single probable malfunctions, which analysis indicates may be likely to occur, should

[11] It is desirable to determine field length data with the antiskid inoperative in order that airplane operation may be conducted with antiskid inoperative if so desired by the operator.

[12] In order to assure stopping distances equivalent to those shown in the Airplane Flight Manual, camera recording, or equivalent recordation methods should be used. To ascertain that the measured stopping distances are equivalent to those in the Airplane Flight Manual it will be necessary to compare the measured antiskid data with the data obtained during the manufacturer's original certification tests for the weight used in the antiskid tests at the highest speed for that weight shown in the Airplane Flight Manual.

[13] If it can be shown by the accelerate-stop distance tests conducted and the data obtained in subdivision (i) of this subparagraph that the landing distances when using normal landing braking techniques, would not exceed the landing distances approved without antiskid devices, then the landing distance tests specified in subdivision (ii) of this subparagraph need not be conducted.

be simulated during landing or simulated landing deceleration tests. If analysis shows clearly that a particular malfunction would not adversely affect controllability, that malfunction need not be simulated in flight tests.

(5) Conduct taxi tests to demonstrate that repeated rapid full brake pedal application and release does not result in excessive delay in brake reapplications and that ground handling maneuvering characteristics and sensitivity of braking effect are satisfactory.

(6) Conduct tests and analyses to determine the effect of automatic cyclic brake action on the emergency brake system fluid supply. The fluid volume (reserved for emergency use in the reservoir or emergency accumulators of the basic brake system) may be adequate for manual braking but may be adversely affected by an antiskid installation. Hence, an engineering evaluation should be conducted to show that the antiskid system will not have an adverse effect on braking when the airplane is stopped by means of the emergency brake system, or to show that the antiskid system is automatically made inoperative when emergency braking is used.

(7) If, during the tests specified in this paragraph, adjustments or modifications to the antiskid device or its installation proved necessary and indicated the possibility of encountering unreliable operation due to maintenance difficulties or the need for frequent adjustments, then accelerated service functioning and reliability tests should be conducted as deemed necessary.

(21 F. R. 2558, Apr. 18, 1956, effective May 15, 1956.)

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 secs. 4b.230 through 4b.236.)

Hulls and Floats

4b.340 *General.* The requirements of sections 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 section 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.

Personnel and Cargo Accommodations

4b.350 *Pilot compartment; general.* All references to flight crew in sections 4b.350 through 4b.353 shall mean the minimum flight crew established in accordance with section 4b.720.

(a) The arrangement of the pilot compartment and its appurtenances shall provide safety and assurance that the flight crew will be able to perform all of their duties and operate the controls in the correct manner without unreasonable concentration and fatigue.

(b) The primary flight controls listed on figure 4b–16, excluding cables and control rods, shall be so located with respect to the propellers that no portion of the flight crew or the controls lies in the region between the plane of rotation of any inboard propeller and the surface generated by a line passing through the center of the propeller hub and making an angle of 5° forward or aft of the plane of rotation of the propeller.

(c) When provision is made for a second pilot, the airplane shall be controllable with equal safety from both seats.

(d) The pilot compartment shall be constructed to prevent leakage likely to be distracting to the crew or harmful to the structure when flying in rain or snow.

(e) A door shall be provided between the pilot compartment and the passenger compartment.

(f) The door prescribed in paragraph (e) of this section shall be equipped with a locking means to prevent passengers from opening the door without the pilot's permission.

(g) Vibration and noise characteristics of cockpit appurtenances shall not interfere with the safe operation of the airplane.

4b.350–1 *Noise and vibration characteristics (CAA policies which apply to sec. 4b.350 (g)).* Noise and vibration characteristics should be observed throughout the flight test program. If possible, noise levels should be measured and recorded in decibels.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.351 *Pilot compartment vision.*

(a) *Nonprecipitation conditions.*

(1) The pilot compartment shall be arranged to afford the pilots a sufficiently extensive, clear, and undistorted view to perform safely all maneuvers within the operating limitations of the airplane, including taxying, take-off, approach, and landing.

(2) It shall be demonstrated by day and night flight tests that the pilot compartment is free of glare and reflections which would tend to interfere with the flight crew's normal duties.

(b) *Precipitation conditions.*

(1) Means shall be provided for maintaining a sufficient portion of the windshield clear so that both pilots are afforded a sufficiently extensive view along the flight path in all normal flight attitudes of the airplane. Such means shall be designed to function under the following conditions without continuous attention on the part of the crew:

(i) In heavy rain at speeds up to 1.6 V_{S_1}, flaps retracted,

(ii) In the most severe icing conditions for which approval of the airplane is desired.

(2) In addition to the means prescribed in subparagraph (1) of this paragraph at least the first pilot shall be provided with a window which, when the cabin is not pressurized, is openable under the conditions prescribed in subparagraph (1) of this paragraph, and which provides the view specified in that subparagraph. The design shall be such that when the window is opened sufficient protection from the elements will be provided against the impairment of the pilot's vision.

4b.351–1 *Procedure for demonstrating pilot compartment visibility (CAA policies which apply to sec. 4b.351).*

(a) *Nonprecipitation conditions.* Such tests as are deemed necessary to show compliance with section 4b.351 (a) should be conducted.

(b) *Precipitation conditions, section 4b.351 (b).*

(1) The operation of the windshield wiper should be checked in actual or simulated precipitation conditions in order to demonstrate that adequate vision is provided for takeoff and landing at speeds up to 1.6 V_{S_1}.

(2) The windshield de-icing system should be checked for distribution and operation.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.351–2 *Vision with reverse thrust (CAA policies which apply to sec. 4b.351).* The policies outlined in section 4b.402–1 (g) and (h) will apply.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

[4b.351–3 *Minimum area of visibility in the flight crew compartment (CAA policies which apply to sec. 4b.351 (a)).* The area of visibility established in this section for the pilot, and an equivalent area for the copilot, should be the minimum for showing compliance with the visibility provisions of section 4b.351 (a).

[(a) *Reference eye position.* A single point established in accordance with the provisions of this paragraph constitutes the reference eye position (i. e., a point midway between the two eyes) from which the central axis may be located. The reference eye position is located 5 inches aft of the rearmost extremity of the elevator control device when the control is in its most rearward position (i. e., against the up elevator control stops), see figure 6, and 30.5 inches ±.5 inch above the point of maximum depression of the seat cushion with:

[(1) The pilot seat in a normal operating position from which all controls can be utilized to their full travel, by an average subject, and which will provide for vertical adjustment of the seat of not less than 2½ inches above and 2½ inches below this initial vertical position.

[(2) The seat back in its most upright position.

[(3) The seat cushion depression being that caused by a subject weighing 170 to 200 pounds.

[(4) The longitudinal axis of the airplane level.

[(5) The point established not beyond one inch to the left or right of the longitudinal center line of the pilot's seat. (See fig. 6.)

[(6) All measurements made from a single point established in accordance with this paragraph.

[(b) *Clear areas of vision.*

[(1) With the reference eye position located as indicated in paragraph (a), and utilizing binocular vision and azimuthal movement of the head and eyes about a radius, the center of which is 3⅝ inches behind the reference eye position (this point to be known as the central axis), the pilot should have the following clear areas of vision measured from the appropriate eye position with the aircraft's longitudinal axis level. The areas defined are based on the cardinal points of reference listed below and indicated in figure 7. A dual lens camera as photo recorder should be used in measuring the angles specified in this paragraph. Other methods, including the use of a goniometer, are acceptable if they produce equivalent areas to those obtained with the dual lens camera. When not using a dual lens camera compensation should be made for one-half the distance which exists between the eyes, or 1¼ inches as indicated in figure 9.

[(i) 20° forward and up from the horizon between 20° left and 10° right allowed to diminish to 15° up at 30° right (this area unbroken).

[(ii) 15° forward and down from the horizon between 20° left and 10° right allowed to diminish to 10° down at 30° right (this area unbroken).

[(iii) 40° above horizon between 85° and 95° left.

[(iv) 30° below horizon between 85° and 95° left.

[(v) 20° up and 15° down from horizon at 135° left.

[(2) There should be no obstruction to vision in the area indicated in subdivisions (i) and (ii) of this paragraph and in figure 7. Beyond 20° left the angles indicated in subdivisions (i) and (ii) should remain constant, or increase progressively until they reach the reference angles in subdivisions (iii) and (iv) at 85° and should not be less than indicated in these subdivisions up to the 95° position, at which time they may diminish gradually to the angles shown in subdivision (v) of this paragraph, and should be governed by the limitations of paragraph (d) (2). The area beyond 135°, if any, should be as large as possible since the human eye does not present any limitation when the use of perceptive rather than binocular vision is the criterion.

[(3) It is possible that in the symmetrical type pilot compartment, there may be an area about the center line of the windshield where the requirements governing pilot and copilot vision areas do not overlap. In this area the angles above and below eye level may diminish due to the increased distance between the appropriate eye position and the windshield, but the windshield dimensions established at the 30° right position, above and below the horizontal plane of the pilot's eye, should be retained. This area should also be governed by the limitations of paragraph (d) (1) and (2) of this section. No attempt is made to define the angles of vision for the pilot, to the right of 30°, since it is assumed that the required vision for the copilot will govern this area. This area not defined by exact limits is indicated by shading in figure 7.

[(c) *Optical properties of windshield.* The windshield should exhibit equivalent optical properties to those covered in MIL–G–8602, dated June 29, 1953, for flat panels, and MIL–G–7767, dated August 14, 1951, for curved panels or any applicable military specifications which may be published subsequent to these specifications. In addition, the optical properties of the windshield should not deteriorate under pressurization loads.

[(d) *Impairments to vision.*

[(1) Any windshield post should not exceed 2.5 inches total obstruction in projected width on the pilot's eyes when located within a sector of 20° and 60° of azimuth to the left of the pilot's forward vision, when measured with head rotated so that the eyes are perpendicular to a vertical plane passing through the center

line of the projected width as indicated in figure 8.

[(2) The location of instruments, equipment, or structure should not impair any of the areas of vision established in this section. In addition, cockpit equipment should not obstruct a line of vision from a point two inches above the reference eye position to any point along the upper limit of the forward windshield panels, and similarly, a line of vision from a point two inches below the reference eye position to the lower limit of the forward windshield panels.]

(22 F. R. 7359, Sept. 14, 1957, effective Sept. 20, 1957.)

4b.352 *Windshield and windows.*

(a) All internal glass panes shall be of a nonsplintering safety type.

(b) The windshield, its supporting structure, and other structure in front of the pilots shall have sufficient strength to withstand without penetration the impact of a four-pound bird when the velocity of the airplane relative to the bird along the airplane's flight path is equal to the value of V_C at sea level selected in accordance with section 4b.210 (b) (4). [Means shall be provided to minimize the danger to the pilots from flying windshield fragments due to bird impact unless it can be shown by analysis or test that the probability of occurrence of a critical fragmentation condition is of low order.]

(c) The design of windshields and windows in pressurized airplanes shall be based on factors peculiar to high altitude operation. (See also sec. 4b.373.)

NOTE: Factors peculiar to high altitude operation as they may affect the design of windshields and windows include the effects of continuous and cyclic pressurization loadings, the inherent characteristics of the material used, the effects of temperatures and temperature differentials, etc.

4b.353 *Controls.*

(a) All cockpit controls shall be located to provide convenience in operation and in a manner tending to prevent confusion and inadvertent operation. (See also sec. 4b.737.)

(b) The direction of movement of controls shall be according to figures 4b–16 and 4b–17. Wherever practicable the sense of motion involved in the operation of other controls shall correspond with the sense of the effect of the operation upon the airplane or upon the part operated. All controls of a variable nature employing a rotary motion shall move clockwise from the off position, through an increasing range, to the full on position.

Controls	Movement and actuation
PRIMARY	
Aileron	Right (clockwise) for right wing down.
Elevator	Rearward for nose up.
Rudder	Right pedal forward for nose right.
SECONDARY	
Flaps (or auxiliary lift devices).	Forward for flaps up; rearward for flaps down.
Trim tabs (or equivalent).	Rotate to produce similar rotation of the airplane about an axis parallel to the axis of the control.

Figure 4b–16.—Aerodynamic controls.

Controls	Movement and actuation
Powerplant	
Throttles	Forward to increase forward thrust and rearward to increase rearward thrust.
Propellers	Forward to increase rpm.
Mixture	Forward or upward for rich.
Carburetor air heat	Forward or upward for cold.
Supercharger	Forward or upward for low blower. In the case of turbosuperchargers, forward, upward, or clockwise to increase pressure.
Auxiliary	
Landing gear	Down to extend.

Figure 4b–17.—Powerplant and auxiliary controls.

(c) The controls shall be so located and arranged with respect to the pilots' seats that there exists full and unrestricted movement of each control without interference from either the cockpit structure or the flight crew's clothing when seated with the seat belt fastened. This shall be demonstrated for individuals ranging from 5′ 2″ to 6′ 0″ in height.

(d) Identical powerplant controls for each engine shall be located to prevent any mis-

leading impression as to the engine to which they relate.

(e) The wing flap (or auxiliary lift device) and landing gear controls shall comply with the following:

(1) The wing flap control shall be located on top of the pedestal aft of the throttle(s), centrally or to the right of the pedestal centerline and shall be not less than 10 inches aft of the landing gear control.

[(2) The landing gear control shall be located forward of the throttles and shall be operable by each of the pilots when seated with seat belts fastened.]

(f) The control knobs shall be shaped in accordance with figure 4b–22, and such knobs shall be of the same color, but of a color in contrast with that of not only the other control knobs but also the surrounding cockpit.

NOTE: Figure 4b–22 is not intended to indicate the exact size or proportion of the control knobs.

(g) Where the work load on the flight crew is such as to require a flight engineer (see sec. 4b.720), a flight engineer station shall be provided. The station shall be so located and arranged that the flight crew members can perform their functions efficiently and without interfering with each other.

4b.353–1 *Control tests (CAA policies which apply to sec. 4b.353).* Such tests as are deemed necessary to show compliance with the control movements and locations specified in section 4b.353 should be conducted.

(19 F. R. 4464, July 20, 1954, effective Sept. 1, 1954.)

4b.354 *Instrument arrangement.* (See sec. 4b.611.)

4b.355 *Instrument marking.* (The operational markings, instructions, and placards required for the instruments, controls, etc., are specified in secs. 4b.730 through 4b.738.)

4b.356 *Doors.*

(a) Airplane cabins shall be provided with at least one easily accessible external door.

(b) Means shall be provided for locking each external door and for safeguarding against opening in flight either inadvertently by persons or as a result of mechanical failure. It shall be possible to open external doors from either the inside or the outside even though persons may be crowding against the door from the inside. (Note: It is not the intent to prohibit the use of inward opening doors if sufficient measures are provided to prevent occupants from crowding against the door to an extent which would interfere with the opening of the door.) The means of opening shall be simple and obvious and shall be so arranged and marked that it can be readily located and operated even in darkness.

(c) Reasonable provisions shall be made to prevent the jamming of any external door as a result of fuselage deformation in a minor crash.

(d) External doors shall be so located that persons using them will not be endangered by the propellers when appropriate operating procedures are employed.

(e) Means shall be provided for a direct visual inspection of the locking mechanism by crew members to ascertain whether all external doors [for which the initial opening movement is outward,] including passenger, crew, service, and cargo doors, are fully locked (see also sec. 4b.362 (e) (5) for emergency exits). In addition, visual means shall be provided to signal to appropriate crew members that all normally used external doors are closed and in the fully locked position.

4b.356–1 *External doors (CAA policies which apply to sec. 4b.356).* The provisions of section 4b.356 should be applied to all cabin and crew compartment external doors usable for entrance or egress. It is not restricted to the main cabin door. Cargo and service doors not suitable for emergency egress need only comply with section 4b.356 (e) and safeguarding against opening in flight as a result of mechanical failure.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.356–2 *Auxiliary latching devices (CAA policies which apply to sec. 4b.356 (b)).*

(a) The use of auxiliary latching devices is permitted. Such devices would include dual locking handles, other types of locking and safetying devices, and two position handles, and where one operation such as pushing or pulling on the handle unlocks the latching mechanism and the second operation of turning the handle unlatches the door for opening. Auxiliary safetying devices should be used only

as an additional safety factor and should not be used as a means of correcting an inadequate design of the primary locking or latching means. The advantages to be gained from the installation of auxiliary or dual safety devices (safety chains and dual handle main locking means) should be weighed against the need to easily and rapidly open the door in case of emergencies so that the overall level of safety is as high as practicable.

(b) All locking or safety means, including safety chains and latches of any kind, should be so positioned and designed that their presence, location and means of operation are obvious to one not familiar with door designs.

(1) The means of fastening safety devices should be sufficiently simple to make removal easy.

(2) Any emergency release mechanism installed to release the safety device should operate with a simple motion and upon the application of relatively small forces.

(3) All locking devices should be readily operable from both inside and outside of the airplane and be appropriately marked both inside and outside.

(c) Auxiliary safety devices meeting the standards of (b) may be fastened in place during the entire flight. It will not be necessary to have such devices unlatched during takeoff and landing. Auxiliary safety devices such as safety chains or bars that do not meet the standards of paragraph (b) of this section may be used provided operating instructions are installed at or near the device and a placard is installed requiring the removal of such devices prior to takeoff and landing.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.356–3 *Power operated external doors (CAA policies which apply to sec. 4b.356 (b)).* Power operated doors should be so designed that the door can be opened by manual means even when power is inactivated. The loss of power should not cause the door to become unlatched.[14]

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

[14] Since emergency landings, such as the wheels-up condition, may reasonably result in the severance of electrical wires or rupture of hydraulic and pneumatic lines, the power which may be needed for operation of the doors or exits may be lost. Similarly, it is conceivable that under emergency conditions, the electrical power source may be purposely interrupted to reduce the possibility of fire.

4b.356–4 *Means for safeguarding against inadvertent opening in flight (CAA policies which apply to sec. 4b.356 (b)).* Auxiliary latching devices may be used to reduce the probability of inadvertent opening in flight provided they meet the standards and conditions covered in section 4b.356–2.

(a) It is acceptable to create a limited access zone in front of the door to eliminate the possibility of a passenger using the door handle as a steadying means and thereby inadvertently opening the door. Although providing a restricted zone by means of a barrier may appear to conflict with the requirements of section 4b.362 (g) for an unobstructed passageway to Type I and II emergency exits, it is considered that it would contribute sufficiently to the overall safety of the aircraft occupants to be permitted. This device may be a rope, chain, rigid bar or gate. Such installations should be waist high to provide the maximum benefits for an adult and the end fastenings should be simple to make removal easy. It is not considered acceptable to install full-length auxiliary doors, but waist-high rigid gates would be acceptable provided they open toward the door and will not block the opening of the cabin door in any way. The locking means should be one which could be easily overridden such as a spring-loaded ball type latch.

(b) Flexible gates such as those made from webbing are not acceptable on the basis that persons may become entangled during an emergency egress. The use of a barrier to prevent persons from inadvertently opening the door in flight does not eliminate the need for a safety means to provide for possible malfunctioning of the primary locking mechanism; however, the auxiliary safetying means of section 4b.356–2 may eliminate the need for a restricted zone.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.356–5 *Direct visual inspection (CAA policies which apply to sec. 4b.356 (e)).* The means of complying with section 4b.356 (e) will depend upon the type of door and locking mechanism used. It should be determined in all cases that means are provided to ascertain that an unsatisfactory condition does not exist after closing the door. In some instances a central window for viewing the position of the

mechanism may be sufficient while other cases may require one or more windows in the door frame to permit inspection of the bayonet location relative to that portion of the lock in the door frame. The need for and/or the number and location of inspection openings or windows will depend on the type of door and locking mechanism used.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.356–6 *Visual indicating system (CAA policies which apply to sec. 4b.356 (e)).*[15]

(a) The visual indicating system may consist of an indicator for each individual door, or a system connecting all doors in series. If the latter system is used, it need not necessarily show which door is not fully locked.

(b) It is not necessary that more than one crew member be able to ascertain by a visual signal that all external doors, normally used by the crew in supplying the airplane, or in loading and unloading passengers and cargo, are fully closed and locked. The visual signal should be located so that it may easily be seen by the appropriate crew member from his station.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.357 *Door louvres.* Where internal doors are equipped with louvres or other ventilating means, provision convenient to the crew shall be made for stopping the flow of air through the door when such action is found necessary.

4b.358 *Seats, berths, and safety belts.*

(a) *General.* At all stations designated as occupiable during take-off and landing, the seats, berths, belts, harnesses, and adjacent parts of the airplane shall be such that a person making proper use of these facilities will not suffer serious injury in the emergency landing conditions as a result of inertia forces specified in section 4b.260. Seats and berths shall be of an approved type (see also sec. 4b.643 concerning safety belts).

(b) *Arrangement.*

(1) Passengers and crew shall be afforded protection from head injuries by one of the following means:

(i) Safety belt and shoulder harness which will prevent the head from contacting any injurious object,

(ii) Safety belt and the elimination of all injurious objects within striking radius of the head,

(iii) Safety belt and a cushioned rest which will support the arms, shoulders, head, and spine.

(2) For arrangements which do not provide a firm hand hold on seat backs, hand grips or rails shall be provided along aisles to enable passengers or crew members to steady themselves while using the aisles in moderately rough air.

(3) All projecting objects which would cause injury to persons seated or moving about the airplane in normal flight shall be padded.

(4) Berths shall be so designed that the forward portion is provided with a padded end board, a canvas diaphragm, or other equivalent means, capable of withstanding the static load reaction of the occupant when subjected to the forward inertia force specified in section 4b.260. Berths shall be free from corners and protuberances likely to cause serious injury to a person occupying the berth during emergency conditions.

[(5) Seats for all crew members at flight deck stations shall incorporate provisions for the use of a shoulder harness and the seats with such provisions shall comply with the strength requirements of paragraph (c) of this section.]

(c) *Strength.* All seats and berths and their supporting structure shall be designed for occupant weight of 170 pounds with due account taken of the maximum load factors, inertia forces, and reactions between occupant, seat, and safety belt or harness corresponding with all relevant flight and ground load conditions, including the emergency landing conditions prescribed in section 4b.260. In the case of berths, the forward inertia force shall be considered in accordance with subparagraph (b) (4) of this section and need not be considered with respect to the safety belt. In addition, the following shall apply.

(1) Pilot seats shall be designed for the reactions resulting from the application of pilot

[15] The objective herein is to be able to ascertain by visual means that the door and/or locking means is sufficiently engaged to eliminate hazards emanating from an improperly closed door. Outward opening doors present a different problem from inward opening doors.

forces to the flight controls as prescribed in section 4b.224.

(2) In determining the strength of the seat or berth attachments to the structure, and the safety belt or shoulder harness attachments to the seat, berth, or structure, the inertia forces specified in section 4b.260 (a) shall be multiplied by a factor of 1.33.

4b.358–1 *Application of loads (CAA policies which apply to sec. 4b.358).* The actual forces acting on seats, berths, and supporting structure in the various flight, ground and emergency landing conditions will consist of many possible combinations of forward, sideward, downward, upward, and aft loads. However, in order to simplify the structural analysis and testing of these structures, it will be permissible to assume that the critical load in each of these directions, as determined from the prescribed flight, ground, and emergency landing conditions, acts separately. If the applicant desires, selected combinations of loads may be used, provided the required strength in all specified directions is substantiated. (TSO C–25, Aircraft Seats and Berths, outlines acceptable methods for testing seats and berths.)

4b.359 *Cargo and baggage compartments.* (See also secs. 4b.382 to 4b.384.)

(a) Each cargo and baggage compartment shall be designed for the placarded maximum weight of contents and the critical load distributions at the appropriate maximum load factors corresponding with all specified flight and ground load conditions, excluding the emergency landing conditions of section 4b.260.

(b) Provisions shall be made to prevent the contents in the compartments from becoming a hazard by shifting under the loads specified in paragraph (a) of this section.

(c) Provisions shall be made to protect the passengers and crew from injury by the contents of any compartment, taking into account the emergency landing conditions of section 4b.260.

Emergency Provisions

4b.360 *General.* The requirements of sections 4b.361 and 4b.362 shall apply to the emergency provisions.

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4b.361 *Ditching.* Compliance with this section is optional. The requirements of this section are intended to safeguard the occupants in the event of an emergency landing during overwater flight. When compliance is shown with the provisions of paragraphs (a) through (c) of this section and with the provisions of sections 4b.362 (d), 4b.645, and 4b.646, the type certificate shall include certification to that effect. When an airplane is certificated to include ditching provisions, the recommended ditching procedures established on the basis of these requirements shall be set forth in the Airplane Flight Manual (see sec. 4b.742 (d)).

(a) All practicable design measures compatible with the general characteristics of the type airplane shall be taken to minimize the chance of any behavior of the airplane in an emergency landing on water which would be likely to cause immediate injury to the occupants or to make it impossible for them to escape from the airplane. The probable behavior of the airplane in a water landing shall be investigated by model tests or by comparison with airplanes of similar configuration for which the ditching characteristics are known. In this investigation account shall be taken of scoops, flaps, projections, and all other factors likely to affect the hydrodynamic characteristics of the actual airplane.

(b) It shall be shown that under reasonably probable water conditions the flotation time and trim of the airplane will permit all occupants to leave the airplane and to occupy the life rafts required by section 4b.645. If compliance with this provision is shown by buoyancy and trim computations, appropriate allowances shall be made for probable structural damage and leakage.

NOTE: In the case of fuel tanks which are equipped with fuel jettisoning provisions and which can be reasonably expected to withstand a ditching without leakage, the jettisonable volume of fuel may be considered as buoyancy volume.

(c) External doors and windows shall be designed to withstand the probable maximum local pressures, unless the effects of the col-

lapse of such parts are taken into account in the investigation of the probable behavior of the airplane in a water landing as prescribed in paragraphs (a) and (b) of this section.

4b.362 *Emergency evacuation.* Crew and passenger areas shall be provided with emergency evacuation means to permit rapid egress in the event of crash landings, whether with the landing gear extended or retracted, taking into account the possibility of the airplane being on fire. If the airplane is divided into separate compartments arranged so that the minimum unobstructed passageway between such compartments is not available as required by paragraph (g) of this section, requirements of this section shall be applied to each compartment independently. Passenger and crew entrances and service doors shall be considered as emergency exits if they meet the applicable requirements of this section.

(a) *Flight crew emergency exits.* Flight crew emergency exits shall be located in the flight crew area, one on each side of the airplane, or, alternatively, a top hatch shall be provided. Such exits shall be of sufficient size and shall be so located as to permit rapid evacuation by the crew. Such exits shall not be required in airplanes having a passenger capacity of 20 or less if the Administrator finds that the proximity of passenger emergency exits to the flight crew area offers a convenient and readily accessible means of evacuation for the flight crew.

(b) *Passenger emergency exits; type and location.* All required exits shall be in such specific locations as will afford the most effective means of passenger evacuation. The type of exits and their general location shall be as follows:

(1) Type I: A rectangular opening of not less than 24 inches wide by 48 inches high, with corner radii not greater than ⅓ the width of the exit. The first Type I exit on each side of the fuselage shall be located on the aft portion of the passenger compartment unless the configuration of the airplane is such that some other location would afford a more effective means of passenger evacuation. All Type I exits shall be floor level exits.

(2) Type II: A rectangular opening of not less than 20 inches wide by 44 inches high, with corner radii not greater than ⅓ the width of the exit. Unless Type I exits are required, one Type II exit on each side of the fuselage shall be located in the aft portion of the passenger compartment except where the configuration of the airplane is such that some other location would afford a more effective means of passenger evacuation. Type II exits shall be floor level exits unless located over the wing in which case they shall have a step-up inside the airplane of not more than 10 inches and a step-down outside the airplane of not more than 17 inches.

(3) Type III: A rectangular opening of not less than 20 inches wide by 36 inches high, with corner radii not greater than ⅓ the width of the exit, located over the wing with a step-up inside the airplane of not more than 20 inches and a step-down outside the airplane of not more than 27 inches.

(4) Type IV: A rectangular opening of not less than 19 inches wide by 26 inches high, with corner radii not greater than ⅓ the width of the exit, located over the wing with a step-up inside the airplane of not more than 29 inches and a step-down outside the airplane of not more than 36 inches.

NOTE: Larger openings than those specified in paragraph (b) of this section shall be acceptable, whether or not of rectangular shape, provided that the specified rectangular openings can be inscribed therein, and provided further that the base of the inscribed rectangular opening meets the specified step-up and step-down heights.

(c) *Passenger emergency exits; number required.* Emergency exits of the type and location prescribed in paragraph (b) of this section shall be accessible to the passengers and shall be provided in accordance with subparagraphs (1) through (5) of this paragraph.

(1) The relation between the passenger seating capacity and the type and number of exits provided on each side of the airplane shall be as follows:

Passenger seating capacity	Emergency exits required on each side of the fuselage			
	Type I	Type II	Type III	Type IV
1 to 19 inclusive			1	
20 to 39 inclusive		1		1
40 to 59 inclusive	1			1
60 to 79 inclusive	1		1	
80 to 109 inclusive	1		1	1
110 to 139 inclusive	2		1	
140 to 179 inclusive	2		2	
180 to 219 inclusive	2	2		

NOTE: Although similar exits and their locations are prescribed for each side of the fuselage, it is not the intent of this regulation to require that the exits necessarily be at locations diametrically opposite each other.

(2) Additional exits shall be provided on airplanes having 220 or more passengers. The additional exits shall provide an effective means of passenger evacuation consistent with the minima provided in the table in subparagraph (1) of this paragraph.

(3) In applying subparagraph (1) of this paragraph, it shall be acceptable to install 2 Type IV exits in lieu of each required Type III exit.

(4) If the Administrator finds that there exist compensating factors in the emergency evacuation means provided, it shall be permissible to increase the passenger seating capacity beyond that shown in subparagraph (1) of this paragraph, except that such increase in seating capacity shall in no case exceed 10 passengers.

(5) On airplanes where the vertical location of the wing does not permit the installation of over-wing exits, an exit the dimensions of which are not less than those prescribed in paragraph (b) (3) of this section shall be installed for each Type III and each Type IV exit required by subparagraph (1) of this paragraph.

(d) *Ditching emergency exits.* It shall be shown that there is not less than one emergency exit located above the water line for every 35 passengers and at least one such exit per side shall meet the minimum dimensions of the exit specified in paragraph (b) (3) of this section. It shall be permissible to substitute for any side exit an easily accessible overhead hatch of not less than the clear dimensions of the exit specified in paragraph (b) (3) of this section.

(e) *Emergency exit arrangement.*

(1) Emergency exits shall consist of movable doors or hatches in the external walls of the fuselage and shall provide an unobstructed opening to the outside.

(2) All emergency exits shall be openable from the inside and from the outside.

(3) The means of opening emergency exits shall be simple and obvious and shall not require exceptional effort of a person opening them.

(4) Means shall be provided for locking each emergency exit and for safeguarding against opening in flight either inadvertently by persons or as a result of mechanical failure.

(5) Means shall be provided for a direct visual inspection of the locking mechanism by crew members to ascertain whether all emergency exits [for which the initial opening movement is outward] are fully locked.

(6) Provision shall be made to minimize the possibility of jamming of emergency exits as a result of fuselage deformation in a minor crash landing.

(7) For all landplane emergency exits other than exits located over the wing which are more than 6 feet from the ground with the airplane on the ground and the landing gear extended, approved means shall be provided to assist the occupants in descending to the ground.

(8) The proper functioning of emergency exit installations shall be demonstrated by test.

(f) *Emergency exit marking.*

(1) All emergency exits, their means of access, and their means of opening shall be marked conspicuously. The identity and location of emergency exits shall be recognizable from a distance equal to the width of the cabin. The location of the emergency exit operating handle and the instructions for opening shall be marked on or adjacent to the emergency exit and shall be readable from a distance of 30 inches.

(2) A source or sources of light, with an energy supply independent of the main lighting system, shall be installed to illuminate all emergency exit markings. Such lights shall be designed to function automatically in a crash landing and shall also be operable manually.

(3) All emergency exits and their means of opening shall be marked on the outside of the airplane for guidance of rescue personnel.

(g) *Emergency exit access.* Passageways between individual compartments of the passenger area and passageways leading to Type I and Type II emergency exits (see paragraph (b) of this section) shall be unobstructed and shall be not less than 20 inches wide. Adjacent to emergency exits where assisting means are required by paragraph (e) (7) of this section, there shall be sufficient additional space to allow a crew member to assist in the evacuation of passengers without reduction in the unobstructed width of the passageway to such exit.

Access shall be provided from the main aisle to all Type III and Type IV exits and such access shall not be obstructed by seats, berths, or other protrusions to an extent which would reduce the effectiveness of the exit, except that minor obstructions shall be permissible if the Administrator finds that compensating factors are present to maintain the effectiveness of the exit.

(h) *Width of main aisle.* The main passenger aisle at any point between seats shall not be less than 15 inches wide up to a height above the floor of 25 inches and not less than 20 inches wide above that height.

For airplanes having a maximum passenger seating capacity of 19 or less, these aisle widths shall not be less than 12 inches wide up to a height above the floor of 25 inches and not less than 20 inches above that height.

Ventilation, Heating, and Pressurization

4b.370 ***General.*** The requirements of sections 4b.371 through 4b.376 shall apply to the ventilation, heating, and pressurization of the aircraft.

4b.371 ***Ventilation.***

(a) All crew compartments shall be ventilated by providing a sufficient amount of fresh air to enable the crew members to perform their duties without undue discomfort or fatigue.

NOTE: An outside air supply of approximately 10 cubic feet per minute is considered a minimum for each crew member.

(b) Ventilating air in crew and passenger compartments shall be free of harmful or hazardous concentrations of gases or vapors.

NOTE: Carbon monoxide concentrations in excess of one part in 20,000 parts of air are considered hazardous. Carbon dioxide in excess of 3 percent by volume (sea level equivalent) is considered hazardous in the case of crew members. Higher concentrations of carbon dioxide may not necessarily be hazardous in crew compartments if appropriate protective breathing equipment is available.

(c) Provision shall be made to insure the conditions prescribed in paragraph (b) of this section in the event of reasonably probable failures or malfunctioning of the ventilating, heating, pressurization, or other systems and equipment. [If accumulation of hazardous quantities of smoke in the cockpit area is reasonably probable, smoke evacuation shall be readily accomplished starting with full pressurization and without depressurizing beyond safe limits (see sec. 4b.374 (b)).]

NOTE: Examples of acceptable provisions include secondary isolation, integral protective devices, and crew warning and shut-off for equipment the malfunctioning of which could introduce harmful or hazardous quantities of smoke or gases.

(d) Where partitions between compartments are equipped with louvres or other means allowing air to flow between such compartments, provision convenient to the crew shall be made for stopping the flow of air through the louvres or other means when such action is found necessary. (See also sec. 4b.357.)

(e) Means shall be provided to enable the crew to control the temperature and quantity of ventilating air supplied to the crew compartment independently of the temperature and quantity of ventilating air supplied to other compartments.

4b.371–1 *Carbon monoxide detection (CAA policies which apply to sec. 4b.371).* Policies outlined in section 4b.467–1 will apply.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.372 ***Heating systems.*** Combustion heaters shall be of an approved type and shall

comply with the fire protection requirements of section 4b.386. Engine exhaust heaters shall comply with the provisions of section 4b.467 (c) and (d).

4b.372–1 *Combustion heaters equipped with carbon dioxide fire extinguishers (CAA policies which apply to sec. 4b.372).* The policies as outlined in section 4b.484–1 apply.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.373 *Pressurized cabins; general.* The design of pressurized cabins shall comply with the requirements of sections 4b.374 through 4b.376. (See also secs. 4b.216 (c) and 4b.352.)

[4b.374 *Pressure equipment and supply.* (See sec. 4b.477 (c).)

[(a) Occupied cabins or compartments of airplanes shall be equipped to provide a cabin pressure altitude of not more than 8,000 feet at the maximum operating altitude of the airplane under normal operating conditions.

[(b) Airplanes certificated for operation at altitudes over 25,000 feet shall be capable of maintaining a cabin pressure altitude of not more than 15,000 feet in the event of any reasonably probable failure or malfunction in the pressurization system.]

4b.375 *Pressure control.* Pressurized cabins shall be provided with at least the following valves, controls, and indicators for controlling cabin pressure.

(a) Two pressure relief valves, at least one of which is the normal regulating valve, shall be installed to limit automatically the positive pressure differential to a predetermined value at the maximum rate of flow delivered by the pressure source. The combined capacity of the relief valves shall be such that the failure of any one valve would not cause an appreciable rise in the pressure differential. The pressure differential shall be considered positive when the internal pressure is greater than the external.

(b) Two reverse pressure differential relief valves (or equivalent) shall be installed to prevent automatically a negative pressure differential which would damage the structure, except that one such valve shall be considered sufficient if it is of a design which reasonably precludes its malfunctioning.

(c) Means shall be provided by which the pressure differential can be rapidly equalized.

(d) An automatic or manual regulator for controlling the intake and/or exhaust air flow shall be installed so that the required internal pressures and air flow rates can be maintained.

(e) Instruments shall be provided at the pilot or flight engineer station showing the pressure differential, the absolute pressure in the cabin, and the rate of change of the absolute pressure.

(f) Warning indication shall be provided at the pilot or flight engineer station to indicate when the safe or preset limits on pressure differential and on absolute cabin pressure are exceeded.

(g) If the structure is not designed for pressure differentials up to the maximum relief valve setting in combination with landing loads (see sec. 4b.216 (c)), a warning placard shall be placed at the pilot or flight engineer station.

4b.376 *Tests.*

(a) ***Strength test.*** The complete pressurized cabin, including doors, windows, and all valves, shall be tested as a pressure vessel for the pressure differential specified in section 4b.216 (c) (3).

(b) ***Functional tests.*** The following functional tests shall be performed.

(1) To simulate the condition of regulator valves closed, the functioning and the capacity shall be tested of the positive and negative pressure differential valves and of the emergency release valve.

(2) All parts of the pressurization system shall be tested to show proper functioning under all possible conditions of pressure, temperature, and moisture up to the maximum altitude selected for certification.

(3) Flight tests shall be conducted to demonstrate the performance of the pressure supply, pressure and flow regulators, indicators, and warning signals in steady and stepped climbs and descents at rates corresponding with the maximum attainable without exceeding the operating limitations of the airplane up to the maximum altitudse elected for certification.

(4) All doors and emergency exits shall be tested to ascertain that they operate properly

after being subjected to the flight tests prescribed in subparagraph (3) of this paragraph.

Fire Protection

4b.380 *General.* Compliance shall be shown with the fire protection requirements of sections 4b.381 through 4b.386. (See also secs. 4b.480 through 4b.490.) In addition, the following shall apply.

(a) *Hand fire extinguishers.* Hand fire extinguishers shall be of an approved type. The types and quantities of extinguishing agents shall be appropriate for the types of fires likely to occur in the compartments where the extinguishers are intended for use. Extinguishers intended for use in personnel compartments shall be such as to minimize the hazard of toxic gas concentrations.

(b) *Built-in fire extinguishers.* Where a built-in fire extinguishing system is required, its capacity in relation to the compartment volume and ventilation rate shall be sufficient to combat any fire likely to occur in the compartment. All built-in fire extinguishing systems shall be so installed that any extinguisher agent likely to enter personnel compartments will not be hazardous to the occupants and that discharge of the extinguisher cannot result in structural damage. (See also sec. 4b.371.)

(c) *Protective breathing equipment.* If the airplane contains Class A or B cargo compartments (see sec. 4b.383), protective breathing equipment shall be installed for the use of appropriate crew members. (See sec. 4b.651 (h).)

4b.380–1 *Protective breathing equipment (CAA policies which apply to sec. 4b.380 (c)).* The policies outlined in section 4b.651–2 apply.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.380–2 *Approved hand fire extinguishers (CAA policies which apply to sec. 4b.380 (a)).*

(a) *Standards for approval.* An approved type fire extinguisher includes those approved by the Underwriters' Laboratories, Inc., Factory Mutual Laboratories, Underwriters' Laboratories of Canada, or any other agency deemed qualified by the Administrator, or approved by the Administrator in accordance with the provisions of section 4b.18.

(b) *General.* When selecting a hand fire extinguisher for use in aircraft, consideration should be given to the most appropriate extinguishing agent for the type and location of fires[16] likely to be encountered. Consideration should also be given to the agent's ratio of extinguishing ability to quantity required, toxicity, [17] corrosive properties, freezing point, and to the unit's gross weight, ease of operation, and maintenance requirements. Aircraft hand fire extinguishers using agents having a rating in toxicity Group 4 or under should not be installed in airplanes for which an application for a type certificate was made on or after March 5, 1952.[18]

(c) *Types of extinguishers.*

(1) *Carbon dioxide extinguishers.*[19] Carbon dioxide extinguishers are acceptable when the principal hazard is a Class B or Class C fire. Carbon dioxide portable installations should not exceed five pounds of agent per unit to insure extinguisher portability and to minimize crew compartment CO_2 concentrations.

(2) *Water extinguishers.* [20] Water extinguishers are acceptable when the principal

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[16] *Class A fires*—Fires in ordinary combustible materials where the quenching and cooling effects of quantities of water, or solutions containing large percentages of water, are of first importance.

Class B fires—Fires in flammable liquids, greases, etc., where a blanketing effect is essential.

Class C fires—Fires in electrical equipment, where the use of a nonconducting extinguishing agent is of first importance.

[17] The toxicity ratings listed by the Underwriters' Laboratories for some of the commonly known fire extinguisher chemicals are as follows:

Bromochloromethane	Group 3
Bromotrifluoromethane	Group 6
Carbon dioxide	Group 5
Carbon tetrachloride	Group 3
Dibromodifluoromethane	Group 4
Methyl bromide	Group 2

[18] Many transport type airplanes, due to their type certification basis, are not required to comply with section 4b.380. For such airplanes, it is recommended that hand fire extinguishers employing agents in toxicity Group 4 or higher be installed when renewing or replacing hand fire extinguishers employing toxic agents.

[19] Carbon dioxide is noncorrosive and will not injure food or fabric. Extinguishers must be winterized if they are to operate at temperatures below −40° F. Approved unit capacity ranges upwards from two pounds. These extinguishers have only limited value for the extinguishment of Class A fires, the action of the agent being to blanket the fire by excluding oxygen.

[20] Certain antifreeze agents may be corrosive. Approved extinguishers are either protected against freezing to −40° F. or must be handled as any other unprotected water on the airplane. Technical Standard Order C19a covers a minimum 1⅜ quart capacity approved water extinguisher. Water extinguishers of the kinds currently on the market are not acceptable for flammable liquid or electrical fires.

hazard is a Class A fire and where a fire might smolder if attacked solely by such agents as carbon dioxide or dry chemical.

(3) *Vaporizing liquid extinguishers.* [21] Vaporizing liquid type fire extinguishers are acceptable when the principal hazard is a Class B or Class C fire.

(4) *Dry chemical extinguishers.* [22] Dry chemical extinguishers are acceptable where the principal hazard is a Class B or Class C fire. The extinguisher should not be used in crew compartments because of interference with visibility during discharge and because of the possibility of the nonconductive powders being discharged on electrical contacts not otherwise involved.

(21 F. R. 5735, Aug. 1, 1956, effective Sept. 1, 1956.)

4b.381 *Cabin interiors.* All compartments occupied or used by the crew or passengers shall comply with the following provisions.

(a) The materials in no case shall be less than flash-resistant.

(b) The wall and ceiling linings, the covering of all upholstering, floors, and furnishings shall be flame-resistant.

(c) Compartments where smoking is to be permitted shall be equipped with ash trays of the self-contained type which are completely removable. All other compartments shall be placarded against smoking.

(d) All receptacles for used towels, papers, and waste shall be of fire-resistant material, and shall incorporate covers or other provisions for containing possible fires.

(e) At least one hand fire extinguisher shall be provided for use by the flight crew.

(f) In addition to the requirements of paragraph (e) of this section at least the following number of hand fire extinguishers conveniently located for use in passenger compartments shall be provided according to the passenger capacity of the airplane:

Passenger capacity:	*Minimum number of fire extinguishers*
6 or less	0
7 through 30	1
31 through 60	2
61 or more	3

4b.381–1 *Hand fire extinguishers for cabin interiors (CAA policies which apply to sec. 4b.381 (e) and (f)).*

(a) *Crew compartment.* At least one hand fire extinguisher suitable for Class B and C fires should be installed in the crew compartment. Additional extinguishers may be required as dictated by potential fire hazards, extinguisher accessibility, and agent capacity.

(1) The extinguisher(s) should be readily accessible to crew members and mounted so as to facilitate quick removal from its mounting bracket.

(b) *Passenger compartments.* Fire extinguisher type and capacity should be based on the hazard, e. g., if a unit must protect large accessible baggage compartments, galleys, or electrical equipment racks, portables larger than minimum size should be provided. The size of the extinguisher should not, however, preclude ready portability by a flight attendant or even a passenger.

(1) Each fire extinguisher should be located adjacent to the most prominent hazard such as a baggage compartment, galley, etc.

(i) Where no such obvious hazard exists, or when only one unit is required, the extinguisher should be located at the flight attendant's station or at the entrance door on aircraft with no flight attendant.

(ii) Where two or more extinguishers are required and location is not dictated by special hazards, the units should be located at opposite ends of the passenger cabin.

(2) An extinguisher should be installed in each separate cabin, lounge, or smoking compartment unless the extinguisher in the adjacent compartment is in close proximity and easily accessible.

[21] These agents are not normally corrosive to aircraft structure and approved units will be satisfactorily protected against freezing to at least −40° F. Up to the effective date of this policy, no vaporizing liquid extinguisher with Underwriters' Laboratories toxicity rating higher than Group 4 is commercially available. Approved units have a minimum capacity of one quart. They are of only limited value for the extinguishment of Class A fires, having a cooling effect of about one-tenth that of water.

[22] The powder is nontoxic and noncorrosive and approved units are protected against freezing to at least −40° F. Minimum capacity of approved units is two pounds.

(3) All extinguishers should be easily accessible and clearly visible to the crew and passengers; however, if they cannot be clearly visible, their location should be indicated by a clearly legible placard or sign visible to the crew and passengers.[23]

(21 F. R. 5735, Aug. 1, 1956, effective Sept. 1, 1956.)

4b.382 *Cargo and baggage compartments.*

(a) Cargo and baggage compartments shall include no controls, wiring, lines, equipment, or accessories the damage or failure of which would affect the safe operation of the airplane, unless such items are shielded, isolated, or otherwise protected so that they cannot be damaged by movement of cargo in the compartment, and so that any breakage or failure of such item will not create a fire hazard.

(b) Provision shall be made to prevent cargo or baggage from interfering with the functioning of the fire-protective features of the compartment.

(c) All materials used in the contruction of cargo or baggage compartments, including tie-down equipment, shall be flame-resistant.

4b.383 *Cargo compartment classification.* All cargo and baggage compartments shall include provisions for safe-guarding against fires according to the following classification.

(a) *Class A.* Cargo and baggage compartments shall be classified as "A" if the presence of a possible fire therein would be easily discernible to a member of the crew while at his station, and if all parts of the compartment are easily accessible in flight. A hand fire extinguisher shall be available for each compartment. (See sec. 4b.380 (c) for protective breathing requirements.)

(b) *Class B.* Cargo and baggage compartments shall be classified as "B" if sufficient access is provided while in flight to enable a member of the crew to move by hand all contents and to reach effectively all parts of the compartment with a hand fire extinguisher. Compliance shall be shown with the following:

(1) The design of the compartment shall be such that, when the access provisions are being used, no hazardous quantity of smoke, flames, or extinguishing agent will enter any compartment occupied by the crew or passengers. (See sec. 4b.380 (c) for protective breathing requirements.)

(2) Each compartment shall be equipped with a separate system of an approved type smoke detector or fire detector to give warning at the pilot or flight engineer station.

(3) Hand fire extinguishers shall be readily available for use in each compartment.

(4) The compartment shall be completely lined with fire-resistant material.

(c) *Class C.* Cargo and baggage compartments shall be classified as "C" if they do not conform to the prerequisites for the "A" or "B" classifications. Compliance shall be shown with the following:

(1) Each compartment shall be equipped with:

(i) A separate system of an approved type smoke detector or fire detector to give warning at the pilot or flight engineer station, and

(ii) An approved built-in fire-extinguishing system controlled from the pilot or flight engineer station.

(2) Means shall be provided to exclude hazardous quantities of smoke, flames, or extinguishing agent from entering into any compartment occupied by the crew or passengers.

(3) Ventilation and drafts shall be controlled within each compartment so that the extinguishing agent provided can control any fire which may start within the compartment.

(4) The compartment shall be completely lined with fire-resistant material.

(d) *Class D.* Cargo and baggage compartments shall be classified as "D" if they are so designed and constructed that a fire occurring therein will be completely confined without endangering the safety of the airplane or the occupants. Compliance shall be shown with the following:

(1) Means shall be provided to exclude hazardous quantities of smoke, flames, or other noxious gases from entering into any compartment occupied by the crew or passengers.

(2) Ventilation and drafts shall be controlled within each compartment so that any

[23] It is recommended that signs indicating location of extinguishers have letters at least 3/8 inch in height mounted on a contrasting background.

fire likely to occur in the compartment will not progress beyond safe limits.

NOTE: For compartments having a volume not in excess of 500 cu. ft. an airflow of not more than 1,500 cu. ft. per hour is considered acceptable. For larger compartments lesser airflow may be applicable.

(3) The compartment shall be completely lined with fire-resistant material.

(4) Consideration shall be given to the effect of heat within the compartment on adjacent critical parts of the airplane.

4b.384 *Proof of compliance.*

(a) Compliance with those provisions of section 4b.383 which refer to compartment accessibility, to the entry of hazardous quantities of smoke or extinguishing agent into compartments occupied by the crew or passengers, and to the dissipation of the extinguishing agent in class C compartments shall be demonstrated by tests in flight.

(b) It shall also be demonstrated during the tests prescribed in paragraph (a) of this section that no inadvertent operation of smoke or fire detectors in adjacent or other compartments within the airplane would occur as a result of fire contained in any one compartment, either during or after extinguishment, unless the extinguishing system floods such compartments simultaneously.

4b.384–1 *Cargo and baggage compartments equipped with carbon dioxide fire extinguishers (CAA policies which apply to sec. 4b.384).* The policies outlined in section 4b.484–1 apply.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.385 *Flammable fluid fire protection.* In areas of the airplane where flammable fluids or vapors might be liberated by leakage or failure in fluid systems, design precautions shall be made to safeguard against the ignition of such fluids or vapors due to the operation of other equipment, or to control any fire resulting from such ignition.

4b.386 *Combustion heater fire protection.*

(a) *Combustion heater fire zones.* The following shall be considered as combustion heater fire zones and shall be protected against fire in accordance with applicable provisions of sections 4b.480 through 4b.486 and section 4b.489:

(1) Region surrounding the heater, if such region contains any flammable fluid system components other than the heater fuel system which might be damaged by heater malfunctioning or which, in case of leakage or failure, might permit flammable fluids or vapors to reach the heaters.

(2) Region surrounding the heater, if the heater fuel system incorporates fittings the leakage of which would permit fuel or vapors to enter this region.

(3) That portion of the ventilating air passage which surrounds the combustion chamber except that no fire extinguishment need be provided in cabin ventilating air passages.

(b) *Ventilating air ducts.*

(1) Ventilating air ducts which pass through fire zones shall be of fireproof construction.

(2) Unless isolation is provided by the use of fireproof valves or other equivalently effective means, the ventilating air duct downstream of the heater shall be of fireproof construction for a sufficient distance to assure that any fire originating from within the heater can be contained within the duct.

(3) Portions of ventilating ducts passing through regions in the airplane where flammable fluid systems are located shall be so constructed or isolated from such systems that failure or malfunctioning of the flammable fluid system components cannot introduce flammable fluids or vapors into the ventilating airstream.

(c) *Combustion air ducts.*

(1) Combustion air ducts shall be of fireproof construction for a distance sufficient to prevent damage from backfiring or reverse flame propagation.

(2) Combustion air ducts shall not communicate with the ventilating airstream unless it is demonstrated that flames from backfires or reverse burning cannot enter the ventilating airstream under any conditions of ground or flight operation including conditions of reverse flow or malfunctioning of the heater or its associated components.

(3) Combustion air ducts shall not restrict prompt relief of backfires which can cause

heater failure due to pressures generated within the heater.

(d) *Heater controls; general.* Provision shall be made to prevent hazardous accumulations of water or ice on or within any heater control components, control system tubing, or safety controls.

(e) *Heater safety controls.*

(1) In addition to the components provided for normal continuous control of air temperature, air flow, and fuel flow, means independent of such components shall be provided with respect to each heater to shut off automatically that heater's ignition and fuel supply at a point remote from the heater when the heat exchanger temperature or ventilating air temperature exceed safe limits or when either the combustion air flow or the ventilating air flow becomes inadequate for safe operation. The means provided for this purpose for any individual heater shall be independent of all components serving other heaters the heat output of which is essential to the safe operation of the airplane.

(2) Warning means shall be provided to indicate to the crew when a heater, the heat output of which is essential to the safe operation of the airplane, has been shut off by the operation of the automatic means prescribed in subparagraph (1) of this paragraph.

(f) *Air intakes.* Combustion and ventilating air intakes shall be so located that no flammable fluids or vapors can enter the heater system under any conditions of ground or flight operation either during normal operation or as a result of malfunctioning, failure, or improper operation of other airplane components.

(g) *Heater exhaust.* Heater exhaust systems shall comply with the provisions of section 4b.467 (a) and (b). In addition, provisions shall be made in the design of the heater exhaust system so that the products of combustion will be safely conveyed overboard to prevent the occurrence of the following:

(1) Fuel leakage from the exhaust to surrounding compartments;

(2) Exhaust gas impingement on surrounding equipment or structure;

(3) Ignition of flammable fluids by the exhaust, when the exhaust is located in a compartment containing flammable fluid lines;

(4) Restriction by the exhaust of the prompt relief of backfires which can cause heater failure due to pressure generated within the heater.

(h) *Heater fuel systems.* Heater fuel systems shall comply with all portions of the powerplant fuel system requirements which affect safe heater operations. In addition, heater fuel system components within the ventilating airstream shall be protected by shrouds so that leakage from such components cannot enter the ventilating airstream.

(i) *Drains.* Means shall be provided for safe drainage of fuel accumulations which might occur within the combustion chamber or the heat exchanger. Portions of such drains which operate at high temperatures shall be protected in the same manner as heater exhausts (see paragraph (g) of this section). Drains shall be protected against hazardous ice accumulations in flight and during ground operation.

Miscellaneous

4b.390 *Reinforcement near propellers.* Portions of the airplane near propeller tips shall have sufficient strength and stiffness to withstand the effects of the induced vibration and of ice thrown from the propeller. Windows shall not be located in such regions unless shown capable of withstanding the most severe ice impact likely to occur.

4b.391 *Leveling marks.* Reference marks shall be provided for use in leveling the airplane to facilitate weight and balance determinations on the ground.

Powerplant Installation

Installation

4b.400 *General.* The powerplant installation shall be considered to include all components of the airplane which are necessary for its propulsion. It shall also be considered to include all components which affect the control of the major propulsive units or which affect their safety of operation between normal

inspections or overhaul periods. (See secs. 4b.604 and 4b.613 for instrument installation and marking.)

(a) *Scope.* Reciprocating engine installations shall comply with the provisions of this subpart. Turbine engine installations shall comply with such of the provisions of this subpart as are found applicable to the specific type of installation.

(b) *Functioning.* All components of the powerplant installation shall be constructed, arranged, and installed in a manner which will assure their continued safe operation between normal inspections or overhaul periods.

(c) *Accessibility.* Accessibility shall be provided to permit such inspection and maintenance as is necessary to assure continued airworthiness.

(d) *Electrical bonding.* Electrical interconnections shall be provided to prevent the existence of differences of potential between major components of the powerplant installation and other portions of the airplane.

4b.400–1 *Engine and propeller operation (CAA policies which apply to sec. 4b.400).* The engines and propellers should be observed during the flight test program to determine satisfactory operation of these systems and their associated components.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.401 *Engines.*

(a) *Type certification.* All engines shall be type certificated in accordance with the provisions of Part 13 of this subchapter.

(b) *Engine isolation.* The powerplants shall be arranged and isolated each from the other to permit operation in at least one configuration in a manner such that the failure or malfunctioning of any engine, or of any system of the airplane the failure of which can affect an engine, will not prevent the continued safe operation of the remaining engine(s) or require immediate action by a crew member for continued safe operation.

(c) *Control of engine rotation.* Means shall be provided for individually stopping and restarting the rotation of any engine in flight, except that for turbine engine installations means for stopping the rotation need be provided only if such rotation could jeopardize the safety of the airplane. All components provided for this purpose which are located on the engine side of the firewall and which might be exposed to fire shall be of fire-resistant construction. If hydraulic propeller feathering systems are used for this purpose, the feathering lines on all airplanes manufactured after June 30, 1954, shall be fire-resistant under the operating conditions which may be expected to exist when feathering is being accomplished. (See also sec. 4b.449.)

[(d) *Rotor blade protection.* Turbine powerplant installations shall include a means of protection such that the occurrence of rotor blade failure in any engine will not affect the operation of remaining engines nor jeopardize the continued safe operation of the airplane, unless the engine type certificate specifies that the engine rotor cases have been substantiated as capable of containing the damage resulting from rotor blade failure.

[(e) *Engine turbine rotor.* Design precautions shall be taken to minimize the probability of jeopardizing the safety of the airplane in the event of engine turbine rotor failure, unless the engine type certificate specifies that the turbine rotors have been demonstrated to provide sufficient strength to withstand damage inducing factors such as those which might result from abnormal rotor speeds, temperature, or vibration and the design and functioning of the powerplant systems associated with engine control devices, systems, and instrumentation are such as to give reasonable assurance that those engine operating limitations which adversely affect turbine rotor structural integrity will not be exceeded in service.]

4b.401–1 *Approval of automatic propeller feathering system (CAA policies which apply to sec. 4b.401 (c)).* All parts of the feathering device which are integral with the propeller or attached to it in a manner that may affect propeller airworthiness should be considered from the standpoint of the applicable provisions of Part 14. The determination of the continuing eligibility of the propeller under the existing type certificate, when the device is installed or attached, will be made on the following basis:

(a) The automatic propeller feathering system should not adversely affect normal propeller operation and should function properly

under all temperature, altitude, airspeed, vibration, acceleration, and other conditions to be expected in normal ground and flight operation.

(b) The automatic device should be demonstrated to be free from malfunctioning which may cause feathering under any conditions other than those under which it is intended to operate. For example, it should not cause feathering during:

(1) Momentary loss of power.

(2) Approaches with reduced throttle settings.

(c) The automatic propeller feathering system should be capable of operating in its intended manner whenever the throttle control is in the normal position to provide takeoff power. No special operations at the time of engine failure should be necessary on the part of the crew in order to make the automatic feathering system operative.

(d) The automatic propeller feathering installation should be such that not more than one engine will be feathered automatically even if more than one engine fails simultaneously.

(e) The automatic propeller feathering installation should be such that normal operation may be regained after the propeller has begun to feather automatically.

(f) The automatic propeller feathering installation should incorporate a switch or equivalent means by which to make the system inoperative. (See also sec. 4b.10–2.)

(19 F. R. 1818, Apr. 2, 1954, effective Apr. 2, 1954.)

4b.401–2 *Propeller feathering system operational tests (CAA policies which apply to sec. 4b.401 (c)).*

(a) Tests should be conducted to determine the time required for the propeller to change from windmilling (with the propeller controls set for takeoff) to the feathered position at the takeoff safety speed, V_2.

(b) The propeller feathering system should be tested to demonstrate nonrotation up to 1.2 times the maximum level flight speed with one engine inoperative or the speed employed in emergency descents whichever is higher with:

Critical engine—inoperative.

Wing flaps—retracted.

Landing gear—retracted.

Cowl flaps—closed.

A sufficient speed range should be covered to assure that the propeller feathering angle established on the basis of the high speed requirement should not permit rotation in reverse at the lower speeds. In addition, the propeller should not inadvertently unfeather during these tests.

(c) In order to demonstrate that the feathering system operates satisfactorily, the propeller should be feathered and unfeathered at the maximum operating altitude established in accordance with section 4b.722. The following data should be recorded:

Time to feather propeller at the one-engine-inoperative cruising speed.

Time to unfeather propeller to 1000 r. p. m. at maximum operating altitude and one-engine-inoperative cruising speed.

Altitude of propeller feathering tests.

Ambient air temperature of propeller feathering tests.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.401–3 *Continued rotation of turbine engines (CAA policies which apply to sec. 4b.401 (c)).*

(a) If means are not provided to completely stop the rotation of turbine engines it should be shown that continued rotation,[24] either windmilling or controlled, of a shutdown turbine engine will not cause:

(1) Powerplant (including engine and accessories) structural damage which will adversely affect other engines or the aircratf structure;

(2) Flammable fluid to be pumped into a fire or onto an ignition source; or

(3) A vibration mode which will adversely affect the aerodynamic or structural integrity of the airplane.

(b) Feathered propellers, brakes, doors or other means used to control turbine engine rotation need not produce a complete stop of engine rotation [24] under all flight conditions unless continued rotation will result in any of the conditions set forth in paragraph (a).

(c) If engine induction air duct doors, or shaft, or other types of brakes [25] are provided

[24] It may be assumed that the conditions in paragraph (a) will not occur at engine rotor speeds up to 400 r. p. m.

[25] The provision of doors or brakes is a protective feature to assure that the conditions of paragraph (a) will not occur. Such provision, therefore, should be of a high order of reliability, and the probability should be remote that doors or brakes will not function normally on demand.

to control engine rotation, no single fault or failure of the system controlling engine rotation should cause the inadvertent travel of the doors toward the closed position, or the inadvertent energizing of braking means, unless compensating features are provided to assure that engine failure or a critical operating condition will not occur.

(22 F. R. 5793, July 20, 1957, effective Aug. 15, 1957.)

[4b.401–4 *Engine operation with automatic propeller control system installed (CAA policies which apply to sec. 4b.401 (b)).*

[(a) When an automatic control system for simultaneous r. p. m. control of all propellers is installed, it should be shown that no single failure or malfunction in this system or in an engine controlling this system will:

[(1) Cause the tolerable engine overspeed for this condition [26] to be exceeded at any time, and

[(2) Cause a loss of thrust which will cause the airplane to descend below the established takeoff path (sec. 4b.116) if such system is certificated for use during takeoff and climb. This should be shown for all weights and altitudes for which certification is desired. A preiod of five seconds should be allowed from the time the malfunction occurs to the initial motion of the cockpit control for corrective action taken by the crew.

[(b) Compliance with this policy may be shown by (1) analysis, (2) flight demonstration, or (3) a combination of analysis and flight demonstration.]

(22 F. R. 6883, Aug. 27, 1957, effective Sept. 15, 1957.)

4b.402 *Propellers.* Propellers shall be type certificated in accordance with the provisions of Part 14 of this subchapter. The maximum propeller shaft rotational speed and the engine power permissible for use in the airplane shall not exceed the corresponding limits for which the propeller has been certificated.

4b.402–1 *Reverse thrust propeller installations (CAA policies which apply to sec. 4b.402).* The Administrator may approve reverse thrust propeller installations which comply with the following:

(a) Exceptional pilot skill should not be required in taxiing or any condition in which reverse thrust is to be used.

(b) Necessary operating procedures, operating limitations and placards should be established.

(c) The airplane control characteristics should be satisfactory with regard to control forces encountered, and buffeting should not be likely to cause structural damage.

(d) The directional control should be adequate using normal piloting skill.

(e) It should be determined that no dangerous condition is encountered in the event of sudden failure of one engine in any likely operating condition.

(f) The operating procedures and airplane configuration should be such as to provide reasonable safeguards against serious structural damage to parts of the airplane due to the reverse airflow.

(g) It should be determined that the pilot's vision is not dangerously obscured under normal operating conditions on dusty or wet runways and where light snow is on the runway.

(h) It should be determined that the pilot's vision is not dangerously obscured by spray due to reverse airflow under normal water operating conditions with seaplanes.

(i) The procedure and mechanisms for reversing should provide a reverse idle setting such that without requiring exceptional piloting skill at least the following conditions are met:

(1) Sufficient power is maintained to keep the engine running at an adequate speed to prevent engine stalling during and after the propeller reversing operation.

(2) The propeller does not overspeed during and after the propeller reversing operation.

(3) This idle setting does not exceed 25% of the maximum continuous rating.

(j) The engine cooling characteristics should be satisfactory in any likely operating condition.

(k) The use of reverse thrust will be permitted, in combination with the brakes installed, in establishing the accelerate-stop distance, if it is shown that such use provides a level of safety equivalent to that when wheel brakes alone are used, taking into consideration pilot skill required and the likelihood of attaining the necessary performance under conditions

[26 105 percent of takeoff r. p. m. will be considered tolerable for this condition for all engines, except that higher overspeeds may be acceptable if the engine manufacturer substantiates a higher value to the CAA.]

of simulated engine failure. Either of the following conditions and limitations should be used:

(1) Symmetrical reverse thrust on (n-2) engines with power not to exceed the maximum continuous rating, where n is equal to the number of engines.

(2) Asymmetrical reverse thrust on (n-1) engines in reverse idle setting. This operation should be permitted only where it can be shown that with use of this asymmetrical reverse thrust the airplane can be satisfactorily controlled on a wet runway.

(l) On four-engine aircraft the use of reverse thrust will be permitted in combination with the brakes installed in establishing the landing distance if it is shown that such use provides a level of safety equivalent to that when wheel brakes alone are used taking into consideration pilot skill required and the likelihood of attaining the necessary performance under conditions of simulated engine failure. Determination of landing distance should be conducted in accordance with section 4b.122 and section 4b.123 with the following additional provisions:

(1) A steady gliding approach should be made on an ILS flight path corresponding to the average value of 2½ degrees, except that this prescribed approach will not be required if the application of reverse thrust credit is limited to operations on dry and ice free runways under VFR conditions.

(2) The two most critical symmetrical engines may be placed in the reverse idle position not sooner than four seconds after the aircraft is firmly on the ground.

(3) An accelerated service test should be conducted in accordance with section 4b.16 (b) to establish reliability of the installation which should include not less than 25 landings, covering a range of power settings during the approach and a range of altitudes for which approval is desired.

(20 F. R. 2279, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.403 *Propeller vibration.* The magnitude of the propeller blade vibration stresses under all normal conditions of operation shall be determined by actual measurement or by comparison with similar installations for which such measurements have been made. The vibration stresses thus determined shall not exceed values which have been demonstrated to be safe for continuous operation.

4b.404 *Propeller pitch and speed limitations.*

(a) The propeller pitch and speed shall be limited to values which will assure safe operation under all normal conditions and which will assure compliance with the performance requirements specified in sections 4b.110 through 4b.125.

(b) A propeller speed limiting means shall be provided at the governor. Such means shall be set to limit the maximum possible governed engine speed to a value not exceeding the maximum permissible r. p. m.

(c) The low pitch blade stop in the propeller, or other means used to limit the low pitch position, shall be set so that the engine speed does not exceed 103 percent of the maximum permissible engine r. p. m. under the following conditions:

(1) Propeller blades at the low pitch limit and governor inoperative, and

(2) Engine operating at take-off manifold pressure with the airplane stationary under standard atmospheric conditions.

4b.405 *Propeller clearance.* With the airplane loaded to the maximum weight and at the most adverse center of gravity position and the propellers in the most adverse pitch position, the propeller clearances shall not be less than the following, unless smaller clearances are substantiated for the particular design involved.

(a) *Ground.* Seven inches of ground clearance for airplanes equipped with nose-wheel type landing gears, or nine inches of ground clearance for airplanes equipped with tail-wheel type landing gears shall be provided with the landing gear statically deflected and the airplane in the level take-off or in the taxying attitude, whichever is most critical. In addition, there shall be positive clearance between the propeller and the ground when, with the airplane in the level take-off attitude, the critical tire is completely deflated and the corresponding landing gear strut is completely bottomed.

(b) *Water.* A water clearance of 18 inches shall be provided unless compliance with sec-

tion 4b.182 (a) is demonstrated with less clearance.

(c) *Structure.*

(1) One inch radial clearance shall be provided between the blade tips and the airplane structure, or whatever additional radial clearance is necessary to preclude harmful vibration of the propeller or airplane.

(2) One-half inch longitudinal clearance shall be provided between the propeller blades or cuffs and all stationary portions of the airplane.

(3) Positive clearance shall be provided between other rotating portions of the propeller or spinner and all stationary portions of the airplane.

[CAR, 15 F. R. 3543, June 8, 1950, as amended by Amdt. 4 b-7, 17 F. R. 11631, Dec. 20, 1952.]

4b.406 *Propeller de-icing provisions.*

(a) Airplanes intended for operation under atmospheric conditions conducive to the formation of ice on propellers or on accessories where ice accumulation would jeopardize engine performance shall be provided with means for the prevention or removal of hazardous ice accumulations.

(b) If combustible fluid is used for propeller de-icing, the provisions of sections 4b.480 through 4b.483, inclusive, shall be complied with.

4b.406–1 *Fluid type propeller de-icing test (CAA policies which apply to sec. 4b.406).* If the propellers are equipped with fluid type de-icers, the flow test should be conducted starting with a full tank of fluid and operated at maximum flow for a 15-minute timed period. The operation should be checked at all engine speeds and powers. The tank should be refilled to determine the amount of fluid used after the airplane is landed.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.407 *Propeller reversing system.* The propeller reversing system, if installed, shall be such that no single failure or malfunctioning of the system during normal or emercency operation will result in unwanted travel of the propeller blades to a position substantially below the normal flight low-pitch stop. Failure of structural elements need not be considered if occurrence of such failure is expected to be extremely remote.

[4b.407–1 *Investigation of propeller systems which produce negative thrust (CAA policies which apply to sec. 4b.407).*

[(a) Compliance with section 4b.407 may be demonstrated by failure analysis, testing, or a combination of both for propeller systems that allow propeller blades to move from the flight low-pitch position to a position [27] that is substantially less than that at the normal flight low-pitch stop position.

[(b) The analysis should disclose, for all components involved in the reversing system, the types of failure or malfunction likely to occur, how such failures or malfunctions affect propeller pitch, and the design feature that prevents unwanted travel of the propeller blades to a position substantially below the normal flight low-pitch stop. The analysis may include, or be supported by, the analysis made to demonstrate compliance with the requirements of section 14.103 of this subchapter for the propeller and associated installation components supplied with it.

[(c) When necessary, testing should be conducted to verify assumptions made in the analysis of how the propeller will function with a failed system component and that the design feature provided does in fact prevent unwanted travel of the propeller blades.]

(22 F. R. 6885, Aug. 27, 1957, effective Sept. 15, 1957).

[4b.408 *Turbo-propeller-drag limiting systems.* For turbo-propeller-powered airplanes, propeller-drag limiting systems shall be such that no single failure or malfunction of any of the systems during normal or emergency operation will result in propeller drag in excess of that for which the airplane was designed in compliance with section 4b.216 (d). Failure of structural elements of the drag limiting systems need not be considered if occurrence of such failure is expected to be extremely remote. (See also sec. 4b.310.)]

Fuel System Operation and Arrangement

4b.410 *General.*

(a) The fuel system shall be constructed and arranged in such a manner as to assure a flow

[27 Where the blade position is intended to provide increased drag during the landing run (ground fine pitch) or a reversed propeller blade position.]

of fuel to each engine at a rate and pressure which have been established for proper engine functioning under all normal conditions, including all maneuvers for which the airplane is intended. (For fuel system instruments see sec. 4b.604.)

(b) The fuel system shall be so arranged that no one fuel pump can draw fuel from more than one tank at a time unless means are provided to prevent introducing air into the system.

4b.411 *Fuel system independence.* The design of the fuel system shall comply with the requirements of section 4b.401 (b). Unless other provisions are made in compliance with this requirement, the fuel system shall be arranged to permit the supply of fuel to each engine through a system independent of any portion of a system supplying fuel to any other engine.

4b.412 *Pressure cross-feed arrangements.*

(a) Pressure cross-feed lines shall not pass through portions of the airplane intended to carry personnel or cargo, unless means are provided to permit the flight personnel to shut off the supply of fuel to these lines, or unless the lines are enclosed in a fuelproof and fumeproof shroud which is ventilated and drained to the exterior of the airplane.

(b) The shrouds specified in paragraph (a) of this section need not be used if the lines are routed or protected to safeguard against accidental damage and if they do not incorporate any fittings within the personnel or cargo areas.

(c) Lines which can be isolated from the remainder of the fuel system by means of valves at each end shall incorporate provisions for the relief of excessive pressures which might result from exposure of the isolated line to high ambient temperatures.

4b.413 *Fuel flow rate.*

(a) The ability of the fuel system to provide the required fuel flow rate shall be demonstrated when the airplane is in the attitude which represents the most adverse condition from the standpoint of fuel feed which the airplane is designed to attain. The following shall be considered in this respect:

(1) Normal ground attitude,

(2) Climb with take-off flaps, landing gear up, using take-off power, at speed V_2 as determined in section 4b.114 (b), at landing weight,

(3) Level flight at maximum continuous power or at the power required for level flight at V_C, whichever is the lesser,

(4) Glide at a speed of 1.3 V_{s_0}, at landing weight.

(b) During the demonstration prescribed in paragraph (a) of this section, fuel shall be delivered to the engine at a pressure not less than the minimum pressure established for proper engine operation. In addition the following shall be met.

(1) The quantity of fuel in the tank being considered shall not exceed the amount established as the unusable fuel supply for that tank, as determined by demonstrating compliance with the provisions of section 4b.416 (see also secs. 4b.420 and 4b.613 (b)), together with whatever minimum quantity of fuel it may be necessary to add for the purpose of conducting the flow test.

(2) If a fuel flowmeter is provided, the meter shall be blocked during the flow test and the fuel shall flow through the meter by-pass.

(3) It shall be acceptable to conduct the demonstration prescribed in paragraph (a) of this section by a ground test on the airplane or on a representative mock-up of the fuel system.

(4) In systems where sec. 4b.435 (d) requires a fuel filter by-pass arrangement, the fuel flow rate corresponding with 100 percent of the engines' maximum fuel demand at standard atmospheric conditions shall be demonstrated with the fuel filter blocked.

4b.414 *Pump systems.*

(a) For reciprocating engines, the fuel flow rate for pump systems (main and reserve supply) shall be 0.9 pounds per hour for each take-off horsepower or 125 percent of the actual take-off fuel consumption of the engine, whichever is the greater.

(b) For turbine engines, the fuel flow rate for pump systems shall be 125 percent of the fuel flow required to develop the standard sea level atmospheric condition take-off power selected by the applicant and included as an operating limitation in the Airplane Flight Manual.

(c) The fuel flow rate specified in this section shall be applicable to both the primary engine-driven pump and to emergency pumps. The fuel flow rate shall be available when the pump is running at the speed at which it would nor-

mally be operating during take-off. In the case of hand-operated pumps, the speed required shall not be more than 60 complete cycles (120 single strokes) per minute.

4b.415 *Transfer systems.* The provisions of section 4b.414 shall apply to transfer systems, except that the required fuel flow rate for the engine or engines involved shall be established upon the basis of maximum continuous power and its corresponding speed instead of take-off power and its corresponding speed.

4b.416 *Determination of unusable fuel supply and fuel system operation on low fuel.*

(a) The quantity of fuel with which compliance with the provision of this paragraph is demonstrated shall be selected by the applicant who, in addition, shall indicate which of the conditions specified in paragraph (b) of this section are most likely to be critical from the standpoint of establishing the unusable fuel supply, and also indicate the order in which the other conditions may be critical.

(b) The unusable fuel supply for each tank used for take-off and landing shall be established as not less than the quantity at which the first evidence of malfunctioning occurs under the following conditions: (See sec. 4b.420.)

(1) Level flight at maximum continuous power or at the power required for level flight at V_c, whichever is the lesser,

(2) Climb with take-off flaps and landing gear up, at take-off power, at landing weight, and at speed V_2 determined in accordance with sec. 4b.114 (b),

(3) Rapid application of maximum continuous power and subsequent transition to a climb at speed V_2 determined in accordance with sec. 4b.114 (b), with retraction of flaps and landing gear, from a power-off glide at 1.3 V_{S_0}, with flaps and landing gear down, at landing weight.

(c) If an engine can be supplied with fuel from more than one tank, it shall be possible to regain the full fuel pressure of that engine in not more than 20 seconds after switching to any fuel tank after engine malfunctioning becomes apparent due to the depletion of the fuel supply in any tank from which the engine can be fed. Compliance with this provision shall be demonstrated in level flight.

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(d) The unusable fuel supply for all tanks other than those used for takeoff and landing shall be established as not less than the quantity at which the first evidence of malfunctioning occurs under the conditions specified in paragraph (b) (1) of this section. It shall be acceptable to demonstrate compliance with this requirement by a ground test.

4b.416–1 *Unusable fuel (CAA interpretation which applies to sec. 4b.416).* The unusable fuel should be considered that fuel drainable from the tank sump with the airplane on the ground in a normal attitude with the wings leveled laterally after a fuel tank runout [28] test has been made.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.416–2 *Determination of unusable fuel supply and fuel system operation (CAA policies which apply to sec. 4b.416).*

(a) *General test program.* Tests for unusable fuel may be conducted at optional altitudes with all engines operating. The auxiliary fuel pumps should be turned "off" or "on" during the tests depending upon the normal operating procedure established for the airplane, or if the auxiliary pumps are being considered for use as emergency pumps they should be inoperative to at least 6,000 feet. The unusable fuel should be determined in each unique tank selection arrangement used for takeoff and landing by making runouts during the most critical of the three conditions specified in (b), (c), and (d). When a runout occurs, the fuel selector switch should be turned to a full tank. It should be possible to regain engine fuel pressure in not more than 20 seconds after switching to any full tank when engine malfunctioning has become apparent due to depletion of the fuel supply in any tank from which the engine can be fed after the airplane has been restored to a level flight condition. The tanks should be drained after landing to determine the unusable fuel quantity. In the case of fuel in tanks other than those used for takeoff and landing, the unusable fuel should be determined in the manner prescribed in (b) or during ground tests.

[28] A fuel tank runout is considered to have occurred when the engine fuel pressure shows a marked decrease and/or the first evidence of engine malfunctioning occurs.

(b) *Level flight at maximum continuous power or at the power required for level flight at* Vc *whichever is the lesser, section 4b.416 (b) (1).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—optional.
C. G. position—optional.
Wing flaps—retracted.
Landing gear—retracted.
Cowl flaps—optional.

(2) *Test procedure.* See (a).

(c) *Climb with takeoff power at speed* V_2, *section 4b.416 (b) (2).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

Weight—not more than maximum landing weight.
C. G. position—optional.
Wing flaps—takeoff position.
Landing gear—retracted.
Cowl flaps—optional.

(2) *Test procedure.* See (a).

(d) *Rapid application of maximum continuous power and subsequent transition to a climb at a speed* V_2 *determined in accordance with section 4b.114 (b), with retraction of flaps and landing gear, from a power-off glide at 1.3* V_{S_0} *with flaps and landing gear down at landing weight, section 4b.416 (b) (3).*

(1) *Configuration.* This test should be conducted in the configuration that follows:

C. G. position—optional.
Cowl flaps—optional.

(2) *Test procedure.* See (a).

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.417 *Fuel system hot weather operation.*

(a) To prove satisfactory hot weather operation the airplane shall be climbed from the altitude of the airport chosen by the applicant to the altitude corresponding with that at which the one-engine-inoperative best rate of climb is not greater than the en route climb with the configuration and at the weight specified in section 4b.120 (c). There shall be no evidence of vapor lock or other malfunctioning. The climb test shall be conducted under the following conditions:

(1) For reciprocating-engine-powered airplanes, all engines shall operate at maximum continuous power, except that take-off power shall be used for the altitude range extending from 1,000 feet below the critical altitude through the critical altitude. The time interval during which take-off power is used shall not be less than the take-off time limitation. For turbine-engine-powered airplanes, all engines shall operate at take-off power for the time interval selected by the applicant in demonstrating the take-off flight path and thereafter shall operate at maximum continuous power for the duration of the climb.

(2) The weight shall be with full fuel tanks, minimum crew, and such ballast as is required to maintain the center of gravity within allowable limits.

(3) The speed of climb shall not exceed that which will permit compliance with the minimum climb requirement specified in section 4b.119 (a).

(4) The fuel temperature shall be not less than 110° F.

(b) The test prescribed in paragraph (a) of this section shall be performed either in flight or on the ground closely simulating flight conditions. If a flight test is performed in weather sufficiently cold to interfere with the proper conduct of the test, the fuel tank surfaces, fuel lines, and other fuel system parts subjected to cooling action from cold air shall be insulated to simulate, in so far as practicable, flight in hot weather.

4b.417–1 *Hot weather fuel system tests (CAA policies which apply to sec. 4b.417).*

(a) Hot weather fuel system tests should be conducted with fuel in the tanks normally used for takeoff and landing and with the maximum number of engines drawing fuel from the tank as would normally occur in flight. In the case of symmetrical fuel tank systems, the tests may be confined to one of each such system. Unweathered fuel should be used during these demonstrations. The fuel temperature should be 110° F. just prior to takeoff. If the fuel must be heated to this temperature, caution should be taken to prevent overheating during the process. The auxiliary fuel pumps should be turned "off" or "on" during the tests depending upon the normal operating procedure established for the airplane. If the auxiliary pumps are being considered for use as emer-

gency pumps they should be inoperative to at least 6,000 feet. A fuel pressure failure is considered to occur when the fuel pressure decreases below the minimum prescribed by the engine manufacturer.

(b) *Configuration.* This test should be conducted in the configuration that follows:

Weight—corresponding to operation with full fuel tanks, minimum crew and ballast required to maintain airplane within center of gravity limits.
C. G. position—optional, within allowable limits.
Wing flaps—most favorable position.
Landing gear—retracted.
Cowl flaps—in a position that provides adequate cooling in the hot day condition.
Engines—See (c).

(c) *Test procedure and required data.* The takeoff and climb should be made as soon as possible after the fuel in the tank has been heated to 110° F. The airspeed during the climb should not exceed that speed used in demonstrating the requirements specified in section 4b.119 (a). If the engines are normally operated with the auxiliary pumps "off," they should be turned "on" when a fuel pressure failure occurs. Restoration of fuel pressure should be noted and the climb continued to the maximum operating altitude selected by the applicant for certification. The following data should be recorded at reasonable time intervals:

Fuel temperature at start of test.
Fuel pressure at start of test and continuously during climb noting any pressure failures.
Auxiliary fuel pump operation.
Pressure altitude.
Ambient air temperature.
Airspeed.
Engines, r. p. m. and manifold pressure.
Comments on engine operation.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954; amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957.)

4b.418 *Flow between interconnected tanks.*

(a) Where tank outlets are interconnected and permit flow through the interconnection due to gravity or flight accelerations, it shall not be possible for fuel to flow between tanks in quantities sufficient to cause an overflow of fuel from the tank vent with the tanks full when the airplane is operated as prescribed in section 4b.416 (b) except that weights greater than the landing weight shall be acceptable if necessary because of the fuel loading.

(b) If it is possible to pump fuel from one tank to another in flight, the design of the fuel tank vents and the fuel transfer system shall be such that structural damage to tanks will not occur in the event of overfilling.

4b.418–1 *Determination of fuel flow between interconnected tanks (CAA policies which apply to sec. 4b.418).* If there is a possibility of flow between interconnected tanks, it should be demonstrated that this flow is not sufficient to cause fuel to overflow from the tank vents during the conditions specified in section 4b.416 (b) for the determination of unusable fuel. These maneuvers should be accompanied by side slips, skids and other uncoordinated maneuvers that might occur in normal service. The tests should be conducted with full tanks.

(19 F. R. 4464, July 20, 1954, effective Sept. 1, 1954.)

Fuel System Construction and Installation

4b.420 *General.*

(a) Fuel tanks shall be capable of withstanding without failure all vibration, inertia, fluid, and structural loads to which they may be subjected in operation.

(b) Flexible fuel tank liners shall be of an approved type or shall be shown to be suitable for the particular application.

(c) Integral type fuel tanks shall be provided with facilities for inspection and repair of the tank interior.

(d) The unusable fuel capacity shall be the minimum quantity of fuel which will permit compliance with the provisions of section 4b.416.

[(e) Fuel tanks located within the fuselage contour shall be capable of resisting rupture and retaining the fuel under the inertia forces prescribed for the emergency landing conditions in section 4b.260. In addition, these tanks shall be located in a protected position so that exposure of the tanks to scraping action with the ground will be unlikely.

[(f) The augmentation liquid tank capacity available for the use of each engine shall be sufficient to permit operation of the airplane in accordance with the procedures for the use of liquid augmented powers which are established and approved with respect to compliance with the related requirements of this part. The computation of liquid consumption shall be based on the maximum approved rate appropriate for the desired engine output and shall include the effect of temperature on engine performance as well as any other factors that might cause a variation in the amount of liquid required.]

4b.420–1 *Minimum quantity of antidetonant fluid required (CAA policies which apply to sec. 4b.420 (e)).*

(a) *Airplanes equipped with a common tank for two engines.* The usable capacity of the tank should be sufficient for operation of the engines served by that tank for a duration equal to that determined by Case A, B, or C, whichever is applicable and results in the greater value (see table 2). The capacity should be based on the flow rate approved during engine type certification.

TABLE 2. ANTI-DETONANT TANK CAPACITY

(Total for tank equals sum of totals for both engines served by tank)

	Case A		Case B		Case C	
	Engine #1	Engine #2	Engine #1	Engine #2	Engine #1	Engine #2
Takeoff	X[1]	X	X	X	X	X
Approach[2]			X		X	X
Landing[3]	X/2[4]	X/2[4]				
Reserve	X/2[4]	X/2[4]	X		X	X

[1] Wherever "X" appears in the table, it denotes a duration equal to the maximum time for which the use of wet takeoff power is used for determination of the takeoff flight path of the airplane. However, in no case should the value of either "X" or "X/2" be considered to be less than one minute.

[2] Applies as indicated by "X" only if wet takeoff power is used to demonstrate compliance with the approach climb requirement of section 4b.120 (d).

[3] Applies as indicated by "X" only if wet takeoff power is used to demonstrate compliance with the landing climb requirement of section 4b.119 (b).

[4] "X/2" is specified for the reserve in the all-engine operating case rather than "X" because this type of operation is considered less critical than operation with one engine inoperative and the reserve need not therefore be as large.

Case A. Case A is intended to provide for conditions with all engines operating and, therefore, the approach climb requirement is not involved.

Case B. Case B is intended to provide for failure of one engine during the course of a flight between takeoff and landing and may, therefore, involve the approach climb requirement but not the landing climb requirement.

Case C. Case C provides for failure of an engine during the course of a flight between takeoff and landing on a four-engine aircraft which has two tanks; each feeding a pair of engines on one side of the airplane. The tables show the quantities required to assure an adequate supply of fluid on the side of the airplane opposite to the side on which the failure occurs since this is the critical consideration for determining the tank quantity. Both tanks on the airplane should, of course, have this capacity. For the same reason as in Case B, the landing climb is not involved for Case C, but the approach climb requirement may be involved.

(b) *Airplanes equipped with a separate tank for each engine.* The capacity of the tank should be sufficient for operation of the engine for a duration equal to the greatest value specified for engine #1 in the three cases listed in table 2. However, in no case should the quantity be less than that required for three minutes of engine operation.

(20 F. R. 2280, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.421 *Fuel tank tests.*

(a) Fuel tanks shall be demonstrated capable of withstanding the most critical of the following pressures without failure or leakage as mounted in the airplane:

(1) Internal pressure of 3.5 psi;

(2) 125 percent of the maximum air pressure developed in the tank from ram effect;

(3) The fluid pressures developed during maximum limit accelerations of the airplane

with a full tank. If any of these pressures exceed the greater of the pressures prescribed in subparagraphs (1) and (2) of this paragraph, the test shall be conducted so as to simulate the pressure distribution insofar as practicable. The minimum pressure at any point in the tank shall not be less than the greater of the pressures prescribed in subparagraphs (1) and (2) of this paragraph.

(b) Tanks with large unsupported or unstiffened flat surfaces, the failure or deformation of which could cause fuel leakage, shall be capable of withstanding a vibration test in accordance with the conditions of subparagraphs (1) through (4) of this paragraph, or other equivalent test, without leakage or excessive deformation of the tank walls.

(1) The complete tank assembly together with its supports shall be subjected to a vibration test when mounted in a manner simulating the actual installation.

(2) The tank assembly shall be vibrated for 25 hours while filled two-thirds full of water or any suitable test fluid. The amplitude of vibration shall not be less than one thirty-second of an inch, unless otherwise substantiated.

(3) The frequency of vibration shall be 90 percent of the maximum continuous rated speed of the engine unless some other frequency within the normal operating range of speeds of the engine is more critical, in which case the latter speed shall be employed and the time of test shall be adjusted to accomplish the same number of vibration cycles.

(4) During the test, the tank assembly shall be rocked at the rate of 16 to 20 complete cycles per minute through an angle of 15° on either side of the horizontal (30° total) about the most critical axis for 25 hours. If motion about more than one axis is likely to be critical, the tank shall be rocked about each axis for 12½ hours.

(c) In the case of nonmetallic tanks a specimen tank of the same basic construction as that to be used in the airplane, when installed in a representative test tank, shall withstand the test as specified in paragraph (b) of this section with fuel at a temperature of 110° F.

4b.422 *Fuel tank installation.*

(a) The method of support for fuel tanks shall not permit concentration of loads, resulting from the weight of the fuel in the tank, on unsupported tank surfaces. The following shall be applicable:

(1) Pads shall be provided to prevent chafing between the tank and its supports.

(2) Materials employed for padding shall be nonabsorbent or shall be treated to prevent the absorption of fluids.

(3) If flexible tank liners are employed they shall be so supported that the liner is not required to withstand fluid loads.

(4) Interior surfaces of tank compartments shall be smooth and free of projections which could cause wear of the liner, unless provisions are made for protection of the liner at such points or unless the construction of the liner itself provides such protection.

(b) Spaces adjacent to the surfaces of the tank shall be ventilated consistent with the size of the compartment to avoid fume accumulation in the case of minor leakage. If the tank is in a sealed compartment it shall be acceptable to limit the ventilation to that provided by drain holes of sufficient size to prevent excessive pressure resulting from altitude changes.

(c) Location of fuel tanks shall comply with the provisions of section 4b.481 (a).

(d) No portion of engine nacelle skin which lies immediately behind a major air egress opening from the engine compartment shall act as the wall of an integral tank.

(e) Fuel tanks shall be isolated from personnel compartments by means of fumeproof and fuelproof enclosures.

4b.423 *Fuel tank expansion space.*

(a) Fuel tanks shall be provided with an expansion space of not less than 2 percent of the tank capacity.

(b) It shall not be possible to fill the fuel tank expansion space inadvertently when the airplane is in the normal ground attitude.

4b.424 *Fuel tank sump.*

(a) Each fuel tank shall be provided with a sump having a capacity of not less than either 0.10 percent of the tank capacity or one-sixteenth of a gallon, whichever is the greater, except that a smaller capacity shall be acceptable if operating limitations are established to

assure that in service the accumulation of water will not exceed the sump capacity.

(b) The fuel tank sump capacity specified in paragraph (a) of this section shall be effective with the airplane in the normal ground attitude. The fuel tank shall be constructed to permit drainage of any hazardous quantity of water from all portions of the tank to the sump when the airplane is in the ground attitude.

(c) Fuel tank sumps shall be provided with an accessible drain to permit complete drainage of the sump on the ground. The drain shall discharge clear of all portions of the airplane and shall be provided with means for positive locking of the drain in the closed position, either manually or automatically.

4b.425 *Fuel tank filler connection.*

(a) The design of fuel tank filler connections shall be such as to prevent the entrance of fuel into the fuel tank compartment or any other portion of the airplane other than the tank itself.

(b) Recessed fuel tank filler connections which retain any appreciable quantity of fuel shall incorporate a drain, and the drain shall discharge clear of all portions of the airplane.

(c) The fuel tank filler cap shall provide a fuel-tight seal.

(d) The fuel tank filler connections shall be marked as prescribed in section 4b.738 (b).

4b.426 *Fuel tank vents and carburetor vapor vents.*

(a) Fuel tanks shall be vented from the top portion of the expansion space in such a manner that venting of the tank is effective under all normal flight conditions. The following shall be applicable:

(1) Vent outlets shall be located and constructed to prevent the possibility of being obstructed by ice or other foreign matter.

(2) The vent shall be constructed to preclude the possibility of siphoning fuel during normal operation.

(3) The vent shall be of sufficient size to prevent the existence of excessive differences of pressure between the interior and exterior of the tank during normal flight operation, during maximum rate of descent, and, if applicable, during refueling and defueling.

(4) Air spaces of tanks with interconnected outlets shall also be interconnected.

(5) There shall be no points in the vent line where moisture could accumulate with the airplane in either the ground or the level flight attitude unless drainage is provided.

(6) Vents and drainage shall not terminate at points where the discharge of fuel from the vent outlet would constitute a fire hazard or from which fumes could enter personnel compartments.

(b) Carburetors which are provided with vapor elimination connections shall be provided with a vent line to lead vapors back to one of the fuel tanks. The vents shall comply with the following:

(1) Provisions shall be incorporated in the vent system to avoid stoppage by ice.

(2) If more than one fuel tank is provided and it is necessary to use the tanks in a definite sequence, the vapor vent return line shall lead back to the fuel tank used for take-off and landing.

4b.426–1 *Determination of syphoning of fuel system vents (CAA policies which apply to sec. 4b.426).* Taxiing tests should be conducted which involve sharp turns followed by rapid acceleration into the takeoff run and other ground maneuvers to assure that fuel will not escape from, or syphon from, the tank vents; nor should syphoning occur under the flight conditions specified in the test program for section 4b.418–1. All tests should be conducted with full tanks.

(19 F. R. 4464, July 20, 1954, effective Sept. 1, 1954.)

4b.427 *Fuel tank outlet.* A fuel strainer of 8 to 16 meshes per inch shall be provided either for the fuel tank outlet or for the booster pump. Strainers shall comply with the following:

(a) The clear area of the fuel tank outlet strainer shall not be less than 5 times the area of the fuel tank outlet line.

(b) The diameter of the strainer shall not be less than the diameter of the fuel tank outlet.

(c) Finger strainers shall be accessible for inspection and cleaning.

4b.428 *Under-wing fueling provisions.* Under-wing fuel tank connections shall be provided with means to prevent the escape of hazardous quantities of fuel from the tank in the event of malfunctioning of the fuel entry

valve while the cover plate is removed. In addition to the normal means provided in the airplane for limiting the tank content, a means shall be installed to prevent damage to the tank in case of failure of the normal means.

Fuel System Components

4b.430 *Fuel pumps.*

(a) *Main pumps.*

(1) If the engine fuel supply is maintained by means of pumps, one fuel pump for each engine shall be engine-driven.

(2) Fuel pumps shall meet the pertinent flow requirements of section 4b.413.

(3) All positive displacement fuel pumps shall incorporate an integral bypass, unless provision is made for a continuous supply of fuel to all engines in case of failure of any one pump. Engine fuel injection pumps which are approved as an integral part of the engine need not incorporate a by-pass.

(4) If the emergency fuel pumps are all dependent upon the same source of motive power, the main fuel pumps shall be capable of providing sufficient fuel flow and pressure to maintain level flight at maximum weight and normal cruising power at an altitude of 6,000 feet with 110° F. fuel without the aid of any emergency fuel pump.

(b) *Emergency pumps.*

(1) Emergency fuel pumps shall be provided to permit supplying all engines with fuel in case of failure of any one main fuel pump, except in the case of installations in which the only fuel pump used in the system is an engine fuel injection pump which is approved as an integral part of the engine.

(2) Emergency fuel pumps shall be available for immediate use in case of failure of any other fuel pump. No manipulation of fuel valves shall be necessary on the part of the crew to make an emergency fuel pump available to the engine which it is normally intended to serve when the fuel system is being operated in the configuration complying with the provisions of section 4b.411.

4b.431 *Fuel pump installation.*

(a) Provision shall be made to maintain the fuel pressure at the inlet to the carburetor within the range of limits established for proper engine operation. In turbine engine fuel systems, provisions shall be made to maintain the fuel pressure at the inlet to the engine fuel system within the limits established for engine operation.

(b) When necessary for the maintenance of the proper fuel delivery pressure, a connection shall be provided to transmit the carburetor air intake static pressure to the proper fuel pump relief valve connection. In such cases, to avoid erroneous fuel pressure reading, the gauge balance lines shall be independently connected to the carburetor inlet pressure.

4b.432 *Fuel system lines and fittings.*

(a) Fuel lines shall be installed and supported to prevent excessive vibration and to withstand loads due to fuel pressure and due to accelerated flight conditions.

(b) Fuel lines which are connected to components of the airplane between which relative motion could exist shall incorporate provisions for flexibility.

(c) Flexible connections in fuel lines which may be under pressure and subjected to axial loading shall employ flexible hose assemblies rather than hose clamp connections.

(d) Flexible hose shall be of an approved type or shall be shown to be suitable for the particular application.

(e) Flexible hoses which might be adversely affected by exposure to high temperatures shall not be employed in locations where excessive temperatures will exist during operation or after engine shut-down.

4b.433 *Fuel lines and fittings in designated fire zones.* Fuel lines and fittings in all designated fire zones (see sec. 4b.480) shall comply with the provisions of section 4b.483.

4b.434 *Fuel valves.* In addition to the requirements of section 4b.482 for shutoff means, all fuel valves shall be provided with positive stops or suitable index provisions in the "on" and "off" positions and shall be supported so that loads resulting from their operation or from accelerated flight conditions are not transmitted to the lines attached to the valve.

[4b.435 *Fuel strainer.* A fuel strainer shall be provided between the fuel tank outlet and the fuel metering device of the engine. The following provisions of this section shall be complied with:]

(a) If an engine-driven fuel pump is provided, the strainer shall be located between the tank outlet and the engine-driven pump inlet.

(b) The fuel strainer shall be accessible for drainage and cleaning, and the strainer screen shall be easily removable.

(c) The strainer shall be mounted in a manner not to cause its weight to be supported by the connecting lines or by the inlet or outlet connections of the strainer itself.

(d) When filter or strainers susceptible to icing are incorporated in the fuel system, a means shall be provided to maintain automatically the fuel flow in the event ice particles accumulate and restrict flow by clogging the filter or screen.

4b.436 *Fuel system drains.* Drainage of the system shall be accomplished by fuel strainer drains and other drains as provided in section 4b.424. The following shall apply:

(a) Drains shall discharge clear of all portions of the airplane and shall incorporate means for positive locking of the drain in the closed position, either manually or automatically.

(b) All fuel system drains shall be accessible.

(c) If drainage of the fuel strainer permits compliance with paragraphs (a) and (b) of this section, no additional drains need be provided unless it is possible for a hazardous quantity of water or sediment to be trapped therein. (See also sec. 4b.483 (c).)

4b.437 *Fuel jettisoning system.* If the maximum take-off weight for which the airplane is certificated exceeds 105 percent of the certificated maximum landing weight, provision shall be made for the jettisoning of fuel from the maximum take-off to the maximum landing weight.

(a) The average rate of fuel jettisoning shall be 1 percent of the maximum take-off weight per minute, except that the time required to jettison the fuel need not be less than 10 minutes. Compliance with these provisions shall be shown at maximum take-off weight, with flaps and landing gear up, and in the following flight conditions:

(1) Power-off glide at a speed of 1.4 V_{s_1}.

(2) Climb at the one-engine-inoperative best rate-of-climb speed with the critical engine inoperative, the remaining engine(s) at maximum continuous power.

(3) Level flight at a speed of 1.4 V_{s_1}, if the results of tests in conditions specified in subparagraphs (1) and (2) of this paragraph indicate that this condition could be critical.

(b) During the flight tests prescribed in paragraph (a) of this section it shall be demonstrated that the fuel jettisoning system complies with the following provisions:

(1) The fuel jettisoning system and its operation shall be free of fire hazard.

(2) The fuel shall discharge clear of all portions of the airplane.

(3) Fuel or fumes shall not enter any portion of the airplane.

(4) The jettisoning operation shall not affect adversely the controllability of the airplane.

(c) The design of the jettisoning system shall be such that it would not be possible to jettison fuel in the tanks used for take-off and landing below the level providing 45 minutes flight at 75 percent maximum continuous power, except that it shall be permissible to jettison all fuel where an auxiliary control is provided independent of the main jettisoning control. For turbine-powered airplanes, the design of the jettisoning system shall be such that it would not be possible to jettison fuel in the tanks used for take-off and landing below the level providing climb from sea level to 10,000 feet and thereafter providing 45 minutes cruise at a speed for maximum range.

(d) The fuel jettisoning valve shall permit the flight personnel to close the valve during any portion of the jettisoning operation. (See sec. 4b.475 for fuel jettisoning system controls.)

(e) Unless it is demonstrated that lowering of the flaps does not adversely affect fuel jettisoning, a placard shall be provided adjacent to the jettisoning control to warn flight personnel against jettisoning fuel while the flaps are lowered. A notation to this effect shall also be included in the Airplane Flight Manual. (See sec. 4b.740.)

[(f) The design of the fuel jettisoning system shall be such that any reasonably probable single malfunction in the system will not result in a hazardous condition due to unsymmetrical jettisoning or inability to jettison fuel.]

4b.437–1 *Test procedure for fuel jettisoning (CAA policies which apply to sec. 4b.437).*

(a) In the case where the maximum takeoff weight exceeds 105 percent of the maximum landing weight, provisions should be available for jettisoning fuel from the maximum takeoff weight to the maximum landing weight at the corresponding altitude range of airports for which certification is sought. If the applicant has made sufficient jettisoning tests [29] to prove the safety of the jettisoning system, the tests may be made with fuel only. Otherwise, preliminary tests should be made with noninflammable fluid first and the results then checked using fuel. The following procedures and methods should be observed for demonstrating the operation of the fuel jettisoning system:

(1) *Fire hazard.*

(i) Fuel in liquid or vapor form should not impinge upon any external surface of the airplane during or after jettisoning. Colored fuel, or surfaces so treated that liquid or vaporous fuel changes the appearance of the airplane surface may be used for detection purposes. Other equivalent methods for detection may be acceptable.

(ii) Fuel in liquid or vapor form should not enter any portion of the airplane during or after jettisoning. The fuel may be detected by its scent, combustible mixture detector or by visual inspection. In supercharged aircraft the presence of liquid or vaporous fuel should be checked with the airplane unpressurized.

(iii) There should be no evidence of fuel valve leakage after it is closed.

(iv) If there is any evidence that wing flap positions, other than that used or the test may adversely affect the flow pattern, the airplane should be placarded "Fuel should not be jettisoned except when flaps are set at —°."

(v) The applicant should select for demonstration the tanks or tank combinations which are critical for demonstrating the flow rate during jettisoning.

(vi) Fuel jettisoning flow pattern should be demonstrated from all normally used tank or tank combinations on both sides of airplane whether or not both sides are symmetrical.

(vii) Fuel jettisoning rate may be demonstrated from only one side of symmetrical tank or tank combinations which are critical for flow rate.

(viii) Fuel jettisoning rate and flow pattern should be demonstrated when jettisoning from full tanks using fuel.

(2) *Control.*

(i) Changes in the airplane control qualities during the fuel jettisoning tests should be noted.

(ii) Discontinuance of fuel jettisoning should be demonstrated in flight.

(3) *Residual fuel.* The residual fuel should be measured by draining the tanks from which fuel has been jettisoned in flight, measuring the total drained fuel and subtracting from the total the unusable fuel quantity for each tank to determine if there is sufficient reserve fuel after jettisoning to meet section 4b.437. This may be a ground test.

(b) *Configuration.* Fuel jettisoning tests should be conducted in the configurations that follow:

(1) *Glide.*

Weight—maximum takeoff.
C. G. position—optional.
Wing flaps—retracted or in a position desired for approval.
Landing gear—retracted or extended as desired by applicant.
Engines—poweroff, propellers windmilling.
Cowl flaps—optional.
Airspeed—1.4 V_{s_1}.

(2) *Climb.*

Weight—maximum takeoff.
C. G. position—optional.
Wing flaps—retracted or in a position desired for approval.
Landing gear—retracted or extended.
Operating engine(s)—maximum continuous power, cowl flaps optional.
Critical inoperative engine—throttle closed on engine most critical for fuel flow pattern, propeller feathered, cowl flaps closed.
Airspeed—one engine inoperative best rate of climb speed.

[29] The basic purpose of these tests is to determine that the required amount of fuel may be safely jettisoned under reasonably anticipated operating conditions within the prescribed time limit without danger from fire, explosion, or adverse effects on the flying qualities.

(3) *Level flight.*

Weight—maximum takeoff.
C. G. position—optional.
Wing flaps—retracted or in a position desired for approval.
Landing gear—retracted or extended.
Engines—power required for airspeed of 1.4 V_{s_1}.
Cowl flaps—optional.

(c) *Test procedure and required data.* When the airplane is trimmed in the configuration specified in items (b) (1) and (b) (2), the jettisoning valves should be opened and allowed to remain open until all jettisoning liquid has been disposed. If the configuration of (b) (3) is critical, tests should also be conducted for this condition. This procedure may be carried out in segments if desired. The following data should be recorded:

Time to jettison fuel.
Fuel gauge quantity at reasonable time intervals.
Pressure altitude.
Indicated airspeed.
Engines, r. p. m. and manifold pressure.
Carburetor air temperature.

(19 F. R. 4464, July 20, 1954, effective Sept. 1, 1954.)

Oil System

4b.440 *General.*

(a) Each engine shall be provided with an independent oil system capable of supplying the engine with an appropriate quantity of oil at a temperature not exceeding the maximum which has been established as safe for continuous operation. (For oil system instruments see secs. 4b.604 and 4b.735.)

(b) The oil tank capacity available for the use of the engine shall not be less than the product of the endurance of the airplane under critical operating conditions times the [approved] maximum permissible oil consumption rate of the engine under the same conditions, plus a suitable margin to assure system circulation. In lieu of a rational analysis of airplane range [for reciprocating engines], a fuel-oil ratio of 30:1 by volume shall be acceptable for airplanes not provided with a reserve or transfer system.

(c) If either an oil transfer system or a reserve oil system is provided [for reciprocating engines], the total oil capacity need not exceed one gallon for each 40 gallons of fuel capacity.

(d) Oil-fuel ratios lower than those prescribed in paragraphs (b) and (c) of this section shall be acceptable if substantiated by data on the actual oil consumption of the engine.

(e) The ability of the oil cooling provisions to maintain the oil inlet temperature to the engine at or below the maximum established value shall be demonstrated in accordance with pertinent provisions of sections 4b.450 through 4b.454.

4b.440–1 *Procedure for demonstrating oil cooling (CAA policies which apply to sec. 4b.440 (e)).* Procedures for conducting cooling tests are those outlined in sections 4b.452–1 and 4b.453–1.

(19 F. R. 4464, July 20, 1954, effective Sept. 1, 1954.)

4b.441 *Oil tank construction.* The following requirements shall apply to the construction of the oil tank:

(a) *Oil tank expansion space.*

(1) Oil tanks shall have an expansion space of not less than either 10 percent of the tank capacity or 0.5 gallon, whichever is the greater.

(2) Reserve oil tanks which have no direct connection to any engine shall have an expansion space which is not less than 2 percent of the tank capacity.

(3) It shall not be possible to fill the oil tank expansion space inadvertently when the airplane is in the normal ground attitude.

(b) *Oil tank filler connection.*

(1) Recessed oil tank filler connections which retain any appreciable quantity of oil shall incorporate a drain, and the drain shall discharge clear of all portions of the airplane.

(2) The oil tank filler cap shall provide an oil-tight seal.

(3) Oil tank filler connections shall be marked as prescribed in section 4b.738 (b).

(c) *Oil tank vent.*

(1) Oil tanks shall be vented from the top portion of the expansion space in such a manner that venting of the tank is effective under all normal flight conditions.

(2) Oil tank vents shall be arranged so that condensation of water vapor which might freeze and obstruct the line cannot accumulate at any point. (See also section 4b.483 (c).)

(d) *Oil tank outlet.* Provision shall be made either to prevent entrance into the tank itself or into the tank outlet of any foreign object which might obstruct the flow of oil through the system. The oil tank outlet shall not be enclosed by any screen or guard which would reduce the flow of oil below a safe value at any operating temperature condition.

(e) *Flexible oil tank liners.* Flexible oil tank liners shall be of an approved type or shall be shown to be suitable for the particular application.

4b.442 *Oil tank tests.*

(a) Oil tanks shall be capable of withstanding without failure all vibration, inertia, and fluid loads to which they would be subjected in operation.

(b) The provisions of section 4b.421 shall be applicable to oil tanks, except as follows:

(1) The test pressure specified in section 4b.421 (a) shall be 5 p. s. i.

(2) The test fluid specified in section 4b.421 (c) shall be oil at a temperature of 250° F.

4b.443 *Oil tank installation.* The oil tank installation shall comply with the provisions of section 4b.422, except that the location of an engine oil tank in a designated fire zone shall be acceptable if the tank and its supports are of fireproof construction to the extent that damage by fire to any nonfireproof parts would not result in leakage or spillage of oil.

4b.444 *Oil lines and fittings.*

(a) *General.* The provisions of section 4b.432 shall be applicable to oil lines.

(b) *Lines and fittings in designated fire zones.* Oil lines and fittings in all designated fire zones (see sec. 4b.480) shall comply with the provisions of section 4b.483.

(c) *Engine breather lines.*

(1) Engine breather lines shall be arranged so that condensation of water vapor which might freeze and obstruct the line cannot accumulate at any point.

(2) Breathers shall discharge in a location which will not constitute a fire hazard in case foaming occurs and in a manner so that the emitted oil will not impinge upon the pilot windshield.

(3) The breather shall not discharge into the engine air induction system. (See also sec. 4b.483 (c).)

4b.445 *Oil valves.*

(a) The requirements of section 4b.482 for shut-off means shall be complied with. Closing of oil shut-off means shall not prevent feathering the propeller.

(b) All oil valves shall be provided with positive stops or suitable index provisions in the "on" and "off" positions, and they shall be supported so that loads resulting from their operation or from accelerated flight conditions are not transmitted to the lines attached to the valve.

4b.446 *Oil radiators.*

(a) Oil radiators shall be capable of withstanding without failure all vibration, inertia, and oil pressure loads to which they would be subjected in operation.

(b) Oil radiator air ducts shall be located so that, in case of fire, flames issuing from normal openings of the engine nacelle cannot impinge directly upon the radiator.

4b.447 *Oil filters.* If the airplane is equipped with an oil filter, the filter shall be constructed or installed in such a manner that complete blocking of the flow through the filter element will not prevent the safe operation of the engine oil supply system.

4b.448 *Oil system drains.* Accessible drains shall be provided to permit safe drainage of the entire oil system and shall incorporate means for the positive locking of the drain in the closed position, either manually or automatically. (See also sec. 4b.483 (c).)

4b.449 *Propeller feathering system.*

(a) If the propeller feathering system is dependent upon the use of the engine oil supply, provision shall be made to trap a quantity of oil in the tank in case the supply becomes depleted due to failure of any portion of the lubricating system other than the tank itself.

(b) The quantity of trapped oil shall be sufficient to accomplish the feathering operation and shall be available only to the feathering pump.

(c) The ability of the system to accomplish feathering with the trapped supply of oil shall be demonstrated. It shall be acceptable to make this demonstration on the ground.

4b.449–1 *Procedure for demonstrating propeller feathering (CAA policies which apply to sec. 4b.449).* Tests should be conducted to demonstrate that the oil reserve for propeller feathering is adequate to accomplish the feathering procedure. This may be done on the ground by using an auxiliary source of oil for lubricating the engine during its operation.

(19 F. R. 4464, July 20, 1954, effective Sept. 1, 1954.)

Cooling System

4b.450 *General.* The powerplant cooling provisions shall be capable of maintaining the temperatures of major powerplant components, engine fluids, and the carburetor intake air within the established safe values under all conditions of ground and flight operation. (For cooling system instruments see secs. 4b.604 and 4b.734.)

4b.450–1 *Cooling with reverse thrust (CAA policies which apply to sec. 4b.450).* The policies outlined in section 4b.402–1 (j) will apply.

(20 F. R. Apr. 8, 1955, effective Apr. 30, 1955.)

4b.451 *Cooling tests.*

(a) *General.* Compliance with the provisions of section 4b.450 shall be demonstrated under critical ground, water, and flight operating conditions. If the tests are conducted under conditions which deviate from the maximum anticipated air temperature (see paragraph (b) of this section), the recorded powerplant temperatures shall be corrected in accordance with the provisions of paragraphs (c) and (d) of this section. The corrected temperatures determined in this manner shall not exceed the maximum established safe values. The fuel used during the cooling tests shall be of the minimum octane number approved for the engines involved, and the mixture settings shall be those used in normal operation. The test procedures shall be as outlined in sections 4b.452 through 4b.454.

(b) *Maximum anticipated air temperature.* The maximum anticipated air temperature (hot day condition) shall be 100° F. at sea level, decreasing from this value at the rate of 3.6° F. per thousand feet of altitude above sea level until a temperature of −67° F. is reached above which altitude the temperature shall be constant at −67° F.

(c) *Correction factor for cylinder head, oil inlet, and carburetor air temperatures.* The cylinder head, oil inlet, and carburetor air temperatures shall be corrected by adding the difference between the maximum anticipated air temperature and the temperature of the ambient air at the time of the first occurrence of maximum head, oil, or air temperature recorded during the cooling test, unless a more rational correction is shown to be applicable.

(d) *Correction factor for cylinder barrel temperatures.* Cylinder barrel temperatures shall be corrected by adding 0.7 of the difference between the maximum anticipated air temperature and the temperature of the ambient air at the time of the first occurrence of the maximum cylinder barrel temperature recorded during the cooling test, unless a more rational correction is shown to be applicable.

4b.452 *Climb cooling test procedure.*

(a) The climb cooling test shall be conducted with the critical engine inoperative and its propeller feathered.

(b) All remaining engines shall be operated at their maximum continuous power or at full throttle when above the critical altitude.

(c) After stabilizing temperatures in flight, the climb shall be started at or below the lower of the two following altitudes and shall be continued until at least 5 minutes after the occurrence of the highest temperature recorded, or until the maximum altitude is reached for which certification is desired:

(1) 1,000 feet below the engine critical altitude,

(2) 1,000 feet below the maximum altitude at which the rate of climb is equal to that established in accordance with section 4b.120 (c).

(d) The climb shall be conducted at an air speed which does not exceed the speed used in establishing the rate of climb required in section 4b.120 (c). It shall be acceptable to conduct the climb cooling test in conjunction with the take-off cooling test of section 4b.453.

4b.452–1 *Procedure for demonstrating cooling climb (CAA policies which apply to sec. 4b.452).*

(a) If the applicant is not able to provide data for the location of the engine having the hottest

cylinder heads and bases, the following procedure should be accomplished. The cylinder heads and bases on one engine should be fully instrumented for the purpose of determining the location of the hottest cylinder head and base to be checked during the climb cooling. Thermocouples should be installed on one head of each of the remaining engines at the location shown to be critical on the fully instrumented engine. The hottest of the critical cylinder heads may be determined by measuring the temperatures of each of the engines under simulated climb conditions. The engine having the hottest cylinder head should be chosen as the engine to be tested for the cooling demonstration. Instruments for determining the oil inlet and cylinder base temperatures should be installed on this engine. The cooler operating outboard engine should be considered to be the critical inoperative engine unless there is reason to believe that another engine is more critical. The cooling tests should be conducted in an atmosphere which is free of any visible moisture.

(b) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—optional.
Wing flaps—optional.
Landing gear—optional.
Operating engine(s)—maximum continuous power, mixture setting the same as used in normal operation and cooling controls in CAA hot day cooling position.
Critical inoperative engine—throttle closed on cooler operating outboard engine, propeller feathered and cowl flaps closed.

(c) *Test procedure and required data.*

(1) Prior to commencing the cooling climb, the engine temperatures should be stabilized in level flight at the lower of the two altitudes specified in section 4b.452 (c). During level flight the cooling climb conditions should be simulated by adjusting the airplane configuration to that shown in (b) and maintaining the necessary power on the operating engine(s) to obtain the speed specified in section 4b.452 (d).

(2) When the temperatures have stabilized, i. e., the rate of temperature change is less than 2° F. per minute, the propeller on the inoperative engine should be feathered and the cooling climb commenced at maximum continuous power and at the specified configuration and speed. The climb should be continued for five minutes after occurrence of the highest temperature or until the maximum altitude desired for certification is reached.

(3) The above procedure should be repeated when demonstrating engine cooling for high blower except that temperatures should be stabilized in level flight with simulated climb conditions at an altitude of 1,000 feet below the critical altitude established for the high blower. The weight of the airplane should be such that it will permit a rate of climb equal to that specified in section 4b.120 (c).

(4) The following data should be recorded at no greater than one minute intervals:

Pressure altitude.
Ambient air temperature.
Engines, r. p. m. and manifold pressure.
Carburetor air temperature.
Indicated airspeed.
Hottest cylinder head temperature.
Hottest cylinder base temperature.
Oil inlet temperature.
Coolant temperature.
Fuel flow.

(5) In addition a record should be made of the mixture setting, blower setting, cooling control settings, and fuel grade.

4b.453 *Take-off cooling test procedure.* A take-off cooling test shall be conducted to demonstrate cooling during take-off and during subsequent climb with one engine inoperative. The following procedure shall be applicable:

(a) The take-off cooling test shall be commenced by stabilizing temperatures during level flight with all engines operating at 75 percent of maximum continuous power with the appropriate cowl flap and shutter settings.

(b) After all temperatures have stabilized, the climb shall be started at the lowest practicable altitude and shall be conducted with one engine inoperative and its propeller feathered.

(c) The remaining engines shall be operated at take-off rpm and power (or at full throttle when above the take-off critical altitude) for the same time interval as take-off power is used during determination of the take-off flight path (see sec. 4b.116).

(d) At the end of the time interval prescribed in paragraph (c) of this section the power shall

be reduced to the maximum continuous power and the climb continued until at least 5 minutes after the occurrence of the highest temperature recorded.

(e) The speed used during take-off power operation (paragraph (c) of this section) shall not exceed the speed used during determination of the take-off flight path (see sec. 4b.116).

4b.453–1 *Procedure for demonstrating takeoff cooling (CAA policies which apply to sec. 4b.453).*

(a) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—optional.
Wing flaps—takeoff position.
Landing gear—optional.
Operating engine(s)—takeoff r. p. m. or full throttle, mixture setting at takeoff and cooling controls in takeoff position.
Critical inoperative engine—throttle closed on cooler operating outboard engine (see sec. 4b.452–1 (a)), propeller feathered and cowl flaps in optional position.

(b) *Test procedure and required data.* The temperature should be permitted to stabilize during level flight at the lowest practical altitude using 75 percent maximum continuous power on all engines and normal takeoff cowl flap or coolant door setting. After the temperatures have stabilized, the configuration of the airplane should be adjusted as specified in (a) of this section and the climb commenced at the speed and continued for the same time interval as takeoff power is used during determination of the takeoff flight path (sec. 4b.116). At the end of the takeoff power time limit, the power should be reduced to maximum continuous. After power has been reduced, the configuration may be adjusted to the en route condition specified in section 4b.452–1 (b) and the airplane accelerated to the en route climb speed specified in section 4b.452 (d). The cooling climb should be continued for five minutes after the occurrence of the highest temperature. The same data as outlined in section 4b.452–1 (c) (4) and (5) should be recorded.

4b.454 *Cooling test procedure for flying boat operation.* In the case of flying boats, cooling shall be demonstrated during taxying down wind for 10 minutes at 5 mph above the step speed.

4b.454–1 *Procedure for demonstrating cooling for seaplanes during water taxiing operations (CAA policies which apply to sec. 4b.454).*

(a) The cooling test for seaplanes should be conducted while taxiing on water. The tank system should contain fuel of the minimum grade approved for the engine installed. Cylinder and oil inlet temperatures should be permitted to stabilize in flight or by taxiing at reduced speed. The test should be conducted in an atmosphere which is free of visible moisture.

(b) *Configuration.* This test should be conducted in the configuration that follows:

Weight—maximum takeoff.
C. G. position—optional.
Wing flaps—optional.
Engines—sufficient power for airspeed required in (c).
Cooling controls—takeoff position.
Mixture setting—normal position for taxiing.

(c) *Test procedure and required data.* After temperatures have stabilized, the seaplane should be taxied down wind for at least 10 minutes at a speed which is not more than 5 m. p. h. above the step speed. The same data as outlined in section 4b.452–1 (c) (4) and (5) should be recorded.

(19 F. R. 4465, July 20, 1954, effective Sept. 1, 1954.)

Induction and Exhaust Systems

4b.460 *General.*

(a) The engine air induction system shall permit supplying the proper quantity of air to the engine under all conditions of operation.

(b) The induction system shall provide air for proper fuel metering and mixture distribution with the induction system valves in any position.

(c) Each [reciprocating] engine shall be provided with an alternate air source.

(d) Air intakes shall not open within the cowling, unless that portion of the cowling is isolated from the engine accessory section by means of a fireproof diaphragm, or unless provision is made to prevent the emergence of backfire flames.

(e) Alternate air intakes shall be so located as to preclude the entrance of rain, ice, or any other foreign matter.

(f) For turbine-engine-powered airplanes, provisions shall be made to prevent hazardous quantities of fuel leakage or overflow from drains, vents, or other components of flammable fluid systems to enter the engine intake system.

[(g) For turbine engines, the air inlet ducts shall be so located or protected as to minimize the ingestion of foreign matter during take-off, landing, or taxying.]

4b.461 *Induction system de-icing and anti-icing provisions.*

(a) *General.* The engine air induction system shall incorporate means for the prevention and elimination of ice accumulations.

(b) *Heat Rise.* Unless it is demonstrated that other means will accomplish the intent of paragraph (a) of this section, compliance with the following heat-rise provisions shall be demonstrated in air free of visible moisture at a temperature of 30° F.

(1) Airplanes equipped with altitude engines employing conventional venturi carburetors shall have a preheater capable of providing a heat rise of 120° F. when the engine is operating at 60 percent of its maximum continuous power.

(2) Airplanes equipped with altitude engines employing carburetors which embody features tending to reduce the possibility of ice formation shall have a preheater capable of providing a heat rise of 100° F. when the engine is operating at 60 percent of its maximum continuous power.

[(c) *Turbine powerplants.* Turbine-powered airplanes shall be capable of operation throughout the flight power range without accumulation of ice in the air induction system such as to adversely affect engine operation or cause a serious loss of power and/or thrust in the continuous maximum and intermittent maximum icing conditions as defined in section 4b.1 (b) (7) and (8).]

4b.461–1 *Procedure for demonstrating carburetor air heat rise (CAA policies which apply to sec. 4b.461 (b)).*

(a) [The carburetor air temperature should be measured by a minimum of three thermocouples so arranged as to give an average air temperature.] This indicator should be calibrated prior to the test. The tests should be conducted at an altitude where the free air temperature is 30° F. or at two altitudes of different temperatures, one of which is near 30° F.

(b) *Configuration.* This test should be conducted in the configuration that follows:

Weight—optional.
C. G. position—optional.
Wing flaps—optional.
Landing gear—optional.
Engines—60 percent maximum continuous power.
Cowl flaps—appropriate for flight condition.
Mixture setting—normal cruising position.

(c) *Test procedure and required data.*

(1) After all temperatures have stabilized (i. e., when the rate of temperature change is less than 2° F. per minute) and with the airplane in level flight and full cold carburetor at 60 percent maximum continuous power, the following data should be recorded:

Pressure altitude.
Ambient air temperature.
Indicated airspeed.
Carburetor air temperature.
Engines, r. p. m. and manifold pressure.
Torque pressure.
Mixture setting.
Cowl flap setting.

(2) Preheat should then be applied slowly (power may be restored to 60 percent maximum continuous at the applicant's option) and the above data recorded again after the carburetor air temperature has stabilized. The carburetor heat rise should be determined from the results of the data.

19 F. R. 4465, July 20, 1954, effective Sept. 1, 1954; amended 22 F. R. 6963, Aug. 29, 1957, effective Sept. 15, 1957.)

4b.462 *Carburetor air preheater design.* Carburetor air preheaters shall incorporate the following provisions:

(a) Means shall be provided to assure ventilation of the preheater when the engine is being operated with cold air.

(b) The preheater shall be constructed to permit inspection of exhaust manifold parts

which it surrounds and also to permit inspection of critical portions of the preheater itself.

4b.463 *Induction system ducts.* Induction system ducts shall incorporate the following provisions:

(a) Induction system ducts ahead of the first stage of the supercharger shall be provided with drains to prevent hazardous accumulations of fuel and moisture in the ground attitude. The drains shall not discharge in locations which might cause a fire hazard.

(b) Sufficient strength shall be incorporated in the ducts to prevent induction system failures resulting from normal backfire conditions.

(c) Ducts which are connected to components of the airplane between which relative motion could exist shall incoporate provisions for flexibility.

(d) Induction system ducts within any fire zone for which a fire-extinguishing system is required shall be of fire-resistant construction.

4b.464 *Induction system screens.* If induction system screens are employed, they shall comply with the following provisions: .

(a) Screens shall be located upstream from the carburetor.

(b) Screens shall not be located in portions of the induction system which constitute the only passage through which air can reach the engine, unless the screen is so located that it can be de-iced by heated air.

(c) De-icing of induction system screens by means of alcohol alone shall not be acceptable.

(d) It shall not be possible for fuel to impinge upon the screens.

4b.465 *Carburetor air cooling.* Installations employing two-stage superchargers shall be provided with means to maintain the air temperature at the inlet to the carburetor at or below the maximum established value. The demonstration of this provision shall be accomplished in accordance with section 4b.451.

4b.465–1 *Procedure for demonstrating carburetor air cooling (CAA policies which apply to sec. 4b.465).* Carburetor air cooling should be demonstrated in conjunction with the tests required by sections 4b.452 and 4b.453.

(19 F. R. 4465, July 20, 1954, effective Sept. 1, 1954.)

4b.466 *Inter-coolers and after-coolers.* Inter-coolers and after-coolers shall be capable of withstanding without failure all vibration, inertia, and air pressure loads to which they would be subjected in operation.

4b.467 *Exhaust system and installation components.*

(a) *General.*

(1) The exhaust system shall be constructed and arranged to assure the safe disposal of exhaust gases without the existence of a fire hazard or carbon monoxide contamination of air in personnel compartments.

(2) Unless appropriate precautions are taken, exhaust system parts shall not be located in hazardous proximity to portions of any system carrying flammable fluids or vapors nor shall they be located under portions of such systems where the latter could be subject to leakage.

(3) All airplane components upon which hot exhaust gases might impinge, or which could be subjected to high temperatures due to proximity to exhaust system parts, shall be constructed of fireproof material. All exhaust system components shall be separated by means of fireproof shields from adjacent portions of the airplane which are outside the engine compartment.

(4) Exhaust gases shall not discharge in a manner to cause a fire hazard with respect to any flammable fluid vent or drain.

(5) Exhaust gases shall not discharge at a location which will cause a glare seriously affecting pilot visibility at night.

(6) All exhaust system components shall be ventilated to prevent the existence of points of excessively high temperature.

(7) Exhaust shrouds shall be ventilated or insulated to avoid during normal operation a temperature sufficiently high to ignite any flammable fluids or vapors external to the shrouds.

(b) *Exhaust piping.*

(1) Exhaust piping shall be constructed of material resistant to heat and corrosion, and shall incorporate provisions to prevent failure due to expansion when heated to operating temperatures.

(2) Exhaust pipe shall be supported to withstand all vibration and inertia loads to which they would be subjected in operation.

(3) Portions of the exhaust piping which are connected to components between which

relative motion could exist shall incorporate provisions for flexibility.

(c) *Exhaust heat exchangers.*

(1) Exhaust heat exchangers shall be constructed and installed to assure their ability to withstand without failure all vibration, inertia, and other loads to which they would be subjected in operation.

(2) Heat exchangers shall be constructed of materials which are suitable for continued operation at high temperatures and which are resistant to corrosion due to elements contained in exhaust gases.

(3) Provision shall be made for the inspection of all critical portions of exhaust heat exchangers.

(4) Heat exchangers shall incorporate cooling provisions wherever they are subject to contact with exhaust gases.

(5) Heat exchangers or muffs shall incorporate no stagnant areas or liquid traps which would increase the possibility of ignition of flammable fluids or vapors which might be present in case of failure or malfunctioning of components carrying flammable fluids.

(d) *Exhaust heating of ventilating air.* If an exhaust heat exchanger is used for heating ventilating air, a secondary heat exchanger shall be provided between the primary exhaust gas heat exchanger and the ventilating air system, unless it is demonstrated that other means used preclude harmful contamination of the ventilating air.

(e) *Exhaust driven turbo-superchargers.*

(1) Exhaust driven turbines shall be of an approved type or shall be shown to be suitable for the particular application. They shall be installed and supported to assure their safe operation between normal inspection and overhaul periods.

(2) Provision for expansion and flexibility shall be made between exhaust conduits and the turbine.

(3) Provision shall be made for lubrication of the turbine and for cooling of those turbine parts where the temperatures are critical.

(4) Means shall be provided so that, in the event of malfunctioning of the normal turbo-supercharger control system, the turbine speed will not be greater than its maximum allowable value. The components provided for this purpose shall be independent of the normal turbo-supercharger controls with the exception of the waste gate operating components themselves.

4b.467–1 *Carbon monoxide detection (CAA policies which apply to sec. 4b.467 (a) (1) and (d)).*

(a) Any acceptable carbon monoxide detection method may be used in demonstrating compliance with section 4b.467 (a) (1) and (d), and with the ventilating requirements of section 4b.371. The tests should be conducted with the airplane's heater system in operation if there is any possibility of a system containing carbon monoxide. In aircraft employing thermal de-icing, tests should be conducted with the system operating at full capacity.

(b) *Configuration.* Carbon monoxide tests should be conducted in the configurations that follow:

(1) *Power-on level flight.*
Weight—optional.
C. G. position—optional.
Wing flaps—retracted.
Landing gear—retracted.
Engines—maximum continuous power.
Cowl flaps—appropriate for flight condition.

(2) *Power-off glide.*
Wing flaps—retracted.
Landing gear—retracted.
Engines—idling.
Cowl flaps—appropriate for flight condition.

(3) *Power approach.*
Wing flaps—approach position.
Landing gear—extended.
Engines—power for level flight.
Cowl flaps—appropriate for flight condition.
Airspeed—any speed from 1.4 V_{s_1} to 1.6 V_{s_1}.

(c) *Test procedure and required data.* The air should be sampled with a carbon monoxide indicator in front of cabin heater opening(s) with heat on and at representative passenger and crew locations. If the airplane does not have pressurization equipment installed, the air should be sampled at the above locations with the windows closed and also partially opened. If the airplane is equipped for pres-

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surization, carbon monoxide indications should be taken when the cabin is pressurized and also unpressurized.

(19 F. R. 4465, July 20, 1954, effective Sept. 1, 1954.)

4b.467–2 *Determination of exhaust gas interference with visibility (CAA policies which apply to sec. 4b.467 (a) (5)).* The effects of exhaust gas interference with visibility should be observed during tests to demonstrate other night flying requirements.

(19 F. R. 4466, July 20, 1954, effective Sept. 1, 1954.)

Powerplant Controls and Accessories

4b.470 *Powerplant controls; general.*

The provisions of section 4b.353 shall be applicable to all powerplant controls with respect to location, grouping, and direction of motion, and the provisions of section 4b.737 shall be applicable to all powerplant controls with respect to marking. In addition all powerplant controls shall comply with the following:

(a) Controls shall be so located that they cannot be inadvertently operated by personnel entering, leaving, or making normal movements in the cockpit.

(b) Controls shall maintain any set position without constant attention by flight personnel. They shall not tend to creep due to control loads or vibration.

(c) Flexible controls shall be of an approved type or shall be shown to be suitable for the particular application.

(d) Controls shall have strength and rigidity to withstand operating loads without failure and without excessive deflection.

4b.471 *Throttle and A. D. I. system controls.*

(a) A separate throttle control shall be provided for each engine. Throttle controls shall be grouped and arranged to permit separate control of each engine and also simultaneous control of all engines.

(b) Throttle controls shall afford a positive and immediately responsive means of controlling the engines.

(c) If an antidetonant injection system is provided, the flow of ADI fluid shall be automatically controlled in relation to the amount of power produced by the engine. In addition to the automatic control, a separate control shall be provided for the ADI pumps.

4b.472 *Ignition switches.*

(a) Ignition switches shall provide control for each ignition circuit on each engine.

(b) Means shall be provided for quickly shutting off all ignition by the grouping of switches or by providing a master ignition control.

(c) If a master ignition control is provided, a guard shall be incorporated to prevent inadvertent operation of the control.

4b.473 *Mixture controls.*

(a) If mixture controls are provided, a separate control shall be provided for each engine. The mixture controls shall be grouped and arranged to permit separate control of each engine and also simultaneous control of all engines.

(b) Any intermediate position of the mixture control which corresponds with a normal operating setting shall be provided with a sensory and a visual identification.

(c) The mixture controls shall be placed in a location accessible to both pilots, except where a separate flight engineer station with a control panel is provided, in which case the mixture controls shall be accessible to the flight engineer.

4b.474 *Propeller controls.*

(a) *Propeller speed and pitch controls.*

(1) A separate propeller speed and pitch control shall be provided for each propeller. The propeller speed and pitch controls shall be grouped and arranged to permit separate control of each propeller and also simultaneous control of all propellers.

(2) The propeller speed and pitch controls shall provide for synchronization of all propellers. (See also sec. 4b.404.)

(3) Propeller speed and pitch control(s) shall be placed to the right of the pilot's throttle and shall be at least 1 inch lower than the throttle controls.

(b) *Propeller feathering controls.*

(1) A separate propeller feathering control shall be provided for each propeller.

(2) Propeller feathering controls shall be provided with means to prevent inadvertent operation.

(3) If feathering is accomplished by movement of the propeller pitch or speed control lever, provision shall be made to prevent the movement of this control to the feathering position during normal operation.

[4b.474–1 *Propeller feathering pump motors, intermittent duty type (CAA policies which apply to sec. 4b.474 (b)).*

[(a) An intermittent duty type motor[30] in the propeller feathering control system should automatically stop or be made to stop upon the completion of the feathering operation by any of the following means:

[(1) Installation of a pressure cutout switch in the feathering button holding coil circuit.

[(2) Installation of a timer switch in the feathering button holding coil circuit.

[(3) Manually interrupting the feathering pump circuit by pulling out the feathering button. In this arrangement, a warning light should be installed in the pump circuit to illuminate while the pump motor is operating. The light may be either in the feathering button or adjacent to it.

[(b) Timer switches of either the mechanical or the thermal types are acceptable.]

(22 F. R. 6885, Aug. 27, 1957, effective Sept. 15, 1957.)

[4b.474a *Reverse thrust controls.*

[(a) Propeller reverse thrust controls shall incorporate a means to prevent their inadvertent movement to a reverse thrust position. The means provided shall incorporate a positive lock or stop at the flight idle position and shall require a separate and distinct operation by the crew in order to displace the control from the flight regime.

[(b) Turbo-jet reverse thrust controls shall incorporate a means to prevent their inadvertent movement to a reverse thrust position. The means provided shall incorporate a positive lock or stop at the flight idle position and shall require a separate and distinct operation by the crew in order to displace the control from the forward thrust regime.]

4b.475 *Fuel system controls.* (See also sec. 4b.434.)

(a) Fuel jettisoning system controls shall be provided with guards to prevent their inadvertent operation.

(b) Fuel jettisoning system controls shall not be located in close proximity to fire extinguisher controls nor to any other controls intended to combat fire.

4b.476 *Carburetor air preheat controls.* **Separate carburetor air preheat controls shall be provided to regulate the temperature of the carburetor air for each engine.**

4b.476a *Supercharger controls.* **Supercharger controls shall be accessible to the pilots, except where a separate flight engineer station with a control panel is provided, in which case they shall be accessible to the flight engineer.**

4b.477 *Powerplant accessories.*

(a) Engine mounted accessories shall be of a type approved for installation on the engine involved, and shall utilize the provisions made on the engine for mounting.

(b) Items of electrical equipment subject to arcing or sparking shall be installed to minimize the possibility of their contact with any flammable fluids or vapors which might be present in a free state.

(c) If continued rotation of an engine-driven cabin supercharger or any remote accessory driven by the engine will constitute a hazard in case malfunctioning occurs, means shall be provided to prevent hazardous rotation of such accessory without interfering with the continued operation of the engine. (See also sec. 4b.371 (c).)

NOTE: Hazardous rotation may involve consideration of mechanical damage or sustained air flows which may be dangerous under certain conditions.

4b.478 *Engine ignition systems.*

(a) Battery ignition systems shall be supplemented with a generator which is automatically made available as an alternate source of electrical energy to permit continued engine operation in the event of the depletion of any battery.

(b) The capacity of batteries and generators shall be sufficient to meet the simultaneous demands of the engine ignition system and the greatest demands of any airplane electrical system components which would draw electrical energy from the same source.

[30 Intermittent duty type motors may fail if operated continuously for more than two minutes.]

(1) The design of the engine ignition system shall take into consideration the condition of an inoperative generator and the condition of a completely depleted battery when the generator is running at its normal operating speed.

(2) If only one battery is provided the design of the engine ignition system shall take into consideration the condition in which the battery is completely depleted and the generator is operating at idling speed.

(3) Portions of magneto ground wires for separate ignition circuits which lie on the engine side of the fire wall shall be installed, located, or protected so as to minimize the possibility of simultaneous failure of two or more wires as a result of mechanical damage, electrical faults, etc.

(4) Ground wires for any engine shall not be routed through fire zones, except those associated with the engine which the wires serve, unless those portions of the wires which are located in such fire zones are fireproof or are protected against the possibility of damage by fire in a manner to render them fireproof. (See sec. 4b.472 for ignition switches.)

(5) Ignition circuits shall be electrically independent of all other electrical circuits except circuits used for analyzing the operation of the ignition system.

(c) Means shall be provided to warn flight personnel if malfunctioning of any part of the electrical system is causing the continuous discharging of a battery which is necessary for engine ignition. (See sec. 4b.472 for ignition switches.)

Powerplant Fire Protection

4b.480 *Designated fire zones.*

(a) Designated fire zones shall comprise the following regions:

(1) Engine power section,

(2) Engine accessory section,

(3) Complete powerplant compartments in which no isolation is provided between the engine power section and the engine accessory section,

(4) Auxiliary power unit compartments,

(5) Fuel-burning heaters and other combustion equipment installations as defined by section 4b.386.

(6) Compressor and accessory sections of turbine engines.

NOTE: See also section 4b.385.

[(7) Combustor, turbine, and tailpipe sections of turbine engine installations which contain lines or components carrying flammable fluids or gases, except that the fire extinguisher system specified in section 4b.484 need not be provided for such sections if it is demonstrated that any fire occurring therein can be otherwise controlled.]

(b) Designated fire zones shall be protected from fire by compliance with sections 4b.481 through 4b.490.

(c) The nacelle area immediately behind the fire wall shall comply with the provisions of sections 4b.385, 4b.463 (d), 4b.478 (b), (4), 4b.481 (c) 4b.482 through 4b.485 and 4b.489. If a retractable landing gear is located in this area, compliance with this paragraph is required only with the landing gear retracted.

4b.481 *Flammable fluids.*

(a) No tanks or reservoirs which are a part of a system containing flammable fluids or gases shall be located in designated fire zones, except where the fluid contained, the design of the system, the materials used in the tank, the shut-off means, all connections, lines, and controls are such as to provide an equally high degree of safety.

(b) Not less than one-half inch of clear air space shall be provided between any tank or reservior and a fire wall or shroud isolating a designated fire zone.

(c) If absorbent materials are located in proximity to flammable fluid system components which might be subject to leakage, such materials shall be covered or treated to prevent the absorption of hazardous quantities of fluids.

4b.482 *Shut-off means.*

(a) Means for each individual engine and for each individual fire zone specified in section 4b.480 (a) (4) and (5) shall be provided for shutting off or otherwise preventing hazardous quantities of fuel, oil, de-icer, and other flammable fluids from flowing into, within, or through any designated fire zone, except that means need not be provided to shut off flow in lines forming an integral part of an engine. Closing the fuel shutoff valve for any engine

shall not make any of the fuel supply unavailable to the remaining engines.

(b) Operation of the shutoff means shall not interfere with the subsequent emergency operation of other equipment, such as feathering the propeller.

(c) The shut-off means shall be located outside of designated fire zones, unless an equally high degree of safety is otherwise provided (see sec. 4b.481). It shall be shown that no hazardous quantity of flammable fluid could drain into any designated fire zone after shutting-off has been accomplished.

(d) Provisions shall be made to guard against inadvertent operation of the shutoff means and to make it possible for the crew to reopen the shutoff means in flight after it has once been closed.

[4b.483 *Lines and fittings.* All lines and fittings carrying flammable fluids or gases in designated fire zones shall comply with the provisions of paragraphs (a) through (c) of this section.]

(a) Lines and fittings which are under pressure, or which attach directly to the engine, or which are subject to relative motion between components shall be flexible, fire-resistant lines with fire-resistant end fittings of the permanently attached, detachable, or other approved type. The provisions of this paragraph shall not apply to those lines and fittings which form an integral part of the engine.

(b) Lines and fittings which are not subject to pressure or to relative motion between components shall be of fire-resistant materials.

(c) Vent and drain lines and fittings shall be subject to the provisions of paragraphs (a) and (b) of this section, unless a failure of such line or fitting will not result in, or add to, a fire hazard.

4b.484 *Fire extinguisher systems.*

(a) *General.*

(1) Fire extinguisher systems shall be provided to serve all designated fire zones. This requirement shall be effective with respect to applications for type certificates in accordance with the provisions of section [4b.11 (a)]. In addition, all other airplanes manufactured after June 30, 1954, shall comply with this requirement, unless the engine power section is completely isolated from the engine accessory section by a fireproof diaphragm complying with the provisions of section 4b.488 and unless the cowling and nacelle skin comply with the provisions of section 4b.487, in which case fire extinguisher systems need not be provided in the engine power section.

NOTE: Induction systems for reciprocating engines are considered to be located in a designated fire zone, and therefore subject to the fire extinguisher protection provisions unless tests or experience with the particular type of induction and carburetion systems shows that fuel burning in the induction system passages is not likely to occur.

(2) The fire extinguishing system, the quantity of extinguishing agent, and the rate of discharge shall be such as to provide two adequate discharges. It shall be possible to direct both discharges to any main engine installation. Individual "one-shot" systems shall be acceptable in the case of auxiliary power units, fuel-burning heaters, and other combustion equipment.

(3) The fire-extinguishing system for a nacelle shall be capable of protecting simultaneously all zones of the nacelle for which protection is provided.

(b) *Fire extinguishing agents.*

(1) Extinguishing agents employed shall be methyl bromide, carbon dioxide, or any other agent which has been shown to provide equivalent extinguishing action.

(2) If methyl bromide, carbon dioxide, or any other toxic extinguishing agent is employed, provision shall be made to prevent the entrance of harmful concentration of fluid or fluid vapors into any personnel compartments either due to leakage during normal operation of the airplane or as a result of discharging the fire extinguisher on the ground or in flight even though a defect may exist in the extinguishing system. Compliance with this requirement shall be demonstrated by appropriate tests.

(3) If a methyl bromide system is provided, the containers shall be charged with a dry agent and shall be sealed by the fire extinguisher manufacturer or by any other party employing appropriate recharging equipment.

(c) *Extinguishing agent container pressure relief.* Extinguisher agent containers shall be provided with a pressure relief to prevent bursting of the container due to excessive

internal pressures. The following provisions shall apply:

(1) The discharge line from the relief connection shall terminate outside the airplane in a location convenient for inspection on the ground.

(2) An indicator shall be provided at the discharge end of the line to provide a visual indication when the container has discharged.

(d) *Extinguishing agent container compartment temperature.* Under all conditions in which the airplane is intended for operation, the temperature range of the extinguishing agent containers shall be maintained to assure that the pressure in the containers can neither fall below the minimum necessary to provide an adequate rate of extinguisher agent discharge nor rise above a safe limit so that the system will not be prematurely discharged.

(e) *Fire-extinguishing system materials.* Materials in the fire extinguishing system shall not react chemically with the extinguishing agent so as to constitute a hazard. All components of the fire extinguishing systems located in designated fire zones shall be constructed of fireproof materials.

4b.484–1 *Determination of carbon dioxide concentration in flight crew compartments. (CAA policies which apply to sec. 4b.484 (b)).*

(a) Carbon dioxide has been found to adversely affect flight crew personnel in the performance of their duties. Therefore, in aircraft equipped with built-in carbon dioxide fuselage compartment fire extinguishing systems, the carbon dioxide concentration occurring at the flight crew stations as a result of discharging the fire extinguishers should be determined in accordance with paragraphs (b) and (c), except that such determination is not considered necessary if:

(1) Five pounds or less of carbon dioxide will be discharged into any one such fuselage compartment in accordance with established fire control procedures, or

(2) Protective breathing equipment is provided for each flight crew member on flight deck duty.

(b) The carbon dioxide concentrations at breathing level at the flight crew stations should be determined in flight tests during which fuselage compartment fire extinguishers are discharged in accordance with established fire control procedures. Since carbon dioxide is heavier than air, a nose down attitude is likely to produce the critical concentrations in the crew compartment. The following conditions should therefore be investigated:

(1) A rapid descent at the "Never Exceed" speed of the airplane with flaps and landing gear up,

(2) A rapid descent with flaps and landing gear down, at the maximum permissible speed for this configuration. If it appears that any other condition is likely to be critical on a particular airplane, it should also be investigated.

(c) In the flight tests specified in (b), it will be permissible to institute emergency ventilating procedures immediately prior to or following the discharge of carbon dioxide, provided such procedures can be accomplished easily and quickly by the flight crew and do not appreciably reduce the effectiveness of the fire protection system.

(d) If the carbon dioxide concentrations determined in accordance with paragraphs (b) and (c) exceed 3 percent by volume (corrected to standard sea-level conditions), protective breathing equipment should be provided for each flight crew member on flight deck duty.

(e) Appropriate emergency operating procedures should be entered in the Airplane Flight Manual.

(15 F. R. 8904, Dec. 15, 1950, effective Dec. 15, 1950.)

[4b.485 *Fire-detector systems.* Quick-acting fire or overheat detectors of an approved type shall be provided in all designated fire zones and in the combustion, turbine, and tailpipe sections of turbine-engine installations, and they shall be sufficient in number and location to assure prompt detection of fire in such zones and sections. Fire detectors shall comply with the following provisions:]

(a) Fire detectors shall be constructed and installed to assure their ability to resist without failure all vibration, inertia, and other loads to which they would be subjected in operation.

(b) Fire detectors shall be unaffected by the exposure to oil, water, or other fluids or fumes which might be present.

(c) Means shall be provided to permit the crew to check in flight the functioning of the

electric circuit associated with the fire-detection system.

(d) Wiring and other components of detector systems which are located in fire zones shall be of fire-resistant construction.

(e) Detector system components for any fire zone shall not pass through other fire zones, unless they are protected against the possibility of false warnings resulting from fires in zones through which they pass. This requirement shall not be applicable with respect to zones which are simultaneously protected by the same detector and extinguisher systems.

[4b.485–1 *Fire detector test circuit (CAA policies which apply to sec. 4b.485 (c)).*

[(a) The checking means should serve to assure the crew that a fire within the zone of coverage will produce a fire warning if all fire-responsive (detector) elements are operative. The means need not be designed to disclose whether fire detector sensor elements themselves would respond properly to a fire.[31]

[(b) The check should reveal any probable malfunction or failure in the fire-detection system, external to the detector elements, which could interfere with, or prevent, fire warning. Open and short circuits in wiring, and inoperative lights, bells, switches, or relays are examples of malfunctions which should be revealed by such a check.]

(22 F. R. 6885, Aug. 27, 1957, effective Sept. 15, 1957.)

4b.486 *Fire walls.* All engines, auxiliary power units, fuel-burning heaters, and other combustion equipment which are intended for operation in flight as well as the combustion, turbine, and tail pipe sections of turbine engines shall be isolated from the remainder of the airplane by means of fire walls, shrouds, or other equivalent means. The following shall apply:

(a) Firewalls and shrouds shall be constructed in such a manner that no hazardous quantity of air, fluids, or flame can pass from the compartment to other portions of the airplane.

(b) All openings in the fire wall or shroud shall be sealed with close-fitting fireproof grommets, bushings, or firewall fittings.

[31 This is normally a separate ground maintenance operation.]

(c) Firewalls and shrouds shall be constructed of fireproof material and shall be protected against corrosion.

4b.487 *Cowling and nacelle skin.*

(a) Cowling shall be constructed and supported so as to make it capable of resisting all vibration, inertia, and air loads to which it would be subjected in operation.

(b) Cowling shall have drainage and ventilation provisions as prescribed in section 4b.489.

(c) On airplanes equipped with a diaphragm complying with section 4b.488, the parts of the accessory section cowling which might be subjected to flame in the event of a fire in the engine power section of the nacelle shall be constructed of fireproof material and shall comply with the provisions of section 4b.486.

(d) Those portions of the cowling which would be subjected to high temperatures due to their proximity to exhaust system parts or exhaust gas impingement shall be constructed of fireproof material.

(e) The airplane shall be so designed and constructed that, in the event of fire originating in the engine power or accessory sections, the probability is extremely remote for fire to enter either through openings or by burning through external skin into any other zone of the nacelle where such fire could 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 and on turbine engines to isolate the combustion, turbine, and tail pipe sections from the compressor and the accessory sections. This diaphragm shall comply with the provisions of section 4b.486.

4b.489 *Drainage and ventilation of fire zones.*

(a) Complete drainage of all portions of designated fire zones shall be provided to minimize

the hazards resulting from failure or malfunctioning of components containing flammable fluids. The drainage provisions shall be effective under conditions expected to prevail when drainage is needed and 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.*

(a) 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.

(b) Consideration shall be given to the effect on adjacent parts of the airplane of heat within designated fire zones and within the combustion, turbine, and tail pipe sections of turbine engines.

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 sections 4b.603 through 4b.605 shall be the required basic equipment. (See sec. 4b.600.)

4b.603 *Flight and navigational instruments.* (See sec. 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 direction 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 sec. 4b.710.)

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

[(a) Carburetor air temperature indicator for each reciprocating engine.

[(b) Cylinder head temperature indicator for each air-cooled reciprocating engine.

[(c) Gas temperature indicator for each turbine engine.

[(d) Manifold pressure indicator for each reciprocating engine.

[(e) Fuel pressure indicator for each reciprocating engine to indicate the pressure under which the fuel is being supplied.

[(f) Fuel pressure warning means for each engine or a master warning means for all engines with provision for isolating the individual warning means from the master warning means.

[(g) Fuel flowmeter indicator for each turbine engine. For reciprocating engines, a fuel flowmeter or fuel mixture indicator for each engine not equipped with an automatic altitude mixture control.

[(h) Fuel quantity indicator for each fuel tank.

[(i) Augmentation liquid quantity indicator for each tank, which is appropriate to the manner in which the liquid is to be used in operations.

[(j) Oil quantity indicator for each oil tank. (See sec. 4b.613 (d).)

[(k) Oil pressure indicator for each independent pressure oil system of each engine.

[(l) Oil pressure warning means for each engine or a master warning means for all engines with provision for isolating the individual warning means from the master warning means.

[(m) Oil temperature indication for each engine.

[(n) Tachometer for each reciprocating engine.

[(o) Tachometer for each turbine engine to indicate the speed of the rotors for which limiting speeds have been established.

[(p) Fire-warning indicators. (See sec. 4b.485.)

[(q) Thrust indicator for each turbo-jet engine.

[(r) A torque indicator for each turbine-propeller engine. A device for each reciprocating 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.

[(s) Position indicating means for each propeller on a turbine engine to indicate to the flight crew when the propeller blade angle is below the flight low pitch position (see sec. 4b.613). For reciprocating engines, a means for each reversing propeller to indicate to the pilot when the propeller is in reverse pitch.

[(t) Position indicating means for each turbine engine utilizing a thrust reversing device to indicate to the flight crew when the device is in the reverse thrust position.]

4b.605 *Miscellaneous equipment.*

(a) Approved seats for all occupants (see sec. 4b.358),

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

(c) [Deleted.]

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

(e) Electrical protective devices (see sec. 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 sec. 4b.472),

(j) Approved portable fire extinguisher (see sec. 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.

(4) In determining the probable operating combinations and durations of essential loads for the partial power failure conditions prescribed in subparagraphs (2) and (3) of this paragraph, it shall be permissible to assume that the power loads are reduced in accordance with a monitoring procedure which is consistent with safety in the types of operations authorized. If a particular load is not required to maintain controlled flight it need not be considered for the two-engine-inoperative condition on airplanes with four or more engines as prescribed in subparagraph (3) of this paragraph.

4.606–1 *Safety criteria*[32] *for electric utilization systems (CAA policies which apply to sec. 4b.606 (a) and (b)).* Electric utilization systems[33] should be analyzed, inspected or tested to assure conformance to the following safety criteria.

(a) *Loss of system function.* The system should not be rendered inoperative by any probable malfunction,[34] if operation of this system is necessary to maintain controlled flight or effect a safe landing for any authorized flight operation.

(b) *Inadvertent operation of system.* The system should not be inadvertently set into operation by any probable malfunction, if such inadvertent operation can result in the inability to maintain controlled flight or effect a safe landing for any authorized flight operation.

(c) *Systems serving two or more engines.* No probable malfunction in the system should adversely affect the performance of more than one propulsion engine, consistent with the provisions of section 4b.401 (b).

(d) *System independence.* No probable malfunction in one system should render another system inoperative, if both systems are necessary in showing compliance with this part.

(e) *Misleading system indicators.* No probable malfunction in the system should result in a safe indication of an unsafe condition of flight, if such misleading information can result in the inability to maintain controlled flight or effect a safe landing for any authorized flight operation.

(f) *System overheat.* No probable malfunction in the system should result in overheat of electric equipment, such that hazardous quantities of smoke are generated within the cabin, or such that a fire hazard is created, unless adequate means are provided to detect and correct the overheat condition during flight.

(g) *Electric shock exposure.* No probable malfunction in the system should expose crew or passengers to harmful electric shock, during any normal activity on the aircraft.

(21 F. R. 2747, Apr. 28, 1956, effective May 25, 1956.)

Instruments; Installation

4b.610 *General.* The provisions of sections 4b.611 through 4b.613 shall apply to the installation of instruments.

NOTE: It may be necessary to duplicate certain instruments at two or more crew stations to meet the instrument visibility requirements prescribed in section 4b.611, or when required by the operating rules of the Civil Air Regulations for reliability or cross-check purposes in particular types of operations. In the latter case, independent operating systems would be required in accordance with the provisions of section 4b.612 (f).

4b.611 *Arrangement and visibility of instrument installations.*

(a) Flight, navigation, and powerplant instruments for use by each pilot shall be plainly visible to him from his station with the minimum practicable deviation from his normal position and line of vision when he is looking out and forward along the flight path.

[(b) Flight instruments required by section 4b.603 shall be grouped on the instrument panel

[32] When applying these criteria to particular systems, it should be clear that the degree of hazard resulting from a type of malfunction may vary considerably with the type of aircraft in which the system is installed, or with the nature of the operation in which the aircraft is utilized. Examples of systems which should be considered under certain of the above criteria are as follows: (a) Basic flight instruments, minimum navigation equipment; (b) propeller reversing system, trim-tab system, dive brake system, landing gear actuation systems; (c) fuel control valve system, propeller control system; (d) landing gear indicating system, radio navigation system, instrument landing system, gyroscopic instrument systems. Additional safety criteria are contained in sections of this part applicable to particular systems and components of the airplane.

[33] An electric utilization system is a system of electric equipment, devices and connected wiring, which utilizes electric energy to perform a specific aircraft function. The system includes all electric components beyond the nearest bus or sub-bus from which electric energy is supplied. Examples of such systems are: propeller control system, electric flight instrument system, radio navigation equipment system, fuel valve control system, flap and landing gear actuating systems.

[34] A probable malfunction is any single electrical or mechanical malfunction or failure within a utilization system which is considered probable on the basis of past service experience with similar components in aircraft applications. This definition should be extended to multiple malfunctions when: (1) The first malfunction would not be detected during normal operation of the system, including periodic checks established at intervals which are consistent with the degree of hazard involved or (2) the first malfunction would inevitably lead to other malfunctions. This definition of "probable malfunction" applies wherever this term is used in this section.

and centered as early as practicable about the vertical plane of the pilot's forward vision. The four basic instruments specified in subparagraphs (1) through (4) of this paragraph shall be located on the flight instrument panel as follows:

[(1) The top center position on the panel shall contain that instrument which, of all instruments on the panel, most effectively indicates altitude.

[(2) The position adjacent to and directly to the left of the top center position shall contain that instrument, which, of all instruments on the panel, most effectively indicates air speed.

[(3) The position adjacent to and directly to the right of the top center position shall contain that instrument which, of all instruments on the panel, most effectively indicates altitude.

[(4) The position adjacent to and directly below the top center position shall contain that instrument which, of all instruments on the panel, most effectively indicates direction of flight.]

(c) All the required powerplant instruments shall be closely grouped on the instrument panel.

(d) Identical powerplant instruments for the several engines shall be located to prevent any misleading impression as to the engines to which they relate.

(e) Powerplant instruments vital to the safe operation of the airplane shall be plainly visible to the appropriate crew members.

(f) The vibration characteristics of the instrument panel shall be such as not to impair seriously the accuracy of the instruments or to damage them.

4b.611–1 *Procedure for checking arrangement and visibility of instrument installations (CAA policies which apply to sec. 4b.611).* The arrangement and visibility of the instruments should be checked throughout the type tests in order to supply the information which is necessary to complete the pertinent portions of Form ACA 283–4b, Type Inspection Report.

(19 F. R. 4466, July 20, 1954, effective Sept. 1, 1954.)

4b.612 *Flight and navigational instruments.*

(a) ***Air-speed indicating systems.***

(1) Air-speed indicating instruments shall be of an approved type and shall be calibrated to indicate true airspeed at sea level in the standard atmosphere with a minimum practicable instrument calibration error when the corresponding pitot and static pressures are applied to the instrument.

(2) The air-speed indicating system shall be calibrated to determine the system error, i. e., the relation between IAS and CAS, in flight and during the accelerated take-off ground run. The ground run calibration shall be obtained from 0.8 of the minimum value of V_1 to the maximum value of V_2, taking into account the approved altitude and weight range for the airplane. In the ground run calibration, the flap and power settings shall correspond with the values determined in the establishment of the take-off path under the provisions of section 4b.116, assuming the critical engine to fail at the minimum approved value of V_1.

(3) The air-speed error of the installation, excluding the air-speed indicator instrument calibration error, shall not exceed 3 percent or 5 mph, whichever is the greater, throughout the speed range from V_{NO} to 1.3 V_{S_1} with flaps retracted, and from 1.3 V_{S_0} to V_{FE} with flaps in the landing position.

(4) The air-speed indicating system shall be arranged in so far as practicable to preclude malfunctioning or serious error due to the entry of moisture, dirt, or other substances.

(5) The air-speed indicating system shall be provided with a heated pitot tube or equivalent means of preventing malfunctioning due to icing.

(6) Where duplicate air-speed indicators are required, their respective pitot tubes shall be spaced apart to avoid damage to both tubes in the event of a collision with a bird.

(b) ***Static air vent and pressure altimeter systems.***

(1) All instruments provided with static air case connections shall be vented to the outside atmosphere through an appropriate piping system.

(2) The vent(s) shall be so located on the airplane that its orifices will be least affected by air flow variation, moisture, or other foreign matter.

(3) The installation shall be such that the system will be air-tight, except for the vent into the atmosphere.

(4) Pressure altimeters shall be of an approved type and shall be calibrated to indicate pressure altitude in standard atmosphere with a minimum practicable instrument calibration error when the corresponding static pressures are applied to the instrument.

(5) The design and installation of the altimeter system shall be such that the error in indicated pressure altitude at sea level in standard atmosphere, excluding instrument calibration error, does not result in a reading more than 20 feet high nor more than 50 feet low in the speed range between 1.3 V_{s_0} (flaps extended) and 1.8 V_{s_1} (flaps retracted).

(c) *Magnetic direction indicator.*

(1) The magnetic direction indicator shall be installed so that its accuracy will not be excessively affected by the airplane's vibration or magnetic fields of a permanent or transient nature.

(2) After the magnetic direction indicator has been compensated, the calibration shall be such that the deviation in level flight does not exceed $\pm 10°$ on any heading.

(3) A calibration placard shall be provided as specified in section 4b.733.

(d) *Automatic pilot system.* If an automatic pilot system is installed, it shall be of an approved type, and the following shall be applicable:

[(1) The system shall be so designed that the automatic pilot can be quickly and positively disengaged by the human pilots to prevent it from interfering with their control of the airplane.]

(2) A means shall be provided to indicate readily to the pilot the alignment of the actuating device in relation to the control system which it operates, except when automatic synchronization is provided.

[(3) The manually operated control(s) for the system's normal operation shall be readily accessible to the pilots. The quick release (emergency) controls shall be installed on both the pilots' control wheels, on the side of the wheel opposite from the throttles. Attitude controls shall operate in the same plane and sense of motion as specified for the cockpit controls in section 4b.353 (b) and Figure 4b–16. The direction of motion shall be plainly indicated on or adjacent to each control.]

(4) The automatic pilot system shall be of such design and so adjusted that, within the range of adjustment available to the human pilot, it cannot produce hazardous loads on the airplane or create hazardous deviations in the flight path under any conditions of flight appropriate to its use either during normal operation or in the event of malfunctioning, assuming that corrective action is initiated within a reasonable period of time.

[(5) When the automatic pilot integrates signals from auxiliary controls or furnishes signals for operation of other equipment, positive interlocks and sequencing of engagement shall be provided to preclude improper operation. Protection against adverse interaction of integrated components resulting from a malfunction shall be provided.]

(e) *Instruments utilizing a power supply.* Each required flight instrument utilizing a power supply shall be provided with two independent sources of power, a means of selecting either power source, and a means of indicating the adequacy of the power being supplied to the instrument. The installation and power supply system shall be such that failure of one instrument, or of the energy supply from one source, or a fault in any part of the power distribution system, will not interfere with the proper sypply of energy from the other source. (See also secs. 4b.606 (c) and 4b.623.)

(f) *Duplicate instrument systems.* If duplicate flight instruments are required by the operating parts of the Civil Air Regulations (see note under sec. 4b.610), the operating system for a duplicate instrument shall be completely independent of the operating system for the duplicated instrument. Additional instruments shall not be connected to the first pilot system. If additional instruments are connected to the other system, provision shall be made to disconnect or isolate in flight such additional instruments.

4b.612–1 *Airspeed indicating system calibration (CAA policies which apply to sec. 4b.612 (a)).*

(a) Unless a calibrated referenced airspeed system is provided, the airplane's system should be calibrated throughout as wide a range as necessary to cover the intended flight tests. The tests in (c) are for the purpose of showing compliance with section 4b.612(a) and not in-

tended to cover the speed range of the flight tests. If an alternate airspeed indicating system is provided, it should also be calibrated.

(1) The tests should be conducted in stabilized flight at airspeeds throughout the speed range for the airplane configurations to be tested. The airplane's airspeed indicator should be calibrated against a reference airspeed system or against a groundspeed course.

(2) A reference airspeed system should consist of either of the following:

(i) An airspeed impact pressure and static pressure measurement device or devices that are free from error due to airplane angular changes relative to the direction of the free stream or due to slipstream variation resulting from changes in airplane configuration or power. In addition the device or devices should have a known calibration error when located in the free stream, or

(ii) Any other acceptable airspeed calibration method, for example, the altimeter method of airspeed calibration. However, when using the altimeter method care should be exercised to measure the airplane's altitude accurately—especially at speeds below 125 m. p. h.

(3) When establishing the airplane's true airspeed by means of the groundspeed course, flight between the two reference points should be made at constant airspeed in two successive runs in opposite directions to eliminate the effect of wind. The runs should be made only in stable wind. The time to make the runs should be obtained by means of some calibrated device. The speed runs should not be made nearer the ground surface than a wing span's length.

(4) If an alternate system is provided it may be calibrated against either the reference system or the airplane's system.

(b) *Configuration.* Airspeed calibration tests should be conducted in the configurations that follow:

Weight—between maximum takeoff and maximum landing.
C. G. position—optional.
Wing flaps and landing gear retracted.
Wing flaps in landing position and landing gear extended.
Engine—optional power.
Mixture setting—optional.
Cowl flaps—optional.

(c) *Test procedure and required data.* Any one or any desired combination of the procedures in (1) through (3) of this paragraph may be used for calibrating the airspeed instrument. The airspeed should be measured or determined simultaneously from the airplane's and the reference system during stabilized runs for at least five speeds spaced throughout the speed range, the lowest not to exceed 1.3 V_{s_1}. The highest speed should not exceed V_{NO}, placard speed, or speed in level flight using maximum continuous power, whichever is lower. The speed spread between the test speeds should be limited to 10 m. p. h. from 1.3 V_{s_1} to 1.6 V_{s_1} or placard speed, and 30 m. p. h. from 1.6 V_{s_1} to V_{NO}.

(1) *Speed course.* The airspeed and altitude should be stabilized before entering the speed course. Constant airspeed should be maintained during each run. The runs should be made in both directions for each speed over the speed course. The following data should be recorded:

Time of day at beginning of run.
Time to make run.
Pressure altitude.
Ambient air temperature.
Airspeed at several intervals during run.
Wing flap position.
Landing gear position.
Course distance.

(2) *Reference airspeed system.* Stabilized runs at the test speeds listed in (c) should be made. The airspeed from the airplane's airspeed system and the reference airspeed system should be read simultaneously. The following data should be recorded:

Time of day.
Airplane's indicated airspeed.
Reference indicated airspeed.
Pressure altitude.
Ambient air temperature.
Wing flap position.
Landing gear position.

(3) *Other acceptable airspeed calibration methods.* Stabilized flight runs at the test speeds should be made and the necessary data recorded to establish the airplane's airspeed

system error and the configuration of the airplane.

(19 F. R. 4466, July 20, 1954, effective Sept. 1, 1954, amended. 20 F. R. 2280, Apr. 8, 1955, effective Apr. 30, 1955, further amended 20 F. R. Sept. 10, 1955, effective Sept. 30, 1956.)

4b.612–2 *Static air vent system (CAA policies which apply to sec. 4b.612 (b)).*

(a) If the altimeter installation is of the pressure type its operation will be affected by any error that exists in the static air pressure. Since the accuracy of the altimeter is of utmost importance the static air vent system should be calibrated. If separate or alternate vent systems are employed for the altimeter and airspeed indicator, separate calibrations are required. Where the altimeter, rate of climb indicator, and airspeed indicators are vented to the same static systems, the altimeter calibration may be made in conjunction with the airspeed calibrations.

(b) The theoretical relationship between airspeed error and altimeter error is given in Figure 4 so that an altimeter calibration may be derived from the airspeed calibration if both use the same static vent provided that the total head installation is such as to provide true readings over the range of angles involved.

(19 F. R. 4466, July 20, 1954, effective Sept. 1, 1954.)

4b.612–3 *Calibration of magnetic direction indicator (CAA policies which apply to sec. 4b.612 (c)).* It is recommended that the magnetic direction indicator be calibrated while the airplane is on the ground with its engine and electrical equipment operating. The calibration data should be included in Form ACA 283–4b.

(19 F. R. 4466, July 20, 1954, effective Sept. 1, 1954.)

4b.612–4 *Automatic pilot systems (CAA policies which apply to sec. 4b.612 (d)).* To preclude hazardous conditions which may result from any failure or malfunctioning of the automatic pilot system, or its inadvertent use by the human pilot, the conditions of paragraphs (a) through (e) and paragraph (h) of this section should be investigated by flight test.

(a) A signal about any axis equivalent to the cumulative effect of any single failure (or if multiple axis failures can result from the malfunction of any single component, combined signals about all affected axes) should be induced into the automatic pilot system during normal climb,[35] cruise, and descent regimes. When corrective action is taken 3 seconds after the airplane response [36] to the malfunction neither the simulated failure nor the subsequent corrective action should create loads beyond an envelope of 0 to 2 g, or speeds beyond V_{NE} (or M_{NE} where appropriate), or dangerous deviations from the flight path, except that the positive g limitation may be increased up to the positive design maneuvering load factor if it has previously been determined analytically that neither the simulated failure nor subsequent corrective action would result in loads beyond the design limit loads of the airplane.

(1) Recovery should be demonstrated either by overpowering or by manual use of an emergency quick disconnect device after the 3-second delay. The pilot should be able to return the airplane to its normal flight attitude under full manual control without exceeding the loads or speed limits defined in this paragraph and without engaging in any dangerous maneuvers during recovery. If an emergency quick disconnect button is not installed on the control wheel it should be possible to overpower servo forces plus resultant airloads in all configurations and attitudes of flight demonstrated, including maximum speed for which approval is sought, without exceeding the following control forces measured at the pilot's controls: pitch 50 pounds; roll 30 pounds (force applied at rim); yaw 150 pounds. The maximum altitude loss experienced during these tests should be entered in the Airplane Flight Manual under "Emergency Operating Procedures."

(b) The automatic pilot system should be able to perform its intended function throughout all appropriate maneuvers. All such maneuvers should be accomplished smoothly and without subjecting the airplane to loads greater than those described in paragraph (a) of this section.

(c) If the automatic pilot system includes an approach coupler it should be able to per-

[35] The configuration for normal climb will be that for operational all-engine climb with 75 percent maximum continuous power and flaps retracted.

[36] Adequate instrumentation should be installed to register response of the airplane to the induced malfunction. One acceptable method would be by measurement of airplane acceleration.

form its intended function, and the following should apply:

(1) Throughout an approach no signal or combination of signals simulating the cumulative effect of any single failure or malfunction in the automatic pilot system should produce hazardous deviations in the flight path or any degree of loss of control if corrective action is initiated one second after the airplane responds to the malfunction.

(i) The airplane should be flown down the ILS (or along a flight path simulating the ILS) in the approach configuration. At a predetermined point a failure should be induced in the automatic pilot system. One second after the airplane responds to the malfunction, the pilot should take corrective action by either overpowering or manually disconnecting the automatic pilot (utilizing the emergency quick disconnect button on the control wheel). The vertical distance below the glide path, measured from the point at which level flight is regained, should be entered in the Airplane Flight Manual under "Emergency Operating Procedures."

(2) An engine failure during a normal ILS approach should not cause a lateral deviation of the airplane from the flight path at a rate greater than three degrees per second.

(3) If approval is sought for ILS approaches initiated with one engine inoperative, the automatic pilot should be capable of conducting the approach, and the provisions of subparagraph (1) of this paragraph should be complied with.

(4) A visual means should be provided between the automatic pilot and the flight path coupler to indicate to the pilot when the automatic pilot is uncoupled from the airborne navigational reference.

(d) For an automatic pilot without an approach coupler, where the applicant desires approval for low approaches, the conditions outlined in paragraphs (c) (1), (2), and (3) should apply.

(e) If an automatic trim system is incorporated into the automatic pilot, it should be so designed and installed that any failure will not create a hazardous condition to either automatic or manual flight.

(f) When an emergency quick disconnect device is installed on the automatic pilot, the release buttons should be located on both the pilot's and copilot's control wheels, on the side of the wheel opposite from the throttles.

(g) The automatic pilot system should be so installed that its operation will not be adversely affected by spurious signals from other sources, or as a result of normal variations in the automatic pilot system power source, or feedback by other equipment operating from the same power source (see secs. 4b.625 (b) and 4b.650 (c)).

(h) The automatic pilot system should be so installed and adjusted that the servo stall forces established during certification tests can be maintained in normal operation. This may be assured by conducting flight tests throughout the envelope of servo stall forces. Those tests conducted to determine that the automatic pilot system will adequately control the aircraft should establish the lower stall force limit; and those tests to determine that the automatic pilot will not impose dangerous loads or deviations from the flight path should be conducted at the upper stall force limit.

(i) A positive means should be provided to indicate to the pilot when the automatic pilot is ready for operation or when the gyroscopic components are uncaged, unless it is impossible (as a result of design features) to engage the automatic pilot before it is ready for operation.

(j) The following information should be placed on the Aircraft Specification:

(1) Servo motor and gear train model numbers

(2) Servo unit pulley sizes

(3) Upper and lower limiting stall forces measured at the servo motors

(k) The following information should be placed in the Airplane Flight Manual:

(1) Under the operating limitations section, airspeed limitations and other applicable operating limitations.

(2) Under the operating procedures section, normal operation information.

(3) Under the emergency operating procedures section, a statement of altitude lost in the cruising configuration (see subparagraph(a) (1) of this section); a statement of altitude lost on ILS approaches (see paragraph (c) (1) (i) of

this section); and any other applicable emergency procedure information.

(21 F. R. 2124, Apr. 3, 1956, effective Apr. 14, 1956.)

4b.613 *Powerplant instruments.*

(a) *Instrument lines.*

(1) Powerplant instrument lines carrying flammable fluids or gases under pressure shall be provided with restricted orifices or equivalent safety devices at the source of the pressure to prevent the escape of excessive fluid or gas in case of line failure.

(2) The provisions of sections 4b.432 and 4b.433 shall be made applicable to powerplant instrument lines.

(b) *Fuel quantity indicator.* Means shall be provided to indicate to the flight crew the quantity in gallons or equivalent units of usable fuel in each tank during flight. The following shall apply:

(1) Tanks, the outlets and air spaces of which are interconnected, shall be considered as one tank for the purpose of providing separate indicators.

(2) Exposed sight gauges shall be protected against damage.

(3) Fuel quantity indicators shall be calibrated to read zero during level flight when the quantity of fuel remaining in the tank is equal to the unusable fuel supply as defined by section 4b.416 (see sec. 4b.736).

(c) *Fuel flowmeter system.* When a flowmeter system is installed, the metering component shall include a means for bypassing the fuel supply in the event that malfunctioning of the metering component results in a severe restriction to fuel flow.

(d) *Oil quantity indicator.*

(1) A stick gauge or other equivalent means shall be provided to indicate the quantity of oil in each tank. (See sec. 4b.735.)

(2) If an oil transfer system or a reserve oil supply system is installed, means shall be provided to indicate to the crew during flight the quantity of oil in each tank.

[(e) *Turbine-propeller blade position indicating means.* The indicating means required for turbine propellers by section 4b.604 (s) shall initiate indication before the propeller blade has moved more than eight degrees below the flight low pitch stop. The source of the indication shall sense blade position directly.]

Electrical Systems and Equipment

4b.620 *General.* The provisions of sections 4b.621 through 4b.627 shall apply to all electrical systems and equipment. (See also sec. 4b.606.)

4b.621 *Electrical system capacity.* The required generating capacity and the number and type of power sources shall be determined by an electrical load analysis and shall comply with section 4b.606 (c).

4b.622 *Generating system.*

(a) The generating system shall be considered to include electrical power sources, main power busses, transmission cables, and associated control, regulation, and protective devices.

(b) The generating system shall be so designed that the power sources function properly both when connected in combination and independently, and the failure or malfunctioning of any power source cannot create a hazard or impair the ability of the remaining sources to supply essential loads.

[(c) Means accessible in flight to appropriate crew members shall be provided for the independent disconnection of each electrical power source from the system. Controls for this purpose shall be grouped to permit expeditious disconnection of electrical power sources.]

(d) Means shall be provided to indicate to appropriate crew members those generating system quantities which are essential for the safe operation of the system.

NOTE: The voltage and current supplied by each generator are quantities considered essential.

[4b.622–1 *Generating system reliability (CAA policies which apply to sec. 4b.622 (b)).* Generating systems should be analyzed, inspected or tested to assure conformance to the following reliability criteria:

[(a) *Failure of propulsion engines or other prime movers.* The generating system performance (after failure of one or more propulsion engines or other prime movers) should be that specified in section 4b.606 (c).

[(b) *Generating system malfunctions.* No probable malfunction [37] in the generating sys-

[37] A probable malfunction is any single electrical or mechanical malfunction or failure which is considered probable on the basis of past service experience with similar components in aircraft applications. This definition should be extended to multiple malfunctions when: (1) the

tem, or in the generator drive system,[38] should result in the permanent loss of service to electric utilization systems [39] which are necessary to maintain controlled flight and to effect a safe landing,[40] unless the aircraft is equipped with an independent source of electric power capable of supplying continuous emergency service to these utilization systems.

[(c) *Corrective action.* Where corrective action is necessary to comply with (a) and (b) above,

[(1) Adequate warning should be provided for any malfunction or failure requiring such corrective action.

[(2) Controls should be so located as to permit such corrective action during any probable flight situation.

[(3) If corrective action must be taken within a specified time interval for continued safe operation of the generating system, it should be demonstrated that such corrective action can be accomplished within the specified time interval during any probable flight situation.

[(4) The procedure to be followed by the crew should be detailed in the Operating Procedures Section of the Airplane Flight Manual (see sec. 4b.740).

[(d) *Electric system smoke and fire procedures (see sec. 4b.371 (c)).* To cope with electrical smoke or fire of undetermined origin, generating system controls should be designed to permit electrical disconnection of overheated equipment in flight without hazardous interruption of service to electric utilization systems. Procedures for this purpose should be contained in the Operating Procedures Section of the Airplane Flight Manual (see sec. 4b.740).]

(22 F. R. 6885, Aug. 27, 1957, effective Sept. 15, 1957.)

4b.623 *Distribution system.*

(a) The distribution system shall be considered to include all distribution busses, their associated feeders, and control and protective devices.

(b) Individual distribution systems shall be designed to insure that essential load circuits can be supplied in the event of reasonably probable faults or open circuits.

(c) Where two independent sources of electrical power for particular equipment or systems are required by the Civil Air Regulations, their electrical energy supply shall be assured.

NOTE: Various means may be used to assure a supply, such as duplicate electrical equipment, throw-over switching, and multi-channel or loop circuits separately routed.

4b.624 *Electrical protection.*

(a) Automatic protective devices shall be provided to minimize distress to the electrical system and hazard to the airplane in the event of wiring faults or serious malfunctioning of the system or connected equipment.

(b) In the generating system the protective and control devices shall be such as to de-energize and disconnect faulty power sources and power transmission equipment from their associated busses with sufficient rapidity to provide protection against hazardous overvoltage and other malfunctioning.

(c) All resettable type circuit protective devices shall be so designed that when an overload or circuit fault exists, they will open the circuit irrespective of the position of the operating control.

(d) Protective devices or their controls used in essential load circuits shall be accessible for resetting in flight.

(e) Circuits for essential loads shall have individual circuit protection.

NOTE: This provision does not necessarily require individual protection for each circuit in an essential load system (e. g., each position light in the system).

(f) If fuses are used, there shall be provided spare fuses for use in flight equal to at least 50 percent of the number of fuses of each rating required for complete circuit protection.

4b.624–1 *Automatic reset circuit breaker (CAA policies which apply to sec. 4b.624).* Automatic reset circuit breakers (which automatically reset themselves periodically) should

first malfunction would not be detected during normal operation of the system, including periodic checks established at intervals which are consistent with the degree of hazzard involved, or (2) the first malfunction would inevitably lead to other malfunctions.

[38] The generator drive system includes the prime movers (propulsion engines or other) and coupling devices such as gear-boxes or constant-speed drives.

[39] An electric utilization system is a system of electric equipment, devices and connected wiring which utilizes electric energy to perform a specific aircraft function.

[40] The specific electric utilization systems which are necessary to maintain controlled flight and effect a safe landing will vary with the type of aircraft and with the nature of the operation in which the aircraft is utilized. Examples of systems which may be in this category are as follows: basic flight instruments, minimum navigation equipment, minimum two-way radio communications, control system boost.]

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not be applied as circuit protective devices.[41] They may be used as integral protectors for electrical equipment (e. g., thermal cut-outs) provided that circuit protection is also installed to protect the cable to the equipment.

(20 F. R. 2280, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.625 *Electrical equipment and installations.*

(a) In showing compliance with section 4b.606 (a) and (b) with respect to the electrical system, equipment, and installation, consideration shall be given to critical environmental conditions.

NOTE: Critical environmental conditions may include temperature, pressure, humidity, ventilation, position, acceleration, vibration, and presence of detrimental substances.

(b) All electrical equipment, controls, and wiring shall be so installed that operation of any one unit or system of units will not affect adversely the simultaneous operation of any other electrical unit or system of units essential to the safe operation of the airplane.

(c) Cables shall be grouped, routed, and spaced so that damage to essential circuits will be minimized in the event of faults in heavy current-carrying cables.

(d) Batteries and their installations shall provide for ventilation, drainage of fluids, venting of gases, and protection of other parts of the airplane from corrosive battery fluids.

4b.626 *Electrical system fire and smoke protection.* The design and installation of all components of the electrical system shall be in compliance with pertinent fire and smoke protection provisions of sections 4b.371 (c), 4b.385, and 4b.490. In addition, all electrical cables, terminals, and equipment which are necessary in emergency procedures and which are located in designated fire zones shall be fire-resistant.

[4b.626–1 *Fire-resistant electrical equipment*[42] *(CAA policies which apply to sec. 4b.626).* When applied to the electrical equipment and components defined in the last sentence of section 4b.626, an accepted criterion for "fire-resistant" is that such equipment and components, as installed in the aircraft, should withstand a surface temperature of 2000° F. for at least 5 minutes without adverse effect on their circuit function.[43] The 2000° F. surface temperature should be achieved by enveloping the equipment in an oxidizing flame, using a test setup simulating the actual aircraft installation.[44]]

(22 F. R. 6885, Aug. 27, 1957, effective Sept. 15, 1957.)

4b.627 *Electrical system tests and analyses.* It shall be demonstrated by tests and analyses that the electrical system functions properly and without electrical or thermal distress.

Lights

4b.630 *Instrument lights.*

(a) Instrument lights shall provide sufficient illumination to make all instruments, switches, etc., easily readable.

(b) Instrument lights shall be so installed that their direct rays are shielded from the pilot's eyes and so that no objectionable reflections are visible to him.

(c) A means of controlling the intensity of illumination shall be provided, unless it if shown that non-dimmed instrument lights are satisfactory under all expected conditions os flight.

4b.631 *Landing lights.*

(a) Landing lights shall be of an approved type.

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[41] Circuit protective devices are normally installed to limit the hazardous consequences of overloaded or faulted circuits. These devices are resettable (circuit breakers) or replaceable (fuses) to permit the crew to restore service when nuisance trips occur or when the abnormal circuit condition can be corrected in flight. If the abnormal circuit condition can *not* be corrected in flight, the decision to restore power to the circuit involves a careful analysis of the flight situation. It is necessary to weigh the essentiality of the circuit for continued safe flight against the hazards of resetting on a possibly faulted circuit. Such evaluation is properly an aircraft crew function which can not be performed by automatic reset circuit breakers. To assure crew supervision over the resct operation, circuit protective devices should be of such design that a manual operation is required to restore service after tripping.

[42] This policy establishes a basic test standard for fire-resistant electrical equipment. However, installation approval may be granted for equipment which does not conform to this standard, if it can be shown that such equipment would provide equivalent safety when exposed to the probable fire conditions at its particular location.

[43] Excessive temperature may affect electrical equipment and components by causing such malfunctions as short circuit, open circuit, and changes in circuit parameters (for example, reduced insulation resistance and dielectric strength).

[44] In the case of electric cable, only a representative length, not less than 12 inches, need be enveloped in the flame.]

(b) Landing lights shall be installed so that there is no objectionable glare visible to the pilot and so that the pilot is not adversely affected by halation.

(c) Landing lights shall be installed in a location where they provide the necessary illumination for night landing.

(d) A switch for each light shall be provided, except that where multiple lights are installed at one location a single switch for the multiple lights shall be acceptable.

[(e) A means shall be provided to indicate to the pilots when the landing lights are extended.]

4b.632 *Position light system installation.*

(a) *General.* The provisions of sections 4b.632 through 4b.635 shall be applicable to the position light system as a whole. The position light system shall include the items specified in paragraphs (b) through (d) of this section.

(b) *Forward position lights.* Forward position lights shall consist of a red and a green light spaced laterally as far apart as practicable and installed forward on an airplane in such a location that, with the airplane in normal flying position, the red light is displayed on the left side and the green light is displayed on the right side. The individual lights shall be of an approved type.

(c) *Rear position light.* The rear position light shall consist of a white light mounted on the airplane as far aft as practicable. The light shall be of an approved type.

(d) *Light covers and color filters.* Light covers or color filters used shall be of noncombustible material and shall be constructed so that they will not change color or shape or suffer any appreciable loss of light transmission during normal use.

4b.632–1 *Red passing lights (CAA policies which apply to sec. 4b.632 (a)).* When it is desired to improve the conspicuity of the aircraft a steady red light, commonly known as a passing light, may be installed. This light is not considered to be a position light and therefore need not be type certificated. When installed, its location should be one of the following:

(a) Within the left landing light unit.

(b) On the centerline of the aircraft nose.

(c) In the leading edge of the left wing, outboard of the propeller disc.

(16 F. R. 3212, Apr. 12, 1951, effective Apr. 15, 1951.)

4b.633 *Position light system dihedral angles.* The forward and rear position lights as installed on the airplane shall show unbroken light within dihedral angles specified in paragraphs (a) through (c) of this section.

(a) Dihedral angle L (left) shall be considered formed by two intersecting vertical planes, one parallel to the longitudinal axis of the airplane and the other at 110° to the left of the first, when looking forward along the longitudinal axis.

(b) Dihedral angle R (right) shall be considered formed by two intersecting vertical planes, one parallel to the longitudinal axis of the airplane and the other at 110° to the right of the first, when looking forward along the longitudinal axis.

(c) Dihedral angle A (aft) shall be considered formed by two intersecting vertical planes making angles of 70° to the right and 70° to the left, respectively, looking aft along the longitudinal axis, to a vertical plane passing through the longitudinal axis.

4b.634 *Position light distribution and intensities.*

(a) *General.* The intensities prescribed in this section are those to be provided by new equipment with all light covers and color filters in place. Intensities shall be determined with the light source operating at a steady value equal to the average luminous output of the light source at the normal operating voltage of the airplane. The light distribution and intensities of position lights shall comply with the provisions of paragraphs (b) and (c) of this section.

(b) *Forward and rear position lights.* The light distribution and intensities of forward and rear position lights shall be expressed in terms of minimum intensities in the horizontal plane, minimum intensities in any vertical plane, and maximum intensities in overlapping beams, within dihedral angles L, R, and A, and shall comply with the provisions of subparagraphs (1) through (3) of this paragraph.

(1) ***Intensities in horizontal plane.*** The intensities in the horizontal plane shall not be less than the values given in figure 4b–18. (The horizontal plane is the plane containing the longitudinal axis of the airplane and is perpendicular to the plane of symmetry of the airplane).

(2) ***Intensities above and below horizontal.*** The intensities in any vertical plane shall not be less than the appropriate value given in figure 4b–19, where I is the minimum intensity prescribed in figure 4b–18 for the corresponding angles in the horizontal plane. (Vertical planes are planes perpendicular to the horizontal plane.)

(3) ***Overlaps between adjacent signals.*** The intensities in overlaps between adjacent signals shall not exceed the values given in figure 4b–20, except that higher intensities in the overlaps shall be acceptable with the use of main beam intensities substantially greater than the minima specified in figures 4b–18 and 4b–19 if the overlap intensities in relation to the main beam intensities are such as not to affect adversely signal clarity.

Dihedral angle (light involved)	Angle from right or left of longitudinal axis, measured from dead ahead	Intensity (candles)
L and *R* (forward red and green)	0° to 10°	40
	10° to 20°	30
	20° to 110°	5
A (Rear white)	110° to 180°	20

Figure 4b–18.—Minimum intensities in the horizontal plane of forward and rear position lights.

Angle above or below horizontal	Intensity
0°	1.00 I.
0° to 5°	.90 I.
5° to 10°	.80 I.
10° to 15°	.70 I.
15° to 20°	.50 I.
20° to 30°	.30 I.
30° to 40°	.10 I.
40° to 90°	At least 2 candles.

Figure 4b–19.—Minimum intensities in any vertical plane of forward and rear position lights.

Overlaps	Maximum intensity	
	Area A (candles)	Area B (candles)
Green in dihedral angle *L*	10	1
Red in dihedral angle *R*	10	1
Green in dihedral angle *A*	5	1
Red in dihedral angle *A*	5	1
Rear white in dihedral angle *L*	5	1
Rear white in dihedral angle *R*	5	1

NOTE: Area A includes all directions in the adjacent dihedral angle which pass through the light source and which intersect the common boundary plane at more than 10 degrees but less than 20 degrees. Area B includes all directions in the adjacent dihedral angle which pass through the light source and which intersect the common boundary plane at more than 20 degrees.

Figure 4b–20.—Maximum intensities in overlapping beams of forward and rear position lights.

4b.635 ***Position light color specifications.*** The colors of the position lights shall have the International Commission on Illumination chromaticity coordinates as set forth in paragraphs (a) through (c) of this section.

(a) ***Aviation red.***

y is not greater than 0.335,

z is not greater than 0.002;

(b) ***Aviation green.***

x is not greater than $0.440-0.320y$,

x is not greater than $y-0.170$,

y is not less than $0.390-0.170x$;

(c) ***Aviation white.***

x is not less than 0.350,

x is not greater than 0.540,

$y-y_0$ is not numerically greater than 0.01, y_0 being the y coordinate of the Planckian radiator for which $x_0=x$.

CROSS REFERENCE: For Special Civil Air Regulation SR–390, modifying regulations with respect to the position light system, see Note 2 to this part, *supra*.

4b.636 ***Riding light.***

(a) When a riding (anchor) light is required for a seaplane, flying boat, or amphibian, it shall be capable of showing a white light for at least two miles at night under clear atmospheric conditions.

(b) The riding light shall be installed to show the maximum unbroken light practicable when the airplane is moored or drifting on the

water. Externally hung lights shall be acceptable.

4b.637 *Anti-collision light system.* An anti-collision light system shall be installed which shall consist of one or more approved anti-collision lights so located that the emitted light will not be detrimental to the crew's vision and will not detract from the conspicuity of the position lights. The system shall comply with the provisions of paragraphs (a) through (d) of this section.

(a) *Field of coverage.* The system shall consist of such lights as will afford coverage of all vital areas around the airplane with due consideration to the physical configuration and the flight characteristics of the airplane. In any case, the field of coverage shall extend in all directions within 30° above and 30° below the horizontal plane of the airplane, except that a solid angle or angles of obstructed visibility totaling not more than .03 steradians shall be permissible within a solid angle equal to .15 steradians centered about the longitudinal axis in the rearward direction.

(b) *Flashing characteristics.* The arrangement of the system, i. e., number of light sources, beam width, speed of rotation, etc., shall be such as to give an effective flash frequency of not less than 40 and not more than 100 cycles per minute. The effective flash frequency shall be the frequency at which the airplane's complete anti-collision light system is observed from a distance, and shall apply to all sectors of light including the overlaps which might exist when the system consists of more than one light source. In overlaps, flash frequencies higher than 100 cycles per minute shall be permissible, except that they shall not be higher than 180 cycles per minute.

(c) *Color.* The color of the anti-collision lights shall be aviation red in accordance with the specifications of section 4b.635 (a).

(d) *Light intensity.* The minimum light intensities in all vertical planes, measured with the red filter and expressed in terms of "effective" intensities, shall be in accordance with Figure 4b–27. The following relation shall be assumed:

$$I_e = \frac{\int_{t_1}^{t_2} I(t)\,dt}{0.2 + (t_2 - t_1)};$$

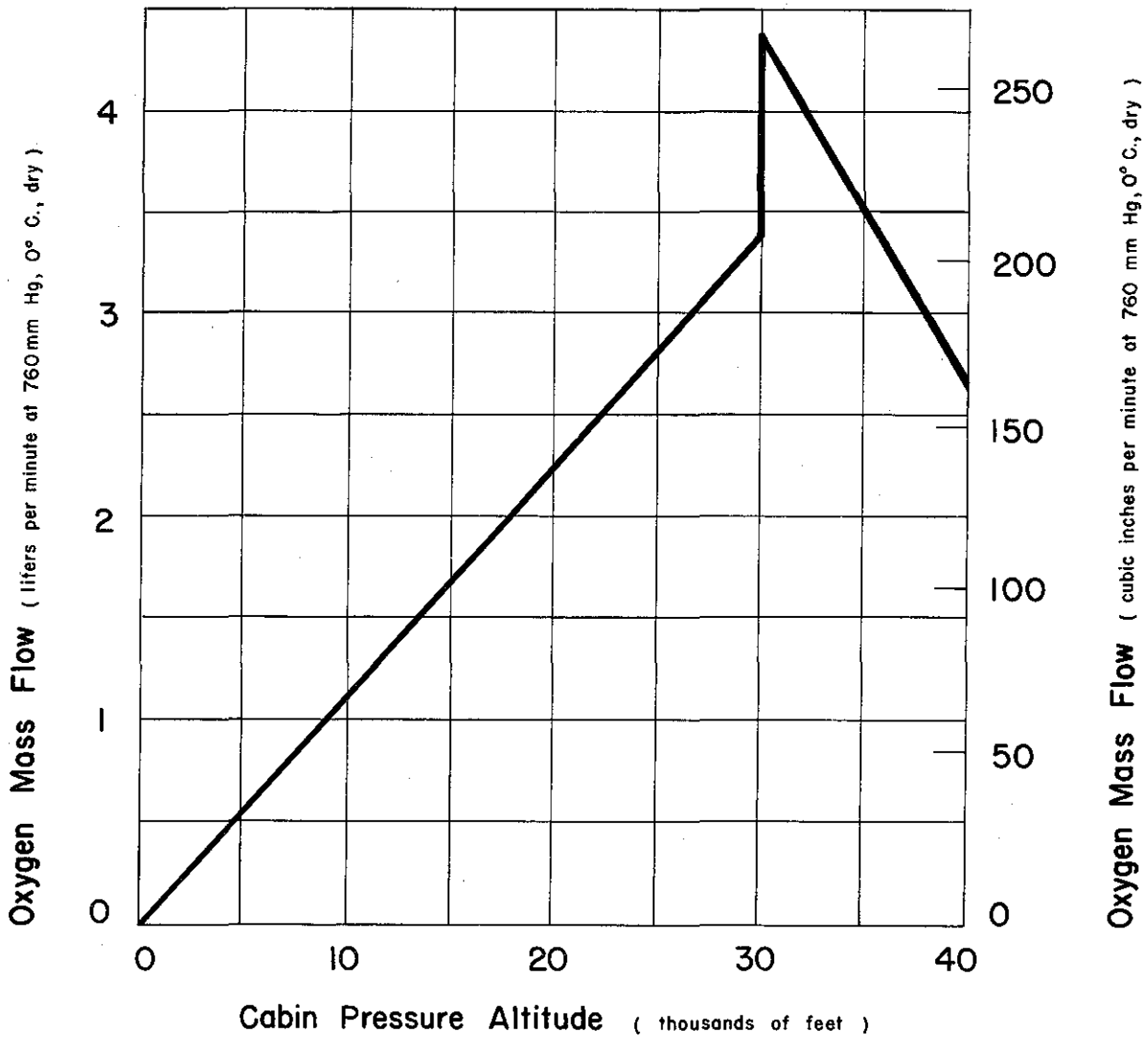
where:

I_e = effective intensity (candles),

$I(t)$ = instantaneous intensity as a function of time,

$t_2 - t_1$ = flash time interval (seconds).

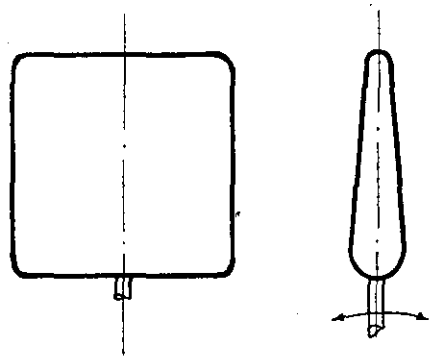
NOTE: Normally, the maximum value of effective intensity is obtained when t_2 and t_1 are so chosen that the effective intensity is equal to the instantaneous intensity at t_2 and t_1.



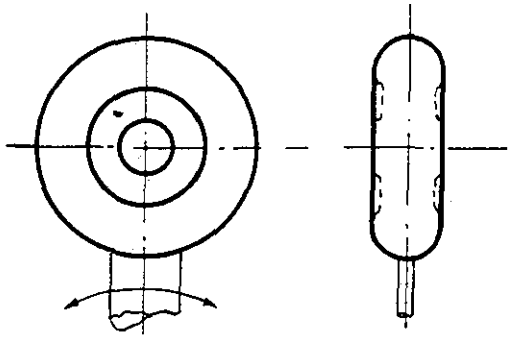
NOTE: 1. Data based on:
a. System 100% efficient.
b. Respiratory minute volume equals 15 liters (915 cubic inches) per minute.
c. 100% oxygen above 30,000 feet.

2. For dilutor–demand regulators use flow characteristics supplied by manufacturer to calculate required supply. Such flows must not be less than those indicated on this graph at delivery rate of 15 liters per minute.

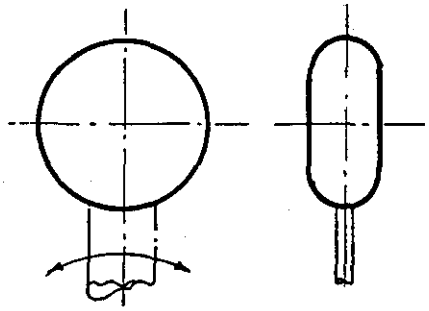
Figure 4b–21.—Minimum flow of oxygen for operation at various altitudes.



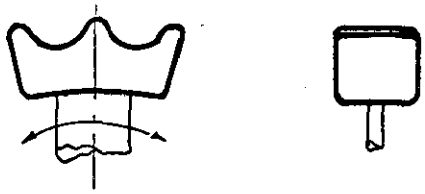
FLAP CONTROL KNOB



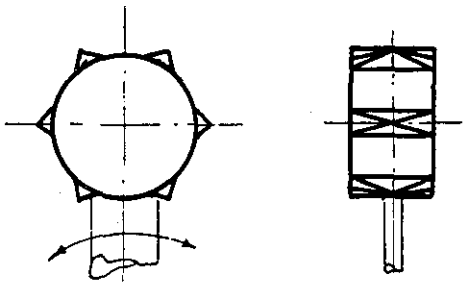
LANDING GEAR CONTROL KNOB



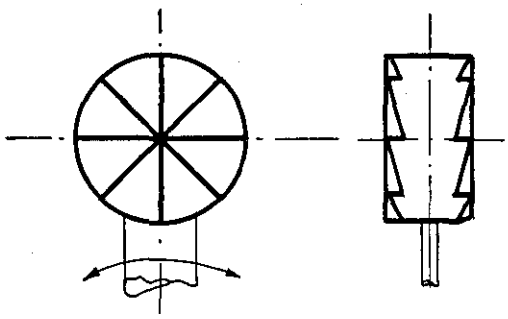
THROTTLE CONTROL KNOB



RPM CONTROL KNOB



MIXTURE CONTROL KNOB



SUPERCHARGER CONTROL KNOB

Figure 4b–22.—Control knob shapes.

The next figure is Figure 4b–24a. (Figure 4b–23 was deleted by Amendment 4b–7.)

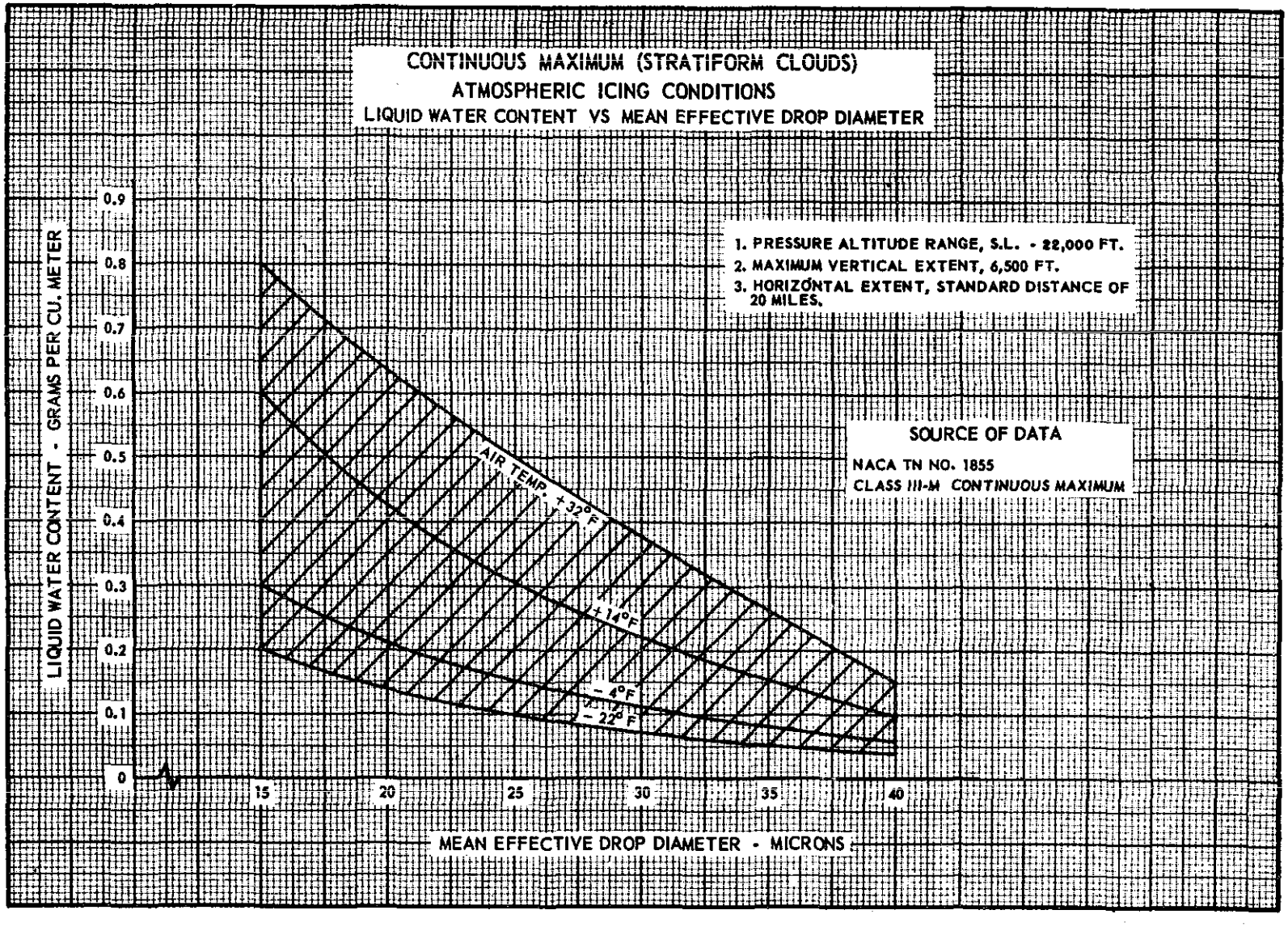


Figure 4b–24a.

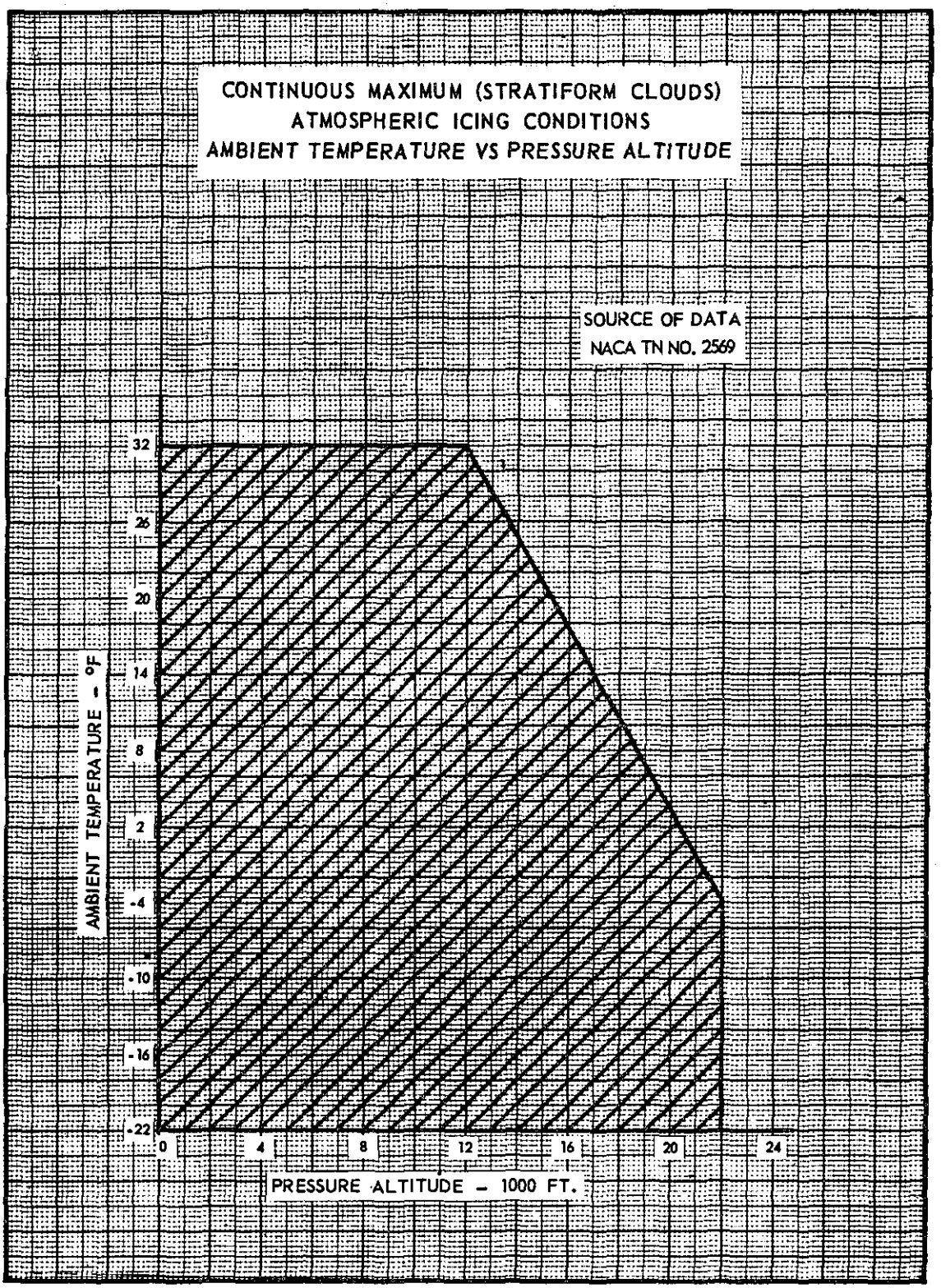


Figure 4b–24b.

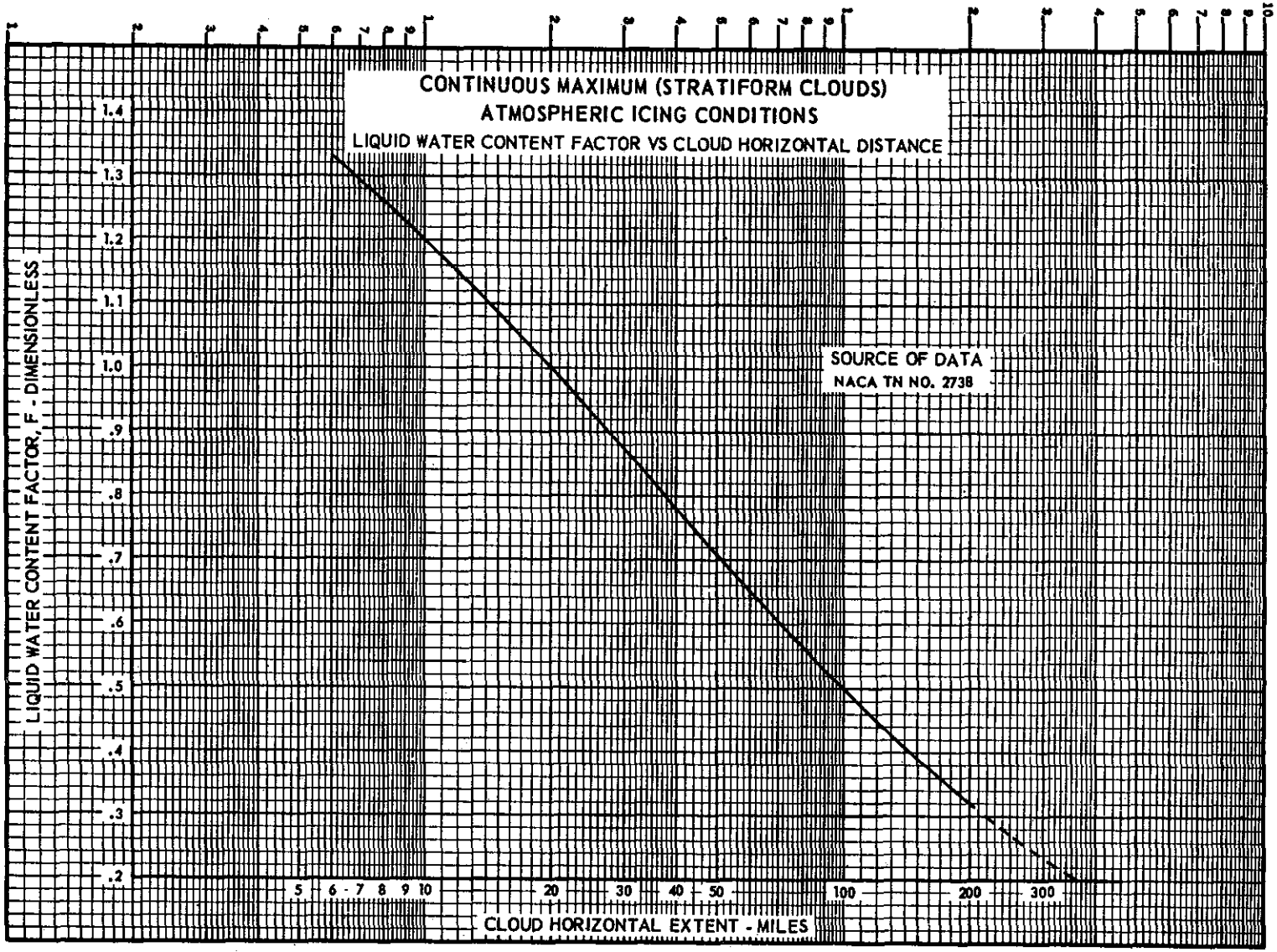
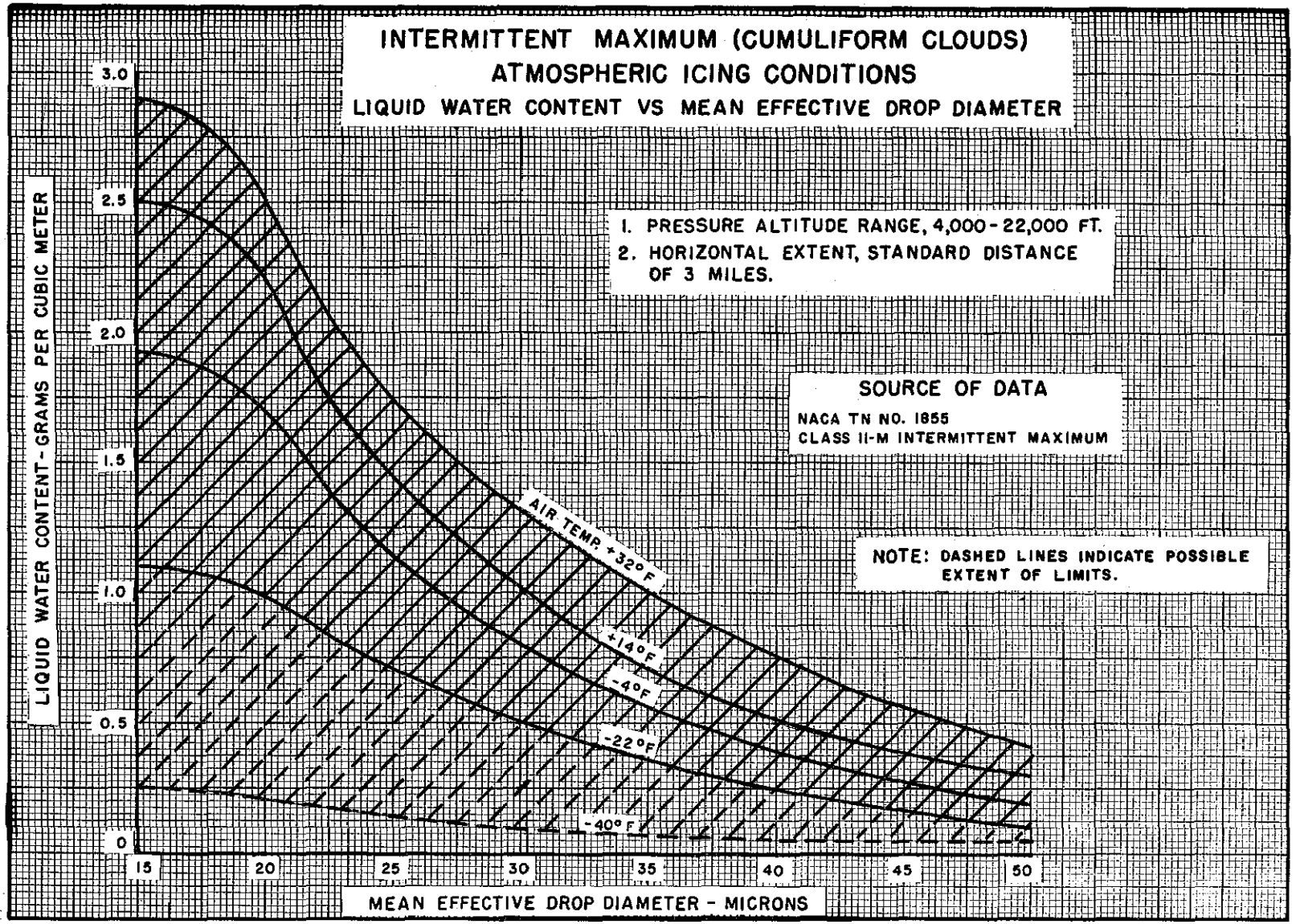


Figure 4b–24c.



[Figure 4b–25a.]

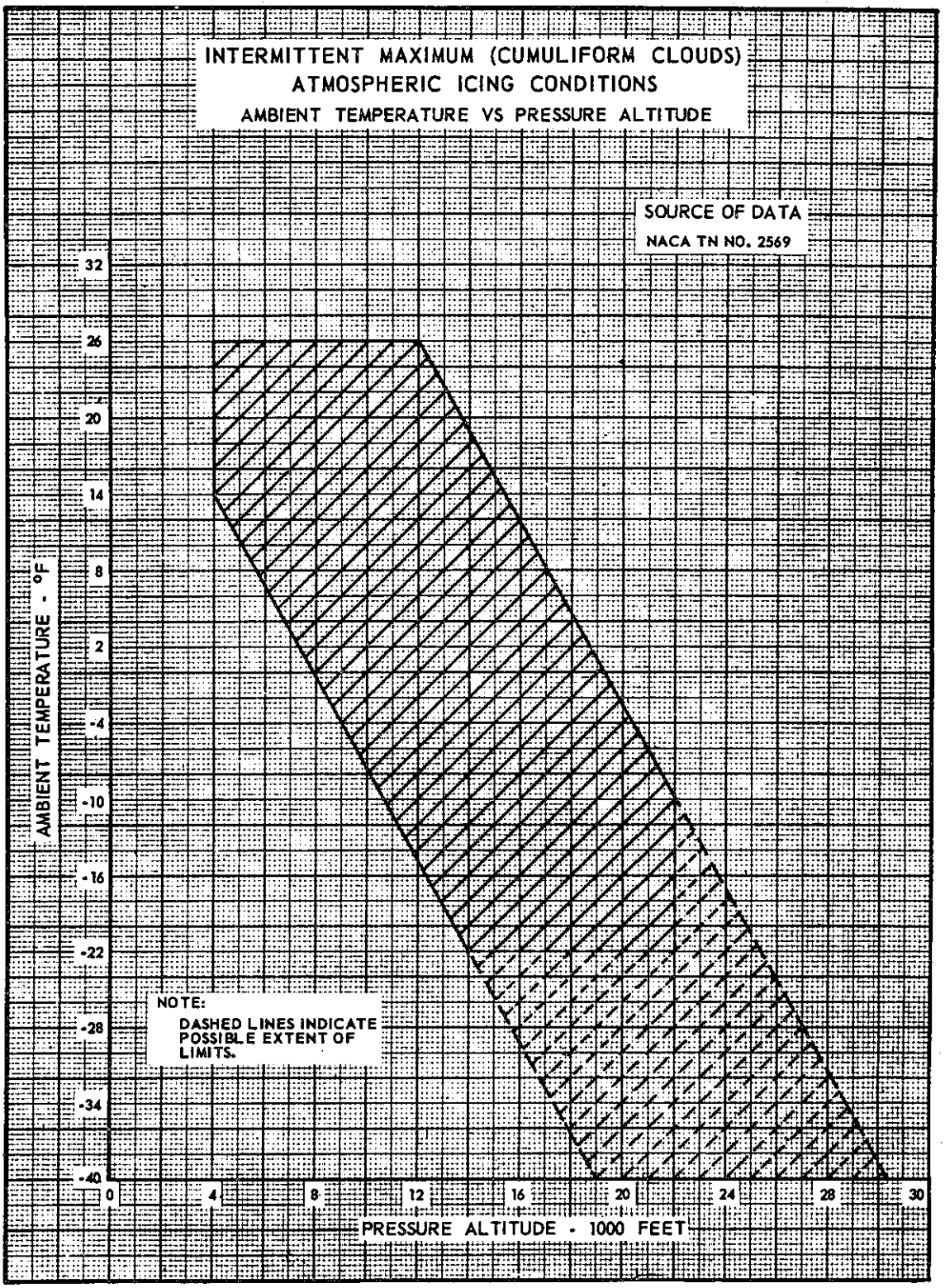
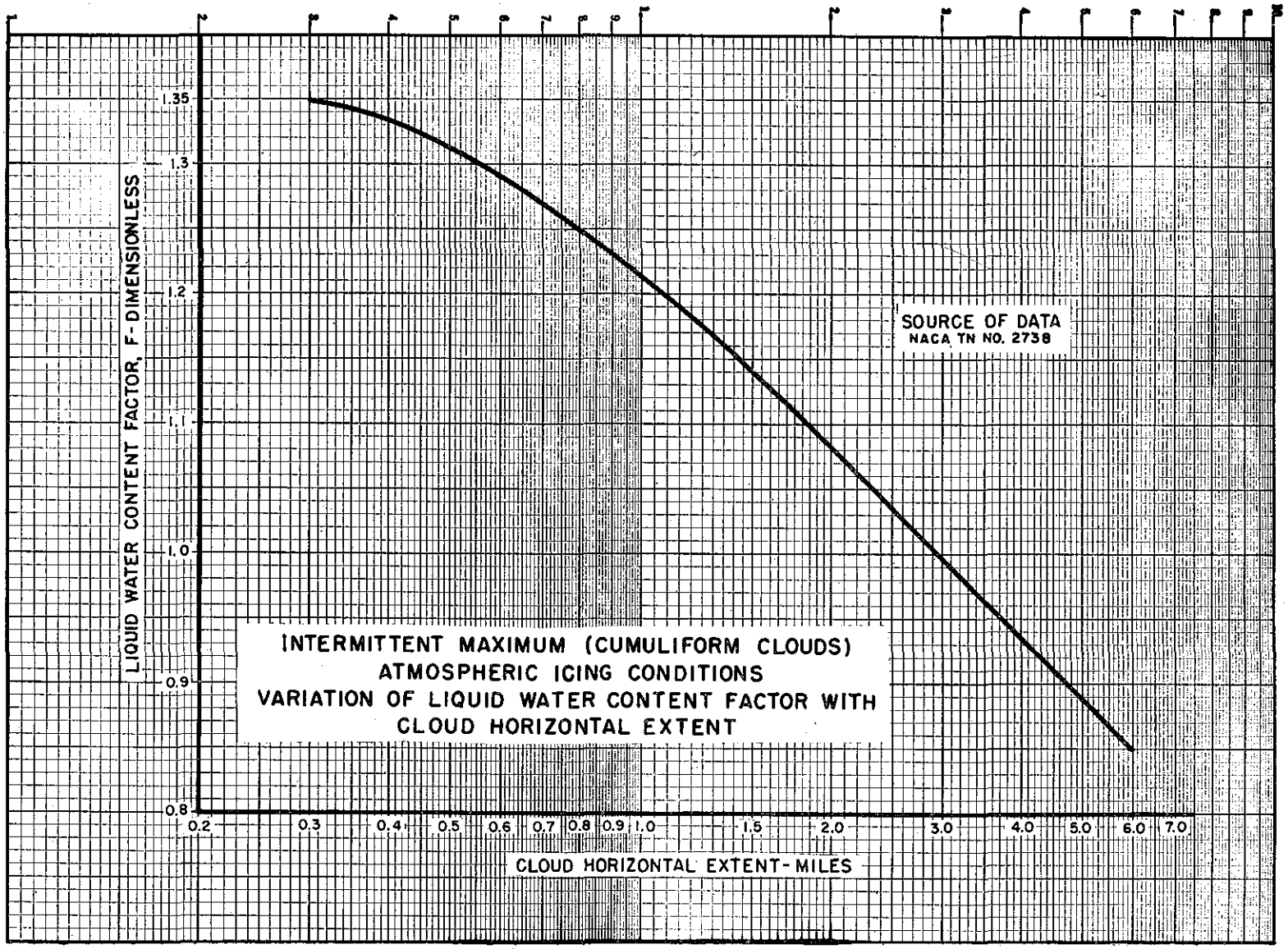


Figure 4b–25b.



[Figure 4b–25c.]

Tow Point	Position	Load		
		Magnitude	No.	Direction
Main gear.		0.75 F_{tow} per main gear unit.	1	Forward, parallel to drag axis.
			2	Forward, at 30° to drag axis.
			3	Aft, parallel to drag axis.
			4	Aft, at 30° to drag axis.
Auxiliary gear.	Swiveled forward.	1.0 F_{tow}.	5	Forward.
			6	Aft.
	Swiveled aft.		7	Forward.
			8	Aft.
	Swiveled 45° from foward.	0.5 F_{tow}.	9	Forward, in plane of wheel.
			10	Aft, in plane of wheel.
	Swiveled 45° from aft.		11	Forward, in plane of wheel.
			12	Aft, in plane of wheel.

BALANCING FORCES

The side component of the towing load at the main gear is reacted by a side force at the static ground line at the wheel to which load is applied.

The towing loads at the auxiliary gear and the drag components of the towing loads at the main gear are reacted in each of the following ways:

a. Reaction applied at the axle of the wheel to which load is applied, this reaction having a maximum value equal to the vertical reaction. Airplane inertia is applied as required for equilibrium.
b. The loads reacted by airplane inertia.

Figure 4b–26.—Towing Loads.

Angle above or below horizontal plane	Effective intensity (candles)
0° to 5°	100
5° to 10°	60
10° to 20°	20
20° to 30°	10

Figure 4b–27.—Minimum effective intensities for anti-collision lights.

Safety Equipment

4b.640 *Ice protection.* **Compliance with this section is optional. The requirements of this section are intended to provide for safe flight in icing conditions. When compliance is shown with the provisions of this section, the type certificate shall include certification to that effect. When an airplane is certificated to include ice protection provisions, the recommended procedures for the use of the ice protection equipment shall be set forth in the Airplane Flight Manual (see sec. 4b.742 (a)). It shall be shown, as prescribed in paragraphs (a) and (b) of this section, that the airplane is capable of operating safely in continuous maximum and intermittent maximum icing conditions as defined in sections 4b.1 (b) (7) and 4b.1 (b) (8).**

(a) An analysis shall be performed to establish, on the basis of the airplane's operational needs, the adequacy of the ice protection system for the various components of the airplane.

(b) In addition to the analysis and physical evaluation prescribed in paragraph (a) of this section, the effectiveness of the ice protection system and its components shall be shown by one or more of the following means:

(1) Laboratory dry air and/or simulated icing tests of the actual components or models thereof.

(2) Flight dry air tests of the ice protection system as a whole, or of its components individually.

(3) Flight tests of the airplane or its components in measured simulated icing conditions.

(4) Flight tests of the airplane in measured natural atmospheric icing conditions.

NOTE: For turbine-powered airplanes, the ice protection provisions of this section are considered to be primarily applicable to the airframe. For the powerplant installation, certain additional provisions of Subpart E of this Part may be found applicable.

4b.641 *Hand fire extinguishers.* (See secs. 4b.381, 4b.382, and 4b.383.)

4b.642 *Flare installation.*

(a) Parachute flares shall be releasable from the pilot compartment and installed to minimize the danger of accidental discharge.

(b) It shall be demonstrated in flight that the flare installation is such that ejection can be accomplished without hazard to the airplane and its occupants.

(c) If recoil loads are involved in the ejection of the flares, the structure of the airplane shall withstand such loads.

4b.642–1 *Procedure for testing flare ejection (CAA policies which apply to sec. 4b.642 (b)).* When flares are released, they should clear the aircraft structure when the airplane is flown at a speed of 1.4 Vs_1 with the wing flaps and landing gear in both extended and retracted positions. If it is obvious that the flaps and gear have no effect upon the flare's path, the tess may be conducted at one configuration. It it permissible to use dummy flares with parachutes for this test.

4b.643 *Safety belts.* **Safety belts shall be of an approved type. In no case shall the rated strength of the safety belt be less than that corresponding with the ultimate load factors specified in section 4b.260 (a), taking due account of the dimensional characteristics of the safety belt installation for the specific seat or berth arrangement. Safety belts shall be attached so that no part of the anchorage will fail at a load lower than that corresponding with the ultimate load factors equal to those specified in section 4b.260 (a) multiplied by a factor of 1.33. In the case of safety belts for berths, the forward load factor need not be applied.**

4b.644 *Safety belt signal.* **When means are provided to indicate to the passengers when seat belts should be fastened, the device shall be so installed that it can be operated from the seat of either pilot or copilot.**

4b.645 *Ditching equipment.* **When the airplane is certificated for ditching in accordance with section 4b.361, and when required by the operating rules for the particular route to be flown, the ditching equipment shall be as prescribed in paragraphs (a) through (d) of this section.**

(a) *Life rafts.* **Life rafts shall be of an approved type. Unless excess rafts of sufficient capacity are provided, the buoyancy and seating capacity beyond the rated capacity of the rafts shall be such as to accommodate all occupants of the airplane in the event of a loss of one life raft of the largest rated capacity on board. Each life raft shall be equipped with a**

trailing line and with a static line, the latter designed to hold the raft near the airplane but to release it in case the airplane becomes totally submerged. Each raft shall contain obvious markings of instruction on the operation of the raft.

(b) *Life raft equipment.* Approved equipment intended for survival shall be attached to each life raft and marked for identification and method of operation.

NOTE: The extent and type of survival equipment will depend upon the route over which the airplane is operated.

(c) *Long-range signalling device.* An approved long-range signalling device shall be provided for use in one of the life rafts.

(d) *Life preservers.* Life preservers shall be of an approved type. They shall be reversible and shall contain obvious markings of instruction on their use.

[(e) *Life line.* Provisions shall be made for the storage of life lines, one attached to each side of the fuselage and arranged so that they can be used to enable occupants to stay on the wing after a ditching.]

4b.646 *Stowage of safety equipment.* Special stowage provisions shall be made for all prescribed safety equipment to be used in emergencies. The stowage provision shall be such that the equipment is directly accessible and its location is obvious. All safety equipment shall be protected against inadvertent damage. The stowage provisions shall be marked conspicuously to identify the contents and to facilitate removal of the equipment. In addition, the following shall specifically apply:

(a) *Emergency exit means.* The stowage provisions for the emergency exit means required by section 4b.362 (e) (7) shall be located at the exits which they are intended to serve.

(b) *Life rafts.* The provisions for the stowage of life rafts required by section 4b.645 (a) shall accommodate a sufficient number of rafts for the maximum number of occupants for which the airplane is certificated for ditching. Stowage shall be near exits through which the rafts can be launched during an unplanned ditching. Rafts automatically or remotely released on the outside of the airplane shall be attached to the airplane by means of the static line prescribed in section 4b.645 (a).

(c) *Long-range signalling device.* The stowage provisions for the long-range signalling device required by section 4b.645 (c) shall be located near an exit to be available during an unplanned ditching.

(d) *Life preservers.* The provisions for the stowage of life preservers required by section 4b.645 (d) shall accommodate one life preserver for each occupant for which the airplane is certificated for ditching. They shall be located so that a life preserver is within easy reach of each occupant while seated.

Miscellaneous Equipment

4b.650 *Radio and electronic equipment.* (a) In showing compliance with section 4b.606 (a) and (b) with respect to radio and electronic equipment and their installations, consideration shall be given to critical environmental conditions.

NOTE: Critical environmental conditions may include temperature, pressure, humidity, ventilation, position, acceleration, vibration, and presence of detrimental substances.

(b) Radio and electronic equipment shall be supplied with power in accordance with the provisions of section 4b.623 (c).

(c) All radio and electronic equipment, controls, and wiring shall be so installed that operation of any one unit or system of units will not affect adversely the simultaneous operation of any other radio or electronic unit or system of units required by the regulations in this subchapter.

4b.651 *Oxygen equipment and supply.* When required by the operating rules of the regulations in this subpart, the supplemental and protective breathing equipment and its installation shall meet the following requirements:

(a) *General.* The oxygen system installed shall be free from hazards in itself, in its method of operation, and in its effect on other components of the airplane. Means shall be provided to enable the crew to determine the quantity of oxygen available in each source of supply. [Aircraft certificated for operation at altitudes over 25,000 feet shall be provided with oxygen

dispensing equipment for each occupant, arranged so that the mask and oxygen are immediately available in the event of uncontrolled cabin pressure loss, unless it is demonstrated that the rate of cabin pressure reduction following any probable failure and the emergency descent rate of the airplane are such that this type of equipment will not be necessary for protection of the occupants.]

(b) *Required minimum mass flow of supplemental oxygen.* The minimum mass flow of supplemental oxygen required per person at various cabin pressure altitudes shall be at least that indicated on figure 4b–21.

(c) *Equipment standards for distribution system.* Where oxygen is to be supplied to both crew and passengers, the distribution system shall be designed to provide either:

(1) A source of supply for the flight crew on duty and a separate source for the passengers and other crew members, or

(2) A common source of supply with means provided so that the minimum supply required by the flight crew on duty can be separately reserved.

[(d) *Equipment standards for dispensing units.* An individual dispensing unit shall be provided for each crew member and passenger for whom supplemental oxygen is required to be furnished. Dispensing units required for aircraft certificated for operation at altitudes above 25,000 feet shall cover the nose and mouth. Crew members on flight deck duty in airplanes certificated to operate above 25,000 feet shall be provided with demand equipment. All dispensing units for airplanes certificated to operate at altitudes of not more than 25,000 feet shall be designed to cover the nose, and at least 25 percent of the units required to be furnished shall, in addition, cover the mouth. Crew masks shall permit utilization of necessary communication equipment. (For crew masks to be used for protective breathing purposes see paragraph (h) of this section.)]

(e) *Means for determining use of oxygen.* Means shall be provided to enable the crew to determine whether oxygen is being delivered to each user.

(f) *Fire protection.*

(1) Oxygen equipment and lines shall not be located in any designated fire zone.

(2) Oxygen equipment and lines shall be protected from heat which may be generated in or escape from any designated fire zone.

(3) Oxygen equipment and lines shall be so installed that escaping oxygen cannot cause ignition of accumulations of grease, fluids, or vapors which are likely to be present in normal operation or as a result of failure or malfunctioning of any system.

(g) *Protection from rupture.* Oxygen pressure tanks and lines between tanks and the shutoff means shall be protected from the effects of unsafe temperatures, and shall be so located in the airplane as to minimize the possibility and the hazards of rupture in a crash landing.

(h) *Protective breathing system.* When protective breathing equipment is required by the Civil Air Regulations, it shall be designed to protect the flight crew from the effects of smoke, carbon dioxide, and other harmful gases while on flight deck duty and while combating fires in cargo compartments (see sec. 4b.380 (c)). The protective breathing equipment and the necessary supply of oxygen shall be in accordance with the following provisions:

(1) The protective breathing equipment shall include masks covering the eyes, nose, and mouth, or only the nose and mouth where accessory equipment is provided to protect the eyes.

(2) A supply of protective oxygen per crew member shall be of 15-minute duration at a pressure altitude of 8,000 feet and a respiratory minute volume of 30 liters per minute BTPD.

NOTE: When a demand type oxygen system is employed, a supply of 300 liters of free oxygen at 70° F. and 760 mm Hg. pressure is considered to be of 15-minute duration at the prescribed altitude and minute volume. When a continuous flow protective breathing system is used, including a mask with a standard rebreather bag, a flow rate of 60 liters per minute at 8,000 feet (45 liters per minute at sea level) and a supply of 600 liters of free oxygen at 70° F. and 760 mm Hg. pressure is considered to be of 15-minute duration at prescribed altitude and minute volume. (BTPD refers to body temperature conditions, i. e., 37° C., at ambient pressure, dry.)

(19 F. R. 4466, July 20, 1954, effective Sept. 1, 1954.)

4b.651–1 *Safety precautions (CAA policies which apply to sec. 4b.651 (a)).* The oxygen system should be so located that leakage or failure

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in other systems carrying inflammable liquids or gases will not cause the inflammable liquid or gas to come in contact with oxygen lines or equipment. A relief valve or some other means is desirable in low pressure (400 p. s. i.) oxygen systems to safely relieve excessive pressures such as might be caused by overcharging. (See also sec. 4b.481 concerning location of tanks containing inflammable fluids.)

(15 F. R. 8904, Dec. 15, 1950, effective Jan. 1, 1951.)

4b.651–2 *Protective breathing equipment (CAA policies which apply to sec. 4b.651 (h)).*

(a) *Conditions under which protective breathing equipment may be necessary.* These conditions are those outlined in sections 4b.484–1, 40.205–2, 41.24c–2, and 42.29–2.

(b) *Oxygen systems for flight deck duty.* The demand type oxygen system, or the diluter-demand type system with the lever of the diluter-demand regulator set at "100% OXYGEN" (Automix "OFF") are recommended for use as protective breathing equipment. However, a continuous flow protective breathing system may also be used. In any case the equipment should meet the requirements of section 4b.651 (h).

(c) *Portable equipment for flight deck duty.* Portable protective breathing units of the demand type may be used to meet the requirement of section 4b.651 in lieu of installing a fixed protective breathing system. Portable continuous flow protective breathing units may also be used, but should not be used during fire fighting in Class A or B cargo compartments since any unused oxygen escaping from around the face mask might aggravate the existing fire.

(d) *Masks and goggles.*

(1) Protective breathing masks should fit snugly to prevent the entry of noxious gases. Continuous flow protective breathing masks should have no apertures through which outside air could be drawn into the system and should have a rebreathing bag of at least ⅔ liter capacity. The masks should be installed so as to be readily available to the appropriate crew members. It should be possible for at least the pilot or copilot to maintain ground to air radio voice communications when utilizing the protective breathing masks.

(2) Eye protecting goggles may be a part of or separate from the breathing mask. The goggles should provide an adequate field of vision and a means should be provided to overcome any unsatisfactory fogging tendency of the goggles. Periodic application of an effective antifogging agent on the lens is a satisfactory means of overcoming fogging.

(e) *Operating Instructions.* Operating instructions appropriate to the type of system and masks installed should be provided for the flight crew on placards and/or in the Airplane Flight Manual.

(15 F. R. 8904, Dec. 15, 1950, effective Jan. 1, 1951, revised 19 F. R. 4446, July 20, 1954, effective Sept. 1, 1954.)

4b.651–3 *Supplemental breathing equipment (CAA policies which apply to sec. 4b.651).*

(a) *Oxygen systems.*

(1) Either a continuous flow type system which uses a rebreather type mask or a diluter-demand type system with the lever of the diluter-demand regulator set in the "NORMAL" (Automix "ON") position will satisfactorily provide the supplemental oxygen required for protection against anoxia. The continuous flow system may be of the type which controls the oxygen flow by means of a hand adjustment type regulator, or an automatic type regulator.

(2) A diluter-demand type system with the lever of the diluter-demand regulator set in the "100% OXYGEN" (Automix "OFF") position or a straight demand type system which uses a nondiluter-demand regulator may be used for supplementary breathing purposes as protection against anoxia. However, such use is not recommended due to the lack of oxygen economy of these systems when used to supply supplementary oxygen. As mentioned in section 4b.651–2, either of these closed demand systems is satisfactory for protection against toxic gases.

(b) *Operating instructions.* Operating instructions appropriate to the type of system and masks installed should be provided for the flight crew and other crew members concerned.

These instructions should include a graph or a table which will show the duration of the

oxygen supply for the various bottled pressures and pressure altitudes.

(17 F. R. 11712, Dec. 24, 1952, effective Jan. 31, 1953.)

4b.651–4 *Design considerations for fixed systems (CAA policies which apply to sec. 4b.651).*

(a) *Location of outlets and equipment for crew members.* Protective breathing equipment should be immediately available for use. It is also desirable that supplementary breathing equipment be available for immediate use; however, the supplemental masks may be stowed in any location in the airplane provided operational procedures require that supplemental masks are at each crew member location when needed. The oxygen outlet should be within reach; the oxygen mask should be stored in such a way that there will be a minimum delay in removing it and putting it into use. Provisions for keeping the masks sanitary and clean are desirable, but cumbersome wrapping or packaging of the mask which involve unnecessary effort and time to open should be avoided. The location of the oxygen outlet for a crew member and the length of tubing connecting the mask of the crew member and his oxygen outlet should be such that the visibility and the movement required of the crew member in the performance of his duties are not impaired or restricted in any way. It should not be necessary for the crew member to loosen or unfasten his seat belt in order for him to obtain his oxygen equipment and to put the system into use.

(b) *Location of outlets for passengers.* The operating regulations require that oxygen be furnished for certain percentages of the passengers at cabin pressure altitudes below 15,000 feet. The number of oxygen outlets need only be sufficient to administer oxygen to the percentage of passengers indicated by the operating rules; however, it is desirable in fixed systems to provide an outlet for each seat to enable a crew member to readily administer oxygen to any passenger requiring it. If this is not accomplished, it is recommended that provision be made by means of portable equipment, extension tubing, or otherwise, to reduce the probability of having to move any passenger who may require the administration of oxygen. At cabin pressure altitudes above 15,000 feet the operating regulations require that oxygen be furnished to all of the passengers, in which case an outlet should be provided for each seat. (See also sec. 4b.651–5 concerning portable walk-around units.)

(c) *Line supports.* In a fixed installation, the oxygen lines should be supported to prevent excessive vibration and should be kept clear of the airplane structure or any other lines as a protection against chafing. Supports approximately every 24 inches along the length of the line should be adequate.

(d) *Shutoff valves.* System shutoff valves should be accessible in flight and should be installed as close as practicable to the cylinders in order to minimize the possibility of oxygen escape due to leakage or damage of lines between cylinders and valves.

(e) *Cylinder supports.* The supporting brackets for all cylinders should be capable of withstanding the inertia forces stipulated under the emergency landing conditions. (See sec. 4b.260.)

(17 F. R. 11713, Dec. 24, 1952, effective Jan. 31, 1953.)

4b.651–5 *Portable walk-around oxygen units (CAA policies which apply to sec. 4b.651).*

(a) Portable walk-around oxygen units of the continuous flow, diluter-demand and straight demand types may be used to satisfy part or all of the crew or passenger breathing requirements.

(b) Each portable oxygen unit should be considered as a complete oxygen system and any regulations or pertinent interpretative material relative to oxygen systems should also be applicable to each portable unit.

(c) The supporting brackets for portable oxygen units should be capable of withstanding the inertia forces stipulated under the emergency landing conditions. (See sec. 4b.260.)

4b.651–6 *Oxygen pressure gage (CAA policies which apply to sec. 4b.651 (a)).* At least one pressure gage, which can be observed by a flight crew member during flight, should be installed to indicate the pressure in each source of oxygen supply.

4b.651–7 *Supply required for continuous flow supplementary breathing systems (CAA policies which apply to sec. 4b.651 (b)).*

(a) *Formula for computing supply.*

(1) In computing the supply of oxygen for a continuous flow system, the formula presented in the following paragraph may be used.

$$S=S_1+S_2+--S_n$$

Where:

S=Total supply of oxygen required in cubic feet. S_1, S_2, $--S_n$=the supply of O_2 needed for each of the various cabin pressure altitudes which will be maintained during the flight.

(2) Each of the above supplies, namely, S_1, S_2, $--S_n$, may be computed as follows:

$S=N\times F\times T\times 2.12$

S=supply of oxygen required in cubic feet (STPD). (To obtain supply in terms of cubic feet at 70° F. multiply cubic feet (STPD) by 1.08.)

N=number of oxygen users.

F=the actual flow in LPM (STPD) delivered to each oxygen mask at the cabin altitude under consideration. (See sec. 4b.651–7 (b).)

T=time in hours at the cabin altitude under consideration.

2.12=multiplying factor for converting the oxygen mass flow from liters per minute to cubic feet per hour.

NOTE: In computing the supply of oxygen for a given installation, those operating rules of the Civil Air Regulations which specify the amount of oxygen to be carried for operating at various altitudes should be considered.

(b) *Flow rates.*

(1) The intent of section 4b.651 (b) is to insure that for each oxygen user, a partial pressure of 149 mm Hg of oxygen is maintained in the inspired air at a breathing rate of 15 l. p. m. BTPD, at altitudes up to 25,000 feet. The rates of flow specified in Figure 4b–21 in Part 4b satisfy the intent of section 4b.651 (b) and constitute the values for "F" in the supply equation when there is no loss of bottle oxygen from the system (including the mask) when a 15 l. p. m. BTPD breathing rate is maintained.

(2) The oxygen mask, since it constitutes part of the system, will influence the value of "F". Continuous flow masks with rebreather bags which are currently standard types for aviation usage are satisfactory with the flow rates indicated by Figure 4b–21. Where a receptacle or mask design differs from these, the manufacturer should be requested to supply information concerning the flow rate necessary to maintain the 149 mm Hg partial pressure at a 15 l. p. m. BTPD breathing rate. If the actual mass flow is greater than the minimum required, then the higher flow rate should be used as the value for "F".

(3) It is possible that certain automatic continuous flow regulators will furnish oxygen flows in excess of the minimum required; in this case, the actual flow rates should be used as the values for "F".

NOTE.—(1) BTPD signifies gas at 37° C. (body temperature), ambient pressure, dry.

(2) STPD signifies gas at 0° C., 760 mm Hg, dry.

(17 F. R. 11713, Dec. 24, 1952, effective Jan. 31, 1953, revised 19 F. R. 4467, July 20, 1954, effective Sept. 1, 1954.)

4b.651–8 *Supply required for diluter-demand system (CAA policies which apply to sec. 4b.651).*

(a) Tests conducted by the Armed Forces on currently available diluter-demand regulators indicate that some types deliver more oxygen than is required by Fig. 4b–21 in Part 4b. Consequently, in computing the supply required for a diluter-demand system, the flow characteristics at various altitudes should be obtained from the manufacturer of the regulator. Where this information is not available, the values listed in the following table may be used for Air Force–Navy approved diluter-demand regulators:

Altitude in feet	Flow per person in LPM (STPD)[1]
8,000	1. 90
10,000	1. 90
15,000	2. 10
20,000	2. 50
25,000	4. 10

[1] These values are based on tests on a large group of men using the equipment at the altitude specified. The values listed are those calculated to completely protect 95 percent of the population.

(b) The formula outlined in section 4b.651–7 (a) may be used in computing the supply of oxygen for supplementary breathing purposes.

(17 F. R. 11713, Dec. 24, 1952, effective Jan. 31, 1953, revised 19 F. R. 4467, July 20, 1954, effective Sept. 1, 1954.)

4b.651–9 *Requirements for approval of oxygen systems (CAA policies which apply to sec. 4b.651 (b)).* Prior to the approval of an oxygen system, the system should be examined to determine that the flow of oxygen through each outlet is at least equal to the minimum required by section 4b.651 (b) at all altitudes for which the aircraft is certificated. This can be accomplished by one of the following methods or by any other satisfactory procedure:

(a) *Pressure measurement.*

(1) In a continuous flow system when the calibration (inlet pressure vs. flow) of the orifices used at the plug-in outlets is known, the pressure in the low pressure distribution line can be measured at the point which is subject to the greatest pressure drop. This should be done with oxygen flowing from all outlets. The pressure thus measured should indicate a flow equal to or greater than the minimum flow required.

(2) In lieu of the above procedure, the flow of oxygen through the outlet which is subject to the greatest pressure drop may be measured. This should be accomplished with all other outlets open. Gas meters, rotometers, or other suitable means may be used to measure flows.

(3) The measurement of oxygen flows in a continuous flow system which uses a manually adjusted regulator can be accomplished at sea level. However, in a continuous flow system which uses an automatic type regulator, it may be necessary to check the flows at the maximum altitude which will be encountered during the normal operation of the aircraft. The manufacturer of the particular continuous flow regulator being used should be able to furnish data on the operating characteristics of the regulator from which it can be determined whether flight tests are necessary.

(b) *Availability of oxygen.*

(1) The checking of the amount of oxygen flow through the various outlets in a diluter-demand or straight demand system is not necessary since the flow characteristics of the particular regulator being used may be obtained from the manufacturer of the regulator. However, in such systems the availability of oxygen to each regulator should be checked as follows:

(i) Turn the lever of the diluter-demand regulator to the "100% OXYGEN" position and inhale through the tube via the mask to determine whether the regulator valve and the flow indicator are operating. Deficient units should be replaced.

(17 F. R. 11713, Dec. 24, 1952, effective Jan. 31, 1953.)

4b.651–10 *Means for determining oxygen flow to crew members (CAA policies which apply to sec. 4b.651 (e)).*

(a) *Supplementary breathing systems.*

(1) Where continuous flow or diluter-demand systems are used for supplementary breathing purposes, each crew member should have an individual flow indicator for determining oxygen flow or the operator may establish a suitable procedure for determining oxygen flow and should include such procedures in the Airplane Flight Manual.

(2) If flow indicators are used, the indicator for any particular crew member should be located so as to be easily observed by him while he is at his crew station. Acceptable flow indicators are listed in section 4b.651–12.

(3) If a suitable procedure is to be used for determining oxygen flow in nonpressurized cabin aircraft, the procedure should include initial and periodic checking of the oxygen flow by each crew member by any acceptable method. Some of the acceptable methods are described under section 4b.651–11 (a) and (b). In pressurized cabin aircraft when supplementary oxygen is required immediately following cabin pressurization failure, positive means for determining flow under emergency conditions should be established which would not involve delay or activities which would interfere with a flight crew member's performance of his primary duties. Since utilizing one of the methods for determining oxygen flow permitted for supplementary breathing equipment described under section 4b.651–11 (a) and (b) involves some time delay, a flight member could don his protective breathing equipment

following a pressurization failure because with such equipment oxygen flow is immediately apparent. As soon as some degree of control of the emergency has been established and sufficient time is available to determine oxygen flow by one of the methods mentioned above, he could change over to his supplementary breathing equipment.

(b) *Protective breathing systems.* No flow indicators are required in protective breathing systems since with these systems the lack of oxygen flow would be immediately evidenced by the oxygen user's inability to inhale while wearing mask.

(17 F. R. 11714, Dec. 24, 1952, effective Jan. 31, 1953, revised 19 F. R. 4467, July 20, 1954, effective Sept. 1, 1954.)

4b.651–11 *Means for determining oxygen flow to passengers (CAA policies which apply to sec. 4b.651 (e)).* Each passenger may be supplied with an individual flow indicator of a type specified in section 4b.651–12 or the operator involved may establish a suitable procedure for checking the oxygen flow to each oxygen user. Procedures which utilize the following means for checking oxygen flow to each user will be satisfactory.

(a) In the case where a continuous flow system is used, the means may be the observing of the rebreather bag on each continuous flow mask by a trained crew member. If oxygen flow is occurring the rebreather bag will continue to expand when the oxygen user periodically refrains from exhaling when the bag is empty or partially empty, or in cases where high oxygen flows are occurring, the rebreather bag may not empty completely during normal inhalation. Any alternate method of checking oxygen flow may be used providing positive indication of flow is given. For example, prior to giving a mask to a passenger, the crew member may find it expedient to feel the flow of oxygen at the oxygen outlet in the mask or to constrict the tubing and listen to audible sounds characteristic of gas flow. If a listening test is employed to determine the flow of oxygen, it should be demonstrated in flight that the test is satisfactory.

(b) In the case where a diluter-demand system is used, the procedure may be checking of the oxygen flow by a trained crew member by momentarily moving the regulator lever to Automix "OFF" (100 PERCENT OXYGEN) while the mask is being worn. Lack of oxygen flow will be immediately evidenced by the user's inability to inhale while wearing his mask.

(c) The oxygen flow to each passenger should be checked when the passenger is first given oxygen and at subsequent intervals if the circumstances prevailing at the time indicate such a check is desirable.

(d) Any crew member assigned by an air carrier for the performance of duty on the aircraft during flight may check the oxygen flow to the passengers if trained to do so.

(17 F. R. 11714, Dec. 24, 1952, effective Jan. 31, 1953.)

4b.651–12 *Types of flow indicators (CAA policies which apply to sec. 4b.651 (e)).* A pith ball flow indicator, vane, or wheel anemometer, lateral pressure indicator which fluctuates with changes in flow or any other satisfactory flow indicator may be used in a continuous flow type system. An Air Force-Navy flow indicator or equivalent may be used in a diluter-demand type system. Each flow indicator should give positive indication when oxygen flow is occurring.

(17 F. R. 11714, Dec. 24, 1952, effective Jan. 31, 1953.)

4b.652 *Engine-driven accessories.* Engine-driven accessories essential to safe operation of the airplane shall be so distributed among two or more engines that the failure of any one engine will not impair the safe operation of the airplane.

4b.653 *Hydraulic systems; strength.*

(a) *Structural loads.* All elements of the hydraulic system shall be designed to withstand, without detrimental permanent deformation, all structural loads which may be imposed simultaneously with the maximum hydraulic loads occurring in operation.

(b) *Proof pressure tests.* All elements of the hydraulic system shall be tested to a proof pressure of 1.5 times the maximum pressure to which the part will be subjected in normal operation. In such test no part of the hydraulic system shall fail, malfunction, or suffer detrimental deformation.

(c) ***Burst pressure strength.*** **Individual hydraulic system elements shall be designed to withstand pressures which are sufficiently increased over the pressures prescribed in paragraph (b) of this section to safeguard against rupture under service conditions.**

NOTE: The following pressures, in terms of percentage of maximum operating pressure for the particular element, in most instances are sufficient to insure against rupture in service: 250 percent in units under oil pressure, 400 percent in units containing air and oil under pressure and in lines, hoses, and fittings, 300 percent in units of system subjected to back pressure.

4b.654 ***Hydraulic systems; design.***

(a) ***Pressure indication.*** **A means shall be provided to indicate the pressure in each main hydraulic power system.**

(b) ***Pressure limiting provisions.*** **Provision shall be made to assure that pressures in any part of the system will not exceed a safe limit above the maximum operating pressure of the system and to insure against excessive pressures resulting from fluid volumetric changes in all lines which are likely to remain closed long enough for such changes to take place. In addition, consideration shall be given to the possible occurrence of detrimental transient (surge) pressures during operation.**

(c) ***Installation.*** **Hydraulic lines, fittings, and components shall be installed and supported to prevent excessive vibration and to withstand inertia loads. All elements of the installation shall be protected from abrasion, corrosion, and mechanical damage.**

(d) ***Connections.*** **Flexible hose, or other means of providing flexibility, shall be used to connect points in a hydraulic fluid line between which there is relative motion or differential vibration.**

4b.655 ***Hydraulic system fire protection.*** **When flammable type hydraulic fluid is used, the hydraulic system shall comply with the provisions of sections 4b.385, 4b.481, 4b.482, and 4b.483.**

4b.658 ***Vacuum systems.***

(a) Means, in addition to the normal pressure relief, shall be provided to relieve automatically the pressure in the discharge lines from the vacuum pump, if the delivery temperature of the air reaches an unsafe value.

(b) Vacuum system lines and fittings on the discharge side of the pump which might contain flammable vapors or fluids shall comply with section 4b.483 if they are located in a designated fire zone. Other vacuum system components located in designated fire zones shall be fire-resistant.

Operating Limitations and Information

General

4b.700 ***Scope.***

(a) The operating limitations listed in sections 4b.710 through 4b.723 shall be established as prescribed in this part.

(b) The operating limitations, together with any other information concerning the airplane found necessary for safety during operation, shall be included in the Airplane Flight Manual (sec. 4b.740), shall be expressed as markings and placards (sec. 4b.730), and shall be made available by such other means as will convey the information to the crew members.

4b.700–1 *Automatic propeller feathering operating limitations and information (CAA policies which apply to sec. 4b.700).*

(a) All limitations on the use of automatic feathering system, including flight conditions when the system must be operative or inoperative, should be determined and noted when appropriate.

(b) Any placards found necessary should be provided in the airplane.

(c) A complete statement of operating limitations and instructions for the use of the system should be included in the Airplane Flight Manual.

(d) If certification is desired both with and without the feathering system operative, two corresponding sets of performance data properly identified should be included in the Airplane Flight Manual. (See also sec. 4b.10–2.)

(19 F. R. 1818, Apr. 2, 1954, effective Apr. 2, 1954.)

Operating Limitations

4b.710 ***Air-speed limitations; general.*** **When air-speed limitations are a function of weight, weight distribution, altitude, or Mach number, the values corresponding with all**

critical combinations of these values shall be established.

4b.711 *Never-exceed speed* V_{NE}.

(a) To allow for possible variations in the airplane characteristics and to minimize the possibility of inadvertently exceeding safe speeds, the never-exceed speed V_{NE} shall be a speed established sufficiently below the lesser of:

(1) The design dive speed V_D chosen in accordance with section 4b.210 (b) (5), or

(2) The maximum speed demonstrated in flight in accordance with section 4b.190.

(b) In the absence of a rational investigation, the value of V_{NE} shall not exceed 0.9 times the lesser of the two speeds referred to in paragraph (a) of this section.

NOTE: Where speeds are limited by compressibility effects, this section is intended to provide an adequate margin between M_{NE} and the lowest of the following Mach values: M_D, M_{DF}, or the Mach number where adverse flight characteristics, such as the followi,ng occur: Undue reduction in ability to recover; rapid or large changes in stability during level flight or recovery which would cause the airplane to exceed structural limits; buffeting so severe as to endanger the structural integrity of the airplane. The speed margin required usually depends upon the effectiveness of the warning provided to the pilots whenever M_{NE} is reached or exceeded, and upon the recovery or speed control characteristics of the airplane. In any case the margin should be sufficient: To enable recovery from mild upsets due to gusts or inadvertent control movements or trim changes; to allow for inadvertent increases in Mach number due to horizontal gusts or temperature inversions; and, for instrument inaccuracies or airplane production differences. The probability of the simultaneous occurrence of the aforementioned speed margin conditions are usually considered, but the effects of all such conditions are not necessarily additive.

4b.712 *Normal operating limit speed* V_{NO}.

(a) The normal operating limit speed V_{NO} shall be established not to exceed the design cruising speed V_C chosen in accordance with section 4b.210 (b) (4) and sufficiently below the never-exceed speed V_{NE} to make it unlikely that V_{NE} would be exceeded in a moderate upset occurring at V_{NO}.

(b) In the absence of a rational investigation, the value of V_{NO} shall not exceed 0.9 times V_{NE}.

(c) At altitudes where V_{NE} is limited by compressibility, a spread between V_{NO} and V_{NE} shall not be required; i. e., M_{NO} equal to the lesser of M_{NE} or M_C shall be acceptable.

4b.713 *Maneuvering speed.* The maneuvering speed shall not exceed the design maneuvering speed V_A determined in accordance with section 4b.210 (b) (2).

4b.714 *Flap extended speed* V_{FE}.

(a) The flap extended speed V_{FE} shall be established not to exceed the lesser of:

(1) The design flap speed V_F chosen in accordance with section 4b.210 (b) (1), or

(2) The design speed for slipstream effects with flaps in the landing position, chosen in accordance with section 4b.221.

(b) The value of V_{FE} established in accordance with paragraph (a) of this section shall not be less than a value which provides a safe speed margin above the stall during approach and landing.

(c) It shall be acceptable to establish supplementary values of V_{FE} for other combinations of flap setting, air speed, and engine power, if the structure and the flight characteristics of the airplane have been shown to be satisfactory for such combinations.

4b.715 *Landing gear operating speed* V_{LO}. The landing gear operating speed V_{LO} shall be established not to exceed a speed at which it is safe to extend or retract the landing gear as limited by design in accordance with section 4b.334 or by flight characteristics.

4b.716 *Landing gear extended speed* V_{LE}. The landing gear extended speed V_{LE} shall be established not to exceed a speed at which it has been shown that the airplane can be safely flown with the landing gear secured in the fully extended position, and for which the structure has been proven in accordance with section 4b.334.

4b.717 *Minimum control speed* V_{MC}. (See sec. 4b.133.)

4b.718 *Powerplant limitations.* The following powerplant limitations shall be established for the airplane. They shall not exceed the corresponding limits established as a part of the type certification of the engine and propeller installed in the airplane.

(a) *Take-off operation.*

(1) Maximum rotational speed (r. p. m.),

(2) Maximum permissible manifold pressure,

(3) The time limit for use of the power which corresponds with the values established in subparagraphs (1) and (2) of this paragraph,

(4) Where the time limit established in subparagraph (3) of this paragraph exceeds two minutes, the maximum allowable cylinder head, and oil temperatures,

(5) Maximum cylinder head and oil temperatures, if these differ from the maximum limits for continuous operation.

(b) *Maximum continuous operation.*

(1) Maximum rotational speed (r. p. m.),

(2) Maximum permissible manifold pressure,

(3) Maximum allowable cylinder head and oil temperatures.

(c) *Fuel octane rating.* The minimum octane rating of fuel required for satisfactory operation of the powerplant at the limits specified in paragraphs (a) and (b) of this section.

(d) *Cooling limitations.* The maximum sea level temperature for which satisfactory cooling has been demonstrated.

4b.718–1 *Powerplant limitations governing minimum quantity of anti-detonant fluid required for takeoff (CAA policies which apply to sec. 4b.718).* The Airplane Flight Manual should include a limitation indicating that the minimum quantity of anti-detonant fluid required is that determined from section 4b.420–1 (a) and (b). If the performance characteristics of the airplane are such that wet power is required for takeoff but may or may not be required for landing, depending upon airport location or characteristics, the Airplane Flight Manual may include information covering minimum allowable quantities under both conditions.

(20 F. R. 2281, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.719 *Airplane weight, center of gravity, and weight distribution limitations.* The airplane weight, center of gravity, and weight distribution limitations shall be those prescribed in sections 4b.101, 4b.102 and 4b.103. Where the airplane is certificated for more than one center of gravity range, the appropriate limitations with regard to weight and loading procedures shall be set forth in the Airplane Flight Manual for each separate center of gravity range.

4b.720 *Minimum flight crew.* The minimum flight crew shall be established by the Administrator as that number of persons which he finds necessary for safety in the operations authorized under section 4b.721. This finding shall be based upon the work load imposed upon individual crew members with due consideration given to the accessibility and the ease of operation of all necessary controls by the appropriate crew members.

4b.721 *Types of operation.* The types of operation to which the airplane is limited shall be established by the category in which it has been found eligible for certification and by the equipment installed. (See the operating rules in this subchapter.)

4b.722 *Maximum operating altitude.* A maximum altitude shall be established up to which operation is permitted, as limited by flight, structural, powerplant, functional, or equipment characteristics.

4b.723 *Maneuvering flight load factors.* Load factor limitations shall be established not to exceed the positive limit load factors determined from the maneuvering diagram, figure 4b–2. (See sec. 4b.211 (a).)

Markings and Placards

4b.730 *General.*

(a) Markings and placards shall be displayed in conspicuous places and shall be such that they cannot be easily erased, disfigured, or obscured.

(b) Additional information, placards, and instrument markings having a direct and important bearing on safe operation of the airplane shall be required when unusual design, operating, or handling characteristics so warrant.

4b.730–1 *Reverse thrust placards (CAA policies which apply to sec. 4b.730).* The policies outlined in section 4b.402–1 (b) will apply.

(20 F. R. 2281, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.731 *Instrument markings; general.*

(a) When markings are placed on the cover glass of the instrument, provision shall be made to maintain the correct alignment of the glass cover with the face of the dial.

(b) All arcs and lines shall be of sufficient width and so located that they are clearly visible to the pilot.

4b.732 *Air-speed indicator.* The following markings shall be placed on the air-speed indicator in terms of IAS. If speeds vary with altitude, means shall be provided to indicate the appropriate limitation to the pilot throughout the operating altitude range.

(a) A radial red line shall indicate the never-exceed speed V_{NE} (see sec. 4b.711).

(b) A yellow arc extending from the red line specified in paragraph (a) of this section to the upper limit of the green arc specified in paragraph (c) of this section shall indicate the caution range.

(c) A green arc with the lower limit at V_{S_1} as determined in accordance with section 4b.112 (b) with maximum take-off weight, landing gear and wing flaps retracted, and the upper limit at the normal operating limit speed V_{NO} established in accordance with section 4b.712 shall indicate the normal operating range.

(d) A white arc with the lower limit at V_{S_0} as determined in accordance with section 4b.112 (a) at the maximum landing weight, and the upper limit at the flaps-extended speed V_{FE} as established in accordance with section 4b.714 shall indicate the flap operating range.

4b.733 *Magnetic direction indicator.* A placard shall be installed on or in close proximity to the magnetic direction indicator which shall comply with the following:

(a) The placard shall contain the calibration of the instrument in a level flight attitude with engine(s) operating.

(b) The placard shall state whether the calibration was made with radio receiver(s) on or off.

(c) The calibration readings shall be in terms of magnetic headings in not greater than 45° increments.

4b.734 *Powerplant instruments; general.* All required powerplant instruments shall be marked as follows:

(a) The maximum and the minimum (if applicable) safe operational limits shall be marked with red radial lines.

(b) The normal operating ranges shall be marked with a green arc not extending beyond the maximum and minimum safe operational limits.

(c) The take-off and precautionary ranges shall be marked with a yellow arc.

(d) Engine or propeller speed ranges which are restricted because of excessive vibration stresses shall be marked with red arcs.

4b.735 *Oil quantity indicators.* Oil quantity indicators shall be marked in sufficient increments to indicate readily and accurately the quantity of oil.

4b.736 *Fuel quantity indicator.* When the unusable fuel supply for any tank exceeds 1 gallon or 5 percent of the tank capacity, whichever is the greater, a red arc shall be marked on the indicator extending from the calibrated zero reading to the lowest reading obtainable in the level flight attitude. A notation in the Airplane Flight Manual shall be made to indicate that the fuel remaining in the tank when the quantity indicator reaches zero in not usable in flight. (See sec. 4b.613 (b).)

4b.737 *Control markings; general.* All cockpit controls, with the exception of the primary flight controls and other controls the function of which is obvious, shall be plainly marked and/or identified as to their function and method of operation. The markings shall include the following:

(a) *Aerodynamic controls.* The secondary aerodynamic controls shall be marked to comply with sections 4b.322 and 4b.323.

(b) *Powerplant fuel controls.*

(1) Controls for fuel tank selector valves shall be marked to indicate the position corresponding with each tank and with all possible cross-feed positions.

(2) When more than one fuel tank is provided, and if safe operation depends upon the use of tanks in a specific sequence, the fuel tank selector controls shall be marked adjacent to or on the control itself to indicate the order in which the tanks should be used.

(3) Controls for engine selector valves shall be marked to indicate the position corresponding with each engine.

(c) *Accessory and auxiliary controls.*

(1) When a retractable landing gear is used, the visual indicator required in section 4b.334 (e) shall be marked so that the pilot can ascertain at all times when the wheels are locked in either extreme position.

(2) Emergency controls, including fuel jettisoning and fluid shutoff controls, shall be

colored red and shall be marked to indicate their function and method of operation.

4b.738 ***Miscellaneous markings and placards.***

(a) ***Baggage compartments and ballast location.*** **Each baggage and cargo compartment as well as the ballast location shall bear a placard stating the maximum allowable weight of contents and, if applicable, any other limitation on contents found necessary due to loading requirements.**

(b) ***Fuel and oil filler openings.*** **The following information shall be marked on or adjacent to the appropriate filler cover:**

(1) The word "fuel", the minimum permissible fuel octane number for the engines installed, and the usable fuel tank capacity (see sec. 4b.416),

(2) The word "oil" and the oil tank capacity.

(c) ***Emergency exit placards.*** **(See sec. 4b.362 (f).)**

(d) ***Safety equipment.***

(1) Safety equipment controls which the crew is expected to operate in time of emergency, such as flares, automatic life raft releases, etc., shall be readily accessible and plainly marked as to their method of operation.

(2) When fire extinguishers and signaling and other lifesaving equipment are carried in lockers, compartments, etc., these locations shall be marked accordingly.

Airplane Flight Manual

4b.740 ***General.***

(a) An Airplane Flight Manual shall be prepared by the applicant for the type certificate and shall be furnished with each airplane except with those airplanes which specifically are not required by the operating parts of the Civil Air Regulations to carry such manual.

(b) The portions of the manual listed in sections 4b.741 through 4b.743 as are appropriate to the airplane shall be verified and approved and shall be segregated, identified, and clearly distinguished from portions not so approved.

(c) Additional items of information having a direct and important bearing on safe operation shall be required when unusual design, operating, or handling characteristics so warrant.

4b.740–1 *Preparation of Airplane Flight Manuals for aircraft certificated in the transport category (CAA policies which apply to sec. 4b.740).* The primary purpose of the manual is to provide for the crew who will operate the airplane any information concerning the airplane considered by the Civil Aeronautics Administration essential to or likely to promote safety during such operation. This will ordinarily require a certain amount of descriptive material concerning those parts of the airplane directly operated or otherwise used by the crew, and understanding by them of the nature, location, and functioning of which is therefore essential. The manual should also contain, in order to serve this purpose, a description and chronological outline of the procedure to be followed by the crew during various phases of the operation both "normal" and "emergency" in which special attention and emphasis should be given to any precaution which should be observed therein in the interest of safety.

Another important purpose of the manual is to implement the operating requirements of Parts 40, 41, and 42 of this subchapter; i. e., to furnish a source for all the airplane information necessary to establish the limitations specified by those requirements as well as that necessary to enable the crew readily to operate the airplane within the limitations so established. This purpose requires the inclusion in the manual of all operating limitations peculiar to the airplane under any circumstances likely to be encountered during its life as well as information concerning each of the items of performance involved by Parts 40, 41 and 42 of this subchapter as functions of weight, altitude, outside air temperature, wind velocity, flap setting, etc., throughout the range of these variables for which it is desired by the applicant to provide; the point being that the scheduled operation of the airplane by an air carrier will be limited to values of all such variables within the range(s) covered by information available in the manual. This situation requires that the applicant consider the extent to which he wishes to limit the usefulness of the airplane subsequent to its certification as a type.

It may be noted, concerning the material to be included in the manual, that two types are involved. The first of these is the operating

limitations which are, in effect, a partial statement of the terms upon which the airworthiness certificate is issued. Compliance with these operating limitations is therefore required by law (see sec. 610 (a) of the Civil Aeronautics Act of 1938 and sec. 4b.738 (d)). The second type of material is the performance information, recommended operating procedures, and loading instructions, the observance or use of which is not legally required of the operator of the airplane by Part 4b but may be required by Parts 40, 41 and 42 of this subchapter. This second type of material is intended to convey information believed likely to promote or contribute to safety in operation.

The following outlines an acceptable arrangement of the Airplane Flight Manual. This policy does not affect the status of manuals which already have final approval. However, whenever such manuals are revised for other reasons, it is recommended that the terminology of this policy be incorporated wherever it will increase clarity and uniformity. It should be noted that not *all* the items outlined below for inclusion in the document for a given airplane, and the Civil Aeronautics Administration is desirous of holding the document to the smallest practicable amount of material as it is believed that the usefulness of the manual will bear some inverse relation to its physical bulk and to the extent of its complexity. It is, therefore, strongly recommended that great care be taken to prepare it in the simplest, most compact form consistent with the completeness and clarity of presentation of the necessary information. Also it is suggested that consideration be given to the likelihood of revisions and the manner in and ease with which this may be accomplished. Only the material (listed below) required by Part 4b should be included in the Civil Aeronautics Administration approved portion of the manual. However, if desired, the manufacturer or operator may add other data in a distinctly separate section in the same cover. The portion of the material (outlined below) that is to be approved by the Civil Aeronautics Administration must be so marked, and clearly separated from any other material so that no one could easily err in regard to the part that is approved. The aircraft specification for the type will list the manual as an item of required equipment and the manual must be made available upon request to any CAA inspector issuing an original airworthiness certificate under the type certificate in order that he may verify that the manual furnished with that individual airplane conforms with the approved manual. Since the manual is necessary for safe operation of the airplane, the manual is considered to be public information.

There is no objection to air carrier operators incorporating the subject manual in their own Operations Manual which is assigned to individual crew members in lieu of carrying two separate manuals provided the manual which is furnished by the air carrier includes a separate and properly identified chapter which contains the manufacturer's issue of the CAA Approved Airplane Flight Manual or a satisfactory reproduction identical in both form and contents. The Airplane Flight Manual or its equivalent may, in lieu of individual identification by serial or N numbers, contain a list of the airplanes to which the manual is applicable. Such manuals may be installed in the aircraft or be issued to members of the flight crew. Regardless of the procedure in effect, it is the air carrier operator's responsibility to establish a satisfactory system whereby an up-to-date copy of the appropriate manual for the particular airplane is readily available to the flight crew during the operation of the airplane. Inasmuch as the subject manual constitutes a required item of equipment, it is the responsibility of the assigned Air Carrier Maintenance Inspector to ascertain that an appropriate and up-to-date copy, or its equivalent, is available to the crew at all times during flight.

The page size for the Airplane Flight Manual will be left to the decision of the manufacturer, although it is believed that an 8″ x 10½″ size will probably be found most convenient and this size is recommended. A cover should be provided and it should indicate the nature of the contents with the following title: "Airplane Flight Manual." Each page of the approved portion should bear the notation "CAA Approved" and the date of issuance. The material should be bound in a semi-permanent fashion so that the pages will not be lost easily, yet should be so bound that revised pages can be inserted. The aircraft specification will iden-

tify the manual, and when different types of the airplane are covered in separate manuals, each will be listed. Also, the latest approved revisions will be shown on the aircraft specification when these changes are considered to be of major importance to airworthiness.

The Airplane Flight Manual should contain as much of the following as is applicable to the individual model. It is suggested that the document be divided into sections as indicated in (a) and (g). The sequence of sections and of items within sections should follow this outline insofar as practicable. This will facilitate revising the document when an airplane is altered in the field. It is recommended that revisions to the manual resulting from major alterations to the airplane be in the form of supplements to the original manual with individual log of revision pages.

(a) *Introduction.*

(1) *Title page.* This page should include the manufacturer's name, airplane model, registration or serial number, date of approval and space for the signature of the Chief, Aircraft Division. In addition the following note should be included: "This airplane must be operated in compliance with the Operating Limitations herein."

(2) *Table of contents.*

(3) *Log of revisions.* This page should be in the form of a table in which to record for each revision an identifying symbol, a date, and the page numbers involved. All revised pages should show a revision date and a vertical bar should be placed along the left-hand margin to indicate the latest revised portion of each page.

(b) *Operating limitations.* The purpose of this section is merely to state the limitations without any unnecessary explanation of what they are. The manual should point out that observance of these limitations is required by law.

(1) *Weight limits.* Indicate the range of maximum take-off and landing weight approved by means of a table or suitable diagram showing these weights at various altitudes throughout the range for which performance information is contained in the manual. State that airplane weight in excess of maximum landing weight must be disposable fuel. State any other limitations on weight. In addition to the maximum weights and any relative information, a statement to the effect that the airplane must be loaded in accordance with the approved loading schedule should be included. (See (e).) The following is a typical example:

(i) Maximum takeoff weight at sea level is 92,000 pounds.

(ii) Maximum landing weight at sea level is 73,000 pounds.

NOTE: This airplane is to be operated in accordance with the approved loading schedule. (See (e).) For maximum permissible weights at various altitudes, see subparagraph (d), Performance Information. In scheduled or irregular passenger operations, operating weights are limited in accordance with Parts 40, 41, and 42 of this subchapter.

(iii) All weight in excess of the maximum permissible landing weight must consist of disposable fuel.

(iv) All weight in excess of 68,000 pounds must consist of fuel for structural reasons.

(v) All fuel weight must be distributed equally on both sides of the airplane. All main tanks must be filled (equally) first, alternate second, and then auxiliaries. Fuel must be used in reverse order from fuel loading except for takeoff, climb and landing—at which time the main tanks should be used.

(2) *Center of gravity limits.* State all authorized c. g. limits and refer to (e) for weight and balance data. All c. g. limits should be given in inches from the datum, which should be identified and in percent of the mean aerodynamic chord, with the landing gear extended in all cases.

(3) *Powerplant.* State all powerplant limitations; i. e., manifold pressure, r. p. m., maximum time for use of takeoff power, cylinder head and barrel and oil temperatures, minimum fuel octane number, etc. Give any limitation on r. p. m. due to vibration, tip speed, etc.; also propeller pitch, cowl flap position limitations, etc. The items should be listed as follows:

(i) *Engine:*

(*a*) Manufacturer.

(*b*) Model.

(*c*) Propeller drive gear ratio.

(*d*) Fuel, minimum octane.

(*e*) Temperatures. Maximum permissible cylinder head and oil inlet.

(*f*) Power limits. Those given by the engine specification; i. e., excluding the effect of ram on critical altitude.

(*g*) Any limitations, such as r. p. m. ranges in which operation is prohibited due to engine or propeller vibration.

(ii) *Propellers.*

(*a*) Manufacturer.

(*b*) Model designation.

(iii) *Instrument markings.* An explanation of the instrument markings should be included. A typical example follows:

(*a*) *General.* Red radial line—Maximum and minimum limits. Yellow arc—Takeoff and precautionary ranges. Green arc—Normal operating ranges. Red arc—Ranges in which operation is prohibited.

(*b*) Fuel quantity indicator (When applicable—Reference sec. 4b.736). Red arc—Fuel which cannot be used safely in flight.

(4) *Speed limitations.* The speeds and explanations of their significance given in subparagraphs (i) through (vi) should be included. Section 4b.710 does specify whether airspeed limitations should be expressed in terms of calibrated or indicated airspeed. However, to agree with past practice it is suggested that the airspeed values be expressed in terms of calibrated airspeed. The indicated airspeed values may also be included, but should be properly identified, e. g. by parentheses.

(i) *Never exceed speed.* V_{NE} (previously known as "glide or dive speed") with and without de-icer boots, if applicable plus a statement to the effect that speeds in excess of this value may result in structural, flutter, or control hazards. The effects of altitude (i. e., Mach number) on this speed should be given if applicable unless the air plane is equipped with a Machmeter, in which case the "never-exceed" Mach number should also be quoted.

(ii) *Normal operating limit speed.* V_{NO} (previously known as "level flight or climb speed" or "maximum structural cruising speed"), with and without de-icer boots if applicable, plus statements to the effect that: Speeds in excess of this value may result in excessive gust loads, whereas speeds below this value will reduce the structural loads produced by severe gusts. (The "manuevering speed" is generally considered the optimum speed to avoid excessive loads as well as inadvertent stalling or loss of control in turbulent air.) The speed V_{NO} should not be deliberately exceeded, even during descents because of the possibility of unexpected gusts. The speed range between V_{NO} and V_{NE} is to provide for inadvertent speed increases. When this speed is reduced at altitude because of Mach number effects, the purpose of such reduction is to maintain the margin between V_{NO} and V_{NE} for inadvertent speed increases.

(iii) *Maneuvering Speed.* V_A, plus a statement of its significance, of which the following is an example: "Maximum use" of the primary flight controls should be confined to speeds below this value. For this purpose, "Maximum use" is defined as the lesser of the following: Rudder—full throw, or ——— pounds force. Elevator—full throw, or ——— pounds force. Aileron—full throw, or ——— pounds force with each hand.

(iv) *Flaps extended speed.* At least the V_{FE} speed determined in accordance with section 4b.714 must be given. However, when desired, speeds for various combinations of flap settings and power conditions may be given, the following is an example:

Flap setting	*Maximum speed (m. p. h.)*	*Maximum power*
Takeoff		Takeoff
Approach		Continuous
		Takeoff
Landing		Idling
		Takeoff

(A note should be added to indicate which of the values is to be marked on the airspeed indicator.)

(v) *Landing gear operating speed.* V_{LO}, plus a statement that this is the maximum speed at which the landing gear may be lowered or raised.

(vi) *Landing gear extended speed.* V_{LE}, plus a statement that this is the maximum speed with landing gear extended and locked.

(vii) *Compressibility effects.* When a speed limitation (e. g., never exceed speed) results from compressibility effects, the manual should include a statement to this effect and information concerning warning symptoms, probable behavior of the airplane and suggested recovery procedure.

(viii) *Airspeed indicator markings.* An explanation of the airspeed indicator markings

should be included. A typical example follows: "AIRSPEED INDICATOR MARKINGS (see definitions of speeds in sub-paragraphs (i) through (vi)). Red radial line—never exceed speed, V_{NE}. Yellow arc—caution range, extending from V_{NO} to V_{NE}. White arc—flaps extended range, extending from stalling speed (V_{S_0}) with flaps in landing position at maximum landing weight to the flaps extended speed (sec. 4b.714). Green arc—normal operating range; i. e., from stalling speed with flaps retracted at maximum takeoff weight to V_{NO}."

(5) *Demonstrated crosswind.* The statement on this item should indicate the maximum cross component of wind velocity at which it has been demonstrated to be safe to take off or land. If the value established during the tests is considered the maximum up to which it is considered safe to operate the airplane on the ground, including takeoffs and landings, it should be entered under this item; i. e., as a limitation. However, if the value established is not considered limiting it should be included as Performance Information, as outlined in (d), instead of a limitation. In the case of flying boats an additional maximum cross component of wind velocity for taxiing may be appropriate material. Crosswind should be based on reported wind velocities measured at 50 feet above the ground.

(6) *Flight load acceleration limits.* Flaps up ———— (at takeoff weight). Flaps down ———— (at landing weight).

(7) *Type of airplane operation.* A typical example would be as follows:

(i) Transport category.

(ii) Instrument night flying (when required equipment is installed).

(iii) Atmospheric icing conditions—should stipulate "none, trace, light, moderate or heavy."

(8) *Minimum crew.* Information should be given in this item for all operations specified under (7) above and any additional conditions if desired or considered pertinent. The number and identity of members of minimum crew necessary to safe operation should be stated.

(9) *Miscellaneous.* This item should include any information not given under the preceding headings that is restrictive and considered necessary for the safe operation of the airplane. Some typical examples are as follows:

(i) The wing and tail anti-icing heaters should not be operated in flight when the outside air temerature is above 50° F.

(ii) Pressurized cabin differential pressure limits, etc.

(iii) A notation should be included to warn flight personnel against jettisoning fuel while the flaps are lowered unless it has been demonstrated that flap position does not adversely affect fuel jettisoning. (See sec. 4b.437 (b).)

(iv) Propeller reversing to be used for taxiing only.

(c) *Operating procedures—general.* This section of the manual should contain information peculiar to the airplane, concerning normal and emergency procedures, knowledge of which might enhance the safety of operation of the airplane. The manual should state that these procedures are not made mandatory by Part 4b. However, they may be made mandatory by other parts of the regulations such as Parts 40, 41, 42, etc., of this subchapter.

(1) *Normal procedures.* This section should contain information and instructions regarding peculiarities of: Starting and warming engines, taxiing, operation of wing flaps, landing gear, automatic pilot, etc. Outline normal procedures for each, noting any special precautions in the interests of safety. Describe or refer to procedure in any emergency likely to occur in each. Also included in this section should be instructions for the operation of any equipment that is considered new in the aeronautical field or comparatively complicated.

(i) A typical example of the former would be: "Wing flaps should be exercised through three complete cycles prior to all initial takeoffs. This operation accomplishes the automatic bleeding and the equalization of pressure to the eight separate hydraulic flap actuating cylinders."

(ii) Typical examples of the latter are: "Recommended operating procedures for thermal ice prevention system, recommended operating procedures for reversible pitch propellers, and cabin pressurization."

(2) *Emergency procedures.*

(i) *Engine failure.* This section should include the procedure to be used in the event of an engine failure, including recommended minimum speeds, trim, operation of remaining engine(s), etc. A typical example would be as follows: "ENGINE FAILURE ON TAKE-OFF. The minimum speed (V_1) at which the airplane can be controlled directionally on the runway with an outboard engine inoperative and its propeller windmilling, and with takeoff power on the remaining engines, is 60 m. p. h. CAS. The minimum speed at which the airplane is controllable in flight with the sudden failure of an outboard engine, with take-off power on the remaining engines, is 96 m. p. h. TIAS. If an engine fails during the ground roll below speed V_1, cut the throttles on all engines and apply brakes. If ground contact has already been broken, land straight ahead if sufficient runway remains. If not, retract landing gear, maintain full power on live engines, and continue takeoff. Feather the dead engine as outlined in item (2) below. Use minimum cowl flap setting on live engines to maintain cylinder temperatures within limits. Retrim airplane as necessary. Speed for best climb under these conditions is 115 m. p. h. CAS. See subparagraph (d) Performance Information, for criterion and V_1 speeds used in determining the runway lengths."

(ii) *Propeller feathering.* This section of the manual should outline the procedure to be followed in stopping the rotation of propellers in flight. A typical procedure is outlined below:

(*a*) Throttle—"CLOSED."

(*b*) Push feathering switch button. When propeller blades are fully feathered the button will kick out automatically.

(*c*) Mixture control—"IDLE CUT-OFF."

(*d*) Fuel and oil fire wall shut-off switches—"OFF" (closed).

(*e*) Cowl flaps—"CLOSED."

(*f*) Fuel booster pump—"OFF."

(*g*) Tank selector for engine being feathered—"OFF". (Do not shut tank selector "OFF" if crossfeed is being used.)

(*h*) Ignition for dead engine—"OFF."

(*i*) Propeller pitch control—"FULL DECREASE RPM."

(iii) *Automatic propeller feathering.*

(iv) *Unusual procedures.* Information on any emergency procedures that are considered unusual or in which a specific sequence of events are required to accomplish the operation satisfactorily should be specified. Some typical examples are as follows:

(*a*) All-engine go-around when it is recommended practice to retract the flap prior to retracting the gear resulting from a design condition in which the flap creates more drag than the landing gear.

(*b*) Fire control procedures.

(*c*) Emergency cabin depressurization.

(*d*) Emergency landing gear extension.

(*e*) Emergency brake operation.

(*f*) Fuel dumping.

(*g*) *Electrical.* In addition to other electrical items, the manual should specify the circuits in which overriding breakers, if any, are used and contain instructions concerning operation of both overriding and non-overriding types. The following is a typical example: "All circuit breakers are of the non-overriding type except the fuel booster pumps and propeller feathering circuits. In an emergency, the breakers in these two circuits may be held closed with the possible risk of fire hazard due to short circuits, etc. Discretion should also be used in repeatedly resetting non-overriding breakers due to the fact that resetting may reestablish an arc and increase the fire hazard."

(*h*) Emergency by day and/or night.

(*i*) Flare release procedure.

(*j*) Wheels up landing procedure.

(*k*) Ditching procedure.

(3) *Other special operating procedures (if any).*

(4) *Alternate operating procedures.* After gaining a large amount of experience with a particular model airplane, some operators may develop various operating procedures that they consider equivalent or better than some of those originally described in the manual. If an operator wants to incorporate new procedures in the Airplane Flight Manual, the operator should apply to the CAA office in the region where he is located for approval of the alternate procedures in the same manner that he would normally use in the case of a structural change or alteration. The local CAA regional office will

coordinate the application with the CAA regional office containing the airplane technical data file if the proposed change in procedure is considered to be of sufficient importance.

(i) *For scheduled air carrier operators only.* For greater flexibility and to avoid duplication of instructions to pilots when operators desire to incorporate Airplane Flight Manual Operating Procedures in their operations manuals or devise their own operating procedures, the CAA will permit the removal of the Operating Procedures Section from the Airplane Flight Manual by scheduled air carrier operators provided the operators include the same or equivalent material in their operations manual and at the same time assume full responsibility of proving the equivalency of any new or altered procedures if called upon to do so by the CAA in connection with airplane accident investigations, etc. When the Operating Procedures Section is removed from the Airplane Flight Manual by an operator, an appropriate notation to this effect should be added to the Airplane Flight Manual of each airplane affected.

In accordance with the foregoing, the following statement should be included under the Operating Procedures Section of the Airplane Flight Manual when the Operating Procedure Section is transferred verbatim from the Airplane Flight Manual to the air carrier operations manual:

"The airplane operating procedures prescribed by section 4b.742 'Operating Procedures' are included in _____
(Show reference to appropriate section of the air carrier operations manual)

If an air carrier operator desires to reword or restate the CAA approved operating procedures or establish new or alternate operating procedures without obtaining prior approval of these procedures from the CAA, the following additional statement should be included with the above statement:

"Where the procedures in the air carrier operations manual differ from those contained in the CAA Approved Airplane Flight Manual for this airplane, _____
(Name of air carrier operator)
has determined that equivalent safety is provided by such alternate procedures and assumes full responsibility for this determination."

If for any reason the alternate operating procedures become inapplicable or inappropriate to the operation of the airplanes affected, the original CAA Approved Operating Procedures Section should be reinserted in the Airplane Flight Manual in order that the contents of the manual will revert to the same text as originally approved by the CAA.

(d) *Performance information.* This section should contain all the performance information necessary to implement the operating requirements of Part 40 of this subchapter, and to operate the airplane safely.

(1) *Introductory information.* This should include any general information or any pertinent descriptions of the conditions under which the performance data were determined. The following examples are considered typical and appropriate:

(i) All climb data are for standard atmospheric conditions.

(ii) The minimum effective takeoff runway lengths given in this section are defined as the longer "accelerate-stop distance" and the distance required to takeoff and clear a 50-foot obstacle with one engine becoming inoperative at speed V_1.

(*a*) The accelerate-stop distance is the distance required to accelerate the airplane from a standing start to the speed V_1, and assuming an engine to fail at this point, to stop.

(*b*) The takeoff distance is defined as the sum of the following: Distance to accelerate to speed V_1 with all engines operating, distance to accelerate from speed V_1 to speed V_2 with one engine inoperative and propeller windmilling in low pitch (it is assumed that gear retraction is initiated at the end of this segment), and the horizontal distance traveled in climbing to a height of 50 feet at speed V_2 with one engine inoperative. (It is assumed that propeller feathering is not commenced prior to the end of this segment.)

(*c*) Speed V_1 is defined as the critical engine failure speed and is a speed at which the controllability has been demonstrated to be adequate to permit proceeding safely with the takeoff when the critical engine is suddenly made inoperative. The minimum V_1 speed for

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this airplane is 60 m. p. h. CAS (airspeed calibration should include ground effect), however, as explained below, speeds in excess of this value were used in determining the runway lengths.

(*d*) Speed V_2 is defined as the minimum takeoff climb speed and is the greater of the following: 1.15 times the power-off-stalling speed with the flaps in the takeoff position (assuming a four-engine airplane). 1.10 times the minimum control speed, V_{MC}.

(*e*) The minimum control speed, V_{MC}, is defined as the minimum speed at which the airplane is controllable in flight with the sudden failure of an outboard engine with takeoff power on the remaining engines.

(*f*) All runway lengths given in this manual are based upon optimum V_1 speeds; i. e., the speed selected for V_1 is such that the accelerate-stop distance is equal to the distance to clear a fifty foot obstacle with one engine becoming inoperative at this speed. Consequently, V_1 varies with weight, altitude, wind, gradient, temperature, etc. Values for V_1 for the various conditions are given under (2) below.

(*g*) All takeoff and landing distances are given for dry, concrete runways.

(*h*) If the maximum cross component of wind velocity in which landings and takeoffs were demonstrated was not considered limiting, it should be included in this section of the manual. A typical example would be as follows: "The maximum crosswind component in which this airplane has been tested is 20 m. p. h. measured at a height of 50 feet above the ground. Consequently, in determining the effective takeoff and landing runway lengths, a crosswind component greater than this value may not be used."

(2) *Performance data.* These data may be given in either graphical or tabular form and should cover the weight range and all airport and terrain altitudes at which the airplane is intended to be operated. The scale of the charts should permit accurate reading within approximately 0.25 of one percent. The following should be included:

(i) *Airspeed calibration.* This should be given for the normal and alternate static sources. Ground effect should be included for V_1 speed range. (A plot of CAS vs. IAS at various flap positions, preferably on one page.)

(ii) *Altimeter calibration.* This should be given for the normal and alternate static source.

(iii) *Stalling speeds.* A table or diagram of calibrated stalling speeds at various weights at all authorized flap settings, power-off should be given.

(iv) *Gross weight summary.* A summary of permissible operating landing and takeoff gross weights as limited by the climb or structural requirements should be provided.

(v) *Minimum takeoff runway length.* Unless optimum values of V_1 are selected, establishing equal distances to accelerate to speed V_1 and stop or to make a takeoff over a 50-foot obstacle with the critical engine becoming inoperative at speed V_1, inclusion of both the accelerate-stop distance and runway length required to takeoff and clear a 50-foot obstacle will be necessary. It is recommended that these data be given for a range of temperatures (see sec. 4b.117) and runway gradients sufficient to permit proper dispatching under the rules of Part 40 of this subchapter, etc., in addition to the standard day temperature data.

(vi) *Takeoff information.* Takeoff flight paths through the final climb segment, flight path slope or data supplementary to that obtained in subparagraph (v) that may be used for dispatching purposes should be included. These should be for the same range of temperatures (see sec. 4b.117) and runway gradients as (v).

(vii) *Minimum takeoff climb speed,* V_2. This speed should be listed for the range of weights, altitudes and conditions covered in subparagraphs (v) and (vi). The distance to accelerate to these speeds should also be included to provide data necessary for gradient problems involving runways with variable gradients of sufficient magnitude that average gradients cannot be assumed.

(viii) *Critical engine failure speed,* V_1. This speed or speeds V_1 for the range of weights, altitudes and conditions covered in subparagraphs (v) and (vi) if applicable should be given. The distances to accelerate to these speeds should also be included to provide data necessary for gradient problems involving runways with variable gradients of sufficient magnitude that average gradients cannot be assumed.

(ix) *Minimum runway length required for landing.* With respect to this item, the following data would be considered appropriate: Landing distance from height of 50 feet. Minimum effective landing runway length—scheduled stops. (See Part 40 of this subchapter.) Minimum effective landing runway length—alternate stops. (See Part 40 of this subchapter.)

(x) *Wind effect in landing and takeoff.* If it is desired to take advantage of wind in determining landing and takeoff distances all data should be based upon wind velocities reported at a height of 50 feet above the runway; i. e., the runway length would be calculated for one half of the reported headwind velocity, or one and one-half times the reported tailwind velocity, measured at a height of 50 feet corrected for wind gradient to the height of the center of aerodynamic drag of the airplane. A note clearly stating the above stipulations should be included in the manual.

(xi) *Rates of climb and climbing speeds.* These rates and speeds should be specified for the desired range of weights and altitudes, together with the corresponding airplane configuration (flap position, gear position, etc.), and should be given for the following when applicable:

(*a*) First segment takeoff climb (sec. 4b.120 (a)).

(*b*) Second segment takeoff climb (sec. 4b.120 (b)).

(*c*) Third segment takeoff climb (sec. 4b.116 (d)).

(*d*) Final segment takeoff climb (sec. 4b.116 (e)).

(*e*) One-engine inoperative en route climb (sec. 4b.120 (c)).

(*f*) All engine en route climb (sec. 4b.119 (a)).

(*g*) Two-engine inoperative en route climb (sec. 4b.121).

(*h*) Approach climb (sec. 4b.120 (d)).

(*i*) Landing climb (sec. 4b.119 (b)).

(xii) *Engine power curve.* A copy of the CAA approved power chart of BHP vs. MP at RPM and BHP vs. altitude at RPM and at MP should be included.

(xiii) *Performance charts.* Any instructions or examples for use of the performance charts should be included.

(xiv) *Removal of performance data.* The Performance Section of the Airplane Flight Manual should not be removed from the Airplane Flight Manual. However, any tables, charts, etc., that an air carrier operator prepares which are based on airplane flight manual performance material for convenience in determination of load limitation data need not be carried in the Airplane Flight Manual even though approved by the CAA if the operator does not care to do so.

(e) *Weight and balance data.*

(1) *General.* Inasmuch as it is desired to eliminate the necessity of submitting revisions of the Airplane Flight Manual to the CAA for approval whenever an item of equipment is altered or added, this section of the manual will not be included in the formally "approved" portion of the document. However, a note to the effect that the airplane should be operated in accordance with the approved loading schedule should be included in the Limitations section. (See (b) (1).)

(2) *Responsibility for control of weight and balance.* It is the intention of the Civil Aeronautics Administration to place the responsibility for the control of weight and balance with the manufacturer and operator. The manufacturer will furnish a weight and balance report for each new airplane which may be included in the manual but not in the "approved" portion. The Civil Aeronautics Administration's representative will not approve each individual report but will make only occasional spot checks to ascertain that the manufacturer's weight control procedure is adequate. The manufacturer will be expected to furnish complete information with the airplane not only regarding its actual weight and balance, but also to include sketches, samples and other data that will assist the operator in checking the balance after alterations.

(3) *Conventional airplanes.* The following material is believed to be complete and adequate for a conventional airplane.

(i) *Weight limits.* A list and explanation (where necessary) of the various weight limits should be given.

(ii) *C. G. limits.* The approved operating c. g. range should be specified.

(iii) *Empty weight and empty weight c. g. location.*

(iv) *Equipment list.* All equipment included in the empty weight should be listed.

(v) *Weight computations.* The computations necessary to determine the empty weight c. g. location, including identification of balance datum should be shown.

(vi) *Loading schedule.*

(vii) *Loading schedule instructions.* Complete instructions in the use of the loading schedule should be provided.

(4) *Unconventional airplanes.* In the case of unconventional airplanes or airplanes with special features, the information specified in subparagraph (3) should be modified or amplified as necessary to cover the case.

(f) *Supplements.* As a general rule, when major alterations are made by an operator (or owner) to an airplane involving appreciable changes to the Airplane Flight Manual it is advisable for the operator to prepare a separate supplement to the original manual under his own name covering the items that are different from the original manual. Then subsequent revisions to the manual by the manufacturer or operator will pertain only to their respective portions of the manual and should eliminate possible confusion.

(g) *Submittal.* Three copies of the above material, less the Weight and Balance Data Section, should be submitted to the appropriate Civil Aeronautics Administration regional office by the applicant for an original approval. The three copies will be signed by the regional Chief, Aircraft Division; one copy will be returned to the applicant, one will be forwarded to the Washington office and the other retained by the regional office. A single copy of the title page to be used for Chief's signature may be substituted for the applicant's copy if desired. In cases where the revisions to the manual are of primary importance to safety in flight, the pertinent Aircraft Specification will contain a description of the change to ensure that all manuals are revised. A revision of this type would usually be the subject of an Airworthiness Directive note. One copy of the Weight and Balance Section should be included in the manual by the applicant for each airplane at the time of certification.

(16 F. R. 1052, Feb. 6, 1951, effective Feb. 6, 1951, amended 19 F. R. 4446, July 20, 1954, effective Sept. 1, 1954.)

4b.740–2 *Reverse thrust operating limitations and procedures (CAA policies which apply to sec. 4b.740).* The policies outlined in section 4b.402–1 (b) will apply.

(20 F. R. 2281, Apr. 8, 1956, effective Apr. 30 1956.)

4b.741 *Operating limitations.*

(a) *Air-speed limitations.* The following air-speed limitations shall be included together with sufficient information to permit marking the air-speed indicator in accordance with section 4b.732;

(1) The never-exceed speed (see sec. 4b.711);

(2) The normal operating limit speed (see sec. 4b.712), together with a statement to the effect that normal flight operations should be confined to speeds below this value, and a further statement to the effect that the range of speeds between the normal operating limit speed and the never-exceed speed should be entered with caution and with due regard to the prevailing flight and atmospheric conditions;

(3) When an air-speed limitation is based upon compressibility effects, a statement to this effect, together with information as to any symptoms, the probable behavior of the airplane, and the recommended recovery procedures;

(4) The maneuvering speed (see sec. 4b.210 (b) (2)), together with a statement to the effect that full application of rudder and aileron controls as well as those maneuvers which involve angles of attack near the stall should be confined to speeds below this value;

(5) The flap extended speed (see sec. 4b.714), together with a description of the pertinent flap positions and engine powers;

(6) The landing gear operating speed (see sec. 4b.715), together with a statement to the effect that this is the maximum speed at which it is safe to extend or retract the landing gear;

(7) The landing gear extended speed (see sec. 4b.716), if greater than the landing gear operating speed, together with a statement to the effect that this is the maximum speed at

which the airplane can be flown safely with the landing gear in the extended position.

(b) *Powerplant limitations.* Information shall be included to outline and to explain all powerplant limitations (see sec. 4b.718) and to permit marking the instruments as required by sections 4b.734 through 4b.736.

(c) *Weight and loading distribution.* The airplane weights and center of gravity limits required by sections 4b.101 and 4b.102 shall be included, together with the items of equipment on which the empty weight is based. Where the variety of possible loading conditions warrants, instructions shall be included to facilitate observance of the limitations.

(d) *Flight load acceleration limits.* The positive maneuvering limit load factors for which the airplane structure has been proven shall be described in terms of accelerations, together with a statement to the effect that these accelerations limit the angle of bank in turns and limit the severity of pull-up maneuvers.

(e) *Flight crew.* The number and functions of the minimum flight crew determined in accordance with section 4b.720 shall be described.

(f) *Type of operation.* The type(s) of operating(s) shall be listed for which the airplane and its equipment installations have been approved. (See sec. 4b.721.)

(g) *Maximum operating altitude.* The altitude established in accordance with section 4b.722 shall be included, together with an explanation of the limiting factors.

4b.742 *Operating procedures.*

(a) *Normal.* Information and instructions shall be included regarding peculiarities of starting and warming the engines, taxiing, operation of wing flaps, landing gear, automatic pilot, etc.

(b) *One engine inoperative.* The recommended procedure shall be described to be followed in the event of engine failure, including minimum speeds, trim, operation of remaining engine(s), operation of flaps, etc.

(c) *Propeller feathering.* The recommended procedure shall be described to be followed in stopping the rotation of propellers in flight.

(d) *Emergency procedures.* Recommended emergency procedures shall be described to be followed in the event of fire, decompression, ditching, etc.

4b.743 *Performance information.*

(a) *Performance data.* A summary of all pertinent performance data shall be given, including the performance data necessary for the application of the operating rules of this subchapter, together with descriptions of the conditions, air speeds, etc., under which these data were determined.

(b) *Flap controls.* Instructions shall be included describing the use and adjustment of the flap controls necessary to obtain the performance referred to in paragraph (a) of this section.

(c) *Air speeds.* The indicated air speeds corresponding with those determined for take-off shall be listed together with the procedures to be followed in the event the critical engine becomes inoperative during take-off (see sec. 4b.742 (b)).

(d) *Miscellaneous.* An explanation shall be included of any significant or unusual flight or ground handling characteristics.

Airplane Identification Data

4b.750 *Identification plate.* A fireproof identification plate shall be securely attached to the structure in an accessible location where it will not likely be defaced during normal service. The identification plate shall not be placed in a location where it might be expected to be destroyed or lost in the event of an accident. The identification plate shall contain the identification data required by section 1.50 of this subchapter.

4b.751 *Identification marks.* The nationality and registration marks shall be permanently affixed in accordance with section 1.100 of this subchapter.

Summary of Appendices

APPENDIX A contains figures 1 through 9 which pertain to Civil Aeronautics Manual material. The figures pertaining to the Civil Air Regulations are included in that text.

APPENDIX B contains a list of the tests normally required to show compliance with the regulations (see sec. 4b.16–2 (a) (2)). The tests are divided into the following four groups: (1) Performance; (2) Flying qualities; (3) Powerplant tests, and (4) Functional and miscellaneous tests. Each item is referenced to its appropriate regulation. These regulations are given in numerical order in the text along with policy material and testing procedure for demonstrating compliance with the subject requirement.

APPENDIX C is a sample of typical flight test programs that would be necessary to substantiate changes in the airplane configuration, such as change in propeller, engine power, aerodynamic drag, etc. Obviously, a hard and fast rule cannot be set up to handle every case, and the required test program will vary depending upon the conditions surrounding each case as well as a consideration of any marginal conditions existing in the original design (see sec. 4b.16–2 (a) (5)).

APPENDIX D presents a general order of testing that has been found convenient from past experience in flight testing. This is presented only as a general guide (see sec. 4b.16–2 (b)).

APPENDIX E has been prepared to facilitate the development of a flight test schedule, by grouping the individual tests according to weight and center-of-gravity location (see sec. 4b.16–2 (c) (1)).

APPENDIX F contains a list of only those tests requiring special instrumentation and a description of pertinent instrument(s) (see sec. 4b.16–2 (c) (2)).

APPENDIX G contains special Civil Air Regulations pertinent to Part 4b.

Abbreviations Used in Appendices

Alt.—Altitude
Appr.—Approach
App.—Appropriate
C. G.—Center of Gravity
Crit.—Critical
Eng.—Engine
Ext.—Extended
Feath.—Feathered
F.T.—Full Throttle
Fwd.—Forward
Inop.—Inoperative
Land.—Landing
Long.—Longitudinal
Max. Cont.—Maximum Continuous
M. P.—Manifold Pressure
M. P. H.—Miles per Hour
O. A. T.—Outside Air Temperatures
Oper.—Operating
Opt.—Optional
Prop.—Propeller
R/C—Rate of Climb
Req'd.—Required
Retr.—Retracted
Stab.—Stability
Stat.—Static
Temp.—Temperature
Thrott.—Throttle
T. O.—Takeoff
Wt.—Weight

Appendix A

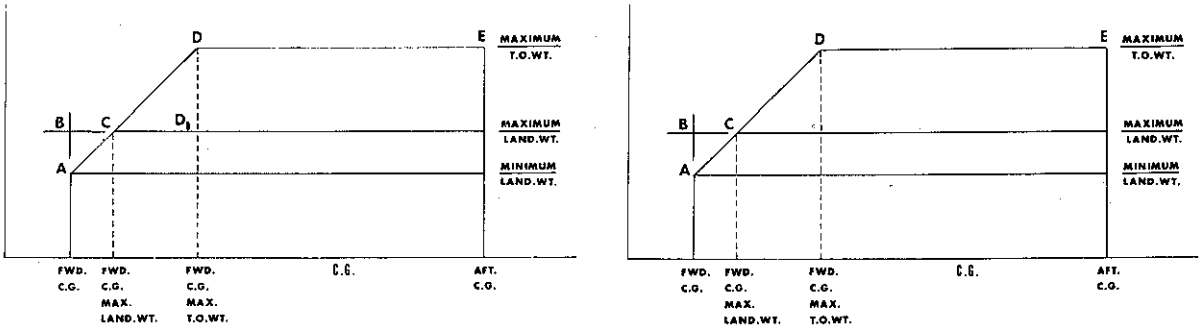


Figure 1.—Weight—c. g. positions.

Case A.—This case may be used when it is possible to conduct stalling speed tests at the c. g.-weight combinations in options (1) or (2) below provided the test weights are within the tolerance limits of 4b.100–1 (b) (2) for both maximum takeoff and minimum landing weights. In this case, stalling speeds for all flap positions may be calculated for the performance weight range from the stall test data at these weights.

OPTION (1)—*For climb requirements based on stalling speed at most forward c. g. position.*

(*a*) Tests may be conducted at c. g.-weight combination only, that is, point "B".

(*b*) In lieu of (*a*) tests should be conducted at c. g.-weight combination points "A" and "C".

OPTION (2)—*For climb requirements based on stalling speed varying with c. g. position.*

(*a*) Tests should be conducted at c. g.-weight combination points "A", "C", and "D", in order to adequately establish the variation of stalling speed with c. g. position.

Case B.—This case should be used when the test weights shown in Case A do not fall within the tolerance limits of 4b.100–1 (b) (2) for both maximum takeoff and minimum landing weights. In this case stalling speeds for the retracted, en route, and takeoff flap should be calculated for the entire performance weight range from the stall test data of the highest weight tested, and stalling speeds for the approach flap should be calculated for the entire performance weight range from stall test data at the lower weights tested. Stalling speeds for the landing flap should be calculated for the entire performance weight range from stall test data at both weights. *Note.*—Both weights are necessary in this latter case since the en route climb requirement is based on stall speed for the landing flap setting and appropriate weight.

OPTION (1)—*For climb requirements based on stalling speed at most forward c. g. position.*

(*a*) Tests may be conducted at two c. g.-weight combinations, that is, points "B" and "D".

(*b*) In lieu of (*a*) tests should be conducted at c. g.-weight combination points "A", "C", and "D".

OPTION (2)—*For climb requirements based on stalling speed varying with c. g. position.*

(*a*) Tests should be conducted at three or more equally spaced c. g.-weight combinations between points "A" and "D" in order to adequately establish the variation of stalling speed with c. g. position.

(22 F. R. 5792, July 20, 1957, effective Aug. 15, 1957.)

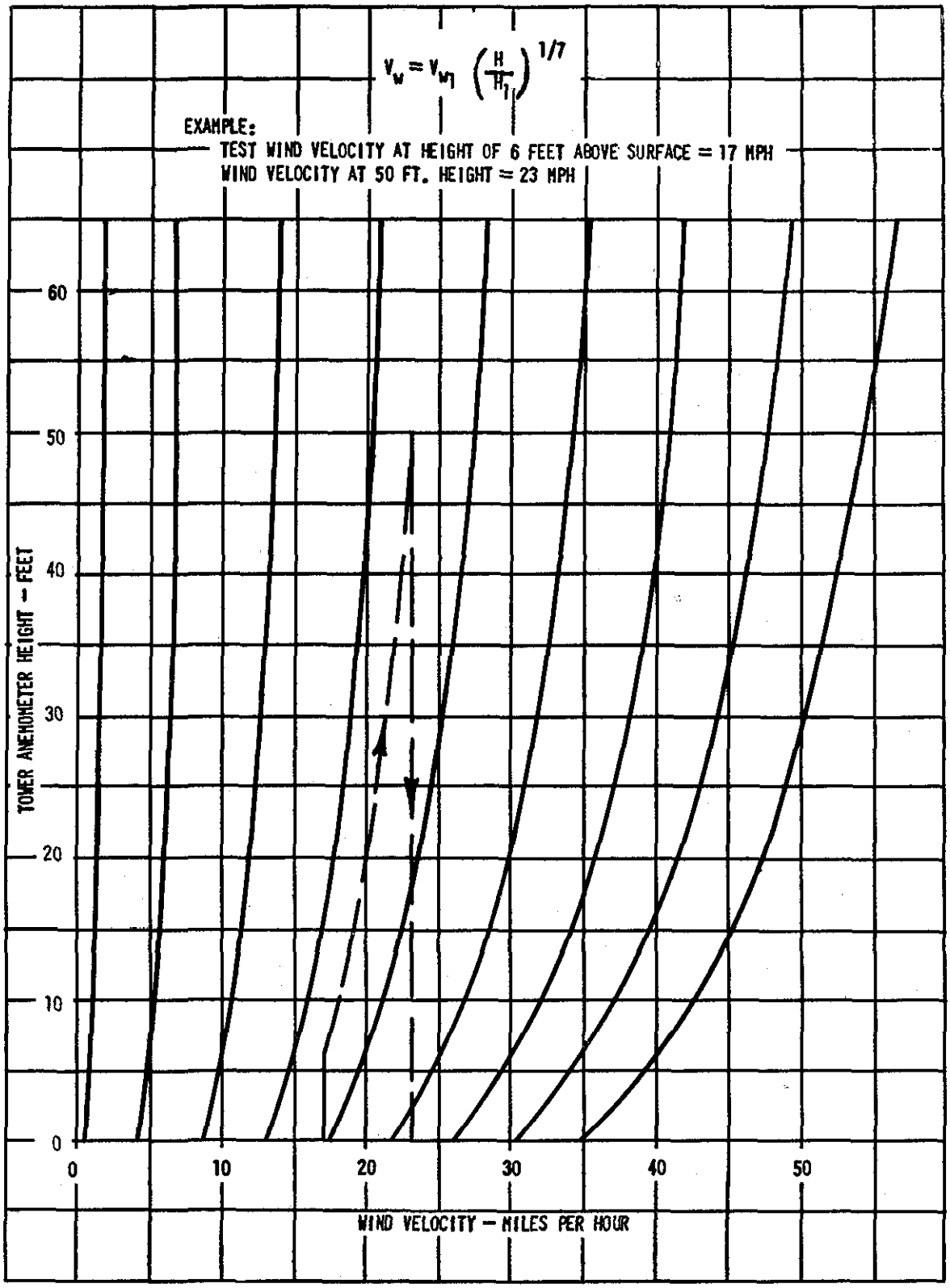


Figure 2.—Wind gradient correction.

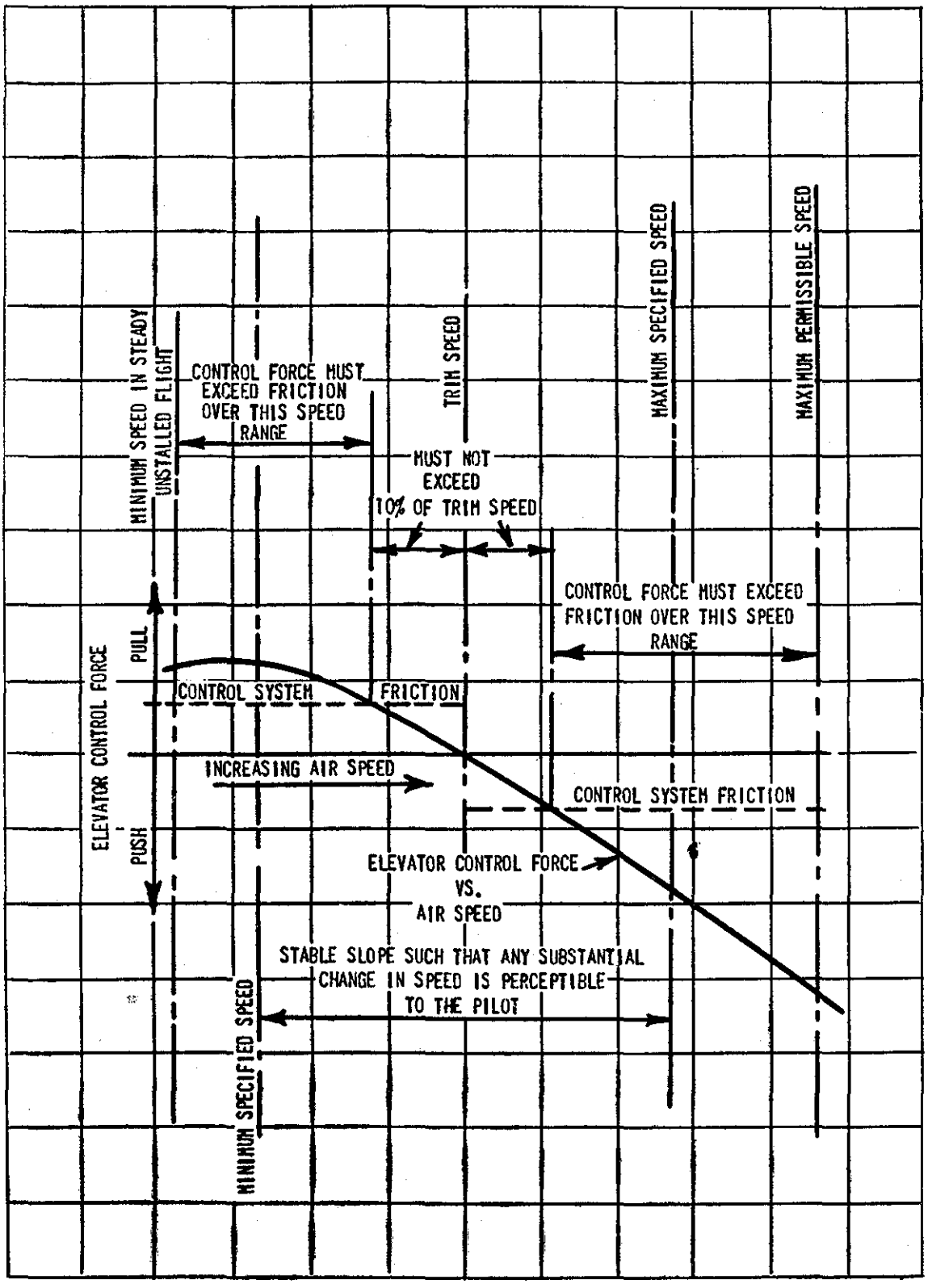


Figure 3.—Static longitudinal stability requirements.

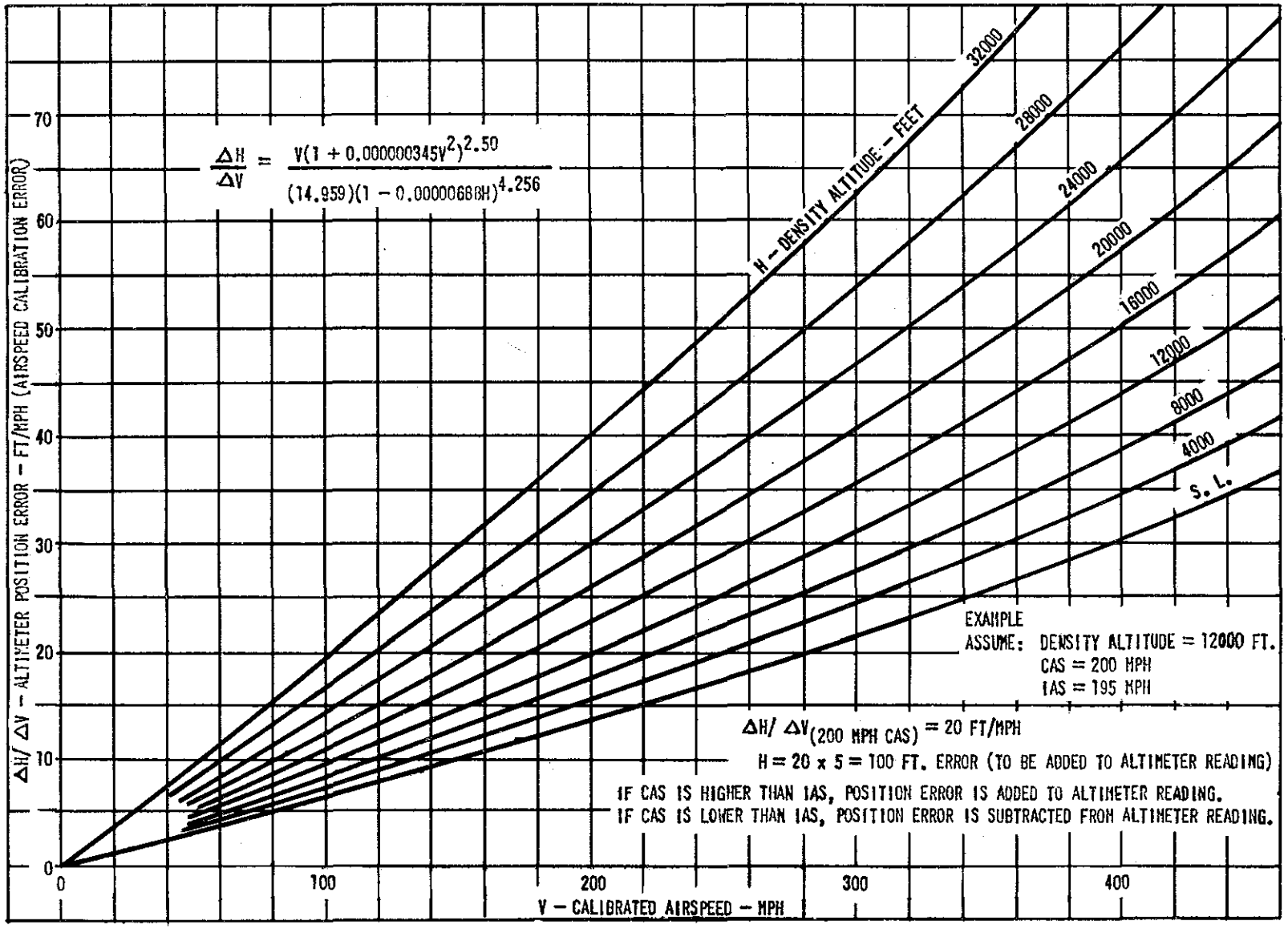


Figure 4.—Altimeter position error.

(22 F.R. 5793, July 20, 1957 effective Aug. 15, 1957.)

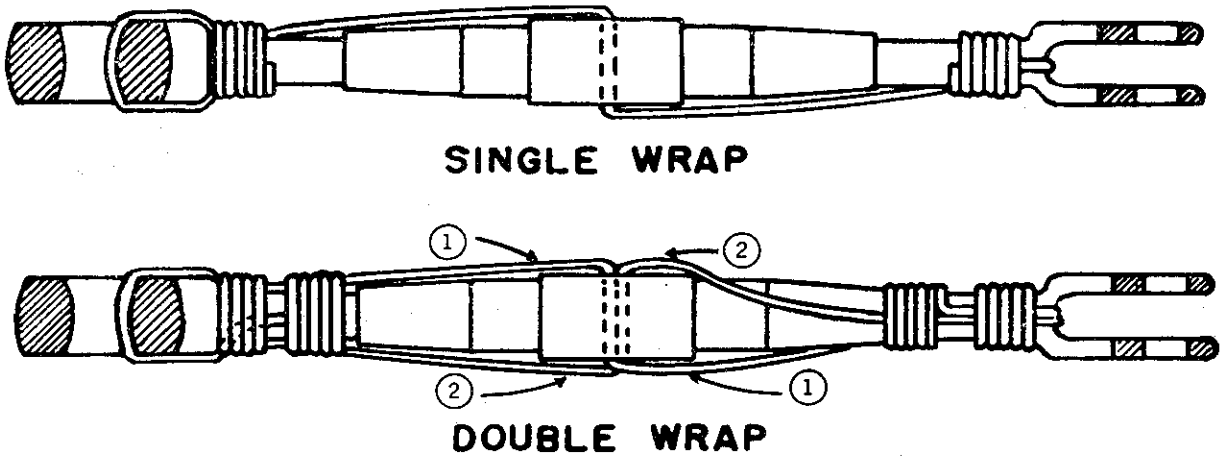
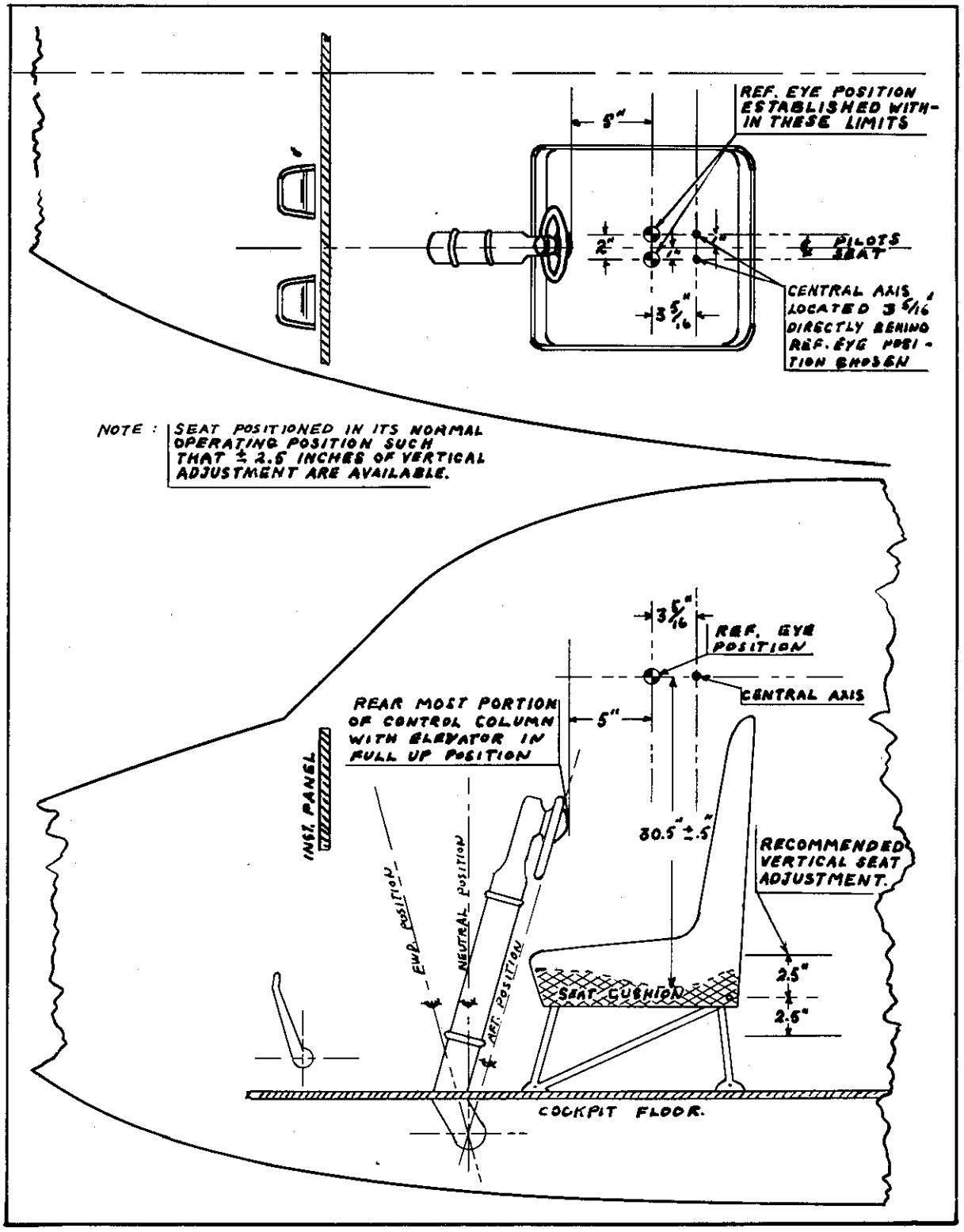
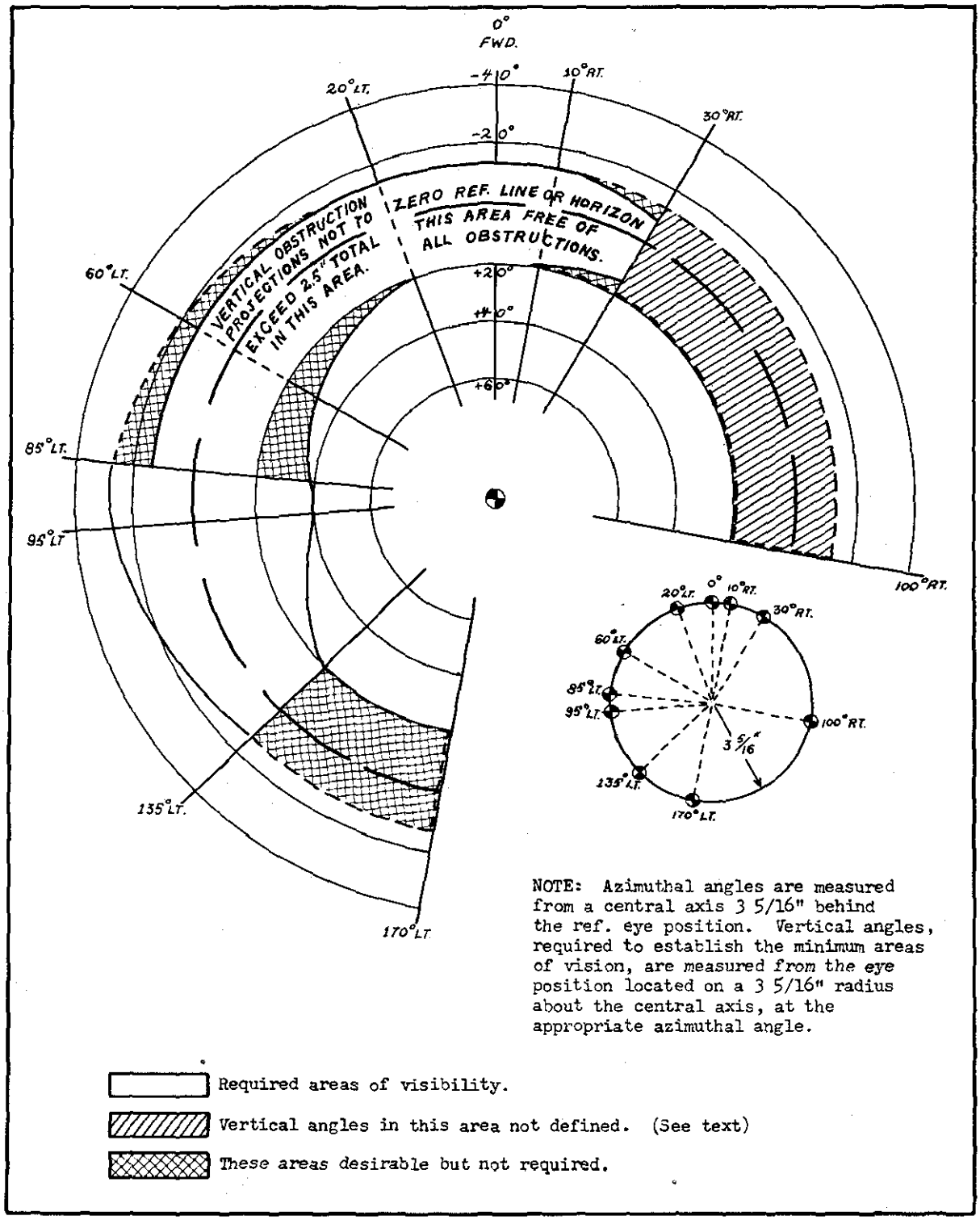


Figure 5.—Turnbuckle safety wiring.

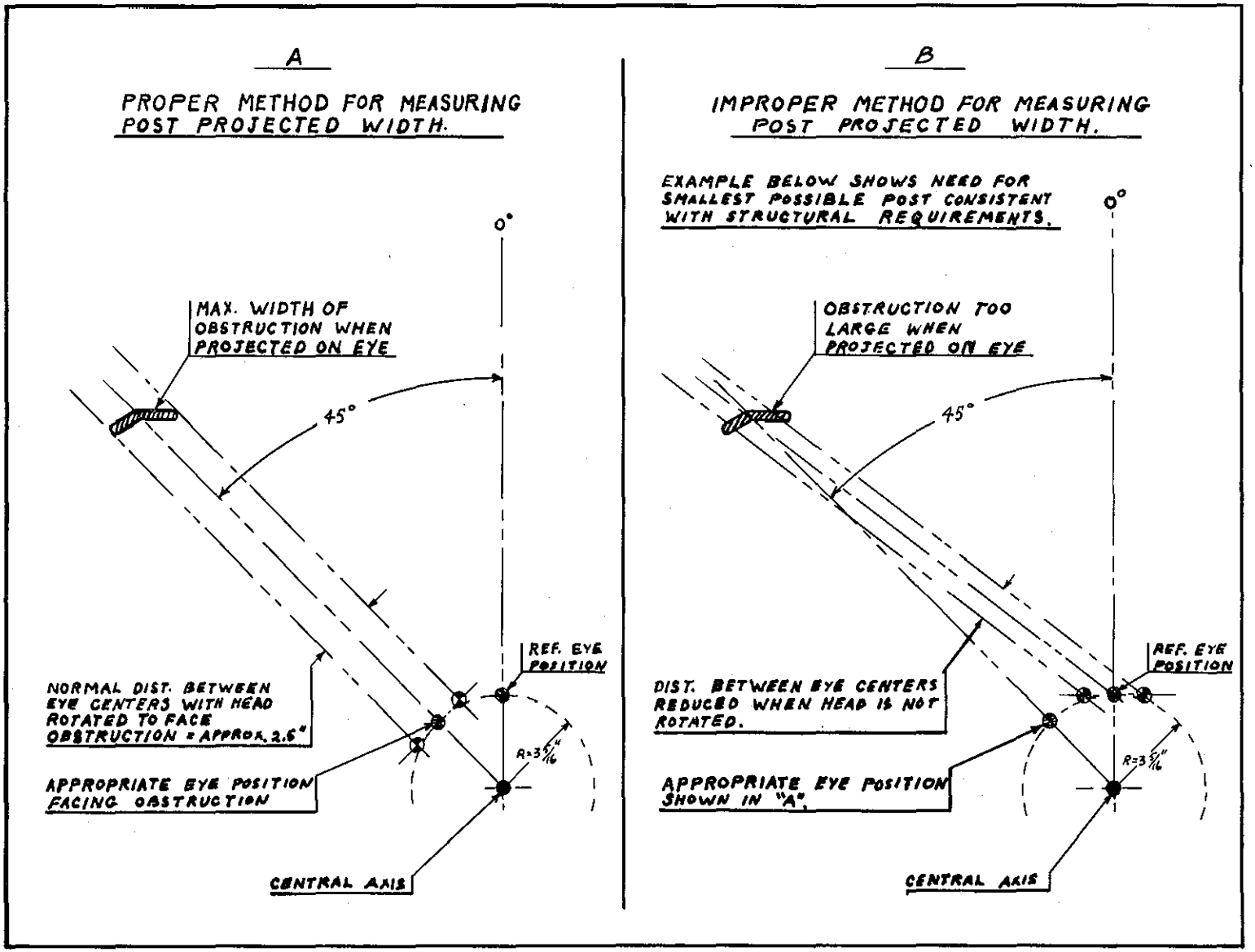
1. Wire 1 is passed through the turnbuckle hole as shown, the two wire ends are passed through the right and left hand ends of the turnbuckle and are then bent back along the barrel of the turnbuckle.
2. Wire 2 is installed and wrapped (these wraps are next to the ends of the turnbuckle).
3. The two loose ends of wire 1 are then wrapped.



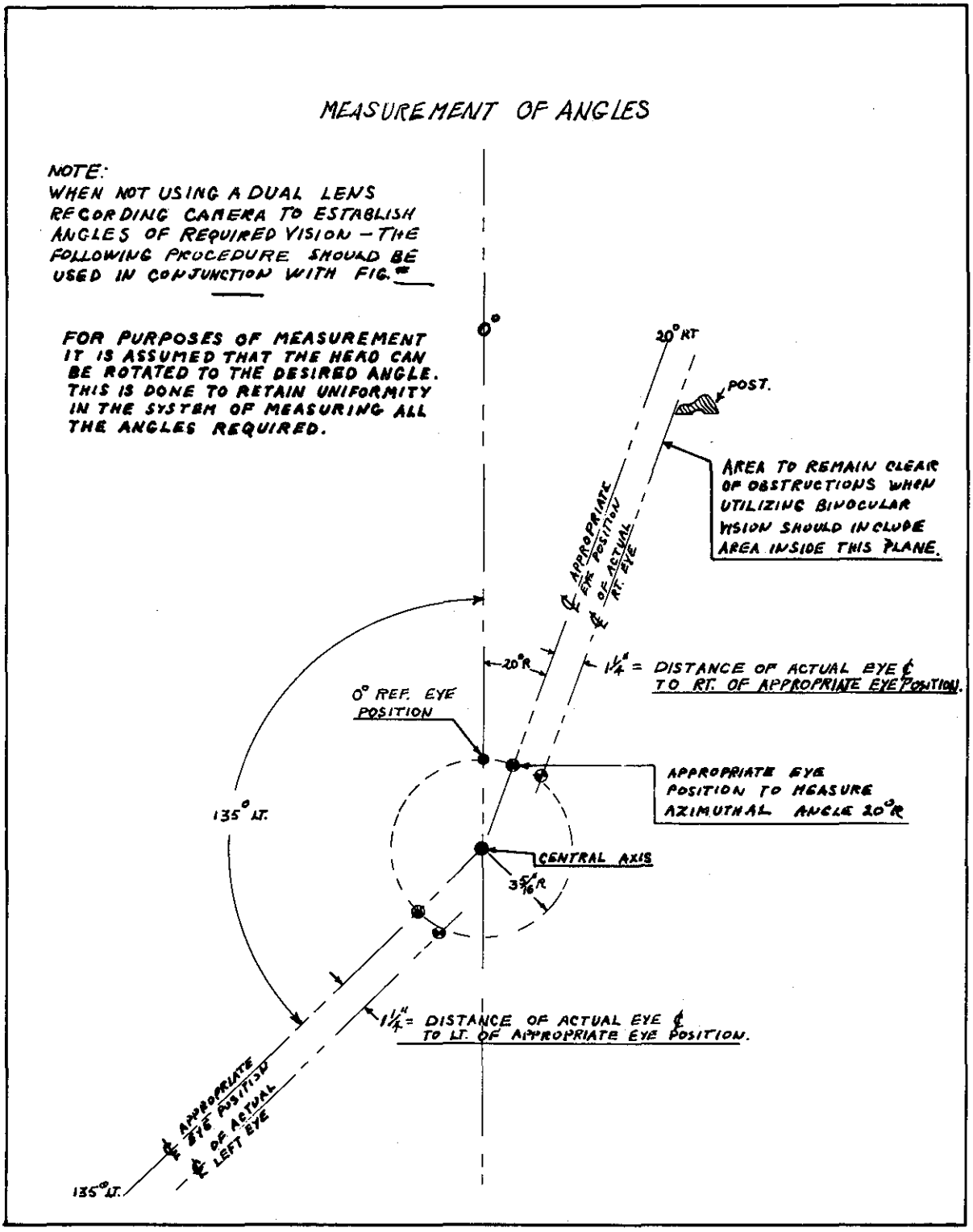
[Figure 6.—Reference eye position.]



[Figure 7.—Clear areas of vision.]



[Figure 8.—Obstruction to vision.]



[Figure 9.—Measurement of angles.]

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Appendix B

Performance Tests

Item	CAR ref. No.	Test description	Wt.	C. G.	Altitude	Flap	Landing gear	Engines						Test	Special instrumentation
								Operating			Inoperative				
								Prop.	Power	Cowl flap	Prop.	Throtl.	Cowl flap		
1	§4b.612 (a)	Airspeed calibration	Between max. T. O. and *max.* land.	Opt.	Opt. greater than one span *length*	Retr.	Retr.	Opt.	Opt.	Opt.	----	----	----	Airspeed indicating system should be calibrated over speed range from 1.3 V_{s_1} to V_{NO} or to max. cont. power whichever is lower.	Reference airspeed system or speed course.
						Land.	Ext.	Opt.	Opt.	Opt.	----	----	----	Airspeed indicating system should be calibrated over speed range from 1.3 V_{s_0} to V_{FE} or max. level flight speed with max. cont. power whichever is lower.	
		Ground speed calibration	*T. O.*	----	----	T. O.	Ext.	T. O.	T. O.	T. O.	Wind milling in T. O. pitch	Closed	T. O.	Airspeed indicating system should be calibrated during ground run between 0.8 minimum value of V_1 to maximum value of V_2.	May be conducted during test item 5 with instrumentation for test item 4.
2 (a)	§4b.110	Engine calibration T. O. power	Opt.	Opt.	Opt.	T. O.	Retr.	T. O.	T. O.	T. O.	----	----	----	Climb should be conducted at V_2 speed with appropriate M. P. until full throttle and then at F. T. through the desired altitude range for engine calibration data.	Instrumentation for measuring humidity.
(b)	§4b.110	Engine calibration max. cont. power	Opt.	Opt.	Opt.	All eng. en route climb	Retr.	Max. cont.	Max. cont.	All eng. en *route* climb position	----	----	----	Same as above procedure except climb should be conducted at en route climb speed.	
3	§4b.112	Stalling speeds	Max. land. or max. at req'd c. g. position	Most fwd or varying	Opt.	En route T. O. appr. land.	Retr. Retr. Retr. Ext.	Opt.	Zero thrust or less	Closed	----	----	----	Stalls should be conducted at each flap setting with not more than sufficient *power for zero thrust at a speed not* greater than 110% of the stalling speed.	Reference airspeed system or suitable calibrated *system, instrument* photo-recorder.
4	§4b.115	Accelerate to V_1 and stop *distance*	Max. T. O. and one *lower*	Most fwd [1]	S. L. to 2,000 ft.	T. O.	Ext.	T. O.	T. O.	T. O.	Windmilling in T. O. pitch [3]	Closed	T. O.	Airplane should be accelerated to V_1 speed, all engines cut and brought to a stop.	Graphically recording vertical and horizontal distance-time instrumentation, wind velocity, direction and humidity meteorological instrumentation.
5	§4b.116 (a)	Accelerate to V_2	Max. T. O. and one lower	Most fwd	S. L. to 2,000 ft.	T. O.	Ext.	T. O.	T. O.	T. O.	Windmilling in T. O. pitch [3]	Closed	T. O.	Airplane should be accelerated to V_1 one engine cut and acceleration continued to V_2. (If V_1 is less than V_2 a demonstration takeoff should be made at max. T. O. weight conditions.)	Same as item 4.
6 (a)	§4b.120 (a)	Climb initial T. O. segment	Max. T. O. and one lower	Opt.	Two opt. altitudes	T. O.	Ext.	T. O. [2]	T. O. [2]	T. O.	Windmilling in T. O. pitch [3]	Closed	T. O.	See §§ 4b.116–2 (b) (2) and 4b.118–1....	Instrumentation for measuring humidity.

For footnotes, see p 208.

Performance Tests—Continued

Item	CAR ref. No.	Test description	Wt.	C. G.	Altitude	Flap	Landing gear	Engines						Test	Special instrumentation
								Operating			Inoperative				
								Prop.	Power	Cowl flap	Prop.	Throtl.	Cowl flap		
6 (b)	§ 4b.120 (b)	Climb 2d T. O. segment	Max. T. O. and one lower	Opt.	Two opt. altitudes	T. O.	Retr.	T. O.[2]	T. O.[2]	T. O.	Windmilling in T. O. pitch [3]	Closed	T. O.	See §§ 4b.116–2 (b) (3) and 4b.118–1.	Instrumentation for measuring humidity—Con.
(c)	§ 4b.116 (d)	Climb 3d T. O. segment	Max. T. O. and one lower	Opt.	Two opt. altitudes	T. O.	Retr.	T. O.[2]	T. O.[2]	T. O.	Feath.	Closed	Opt.	See §§ 4b.116–2 (b) (4) and 4b.118–1.	
(d)	§ 4b.116 (c)	Climb 4th T. O. segment	Max. T. O. and one lower	Opt.	Two opt. altitudes	T. O.	Retr.	Max. cont.	Max. cont.	T. O.	Feath.	Closed	Opt.	See §§ 4b.116–2 (b) (5) and 4b.118–1.	
(e)	§ 4b.119 (a)	Climb cruising config. all engs.	Max. T. O. and one lower	Opt.	Two opt. altitudes	Opt.	Retr.	Max. cont.	Max. cont.	CAA hot day cooling position	----------	----------	----------	See §§ 4b.118–1 and 4b.119–1 (a).	
(f)	§ 4b.120 (c)	Climb en route one eng. inop.	Max. T. O. and one lower	Opt.	Two opt. altitudes	Opt.	Retr.	Max. cont.	Max. cont.	CAA hot day cooling	Feath.	Closed	Opt.	See §§ 4b.118–1 and 4b.120–2 (c).	
(g)	§ 4b.121	Climb two engs. inop.	Two opt. wts.	Opt.	Two opt. altitudes	Opt.	Retr.	Max. cont.	Max. cont.	CAA hot day cooling	Feath.	Closed	Opt.	See §§ 4b.118–1 and 4b.121–1.	
(h)	*§ 4b.120* (d)	*Climb* approach	*Max.* land. and one lower	*Opt.*	*Two* opt. altitudes	Appr.	*Retr.*	*T. O.*[2]	*T. O.*[2]	Appr.	*Feath.*	*Closed*	*Opt.*	*See §§ 4b.118–1 and 4b.120–2 (d).*	
(i)	§ 4b.119 (b)	Climb landing	Max. land. and one lower	Opt.	Two opt. altitudes	Land.	Ext.	T. O.[2]	T. O.[2]	Appr.	----------	----------	----------	See §§ 4b.118–1 and 4b.119–1 (b).	
7	§ 4b.122 § 4b.123	Landing distance	Max. land. and one lower	Most fwd.	S. L. to 2,000 ft.	Land.	Ext.	Opt.	Opt.	Appr.	----------	----------	----------	Landings over 50' obstacle should be conducted to establish the landing distance.	Same as item 4.

NOTES

[1] C. G. should be in the most aft position for demonstration with reverse thrust propeller.

[2] Tests involving takeoff power may be demonstrated using maximum continuous power if additional tests are run at a lower power to determine effects of slipstream.

[3] Propeller should be in feathered position if automatic feathering device is installed.

Flying Qualities

Item	CAR ref. No.	Test description	Wt.	C. G.	Altitude	Flap	Landing gear	Engines						Test	Special instrumentation
								Operating			Inoperative				
								Prop.	Power	Cowl flap	Prop.	Throtl.	Cowl flap		
8 (a)	§ 4b.131 (a)	Long. control recovery to 1.4 V_{s_1} power on	Max. T. O. Max. land.	Most aft	Opt.	Retr. Ext.	Ext.	Max. cont.	Max. cont.	Opt.	----	----	----	Prompt recovery to 1.4 V_{s_1} should be demonstrated from any speed between V_{s_1} and 1.4 V_{s_1} when airplane is pitched down.	
(b)	§ 4b.131 (a)	Long. control recovery to 1.4 V_{s_1} power off	Max. T. O. Max. land.	Most aft	Opt.	Retr. Ext.	Ext.	Opt.	Off	Opt.	----	----	----	Same as test 8 (a).	
(c)	§ 4b.131 (b) (1)	Long. control sudden changes in flaps power off	Max. land.	Most fwd. and most aft	Opt.	Retr.	Ext.	Opt.	Off	Opt.	----	----	----	One hand controllability should be demonstrated when flaps are extended rapidly without change in trim control.	
(d)	§ 4b.131 (b) (2)	Long. control sudden changes in flaps power off	Max. land.	Most fwd. and most aft	Opt.	Ext.	Ext.	Opt.	Off	Opt.	----	----	----	One hand controllability should be demonstrated when flaps are retracted rapidly without change in trim control.	
(e)	§ 4b.131 (b) (3)	Long. control sudden changes in flaps power on	Max. land.	Most fwd. and most aft	Opt.	Ext.	Ext.	T. O.	T. O.	Opt.	----	----	----	Test 8 (d) should be repeated with T. O. power.	
(f)	§ 4b.131 (b) (4)	Long. control sudden changes in power flaps retr.	Max. land.	Most fwd. and most aft	Opt.	Retr.	Ext.	Opt.	Off	Opt.	----	----	----	One hand controllability should be demonstrated when T. O. power is applied quickly without change in trim control.	
(g)	§ 4b.131 (b) (5)	Long. control sudden changes flaps ext.	Max. land.	Most fwd. and most aft	Opt.	Ext.	Ext.	Opt.	Off	Opt.	----	----	----	Test 8 (f) should be repeated with flaps extended.	
(h)	§ 4b.131 (b) (6)	Long. control variation in airspeed	Max. land.	Most fwd	Opt.	Ext.	Ext.	Opt.	Off.	Opt.	----	----	----	One hand controllability should be demonstrated throughout speed range of 1.1 V_{s_1} to 1.7 V_{s_1} or to V_{FE} without change in trim control.	
(i)	§ 4b.131 (c)	Long. control flap retraction	Max. land.	Most fwd. and most aft	Opt.	Ext.	Ext.	Opt.	Off	Opt.	----	----	----	It should be possible to prevent altitude loss when flaps are retracted with simultaneous application of M. C. power.	
9 (a)	§ 4b.132 (a)	Directional control sudden changes in heading	Max. land.	Most aft	Opt.	Appr.	Retr.	Opt.	Power for level flight at 1.4 V_{s_1} but not more than max. cont.	Opt.	Feath.	Closed	Opt.	Satisfactory controllability should be demonstrated when sudden heading changes are executed in either direction with wings level.	Rudder force indicator if force is critical.

Flying Qualities—Continued

Item	CAR ref. No.	Test description	Wt.	C. G.	Altitude	Flap	Landing gear	Engines						Test	Special instrumentation
								Operating			Inoperative				
								Prop.	Power	Cowl flap	Prop.	Throtl.	Cowl flap		
9 (b)	§ 4b.132 (b)	Directional control sudden changes in heading	Max. land.	Most fwd.	Opt.	Climb	Retr.	Opt.	Power for level flight at 1.4 V_{s_1} but not more than max. cont.	Opt.	Feath.	Closed	Opt.	Test 9 (a) should be repeated with 2 crit. engs. inop.	Same as item 9 (a).
(c)	§ 4b.132 (c)	Lateral control 20° banked turns	Max. T. O.	Most aft	Opt.	Climb	Retr. and ext.	Max. cont.	Max. cont.	Opt.	Feath.	Closed	Opt.	20° banked turns with and against inoperative engine should be demonstrated from steady climb at speed of 1.4 V_{s_1}.	Bank angle indicator.
(d)	§ 4b.132 (d)	Lateral control 20° banked turns	Max. land.	Most fwd.	Opt.	Climb	Retr.	Max. cont.	Power for level flight at 1.4 V_{s_1} but not more than max. cont.	Opt.	Feath.	Closed	Opt.	Test 9 (c) should be repeated with 2 crit. engs. inop.	Same as item 9 (c).
10	§ 4b.133	Minimum control speed	Max. T. O. or less if necessary	Most aft	Opt. below T. O. power crit.	T. O.	Retr.	T. O.	T. O.	T. O.	Windmilling or any other logical position	Closed	T. O.	Minimum control speed should be determined when engine is suddenly made inoperative.	Same as item 9 (a). Bank indicator if bank is to be demonstrated.
11	§ 4b.130 § 4b.170 § 4b.171 § 4b.172 § 4b.173 § 4b.180 § 4b.181 § 4b.182	Controllability, maneuverability and stability	App.	Opt. and noted	SEE APPROPRIATE REGULATIONS									Airplane should be demonstrated for: (1) Controllability (2) Attitude during ground roll (3) nose over tendency during takeoff, landing and ground operation (4) Directional stability and control during power-off landings in cross winds and taxying (5) Water handling characteristics.	
12 (a) (b)	§ 4b.115 § 4b.123 (c)	Control Reverse thrust operation of props.													
13	§ 4b.141	Lateral and directional trim [1]	Max. T. O. and land.	Most fwd and most aft.	Opt.	Retr. and ext.	Retr. and ext.	Opt.	Power for level flight	Opt.	----------	----------	----------	Hands-off lateral and directional trim should be demonstrated from 1.4 V_{s_1} to [V_{NO} or M_{NO} whichever is the lesser].	
14 (a)	§ 4b.142 (a)	Long. trim in climb	Max. T. O.	Most fwd.	Opt.	Retr. and T. O.	Retr.	Max. cont.	Max. cont.	Opt.	----------	----------	----------	Hands-off long. trim should be demonstrated at a speed not in excess of 1.4 V_{s_1}.	
(b)	§ 4b.142 (b)	Long. trim in glide	Max. Land.	Most fwd.	Opt.	Retr. and ext.	Ext.	Windmilling	Off	Opt.	----------	----------	----------	Hands-off long. trim should be demonstrated at a speed not in excess of 1.4 V_{s_1}.	

For footnotes, see p. 212.

(c)	§ 4b.142 (c)	Long. trim in level	Max. T. O.	Most fwd and most aft.	Opt.	Retr.	Retr. and ext.	Opt.	Power for level flight	Opt.	----------	----------	----------	Hands-off long. trim should be demonstrated from 1.4 V_{s_1} to [V_{NO} or M_{NO}, whichever is lesser with landing gear and flaps retracted and from 1.4 V_{s_1} to V_{LE} with gear extended].	
15	§ 4b.143	Long., directional and lateral trim	Max. T. O.	Most fwd	Opt.	Retr.	Retr.	Max. cont.	Max. cont.	Opt.	Feath.	Closed	Opt.	Hands-off long., directional and lateral trim should be demonstrated during climb at a speed of 1.4 V_{s_1}.	
16	§4b.144	Trim 2 engs. inop.	See note[2]	Most fwd.	Opt.	Opt.	Retr.	Max. cont.	Max. cont.	Opt.	Feath.	Closed	Opt.	Hands-off long., lateral and directional trim should be demonstrated in rectilinear flight at airspeed used in § 4b.121.	
17	§4b. 152	Static long. stability landing power-off	Max. land.	Most fwd and most aft	Opt.	Ext.	Ext.	Wind-milling	Power-off	Opt.	----------	----------	----------	Static long. stability should be demonstrated from 1.1 V_{s_1} to 1.8 V_{s_1} or to placard speed with airplane trimmed at 1.4 V_{s_1}.	Elevator control force indicator.
18	§ 4b.153	Static long. stability approach	Max. land.	Max. aft	Opt.	Appr.	Retr.	Power for level flight at 1.4 V_{s_1}		Appr.	----------	----------	----------	Same as test 17	Same as item 17.
19	§ 4b.154	Static long. stability climb	Max. T. O.	Most aft	Opt.	Retr.	Retr.	75% max. cont. [for reciprocating engines. For turbine engines, see § 4b.154–1 (a)]		Opt.	----------	----------	----------	Static long. stability should be demonstrated from 85% to 115% of V_{trim} when airplane is trimmed at best R/C speed except that trim speed need not be less than 1.4 V_{s_1}.	Same as item 17.
20 (a)	§ 4b.155 (a)	Static long. stability cruise	Max. T. O.	Most aft	Opt.	Retr.	Retr.	75% max. cont. [See § 4b.155–1 (a) (1).]		Opt.	----------	----------	----------	Static long. stability should be demonstrated from 1.3 V_{s_1} to 1.8 V_{s_1} or to V_{NE} whichever is less, with airplane trimmed at speed for level flight with [power specified in § 4b.155–1 (a) (1)].	Same as item 17.
(b)	§ 4b.155 (b)	Static long. stability cruise	Max. T. O.	Most aft	Opt.	Retr.	Ext.	75% max. cont. [See § 4b.155–1 (b) (1).]		Opt.	----------	----------	----------	Same as test 20 (a) but speed should [not] be in excess of level flight trim or gear down placard speed.	
21	§ 4b.156	Dynamic long. stability	OPTIONAL											Damping of any short period oscillations between stalling speed and max. permissible speed should be demonstrated with controls free and in a fixed position.	
22 (a)	§ 4b.157 (a)	Static directional stability	Max. T. O. Max. land	Most aft	Opt.	Retr. Ext.	Retr. Ext.	See § 4b.157		Opt.	----------	----------	----------	Recovery from skid with rudder free should be demonstrated.	
(b)	§ 4b.157 (b)	Static lateral stability	Max. T. O.	Most aft	Opt.	Retr.	Retr. Ext.	----------		Opt.	----------	----------	----------	Tendency of wing to raise in recovery from turn should be demonstrated.	Rudder force indicator.
(c)	§ 4b.157 (c)	Static directional and lateral stability	Max. T. O. Max. land	Most aft	Opt.	Retr. Ext.	Retr. Ext.	----------		Opt.	----------	----------	----------	Proportionality of aileron and rudder deflections and forces during sideslip should be demonstrated.	
23	§4b.158	Dynamic directional and lateral stability	Max. T. O. and land	Most aft	Opt.	Retr. and ext.	Retr. and ext.	Opt.	Opt.	Opt.	----------	----------	----------	Damping of any short period oscillations should be demonstrated with controls free and fixed at all speeds.	

Flying Qualities—Continued

Item	CAR ref. No.	Test description	Wt.	C. G.	Altitude	Flap	Landing gear	Engines						Test	Special instrumentation
								Operating			Inoperative				
								Prop.	Power	Cowl flap	Prop.	Throtl.	Cowl flap		
24 (a)	§4b.160	Stalls symmetrical power straight flight	Land Land Land Land Land Land Land T. O. T. O. T. O. T. O.	Fwd Fwd Aft Aft Aft Aft Aft Aft Aft Aft Aft	Opt.	Appr. Land Appr. Land Appr. Appr. Land Land Retr. T. O. Retr. T. O.	Ext. Ext. Ext. Ext. Retr. Ext. Retr. Ext. Ext. Ext. Ext. Ext.	Opt.	On On Off Off On On On On Off Off On On	Opt.				See §4b.160 (c) (1)	Means for continuous recording of angle-of-attack indicator, accelerometer; swivel static and shielded total pressure heads; altimeter; pitch and bank angle indicator; accelerometer; elevator position and force indicator; aileron and rudder position indicator.
(b)		Stalls symmetrical power turns	T. O. T. O. Land Land	Aft Aft Aft Aft	Opt.	Retr. Retr. Land Land	Retr. Retr. Ext. Ext.	Opt.	Off On Off On	Opt.				Prompt recovery and regain of control with normal piloting skill should be demonstrated in left and right turns up to 30 degrees of bank.	
25	§4b.161	Stalls asymetrical power	Max. T. O.	Aft	Opt.	Retr.	Retr.	75% maximum continuous power		Opt.	Opt.	Closed	Opt.	Safe recovery from stall without excessive loss of altitude should be demonstrated. Operating engines may be throttled back during recovery.	Rudder control force indicator if force is critical.
26	§4b.173	Controllability T. O. and land. in cross wind	Max. T. O. Max. land	Most aft	Opt.	T. O. Ext.	Ext.	Takeoff and power off		Opt.				Takeoffs and landings in cross winds should be demonstrated.	Wind velocity and direction indicator.
27	§4b.190	Flutter and vibration	Max. T. O. Max. land	Most aft		Retr. Ext.	Retr. Ext.	Cruise power		Opt.				The airplane should be tested from V_{s_1} to Vp or to placard speed, gear up and down, flaps up, T. O. approach and landing.	
28	§4b.324	Wing flap interconnection	REQUIREMENTS SHOULD BE SET UP FOR INDIVIDUAL CASES												

[1] Additional lateral and directional trim should be demonstrated in other configurations in conjunction with tests in § 4b.150.
[2] Weight at which climb is equal to at least 0.01 $V_{s_0}^2$ at 5,000 feet altitude.

Powerplant Tests

Item	CAR ref. No.	Test description	Wt.	C. G.	Altitude	Flap	Landing gear	Engines						Test	Special instrumentation
								Operating			Inoperative				
								Prop.	Power	Cowl flap	Prop.	Throtl.	Cowl flap		
29 (a)	§ 4b.400	Powerplant operation				Opt.	Opt.							Powerplant and propeller operation should be observed for satisfactory operation during the flight test program.	
(b)	§ 4b.400	Propeller operation				Opt.	Opt.								
30 (a)	§ 4b.416 (b) (1)	Unusable fuel level flight	Opt.	Opt.	Opt.	Retr.	Retr.	See test		Opt.				Unusable fuel should be determined in level flight at power required for V_c or at max. cont. power whichever is less. Fuel tank should be turned off when fuel pressure decreases, or the engine malfunctions.	
(b)	§ 4b.416 (b) (2)	Unusable fuel climb	Not more than max. land.	Opt.	Opt.	T. O.	Retr.	T. O.	T. O.	Opt.				Unusable fuel should be determined during climb at V_2 speed. Fuel tank should be turned off when fuel pressure decreases or engine malfunctions.	
(c)	§ 4b.416 (b) (3)	Unusable fuel glide to climb	Land.	Opt.	Opt.	Ext.	Ext.	See test		Opt.				Unusable fuel should be determined during rapid application of max. cont. power and subsequent transition to climb at speed V_2 with retraction of flaps from a power off glide at 1.3 V_{s_0} flaps and gear ext. Fuel tank should be turned off when fuel pressure decreases or the engine malfunctions.	
(d)	§ 4b.416 (c)	Fuel Pressure				Opt.	Opt.							Ability to regain full fuel pressure on an engine should be demonstrated when engine runs out of fuel from any tank which engine can be fed and when engine is then switched to any full tank.	
(e)	§ 4b.416 (d)	Unusable fuel in tanks not used in T. O. and landing												Fuel runout tests on ground or in flight should be conducted as required in § 4b.416 (b) (1).	
31	§ 4b.417	Fuel system hot weather operation	See test	Opt.	See test	Retr.	Retr.	Max. T. O. and max. cont.						Vapor lock or occurrence of any other malfunctioning should be determined when airplane is operated with fuel 110° F at climb speed which should not exceed that permitting compliance with climb requirement of § 4b.119 (a) to the max. operating alt. selected by applicant. Airplane wt. should correspond to operation with full fuel tanks, minimum crew, and ballast to keep airplane within c. g. limits. (This test may be conducted on ground.)	

Powerplant Tests—Continued

Item	CAR ref. No.	Test description	Wt.	C. G.	Altitude	Flap	Landing gear	Engines						Test	Special instrumentation
								Operating			Inoperative				
								Prop.	Power	Cowl flap	Prop.	Throtl.	Cowl flap		
32	§ 4b.430	Fuel pump	Opt.	Opt.	6000	Opt.	Opt.	Power to maintain level flight		Opt.	----------	----------	----------	Engine operation with fuel at 110°F. This may be a ground test.	
33	§ 4b.452 § 4b.440 (e) § 4b.465	Cooling Climb	Max. T. O.	Opt.	See Test	Opt.	Opt.	Max. Cont.	Max. Cont.	CAA hot day cooling position	Feath.	Closed	Opt.	After temperatures are stabilized in level flight, cooling climb should be started at or below the lower of the two altitudes specified in requirement and continued until 5 minutes after peak climb temperatures have been noted or to max. operating alt.	Calibrated temperature indicators for critical head and base, oil inlet, coolant outlet, etc.
34	§ 4b.453 § 4b.440 (e) § 4b.465	Cooling Takeoff	Max. T. O.	Opt.	Lowest practicable	Opt.	Opt.	T. O.	T. O.	CAA hot day cooling	Feath.	Closed	Opt.	After temperatures are stabilized in level flight at 75% max. cont. power (all engines operating) using normal cowl flaps and shutter settings, one engine should be feathered and climb started at lowest practicable altitude and continued for the same time interval as takeoff power is used during the determination of the takeoff flight path, the power then being reduced to max. cont. and the climb continued until at least 5 minutes after occurrence of the peak temperature.	Same as item 33.
35	§ 4b.454	Cooling Seaplane operation	Max. T. O.	Opt.	----------	Opt.	----------	Opt.	Sufficient for test air speed	Opt.	----------	----------	----------	Seaplane should be taxied for 10 mins. at 5 m. p. h. above the step speed after temperatures are stabilized.	Same as item 33.
36	§ 4b.461	Carburetor air heat rise	Opt.	Opt.	Opt.	Opt.	Opt.	60% max. cont. power		Opt.	----------	----------	----------	Airplane should be stabilized in flight with full cold carburetor. Carburetor preheat should be applied slowly and maintained until carburetor air temperature has stabilized. Tests should be conducted at two different ambient air temperatures unless one test is conducted at temperature of 30° F.	

Functional and Miscellaneous Tests

Item	CAR ref. No.	Test description	Wt.	C. G.	Altitude	Flap	Landing gear	Engines						Test	Special instrumentation
								Operating			Inoperative				
								Prop.	Power	Cowl flap	Prop.	Throtl.	Cowl flap		
37 (a)	§ 4b.334 § 4b.116 (b)	Land. gear retracting mechanism operation and time to retract.	Opt.	Opt.										Landing gear retraction and extension at 1.6 V_{s1} and time to retract at V_2 speed should be demonstrated. Structure should be substantiated at 0.67 Vc.	
(b)	§ 4b.334 (c)	Emergency land. gear mechanism operation.												Satisfactory gear extension by use of emergency system should be demonstrated.	
38	§ 4b.337	Brakes	Max. land.	Most fwd.										Braking deceleration should be demonstrated to be at least 50% of that obtained in § 4b.122 with loss of any single source of brake operating energy supply.	
39	§ 4b.116 (c) § 4b.401 (c)	Propeller time to feather												The time required for the propeller to change from windmilling position to feather position should be determined at V_2 speed. Feathering at max. operating altitude should also be demonstrated.	
40 (a)	§ 4b.437 (a) (1)	Fuel jettisoning power-off glide.	Max. T. O.	Opt.	Opt.	Retr. or desired approved position.	Retr. or ext.	Windmilling.	Off	Opt.				The time required to jettison fuel from tanks and the path of jettisoned fuel as to whether it impinges on any part of the airplane during or after jettisoning should be determined.	
(b)	§ 4b.437 (a) (2)	Fuel jettisoning climb.	Max. T. O.	Opt.	Opt.	Retr. or desired approved position.	Retr. or ext.	Max. cont.	Max. cont.	Opt.	Feath.	Closed	Closed	Same as test 40 (a) during climb with critical eng. inoperative.	
(c)	§ 4b.437 (a) (3)	Fuel jettisoning level flight	Max. T. O.	Opt.	Opt.	Retr. or desired approved position	Retr. or ext.		Opt.					Same as test 40 (a) during level flight.	
41 (a)	§ 4b.467	Exhaust system carbon monoxide	Opt.	Opt.										Carbon monoxide concentration should be determined in personnel compartments during T. O., climb, level flight, approach or landing flight and during heater and cabin supercharger operation.	Carbon monoxide detection indicator.

Functional and Miscellaneous Tests—Continued

Item	CAR ref. No.	Test description	Wt.	C. G.	Altitude	Flap	Landing gear	Engines						Test	Special instrumentation
								Operating			Inoperative				
								Prop.	Power	Cowl flap	Prop.	Throtl.	Cowl flap		
41 (b)	§ 4b.467 (a) (5)	Visibility	Opt.	Opt.										The effect of any exhaust gas discharge on pilot visibility at night should be determined.	
42	§ 4b.612 (b)	Altimeter calibration	Between max. land and max. T. O.	Opt.	Opt.	Retr.	Retr. Ext.	Opt.	Opt.	Opt.				If altimeter and airspeed use the same static vent, theoretical calibration from airspeed calibration should be determined and checked by flights at a precise elevation at various speeds.	Instrumentation for accurately determining airplane elevation.
43	§ 4b.640	Pneumatic boots	Opt.	Opt.										Operation of pneumatic boots should be checked in flight from just above stall the buffeting speed to 1.6 V_{s_1} and at power off stall.	
44	§ 4b.642	Flare operation	Opt.	Opt.										Flight demonstration should be conducted to determine that flare ejection can be accomplished without danger to the airplane or its occupants.	

45 (a) § 4b.337 (b) Brake control forces and operation
(b) § 4b.337 (c) Parking brake
(c) § 4b.350 (g) Noise level
(d) § 4b.351 (a) Pilot compartment vision
(e) § 4b.351 (b) Windshield wiper and de-icer operation
(f) § 4b.353 Cockpit controls
(g) § 4b.376 Cabin pressurization
(h) § 4b.384 Cargo and baggage compartment fire precaution
(i) § 4b.404 Propeller pitch and speed limitation
(j) § 4b.406 Propeller de-icing fluid
(k) § 4b.418 Fuel overflow—interconnected tanks
(l) § 4b.426 Fuel overflow and syphoning—fuel tank vents
(m) § 4b.449 Propeller feathering—trapped oil supply
(n) § 4b.611 Visibility of instrument installation
(o) § 4b.630 Instrument lights
(p) § 4b.631 Landing lights

Appendix C

Suggested Flight Programs for Approval of Changes in Airplane *Configuration*

The following assumes that an airplane has been type certificated in the transport category, and that a change is made affecting the operating characteristics of the airplane. Suggested general flight programs are given for common type of changes. This is to be used as a guide only since individual cases may require additional or fewer tests than those listed.

1. Tests Affected by *Change in Propeller*

Items	*Test Description*
5	Accelerate to V_1 cut one engine and continue acceleration to V_2
6(b)	Climb—second T. O. segment
6(e)	Climb—en route—all engines
6(g)	Climb—en route—two engines inoperative
6(h)	Climb—approach
6(i)	Climb—landing
10	Minimum control speed
29(b)	Propeller operation
33, 34 and 35	Cooling tests
36	Time to feather propeller
45(i)	Propeller pitch and speed limitations

2. Tests Affected by *Change in Power Rating*

Items	*Test Description*
2 (a)	Critical altitude—takeoff power
2 (b)	Critical altitude—max. cont. power
5	Accelerate to V_1 cut one engine and continue acceleration to V_2
6 (b)	Climb—2d T. O. segment
6 (e)	Climb—en route—all engines
6 (g)	Climbs—two engines inoperative
6 (h)	Climb—approach
6 (i)	Climb—landing
8 (f)	Control—sudden changes in power
9 (c)	Control 20° banked turns
10	Minimum control speed
15	Trim 2 engines inoperative
30	Cooling climb—max. cont.
31	Cooling—takeoff

3. Tests Affected by *Addition of a Major Drag Item* (Such as External Tank)

Items	*Test Description*
3	Stalling speeds
5	Accelerate to V_1 cut engine and continue acceleration to V_2
6 (a)	Climb—takeoff first segment
6 (e)	Climb—en route—all engines
6 (g)	Climb—en route—2 engines inoperative
6 (h)	Climb—approach
6 (i)	Climb—landing
8 (h)	Control—variation in airspeed
27	Flutter and vibration

4. Tests Affected by *Change in Engines*

Items	*Test Description*
2 (a)	Critical altitude—T. O. power
2 (b)	Critical altitude—max. cont. power
5	Accelerate to V_1, cut one engine and continue acceleration to V_2
6 (b)	Climb, 2d T. O. segment
6 (e)	Climb—en route—all engines
6 (g)	Climb—two engines inoperative
6 (h)	Climb—approach
6 (i)	Climb—landing
8 (f)	Control—sudden changes in power
9 (c)	Control 20° banked turns
10	Minimum control speed
16	Trim 2 engines inoperative
33	Cooling climb—max. cont. power
34	Cooling—takeoff power
36	Carburetor air heat rise

Appendix D

A General Order of Testing

Order	*Test Description*	*Item*
1.	Airspeed and altimeter calibrations	1, 42
2.	Stall speeds	3
	Engine calibration	2
3.	Minimum control speed	10
4.	Engine cooling	33, 34, 35
5.	Ground speed calibration, accelerate and stop, accelerate, landing tests, and reverse thrust propeller control	1, 4, 5, 7, 12
6.	Climb tests	6 (a) through 6 (i)
7.	Fuel system operation and carburetor air heat rise	30 (a) through 30 (e), 31, 32, 36
8.	Control tests	8 (a) through 8 (i), 9 (a) through 9 (d), 11, 26
9.	Stall characteristics	24 (a), 24 (b), 25

10. Trim characteristics and static longitudinal, directional and lateral stability	13, 14 (a) through 14 (c), 15, 16, 17, 18, 19, 20 (a), 20 (b), 21, 22 (a) through 22 (c), 23, 28
11. Flutter and vibration	27
12. Fuel jettisoning	40 (a) through 40 (c)
13. Exhaust system, flare operation, pneumatic boots, landing gear, brakes, propeller feathering, and miscellaneous functional	41 (a), 41 (b), 44, 43, 37 (a), 37 (b), 38, 39, 45

Appendix E

Transport Category (Part 4b) Flight Tests Grouped According to Weight and C. G. Conditions

DEFINITIONS

1. Takeoff weight—The maximum takeoff weight at sea level.
2. Landing weight—The maximum landing weight at sea level.
3. Low weight—A specific weight either lower than maximum takeoff or maximum landing.
4. Optional weight—Any weight that the manufacturer elects to use.
5. Appropriate weight—Appropriate to the airplane configuration; i. e., takeoff or landing.
6. Forward c. g.—The maximum forward center of gravity for which approval is desired. If the manufacturer desires to obtain approval for center of gravity limits varying with weight, he may (1) make the test at the nominal weight at the most forward c. g. regardless of weight, or (2) make the critical tests at both the nominal weight and its forward center of gravity limit and at the weight which gives the most forward center of gravity.
7. Aft c. g.—The maximum aft center of gravity for which approval is desired. See 5.
8. Optional c. g.—Any center of gravity that the manufacturer elects to use.

WEIGHTS

The test numbers listed below correspond to the item numbers in Appendix B

1. Takeoff weight
   - a. Forward c. g.—4, 5, 13, 14 (a), 14 (c), 15
   - b. Aft c. g.—8 (a), 8 (b), 9 (c), 10, 13, 14 (c), 19, 20 (a), 20 (b), 22 (a) through 22 (c), 23, 24, 25, 26, 27
   - c. Optional c. g.—6 (a) through 6 (f), 34, 35, 40 (a) through 40 (c)
2. Landing weight
   - a. Forward c. g.—3, 7, 8 (c) through 8 (i), 9 (b), 9 (d), 13, 14 (b), 14 (c), 16, 17, 38
   - b. Aft c. g.—8 (a), 8 (b), 9 (a), 13, 14 (c), 17, 18, 22 (a) through 22 (c), 23, 24, 26
   - c. Optional c. g.—6 (h), 6 (i), 8 (c) through 8 (i), 30 (c)

3. Low weight
   a. Forward c. g.—4, 5, 7 [1]
   b. Aft c. g.—None
   c. Optional c. g.—6 (a) through 6 (f), 6 (g) (2 wgts.), 6 (h), 6 (i), 30 (b)
4. Optional weight
   a. Forward c. g.—None
   b. Aft c. g.—None
   c. Optional c. g.—1, 2 (a), 2 (b), 21, 27, 28, 29 (a), 29 (b), 30 (a), 30 (d), 30 (e), 32, 36, 37 (a), 37 (b), 39, 41 (a), 41 (b), 42, 43

Appendix F

Instrumentation Summary

1. Performance Tests

Item	*Test Description*	*Special Instrumentation*
1	Airspeed calibration.	Reference airspeed system.
	Ground speed calibration.	May be conducted in conjunction with instrumentation for item 4.
2	Engine calibration.	Humidity indicator.
3	Stalling speeds.	Reference airspeed system, instrument photo-recorder
4	Accel. to V_1 and stop.	Graphically recording vertical and horizontal distance-time instrumentation, wind velocity and direction meteorological instrumentation, humidity indicator.
5	Accel. to V_2.	Same as for item 4.
6 (a) thru 6 (i)	Climbs.	Humidity indicator.
7	Landings.	Same as for item 4.

2. Flying Qualities

Item	*Test Description*	*Special Instrumentation*
9 (a) and 9 (b)	Control—sudden changes in heading.	Rudder force indicator.
10	Minimum control speed.	Rudder force indicator.
17 thru 20 (b)	Static longitudinal stability.	Elevator stick force indicator.
22 (a), 22 (b), and 22 (c)	Directional and lateral stability.	Rudder control force indicator.
24	Stalls.	Angle-of-attack indicator, accelerometer; swivel static and shielded total pressure head; altimeter; pitch and bank angle indicator; elevator position and force indicator; aileron and rudder position indicator.

[1] Most critical c. g. should be used if demonstrations are to be made using reverse thrust.

Item	*Test Description*	*Special Instrumentation*
25	Stalls—one engine out.	Rudder control force indicator required only when rudder control forces are critical.
26	Control—takeoff and landing in crosswind.	Wind velocity and direction measurement instrumentation.

3. Power Plant Tests

Item	*Test Description*	*Special Instrumentation*
33, 34, and 35	Cooling tests.	Temperature indicators for critical head, base, oil inlet, coolant temperatures.
36	Carburetor air heat rise.	Temperature indicator for carburetor.

4. Functional and Miscellaneous Tests

Item	*Test Description*	*Special Instrumentation*
41 (a)	Exhaust system—carbon monoxide.	Carbon monoxide detection indicator.
42	Altimeter calibration.	Instrument for precisely determining airplane elevation.

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Appendix G

Special Civil Air Regulations Which Affect Part 4b

SPECIAL CIVIL AIR REGULATION NO. SR-392A

Superseded by Special Civil Air Regulation No. SR-392B, page 229.

SPECIAL CIVIL AIR REGULATION NO. SR-401A

Effective: August 25, 1955
Adopted: July 20, 1955

Smoke and Fire Detectors

1. Effective until April 1, 1957, notwithstanding the provisions of Parts 40, 41, and 42 of the Civil Air Regulations, no person shall be required to install or maintain smoke or fire detectors in airplane cargo compartments unless otherwise directed by the Administrator.

2. Upon application by an air carrier prior to April 1, 1957, the Administrator may authorize an air carrier to operate without full compliance with the fire detector requirements of Parts 40, 41, or 42 for a temporary period after April 1, 1957, where the Administrator finds that the air carrier has made a diligent effort to comply with the necessary fire detector requirements by April 1, 1957, and that the air carrier has shown that it will comply by a date certain.

This regulation supersedes Special Civil Air Regulation SR-401 and shall terminate on April 1, 1959, unless sooner superseded or rescinded by the Board.

SPECIAL CIVIL AIR REGULATION NO. SR-406C

Effective: July 1, 1956
Adopted: June 28, 1956

Application of Transport Category Requirements to C-46 Type Airplanes

1. Contrary provisions of the Civil Air Regulations notwithstanding (in particular the provisions of sections 42.15 (b) of Part 42), C-46 airplanes may be used in passenger operations conducted under Part 42 of the Civil Air Regulations. Such airplanes shall be operated in accordance with section 42.15 (a) of Part 42 and the provisions of this special regulation.

2. C-46 type airplanes, when used in passenger operations in accordance with paragraph 4 of this regulation, shall not be operated at weights exceeding those which are demonstrated to the Administrator will allow compliance with the performance requirements of Part 4b, except that in determining the maximum take-off weight, such weight shall be limited only to a value at which the airplane has a rate of climb equal to 0.035 $V_{S_1}^2$ in the take-off configuration at sea level with the landing gear retracted but with the propeller of the inoperative engine feathered rather than windmilling.

3. Provisionally, pending a determination by the Administrator of the weights at which C-46 airplanes will meet the standards prescribed by paragraph 2 of this regulation, the maximum take-off weight of such airplanes, when used in the manner herein referred to, shall not exceed 44,300 pounds: *Provided*, that in the case of C-46 airplanes equipped with Hamilton Standard propellers with blades Model Number 6491A-9 or approved equivalent which have been clipped in accordance with specifications approved by the Administrator, such provisional maximum weight shall be increased by 1,000 pounds until such time as the Administrator shall have determined by suitable tests another value to correspond to the additional efficiency obtainable by the use of such propellers, and thereafter by such other value.

4. The Administrator of Civil Aeronautics may authorize continued operation of C-46 airplanes in passenger service in accordance with paragraphs 2 and 3 of this regulation until January 1, 1957, if he finds that the applicant for such authorization has a bona fide, firm contract with the holder of a type certificate indicating that the required modifications will be completed prior to January 1, 1957, except that the Administrator may authorize during the period July 1, 1956, through July 15, 1956, such continued operation without a showing of such firm contract where the Administrator has previously permitted such operations based on genuine and diligent efforts to complete the required modifications. Such type certificate shall indicate that it meets the transport category requirements of Part 4b of the Civil Air Regulations in effect on July 20, 1950, with the exceptions authorized in SR-406A.

5. On and after July 1, 1956 (except as provided in paragraph 4), C-46 airplanes in passenger service shall comply with the provisions of Part 4b as in effect on July 20, 1950, except as otherwise provided hereinafter:

a. The provisions of sections 4b.0 through 4b.19 of Part 4b, effective May 18, 1954, shall be complied with.

b. The provisions of sections 4b.100 through 4b.190 need not be complied with.

c. The birdproof windshield requirements of section 4b.352 need not be complied with.

d. The provisions of sections 4b.480 through 4b.490 effective May 16, 1953, shall be complied with in lieu of sections 4b.480 through 4b.489 effective July 20, 1950, with the exception of subparagraph 4b.484 (a) (1) which shall be applicable as effective July 20, 1950, and paragraph 4b.487 (e) which has no counterpart in the 1950 regulations.

6. On and after January 1, 1957, C–46 airplanes in passenger service shall be recertificated in the transport category in accordance with paragraph 5 of this regulation, and shall comply with the provisions of sections 4b.100 through 4b.190 with the following exception: In determining the take-off path in accordance with section 4b.116 and the one-engine-inoperative climb in accordance with section 4b.120 (a) and (b), the propeller of the inoperative engine may be assumed to be feathered if there is installed either an approved means for automatically indicating when the particular engine has failed or an approved means for automatically feathering the propeller of the inoperative engine.

7. In applying the provisions of paragraphs 5 and 6 of this regulation, where literal compliance with the requirements of sections 4b.130 through 4b.190 of Subpart B and Subparts C, D, E, and F of Part 4b is extremely difficult to accomplish, and where the Administrator finds that service experience with the C–46 type airplane so justifies, the Administrator may authorize deviations from specific details of these requirements, taking into account the effect of design changes.

8. On or after January 1, 1957, C–46 airplanes in passenger service shall be operated in accordance with the performance operating limitations applicable to transport category airplanes.

9. C–46 airplanes which comply with the provisions of paragraphs 5 and 6 of this regulation may be used in passenger operations conducted under the provisions of Parts 40 and 41 provided they are operated in accordance with paragraph 8.

10. This Special Civil Air Regulation supersedes Special Civil Air Regulation SR–406B.

SPECIAL CIVIL AIR REGULATION NO. SR–407

Effective: September 10, 1954
Adopted: August 6, 1954

Basis for Approval of Modification of Airplane Types Douglas DC–3 and Lockheed L–18

1. *Applicability.* Contrary provisions of the Civil Air Regulations regarding certification notwithstanding,[1] this regulation shall provide the basis for approval by the Administrator of modifications of individual Douglas DC–3 and Lockheed L–18 airplanes subsequent to the effective date of this regulation.

2. *General modifications.* Except as modified in sections 3 and 4 of this regulation, an applicant for approval of modifications to a DC–3 or L–18 airplane which result in changes in design or in changes to approved limitations shall show that the modifications were accomplished in accordance with the rules of either Part 4a or Part 4b in effect on September 1, 1953, which

[1] It is not intended to waive compliance with such airworthiness requirements as are included in the operating parts of the Civil Air Regulations for specific types of operation.

are applicable to the modification being made: *Provided,* That an applicant may elect to accomplish a modification in accordance with the rules of Part 4b in effect on the date of application for the modification in lieu of Part 4a or Part 4b as in effect on September 1, 1953: *And provided further,* That each specific modification must be accomplished in accordance with all of the provisions contained in the elected rules relating to the particular modification.

3. *Specific conditions for approval.* An applicant for any approval of the following specific changes shall comply with section 2 of this regulation as modified by the applicable provisions of this section:

(a) *Increase in take-off power limitation—1,200 to 1,350 horsepower.* The engine take-off power limitation for the airplane may be increased to more than 1,200 horsepower but not to more than 1,350 horsepower per engine if the increase in power does not adversely affect the flight characteristics of the airplane.

(b) *Increase in take-off power limitation to more than 1,350 horsepower.* The engine take-off power limitation for the airplane may be increased to more than 1,350 horsepower per engine if compliance is shown with the flight characteristics and ground handling requirements of Part 4b.

(c) *Installation of engines of not more than 1,830 cubic inches displacement and not having a certificated take-off rating of more than 1,350 horsepower.* Engines of not more than 1,830 cubic inches displacement and not having a certificated take-off rating of more than 1,350 horsepower which necessitate a major modification or redesign of the engine installation may be installed, if the engine fire prevention and fire protection are equivalent to that on the prior engine installation.

(d) *Installation of engines of more than 1,830 cubic inches displacement or having certificated take-off rating of more than 1,350 horsepower.* Engines of more than 1,830 cubic inches displacement or having certificated take-off rating of more than 1,350 horsepower may be installed if compliance is shown with the engine installation requirements of Part 4b: *Provided,* That where literal compliance with the engine installation requirements of Part 4b is extremely difficult to accomplish and would not contribute materially to the objective sought, and the Administrator finds that the experience with the DC–3 or L–18 airplanes justifies it, he is authorized to accept such measures of compliance as he finds will effectively accomplish the basic objective.

4. *Establishment of new maximum certificated weights.* An applicant for approval of new maximum certificated weights shall apply for an amendment of the airworthiness certificate of the airplane and shall show that the weights sought have been established, and the appropriate manual material obtained, as provided in this section. (Note: Transport category performance requirements result in the establishment of maximum certificated weights for various altitudes.)

(a) *Weights—25,200 to 26,900 for the DC–3 and 18,500 to 19,500 for the L–18.* New maximum certificated weights of more than 25,200 but not more than 26,900 pounds for DC–3 and more than 18,500 but not more than 19,500 pounds for L–18 airplanes may be established in accordance with the transport category performance requirements of either Part 4a or Part 4b, if the airplane at the new maximum weights can meet the structural requirements of the elected part.

(b) *Weights of more than 26,900 for the DC–3 and 19,500 for the L–18.* New maximum certificated weights of more than 26,900 pounds for

DC–3 and 19,500 pounds for L–18 airplanes shall be established in accordance with the structural, performance, flight characteristics, and ground handling requirements of Part 4b: *Provided*, That where literal compliance with the structural requirements of Part 4b is extremely difficult to accomplish and would not contribute materially to the objective sought, and the Administrator finds that the experience with the DC–3 or L–18 airplanes justifies it, he is authorized to accept such measures of compliance as he finds will effectively accomplish the basic objective.

(c) *Airplane flight manual—performance operating information.* An approved airplane flight manual shall be provided for each DC–3 and L–18 airplane which has had new maximum certificated weights established under this section. The airplane flight manual shall contain the applicable performance information prescribed in that part of the regulations under which the new certificated weights were established and such additional information as may be necessary to enable the application of the take-off, en route, and landing limitations prescribed for transport category airplanes in the operating parts of the Civil Air Regulations.

(d) *Performance operating limitations.* Each airplane for which new maximum certificated weights are established in accordance with paragraphs (a) or (b) of this section shall be considered a transport category airplane for the purpose of complying with the performance operating limitations applicable to the operations in which it is utilized.

5. *Reference.* Unless otherwise provided, all references in this regulation to Part 4a and Part 4b are those parts of the Civil Air Regulations in effect on September 1, 1953.

NOTE: Parts 4a and 4b as amended and in effect on September 1, 1953, were published in the Federal Register at the following citations:

Part 4a, F. R. 14 F. R. 3742, 14 F. R. 6769, 15 F. R. 28, 17 F. R. 11631.

Part 4b, 15 F. R. 3543, 15 F. R. 8903, 15 F. R. 9184, 16 F. R. 314, 16 F. R. 11759, 16 F. R. 12220, 17 F. R. 1087, 17 F. R. 11631, 18 F. R. 2213.

This regulation supersedes Special Civil Air Regulation SR–398 and shall remain effective until superseded or rescinded by the Board.

SPECIAL CIVIL AIR REGULATION NO. SR–411

Effective: July 1, 1955
Adopted: June 30, 1955

Trial Operation of Transport Category Airplanes in Cargo Service at Increased Zero Fuel and Landing Weights

Notwithstanding the applicable structural provisions of the Civil Air Regulations, any air carrier may operate transport category airplanes which were certificated under the provisions of Part 4a or 4b in cargo service only, subject to the conditions hereinafter set forth:

(1) The air carrier shall submit an application to the Administrator indicating its desire to operate its airplane(s) under the provisions of this special regulation, and indicating which airplane(s) would be involved.

(2) The air carrier shall furnish a statement from each manufacturer for each type of airplane involved indicating in each case that the airplane manu-

facturer approves the operation of such type of airplane under the provisions of this regulation and that the airplane manufacturer will establish the inspection procedure prescribed in paragraph (4) of this Special Civil Air Regulation and will supervise such inspection as necessary.

(3) The zero fuel weight (maximum weight of the airplane with no disposable fuel and oil) and the structural landing weight may be increased beyond the maxima approved in full compliance with the applicable Civil Air Regulations: *Provided,* That the Administrator of Civil Aeronautics finds that the increase in either such weight is not likely to reduce seriously the structural strength, that the probability of sudden fatigue failure is not noticeably increased, and that the flutter, deformation, and vibration characteristics do not fall below those required by the Civil Air Regulations: *And provided further,* That any increase in the zero fuel weight approved shall not exceed 5 percent and that the increase in the structural landing weight shall not exceed the amount, in pounds, of the increase in the zero fuel weight.

(4) Airplanes for which the increased weights become effective shall be subject to inspections in addition to those normally performed, such inspections to be established by the manufacturer of the type airplane concerned, subject to the approval of the Administrator of Civil Aeronautics and to be supervised as found necessary by that manufacturer, to safeguard against possible structural distress resulting from the higher operating stress levels. Results of such inspections shall be reported to the Administrator of Civil Aeronautics at such times as he shall establish.

(5) Airplanes for which the increased weights become effective shall be operated in accordance with the transport category performance operating limitations prescribed in Part 40, 41, or 42 of the Civil Air Regulations, whichever is applicable.

(6) The air carrier shall keep and make available, upon request, to the Civil Aeronautics Board, the Administrator of Civil Aeronautics, or the manufacturer of the type airplane concerned, records of all flights conducted with airplanes for which the increased weights become effective, such records to include the actual take-off, zero fuel, and landing weights.

(7) The Airplane Flight Manual of each airplane operating under the provisions of this special regulation shall be appropriately revised so as to include the mecessary operating limitations and operating information.

(8) An airplane which has been operated at increased weights under the provisions of this regulation shall not be used for the carriage of passengers, except under the following conditions:

(a) Special inspections established by the manufacturer and approved by the Administrator of Civil Aeronautics shall have been accomplished.

(b) The effects of the operations at increased weights on structural fatigue shall have been evaluated by the airplane manufacturer and taken into account in any fatigue limitations established for the airplane.

This regulation shall terminate on June 30, 1957, unless sooner superseded or rescinded.

SPECIAL CIVIL AIR REGULATION NO. SR-392B

Effective: February 25, 1957
Adopted: February 25, 1957

Facilitation of Experiments With Exterior Lighting Systems

Special Civil Air Regulation No. SR-392A adopted June 29, 1955, permits air carriers, subject to the approval of the Administrator, to install and use experimentally, on a limited number of their airplanes, exterior lighting systems which do not conform to the specifications contained in Part 4b of the Civil Air Regulations. The purpose of SR-392A was to permit experimentation on large airplanes while retaining their standard airworthiness certification. Prior to that time such experimentation was conducted either on Government-owned aircraft or on private aircraft limited in operations to the conditions of an experimental certificate.

SR-392A does not extend the permission for experimentation with exterior lights to non-air-carrier aircraft because at the time of its adoption only air carrier operators indicated interest in this activity. Recently, however, new experimental developments in anti-collision light systems have aroused the interest of private and corporate operators to the extent that some of the operators apparently wish to install the new systems on their aircraft for purposes of experimentation. The Board sees no valid reason why operators other than air carriers should not be permitted to participate, if they wish, in experiments intended to improve the effectiveness of aircraft exterior lighting, provided that the number of such aircraft is reasonably limited.

Since future experimentation is to be conducted more widely and by private individuals, the Board believes that conditions should be imposed which will assure that the experimental exterior lights are in fact installed for purposes of bona fide experimentation and that the results of such experimentation become available to the Government and to all other interested persons.

Interested persons have been afforded an opportunity to participate in the making of this regulation (21 F. R. 3388), and due consideration has been given to all relevant matter presented. Since this regulation imposes no additional burden on any person, it may be made effective on less than 30 days' notice.

In consideration of the foregoing, the Civil Aeronautics Board hereby makes and promulgates the following Special Civil Air Regulation, effective February 25, 1957.

Contrary provisions of the Civil Air Regulations notwithstanding, experimental exterior lighting equipment which does not comply with the relevant specifications contained in the Civil Air Regulations may, subject to the approval of the Administrator, be installed and used on aircraft for the purpose of experimentation intended to improve exterior lighting for a period not to exceed six months: *Provided*, That

(1) The Administrator may grant approval for additional periods if he finds that the experiments can be reasonably expected to contribute to improvements in exterior lighting;

(2) Not more than 15 aircraft possessing a U. S. certificate of airworthiness may have installed at any one time experimental exterior lighting equipment of one basic type;

(3) The Administrator shall prescribe such conditions and limitations as may be necessary to insure safety and avoid confusion in air navigation;

(4) The person engaged in the operation of the aircraft shall disclose publicly the deviations of the exterior lighting from the relevant specifications contained in the Civil Air Regulations at times and in a manner prescribed by the Administrator; and

(5) Upon application for approval to conduct experimentation with exterior lighting, the applicant shall advise the Administrator of the specific purpose of the expeiments to be conducted; and at the conclusion of the approved period of experimentation, he shall advise the Administrator of the detailed results thereof.

This regulation supersedes Special Civil Air Regulation No. SR–392A and shall terminate February 25, 1962, unless sooner superseded or rescinded.