Civil Aeronautics Manual 6

Rotorcraft Airworthiness

Normal Category

FEDERAL AVIATION AGENCY

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E. R. QUESADA, *Administrator*

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Introductory Note

Civil Aeronautics Manuals are published by the Civil Aeronautics Administration to supplement and explain the Civil Air Regulations. This manual contains rules, policies, and interpretations of the Administrator of Civil Aeronautics which pertain to the current requirements of Part 6 of the Regulations of the Civil Aeronautics Board. This manual will be revised from time to time as a result of amendments to Part 6, and as new manual material is found necessary to keep the public informed on acceptable means of showing compliance with the requirements of Part 6.

CAA *rules* are issued pursuant to authority conferred upon the Administrator in the Civil Air Regulations. Such rules are mandatory and must be complied with.

CAA *interpretations* define or explain words and phrases of the Civil Air Regulations. Such interpretations are for the guidance of the public and will be followed by the Administration in determining compliance with the regulations.

CAA *policies* provide recommended methods of complying with the Civil Air Regulations. Such policies are for the guidance of the public and are not mandatory in nature.

The Administrator's rules, interpretations, and policies set forth acceptable procedures and practices for the guidance of the public in complying with the regulations. Other methods or practices which provide equivalent safety to those specified by the Administrator will also be acceptable. Any provisions which are shown to be inapplicable in a particular case may be modified upon request.

The text of this manual is arranged to set forth in bold type each numbered section of the Civil Air Regulations followed by related rules, policies, or interpretations of the Administrator. The Administrator's sections pertaining to a particular section of the Board's regulations are identified by consecutive dash numbers appended to the regulation section numbers. Thus, section 6.0 means section 6.0 of the Civil Air Regulations, and section 6.0–2 means the second of the Administrator's sections under section 6.0.

Civil Aeronautics Manuals and supplements thereto are published in the Federal Register which, in turn, is codified in the Code of Federal Regulations at the end of each year. Until such time as Federal Register material is picked up in the Code, reference to material published during a current year is cited by volume, page number, and date. Thus, 21 F. R. 2086, May 25, 1956, means volume 21 of the Federal Register, page 2086, published on May 25, 1956.

In future supplements to this manual, the Federal Register publication date and effective date will appear in brackets at the end of each section revised or amended as a matter of information.

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General

Applicability and Definitions

6.0 *Applicability of this part.* This part contains standards with which compliance shall be demonstrated for the issuance of and changes to type certificates for rotorcraft. This part, until superseded or rescinded, shall apply to rotorcraft of any weight for which applications for type certification under this part were made between the effective date of this part (January 15, 1951) and August 1, 1956. For applications for type certificates made after August 1, 1956, this part shall apply only to rotorcraft which have a maximum weight of 6,000 pounds or less.

6.1 *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 a rotorcraft 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. 6.18.)

(b) *Rotorcraft types.*

(1) *Rotorcraft:* A rotorcraft is any aircraft deriving its principal lift from one or more rotors.

(2) *Helicopter.* A helicopter is a rotorcraft which depends principally for its support and motion in the air upon the lift generated by one or more power-driven rotors, rotating on substantially vertical axes.

(3) *Gyroplane.* A gyroplane is a rotorcraft which depends principally for its support upon the lift generated by one or more rotors which are not power driven, except for initial starting, and which are caused to rotate by the action of the air when the rotorcraft is in motion. The propulsion is independent of the rotor system and usually consists of conventional propellers.

(4) *Gyrodyne.* A gyrodyne is a rotorcraft which depends principally for its support upon the lift generated by one or more rotors which are partially power driven, rotating on substantially vertical axes. The propulsion is independent of the rotor system and usually consists of conventional propellers.

(c) *General design.*

(1) *Standard atmosphere.* The standard atmosphere is an atmosphere [(see NACA Technical Report 1235)] 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 lbs. 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. 6.451.)

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

(4) *Autorotation.* Autorotation is a rotorcraft flight condition in which the lifting rotor is driven entirely by the action of the air when the rotorcraft is in motion.

(5) *Autorotative landing.* An autorotative landing is any landing of a rotorcraft in which the entire maneuver is accomplished without the application of power to the rotor.

(6) *Ground resonance.* Ground resonance is the mechanical instability encountered when the rotorcraft is in contact with the ground.

(7) *Mechanical instability.* Mechanical instability is an unstable resonant condition due to the interaction between the rotor blades and the rotorcraft structure, while the rotorcraft is on the ground or airborne.

(d) *Weights.*

(1) *Maximum weight.* The maximum weight of the rotorcraft is that maximum at which compliance with the requirements of this part of the Civil Air Regulations is demonstrated. (See sec. 6.101.)

(2) *Minimum weight.* The minimum weight of the rotorcraft is that minimum at which compliance with the requirements of this part of the Civil Air Regulations is demonstrated. (See sec. 6.101.)

(3) *Empty weight.* The empty weight of the rotorcraft is a readily reproducible weight which is used in the determination of the operating weights. (See sec. 6.104.)

(4) *Design maximum weight.* The design maximum weight is the maximum weight of the rotorcraft at which compliance is shown with the structural loading conditions. (See sec. 6.101.)

(5) *Design minimum weight.* The design minimum weight is the minimum weight of the rotorcraft at which compliance is shown with the structural loading conditions. (See sec. 6.101.)

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

(i) Gasoline 6 lbs. per U. S. gallon,

(ii) Lubricating oil 7.5 lbs. per U. S. gallon,

(iii) Crew and passengers 170 lbs. per person.

(e) *Speeds.*

(1) *IAS.* Indicated air speed is equal to the pitot static airspeed indicator reading as installed in the rotorcraft without correction for air-speed indicator system errors but including the sea level standard adiabatic compressible flow correction. (This latter correction is included in the calibration of the air-speed instrument dials.) (See secs. 6.612 and 6.732.)

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

(3) *EAS.* Equivalent air speed is equal to the air-speed 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 air speed of the rotorcraft relative to undisturbed air.
($TAS = EAS\ (Po/\rho)^{1/2}$)

(5) V_H. The maximum speed obtainable in level flight with rated r. p. m. and power.

(6) V_{NE}. The never-exceed speed. (See sec. 6.711.)

(7) V_X. The speed for best angle of climb.

(8) V_Y. The speed for best rate of climb.

(f) *Structural.*

(1) *Limit load.* A limit load is the maximum load anticipated in normal conditions of operation. (See sec. 6.200.)

(2) *Ultimate load.* An ultimate load is a limit load multiplied by the appropriate factor of safety. (See sec. 6.200.)

(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. 6.200.)

(4) *Load factor.* The load factor is the ratio of a specified load to the total weight of the rotorcraft; 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) *Fitting.* A fitting is a part or terminal used to join one structural member to another. (See sec. 6.307 (d).)

[(g) *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, 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, under the maximum conditions of engine rotor shaft rotational speed and gas temperature approved for normal take-off, and limited in use to a maximum continuous 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, under the maximum conditions of engine 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 continuous power for reciprocating engines is the brake horsepower developed in standard atmosphere at a specified altitude, 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, under the maximum conditions of engine 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, under the maximum conditions of engine 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.

(h) Propellers and rotors.[2]

(1) *Rotor.* Rotor is a system of rotating airfoils.

(2) *Main rotor.* The main rotor is the main system of rotating airfoils providing sustentation for the rotorcraft.

(3) *Auxiliary rotor.* An auxiliary rotor is one which serves either to counteract the effect of the main rotor torque on the rotorcraft, or to maneuver the rotorcraft about one or more of its three principal axes.

(4) *Axis of no feathering.* The axis of no feathering is the axis about which there is no first harmonic feathering or cyclic pitch variation.[3]

(5) *Plane of rotor disc.* The plane of rotor disc is a reference plane at right angles to the axis of no feathering.

[1] For engine airworthiness requirements see Part 13 of the Civil Air Regulations.

[2] For propeller airworthiness requirements see Part 14 of the Civil Air Regulations.

[3] See NACA Technical Note No. 1604.

(6) *Tip speed ratio.* The tip speed ratio is the ratio of the rotorplane flight velocity component in the plane of rotor disc to the rotational tip speed of the rotor blades expressed as follows:

$$\mu=\frac{V \cos \alpha}{\Omega R}$$

where:

V=air speed of the rotorcraft along flight path (feet per second),

α=angle between projection in plane of symmetry of axis of no feathering and a line perpendicular to the flight path (radians, positive when axis is pointing aft),

Ω=angular velocity of rotor (radians per second),

R=rotor radius (feet).

(i) *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.

Certification

6.10 *Eligibility for type certificates.* A rotorcraft shall be eligible for type certification under the provisions of this part if it complies with the airworthiness provisions hereinafter established 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 rotorcraft which renders it unsafe.

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

(a) Unless otherwise established by the Board, the rotorcraft 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 effective 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 three years, a new application for type certificate shall be required, except that for applications pending on May 1, 1954, such three-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 three-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. 6.13 (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 6.13 (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 rotorcraft, and the Administrator finds that the regulations incorporated by reference in the type certificate pursuant to section 6.13 (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 power plant installation which is likely to introduce additional fire or operational hazards unless additional protective measures are incorporated; the installation of a new rotor 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 or rotors;

(2) A change to engines or rotors 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.

6.12 *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. 6.11.)

6.13 *Type certificate.*

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

(b) The type certificate shall be deemed to include the type design (see sec. 6.14 (b)), the operating limitations for the rotorcraft (see sec. 6.700), and any other conditions or limitations prescribed by the Civil Air Regulations.

(c) The applicable provisions of this part recorded by the Administrator in accordance with section 6.12 shall be considered as incorporated in the type certificate as though set forth in full.

6.14 *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 rotorcraft 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 rotorcraft 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 rotorcraft, and such other data as are necessary to permit by comparison the determination of the airworthiness of subsequent rotorcraft of the same type.

6.15 *Inspections and tests.* Inspections and tests shall include all those found necessary by the Administrator to insure that the rotorcraft 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 rotorcraft 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.

6.16 *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 rotorcraft 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 rotorcraft, its components, and equipment are reliable and function properly. The extent of such additional flight tests shall depend upon the complexity of the rotorcraft, the number and nature of new design features, and the record of previous tests and experience for the particular rotorcraft type, its components, and equipment. If practicable, these flight tests shall be conducted on the same rotorcraft used in the flight tests specified in paragraph (a) of this section and in the rotor drive endurance tests specified in section 6.412.

6.17 *Airworthiness, experimental, and production certificates.* (For requirements with regard to these certificates see Part 1 of the Civil Air Regulations.)

6.18 ***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 Civil Air Regulations. 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.

(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.

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 a rotorcraft, or by any other form of approval by the Administrator.

6.18–1 *Approval of aircraft components (CAA rules which apply to sec. 6.18).* Aircraft components made the subject of technical standards orders shall be approved upon the basis and in the manner provided in Part 514 of this title (Regulation of the Administrator).

(16 F. R. 672, Jan. 25, 1951, effective Jan. 25, 1951.)

[6.18–2 *Manufacturer (CAA interpretation which applies to sec. 6.18 (b)).* For the purpose of accepting a statement of conformance for a Technical Standard Order Product, the word "manufacturer" is interpreted to mean a person who designs and fabricates by welding, cutting, drilling, forming, bolting, riveting, glueing, soldering, sewing, etc., a product. This includes products which are composed in whole or in part of components of TSO products. One who merely cleans products or appliances or repairs them by replacing standard parts and/or by replacing components with identical ones is not considered to be the manufacturer. Nor is the distributor of another person's completed product considered to be the manufacturer.

(23 F. R. 10326, Dec. 25, 1958, effective Jan. 31, 1959.)

[6.18–3 *Products approved as a part of the rotorcraft (CAA policies which apply to sec. 6.18).*

[(a) A material, part or appliance (hereinafter called product) may be approved as a part of the rotorcraft type design under a type certificate or a supplemental type certificate.

[(1) If a Technical Standard Order covering the product is in effect, the applicant for approval should submit type design data showing that the product meets the performance standards of the Technical Standard Order except that:

[(i) Deviations from the performance standards may be allowed when the applicant for, or holder of, the type certificate or the supplemental type certificate substantiates that other performance standards are applicable for the product as installed in the rotorcraft. Any deviation from standards prescribed in this part may be allowed only in accordance with section 6.10.

[(2) Where no TSO covering the product exists, the applicant for approval should submit type design data showing compliance with all the requirements of this part which are applicable to the product.

[(3) Products previously approved by the CAA by means of letters of approval, Repair and Alteration Form ACA–337, or listing on CAA Product and Process Specifications will continue to be eligible for installation in aircraft unless the eligibility is restricted by applicable regulations or airworthiness directives issued under section 1.24 of this subchapter.

[(b) Products approved as a part of the rotorcraft type design under a type certificate should be identified by a rotorcraft part number on the approved drawing list.

[(c) Products approved as a part of the rotorcraft under a supplemental type certificate should be identified by a part or drawing number on such certificate.

[(d) Each TSO product that is approved as a part of the rotorcraft should have the TSO identification removed and be identified as set forth in paragraph (b) or (c) of this section, whichever is applicable.]

(23 F. R. 10326, Dec. 25, 1958, effective Jan. 31, 1959.)

6.19 ***Changes in type design.*** **(For requirements with regard to changes in type design and the designation of applicable regulations therefor, see sec. 6.11 (d) and (e), and Part 1 of this subchapter.)**

Flight

General

6.100 ***Proof of compliance.***

(a) Compliance with the requirements prescribed in this subpart shall be established by flight or other tests conducted upon a rotorcraft 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 rotorcraft 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, and trim of the rotorcraft 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 rotorcraft 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.

(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.

6.101 ***Weight limitations.*** **The maximum and minimum weights at which the rotorcraft 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) The maximum weight shall not be less than the sum of weights of the following: (1) The empty weight in accordance with section 6.104, (2) usable fuel appropriate to the operation contemplated with full payload, (3) the full oil capacity, (4) 170 pounds in all seats, except that when the maximum permissible weight to be carried in a seat is less than 170 pounds it shall be acceptable to use this lesser weight. (See sec. 6.738 (a).)

(c) The minimum weight 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.

(d) The minimum weight shall not exceed the sum of the weights of the following: (1) The empty weight in accordance with section 6.104, (2) the minimum crew necessary to operate the rotorcraft, assuming for each crew member the lowest of the following: (i) 170 lbs., (ii) weight selected by the applicant, (iii) weight included in the loading instructions (see secs. 6.102 (b) and 6.738 (a)), (3) oil in the quantity determined in accordance with the provisions of section 6.440 (b).

6.102 *Center of gravity limitations.*

(a) Center of gravity limits shall be established as the most forward position permissible for each weight established in accordance with section 6.101 and the most aft position permissible for each of such weights. Such limits of the center of gravity range shall not exceed any of the following: (1) The extremes selected by the applicant, (2) the extremes for which the structure has been proven, (3) the extremes at which compliance with all of the applicable flight requirements has been demonstrated.

(b) Loading instructions shall be provided if the center of gravity position under any possible loading condition between the maximum and minimum weights as specified in section 6.101, with assumed weights for individual passengers and crew members variable over the anticipated range of such weights, lies beyond: (1) The extremes selected by the applicant, (2) the extremes for which the structure has been proven, (3) the extremes for which compliance with all of the applicable flight requirements has been demonstrated. (See sec. 6.741 (c).)

6.103 *Rotor limitations and pitch settings.*

(a) *Power-on.* A range of power-on operating speeds for the main rotor(s) shall be established which will provide adequate margin to accommodate the variation of rotor rpm attendant to all maneuvers appropriate to the rotocraft type and consistent with the type of synchronizer or governor used, if any (see secs. 6.713 (b) (2) and 6.714 (b)). A means shall be provided to prevent rotational speeds substantially less than the approved minimum rotor rpm in any flight condition with pitch control of the main rotor(s) in the high-pitch position. It shall be acceptable for such means to allow the use of higher pitch in an emergency, provided that the means incorporate provisions to prevent inadvertent transition from the normal operating range to the higher-pitch angles and with the engine(s) operating within the approved limitations.

(b) *Power-off.* A range of power-off operating rotor speeds shall be established which will permit execution of all autorotative flight maneuvers appropriate to the rotorcraft type throughout the range of air speeds and weights for which certification is sought (see secs. 6.713 (a) and 6.713 (b) (1)). A rotor blade low-pitch limiting device shall be positioned to provide rotational speeds within the approved rotor speed range in any autorotative flight condition under the most adverse combinations of weight and air speed with the rotor pitch control in the full low-pitch position.

6.104 *Empty weight.*

(a) The empty weight, and the corresponding center of gravity position, shall be determined by weighing the rotocraft. 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. 6.421), undrainable oil, total quantity of engine coolant, and total quantity of hydraulic fluid.

(b) The condition of the rotorcraft at the time of weighing shall be one which can be easily repeated and easily defined, particularly as regards the contents of the fuel, oil, and coolant tanks, and the items of equipment installed. (See sec. 6.740.)

6.105 *Use of ballast.* Removable ballast may be used to enable the rotorcraft to comply with the flight requirements. (See secs. 6.391, 6.738, and 6.740.)

Performance

6.110 *General.* The performance information prescribed in sections 6.111 through 6.115 shall be determined, and the rotorcraft shall comply with the corresponding requirements in the standard atmosphere in still air.

6.111 *Take-off.* The take-off shall be demonstrated at maximum certificated weight, forward center of gravity, and using take-off power at take-off r. p. m. and made in a manner such that a landing can be made safely at any point along the flight path in case of an engine failure and shall not require an exceptional degree of skill on the part of the pilot or exceptionally favorable conditions. Pertinent information concerning the take-off procedure, including the type of take-off surface and appropriate climb-out air speeds, shall be specified in the operating procedures section of the Rotorcraft Flight Manual. (See secs. 6.715, 6.740, and 6.742.)

6.112 *Climb.*

(a) For all rotorcraft except helicopters the steady rate of climb at the best rate-of-climb speed with maximum continuous power and landing gear retracted shall be determined over the range of weights, altitudes, and temperatures for which certification is sought (see sec. 6.740). This rate of climb shall provide a steady angle of climb under standard sea level conditions of not less than 1:6.

(b) For helicopters the best rate-of-climb speed shall be determined at standard sea level conditions at maximum certificated weight with all engines operating at maximum continuous power.

(c) For multiengine helicopters the steady rate of climb or descent shall be determined at maximum certificated weight, at the best rate-of-climb or descent speed, with one engine inoperative, and the remaining engine(s) operating at maximum continuous power.

6.113 *Minimum operating speed performance.*

(a) Hovering ceilings for helicopters shall be determined over the range of weights, altitudes, and temperatures for which certification is sought with take-off power and landing gear extended in the ground effect at a height above the ground consistent with normal take-off procedures.

(b) At maximum weight, under standard atmospheric conditions, and under conditions prescribed in paragraph (a) of this section, the hovering ceiling for helicopters shall not be less than 4,000 feet.

(c) For rotorcraft other than helicopters, the steady rate of climb at the minimum operating speed appropriate to the type with take-off power and landing gear extended shall be determined over the range of weights, altitudes, and temperatures for which certification is sought.

6.114 *Autorotative or one-engine-inoperative landing.* Landings shall be demonstrated in accordance with the provisions of paragraphs (a) through (d) of this section. Pertinent information concerning the landing procedure, including the type of landing surface and appropriate approach and glide air speeds, shall be specified in the operating procedures section of the Rotorcraft Flight Manual (see secs. 6.740 and 6.742).

(a) The approach speed or speeds in the glide shall be appropriate to the type of rotorcraft and shall be chosen by the applicant.

(b) The approach and landings shall be made with power off for single-engine rotorcraft, and with one engine inoperative for multiengine rotorcraft.

(c) The approach and landing shall be entered from steady autorotation and shall be made in such a manner that its reproduction would not require an exceptional degree of skill on the part of the pilot or exceptionally favorable conditions.

(d) During the landing there shall be no excessive vertical acceleration and no tendency

to bounce, nose over, ground loop, porpoise, or water loop.

[6.114–1 *Autorotative or one-engine-inoperative landing for helicopters with float installations (FAA policies which apply to sec. 6.114).*

[(a) Helicopters equipped with float installations* should comply with the following:

[(1) Landings should be conducted on water at wave heights selected by the applicant to show compliance with sections 6.114 and 6.715.

[(2) When approval is requested under the air carrier operating regulations (see secs. 46.70, 46.71, and 46.206 of this chapter) for operations involving takeoff or landing over water with helicopters certificated under this part, compliance should be shown with subparagraph (1) of this paragraph.

[(3) For approval of night operations, landings from cruising altitude should be conducted in accordance with subparagraph (1) or (2) of this paragraph.

[(4) Pertinent information concerning the operating procedures investigated and the surface conditions prevailing during these landings should be included in the operating procedure section of the Rotorcraft Flight Manual.]

(24 F. R. 965, Feb. 10, 1959, effective Feb. 26, 1959.)

6.115 *Power-off landings for multiengine rotorcraft.* For all multiengine rotorcraft it shall be possible to make a safe landing following complete failure of all power during normal operating conditions.

Flight Characteristics

6.120 *General.*

(a) The rotorcraft shall comply with the requirements prescribed in sections 6.120 through 6.123 at all normally expected operating altitudes, under all critical loading conditions within the range of weight and center of gravity, and for all speeds, power, and rotor rpm conditions for which certification is sought.

(b) It shall be possible to maintain a flight condition and to make a smooth transition from one flight condition to another 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 powerplant failure.

(c) For night or instrument certification the rotorcraft shall have such additional flight characteristics as the Administrator finds are required for safe operation under those conditions.

6.121 *Controllability.*

(a) The rotorcraft shall be safely controllable and maneuverable during steady flight and during the execution of any maneuver appropriate to the type of rotorcraft, including take-off, climb, level flight, turn, glide, and power-on or power-off landings.

(b) The margin of longitudinal and lateral cyclic control shall allow satisfactory pitching and rolling control at V_{NE} (see sec. 6.711) with: (1) Maximum weight, (2) critical center of gravity, (3) power on and power off, (4) critical rotor rpm.

(c) Compliance with paragraph (b) of this section shall include a demonstration with a power failure at V_H or V_{NE} whichever is the lesser.

(d) There shall be established a wind velocity in which the rotorcraft can be operated without loss of control on or near the ground at the critical weight and center of gravity and the critical rotor rpm in any maneuver appropriate to the type of rotorcraft (e. g. cross-wind take-offs, sideward or rearward flight). This wind velocity shall not be less than 20 mph.

6.122 *Trim.* It shall be possible in steady level flight at any speed appropriate to the type of rotorcraft to trim the steady longitudinal and lateral control forces to zero. The trim device shall not introduce any undesirable discontinuities in the force gradients.

6.123 *Stability.*

(a) *General.* It shall be possible to fly the rotorcraft in normal maneuvers, including a minimum of three take-offs and landings, for a continuous period of time appropriate to the

[*"Salvage float gear" constitutes means to keep the helicopter afloat for salvage purposes only and is not to be regarded as a float installation.]

operational use of the particular type of rotorcraft without the pilot experiencing undue fatigue or strain. In addition, the rotorcraft shall comply with the requirements of paragraph (b) of this section.

(b) *Static longitudinal stability.* In the following configurations the characteristics of the longitudinal cyclic control shall be such that, with constant throttle and collective pitch settings, a rearward displacement of longitudinal control shall be necessary to obtain and maintain speeds below the specified trim speed, and a forward displacement shall be necessary to obtain and maintain speeds above the specified trim speed for the ranges of altitude and rotor rpm for which certification is sought:

(1) *Climb.* The stick position curve shall have a stable slope over a speed range from 15 percent of V_Y or 15 mph, whichever is greater, below V_Y to 20 percent of V_Y or 15 mph, whichever is greater, above V_Y, but in no case greater than 1.1 V_{NE}, with:

(i) Critical weight and center of gravity,
(ii) Maximum continuous power,
(iii) Landing gear retracted, and
(iv) Trim at best rate-of-climb speed (V_Y).

(2) *Cruise.* The stick position curve shall have a stable slope over a speed range from 0.7 V_H or 0.7 V_{NE}, whichever is less, to 1.1 V_H or 1.1 V_{NE}, whichever is less, with:

(i) Critical weight and center of gravity,
(ii) Power for level flight at 0.9 V_H or 0.9 V_{NE}, whichever is less,
(iii) Landing gear retracted, and
(iv) Trimmed at 0.9 V_H or 0.9 V_{NE}, whichever is less.

(3) *Autorotation.* The stick position curve shall have a stable slope throughout the speed range for which certification is sought, with: (i) Critical weight and center of gravity, (ii) power off, (iii) landing gear both retracted and extended, (iv) trim at the speed for minimum rate of descent.

(4) *Hovering.* In the case of helicopters the stick position curve shall have a stable slope between the maximum approved rearward speed and a forward speed of 20 mph with: (i) Critical weight and center of gravity, (ii) power required for hovering in still air, (iii) landing gear retracted, (iv) trim for hovering.

Ground and Water Handling Characteristics

6.130 *General.* The rotorcraft shall be demonstrated to have satisfactory ground and water handling characteristics. There shall be no uncontrollable tendencies in any operating condition reasonably expected for the type.

6.131 *Ground resonance.* There shall be no uncontrollable tendency for the rotorcraft to oscillate when the rotor is turning and the rotorcraft is on the ground.

6.132 *Spray characteristics.* For rotorcraft equipped with floats, the spray characteristics during taxying, take-off, and landing shall be such as not to obscure the vision of the pilot nor produce damage to the rotors, propellers, or other parts of the rotorcraft.

Miscellaneous Flight Requirements

6.140 *Flutter and vibration.* All parts of the rotorcraft shall be demonstrated to be free from flutter and excessive vibration under all speed and power conditions appropriate to the operation of the type of rotorcraft. (See also secs. 6.203 (f) and 6.711.)

Structure

General

6.200 *Loads.*

(a) 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 provisions set forth in paragraphs (b) through (e) of this section shall apply.

(b) The factor of safety shall be 1.5 unless otherwise specified. The factor of safety shall apply to the external and inertia loads, unless its application to the resulting internal stresses is more conservative.

(c) 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 rotorcraft.

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

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

6.201 *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 not be such as to interfere with safe operation of the rotorcraft.

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

6.202 *Proof of structure.*

(a) Proof of compliance of the structure with the strength and deformation requirements of section 6.201 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 6.203.

6.203 *Structural and dynamic tests.* At least the following structural tests shall be conducted to show compliance with the strength criteria:

(a) Dynamic and endurance tests of rotors and rotor drives, including controls (see sec. 6.412).

(b) Control surface and system limit load tests (see sec. 6.323).

(c) Control system operation tests (see sec. 6.324).

(d) Flight stress measurements (see secs. 6.221 and 6.250).

(e) Landing gear drop tests (see sec. 6.237).

(f) Ground vibration tests to determine the natural frequencies of the blades and major structural components of the rotorcraft.

(g) Such additional tests as may be found necessary by the Administrator to substantiate new and unusual features of the design.

6.203–1 *Fixed or ground adjustable stabilizing surfaces (CAA policies which apply to secs. 6.10 and 6.203 (b)).* The purpose of section 6.203 is to require the testing of certain components which in the details of their construction, operational characteristics, or loading, do not lend themselves to established and reliable methods of analysis. In this regard, proof testing such items as fixed or ground adjustable stabilizing surfaces is not considered a minimum requirement and will not be necessary provided sufficient experience has been accumulated from previous satisfactory designs, methods of analysis and tests to justify acceptance of these components on the basis of structural analysis. Therefore, these components may be regarded structurally the same as any other part of the basic airframe.

(18 F. R. 2877, May 19, 1953, effective June 15, 1953.)

6.204 *Design limitations.* The following values shall be established by the applicant for purposes of showing compliance with the structural requirements specified in this subpart:

(a) Maximum design weight,

(b) Power-on and power-off main rotor r. p. m. ranges (see secs. 6.103 and 6.713 through 6.714 (b)),

(c) Maximum forward speeds for the power-on and power-off rotor r. p. m. ranges established in accordance with paragraph (b) of this section (see sec. 6.711),

(d) Maximum rearward and sideward flight speeds,

(e) Extreme positions of rotocraft center of gravity to be used in conjunction with the limitations of paragraphs (b), (c), and (d) of this section,

(f) Rotational speed ratios between the powerplant and all connected rotating components,

(g) Positive and negative limit maneuvering load factors.

Flight Loads

6.210 *General.* Flight load requirements shall be complied with at all weights from the design minimum weight to the design maximum weight, with any practicable distribution of disposable load within prescribed operating limitations stated in the Rotorcraft Flight Manual (see sec. 6.741).

6.211 *Flight load factors.* The flight load factors shall represent rotor load factors. The net load factor acting at the center of gravity of the rotorcraft shall be obtained by proper consideration of balancing loads acting in the specific flight conditions.

6.212 *Maneuvering conditions.* The rotorcraft structure shall be designed for a positive maneuvering limit load factor of 3.5 and for a negative maneuvering limit load factor of 1.0, except that lesser values shall be allowed if the manufacturer shows by analytical study and flight demonstrations that the probability of exceeding the values selected is extremely remote. In no case shall the limit load factors be less than 2.0 positive and 0.5 negative. The resultant loads shall be assumed to be applied at the center(s) of the rotor hub(s) and to act in such directions as necessary to represent all critical maneuvering motions of the rotorcraft applicable to the particular type, including flight at the maximum design rotor tip speed ratio under power-on and power-off conditions.

6.213 *Gust conditions.* The rotorcraft structure shall be designed to withstand the loading due to a vertical gust of 30 feet per second in velocity in conjunction with the critical rotorplane air speeds, including hovering.

Control Surface and System Loads

6.220 *General.* The structure of all auxiliary rotors (antitorque and control), fixed or movable stabilizing and control surfaces, and all systems operating any flight controls shall be designed to comply with the provisions of sections 6.221 through 6.225.

6.221 *Auxiliary rotor assemblies.* Auxiliary rotor assemblies shall be tested in accordance with the provisions of section 6.412 for rotor drives. In addition, auxiliary rotor assemblies with detachable blades shall be substantiated for centrifugal loads resulting from the maximum design rotor r. p. m. In the case of auxiliary rotors with highly stressed metal components, the vibration stresses shall be determined in flight, and it shall be demonstrated that these stresses do not exceed safe values for continuous operation.

6.221–1 *Service life of auxiliary rotor assemblies (CAA interpretations which apply to sec. 6.221).* The requirement in section 6.221 that vibration stresses in highly stressed metal components of auxiliary rotors must not exceed safe values for continuous operation is interpreted to mean that the service life of such components should be determined by fatigue tests or by other methods found acceptable by the Administrator. The methods of service life determination for main rotor structure outlined under section 6.250–1 are considered to be acceptable in showing compliance with the pertinent portion of section 6.221.

(16 F. R. 3405, Apr. 19, 1951, effective May 1, 1951.)

6.222 *Auxiliary rotor attachment structure.* The attachment structure for the auxiliary rotors shall be designed to withstand a limit load equal to the maximum loads in the structure occurring under the flight and landing conditions.

6.223 *Tail rotor guard.* When a tail rotor is provided on a rotorcraft it shall not be possible for the tail rotor to contact the landing medium during a normal landing. If a tail rotor guard is provided which will contact the landing medium during landings and thus prevent tail rotor contact, suitable design loads for the guard shall be established, and the guard and its supporting structure shall be designed to withstand the established loads.

6.224 *Stabilizing and control surfaces.* Stabilizing and control surfaces shall be designed to withstand the critical loading from maneuvers or from combined maneuver and gust. In no case shall the limit load be less than 15 lbs. per square foot or a load due to $C_N=0.55$ at the maximum design speed. The load distribution shall simulate closely the actual pressure distribution conditions.

6.225 *Primary control systems.* Manual control systems shall comply with the provisions of paragraphs (a) and (b) of this section.

(a) From the pilot compartment to the stops which limit the range of motion of the pilots' controls, the controls shall be designed to withstand the limit pilot applied forces as set forth in subparagraphs (1) through (3) of this paragraph, unless it is shown that the pilot is unable to apply such loads to the system. In the latter event the system shall be designed for the maximum loads which the pilot is able to apply, except that in any case values less than 0.60 of those specified shall not be employed.

(1) Foot type controls—130 pounds,

(2) Stick type controls—fore and aft 100 pounds—laterally 67 pounds,

(3) Wheel type controls—fore and aft 100 pounds—laterally 53-pound couple applied on opposite sides of the control wheel.

(b) From the stops to the attachment of the control system to the rotor blades (or control areas) the control system shall be designed to withstand the maximum loads which can be obtained in normal operation of the rotorcraft, except that where jamming, ground gusts, control inertia, or friction can cause loads exceeding operational loads, the system shall be capable of supporting without yielding 0.60 of the loads specified in subparagraphs (1), (2), and (3) of paragraph (a) of this section.

Landing Loads

6.230 *General.*

(a) *Loads and equilibrium.* The limit loads obtained in the landing conditions shall be considered as external loads which would occur in a rotorcraft structure if it were acting as a rigid body. In each of the conditions the external loads shall be placed in equilibrium with the linear and angular inertia loads in a rational or conservative manner. In applying the specified conditions the provisions of paragraphs (b) through (e) of this section shall be complied with.

(b) *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.

(c) *Design weight.* The design weight used in the landing conditions shall not be less than the maximum weight of the rotorcraft. It shall be acceptable to assume a rotor lift, equal to one-half the design maximum weight, to exist throughout the landing impact and to act through the center of gravity of the rotorcraft. Higher values of rotor lift shall be acceptable if substantiated by tests and/or data which are applicable to the particular rotorcraft.

(d) *Load factor.* The structure shall be designed for a limit load factor, selected by the applicant, of not less than the value of the limit inertia load factor substantiated in accordance with the provisions of section 6.237, except in conditions in which other values of load factor are prescribed.

(e) *Landing gear position.* The tires shall be assumed to be in their static position, and the shock absorbers shall be assumed to be in the most critical position, unless otherwise prescribed.

(f) *Landing gear arrangement.* The provisions of sections 6.231 through 6.236 shall be applicable to landing gear arrangements where two wheels are located aft and one or more wheels are located forward of the center of gravity.

6.231 *Level landing conditions.*

(a) Under loading conditions prescribed in paragraph (b) of this section, the rotorcraft shall be assumed to be in the following two level landing attitudes:

(1) All wheels contacting the ground simultaneously.

(2) The aft wheels contacting the ground while the forward wheel(s) being just clear of the ground.

(b) The following two level landing loading conditions shall be considered. Where the forward portion of the landing gear has two wheels, the total load applied to the forward wheels shall be divided between the two wheels in a 40:60 proportion.

(1) Vertical loads shall be applied in accordance with the provisions of section 6.230.

(2) The vertical loads specified in subparagraph (1) of this paragraph shall be combined with a drag load at each wheel. The drag loads shall not be less than 25 percent of the respective vertical loads. For the attitude prescribed in paragraph (a) (1) of this section the resulting pitching moment shall be assumed resisted by the forward gear, while for the attitude prescribed in paragraph (a) (2) of this section the resulting pitching moment shall be assumed resisted by angular inertia forces.

6.231–1 *Distribution of vertical ground reaction loads and determination of angular inertia loads (CAA interpretations which apply to sec. 6.231 (b) (2)).*

(a) Although section 6.231 (b) (2) states that the vertical loads are those specified in section 6.231 (b) (1), the distribution of the vertical loads among the ground reaction points is not necessarily the same for the two subparagraphs since the requirements of section 6.230 must be met. Section 6.230 (a) states, in part, that the external loads shall be placed in equilibrium with the linear and angular intertia loads in a rational or conservative manner.

(b) Compliance with section 6.231 (b) (2) is interpreted to require that a vertical inertia load of nW and a horizontal inertia load of 0.25 nW be applied at the center of gravity. For the level landing with drag on all wheels, the vertical ground reaction loads should be distributed between the forward and rear wheels to place the ground reaction loads in equilibrium with the rotorcraft linear inertia loads. For the level landing with drag on main wheels only, the pitching moments arising from the vertical and horizontal ground reactions should be placed in equilibrium with an angular inertia load about the c. g.

(c) The drag load at each wheel, in both cases, is required to be equal to 0.25 times the respective wheel vertical load.

(17 F. R. 8322, Sept. 17, 1952, effective Sept. 17, 1952.)

6.232 *Nose-up landing conditions.* The rotorcraft shall be assumed in the maximum nose-up attitude permitting clearance of the ground by all parts of the rotorcraft. The ground loads shall be applied perpendicularly to the ground.

6.233 *One-wheel landing condition.* The rotorcraft shall be assumed in the level attitude to contact the ground on one of the wheels located aft of the center of gravity. The vertical load shall be the same as that obtained on the one side in the condition specified in section 6.231 (b) (1). The unbalanced external loads shall be reacted by the inertia of the rotorcraft.

6.234 *Lateral-drift landing condition.* (a) The rotorcraft shall be assumed in the level landing attitude. Side loads shall be combined with one-half the maximum ground reactions obtained in the level landing conditions of section 6.231 (b) (1). These loads shall be applied at the ground contact point, unless the landing gear is of the full-swiveling type in which case the loads shall be applied at the center of the axle. The conditions set forth in paragraphs (b) and (c) of this section shall be considered.

(b) Only the wheels aft of the center of gravity shall be assumed to contact the ground. Side loads equal to 0.8 of the vertical reaction acting inward (on one side) and 0.6 of the vertical reaction acting outward (on the other side) shall be combined with the vertical loads specified in paragraph (a) of this section.

(c) The forward and aft wheels shall be assumed to contact the ground simultaneously. Side loads on the wheels aft of the center of gravity shall be applied in accordance with paragraph (b) of this section. A side load at the forward gear equal to 0.8 of the vertical reaction shall be combined with the vertical load specified in paragraph (a) of this section.

6.235 *Brake roll conditions.* The rotorcraft attitudes shall be assumed to be the same as those prescribed for the level landing conditions in section 6.231 (a), with the shock absorbers deflected to their static position. The limit vertical load shall be based upon a load factor of 1.33. A drag load equal to the vertical load multiplied by a coefficient of friction of 0.8 shall be applied at the ground contact point of each wheel equipped with brakes, except that the drag load need not exceed the maximum value based on limiting brake torque.

6.236 *Taxying condition.* The rotorcraft and its landing gear shall be designed for loads which occur when the rotorcraft is taxied over the roughest ground which it is reasonable to expect in normal operation.

6.237 *Shock absorption tests.* Drop tests shall be conducted in accordance with paragraphs (a) and (b) of this section to substantiate the landing limit inertia load factor (see sec. 6.230 (d)) and to demonstrate the reserve energy absorption capacity of the landing gear. The drop tests shall be conducted with the complete rotorcraft or on units consisting of wheel, tire, and shock absorber in their proper relation.

(a) *Limit drop test.* The drop height in the limit drop test shall be 13 inches measured from the lowest point of the landing gear to the ground. A lesser drop height shall be permissible if it results in a drop test contact velocity found by the Administrator to be equal to the greatest probable sinking speed of the rotorcraft at ground contact in power-off landings likely to be made in normal operation of the rotorcraft. In no case shall the drop height be less than 8 inches. If rotor lift is considered (see sec. 6.230 (c)), it shall be introduced in the drop test by the use of appropriate energy absorbing devices or by the use of an effective mass.

NOTE: In lieu of more rational computations, the following may be employed when use is made of an effective mass:

$$W_e = W\left[\frac{h+(1-L)d}{h+d}\right]; \text{ and } n = n_j\frac{W_e}{W}+L$$

where:

W_e = the effective weight to be used in the drop test (lbs.);

$W = W_M$ for main gear units (lbs.), equal to the static reaction on the particular unit with the rotorcraft in the most critical attitude. A rational method may be used in computing a main gear static reaction, taking into consideration the distance between the direction of the main wheel reaction and the aircraft c. g.

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

[$W = W_T$ for tail-wheel units (pounds); (1) equal to the static weight on the tail-wheel with the rotorcraft resting on all wheels; (2) equal to the vertical component of the ground reaction which would occur at the tail-wheel assuming the mass of the rotorcraft acting at the center of gravity and exerting a force of 1g downward with the rotorcraft in the maximum nose-up attitude considered in the nose-up landing conditions. (See sec. 6.246 (c).)]

h = specified free drop height (inches);

L = ratio of assumed rotor lift to the rotorcraft weight;

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);

n = limit inertia load factor;

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).

(b) *Reserve energy absorption drop test.* The reserve energy absorption capacity shall be demonstrated by a drop test in which the drop height is equal to 1.5 times the drop height prescribed in paragraph (a) of this section, and the rotor lift is assumed to be not greater than 1.5 times the rotor lift used in the limit drop tests, except that the resultant inertia load factor need not exceed 1.5 times the limit inertia load factor determined in accordance with paragraph (a) of this section. In this test the landing gear shall not collapse.

NOTE: The effect of rotor lift may be considered in a manner similar to that prescribed in paragraph (a) of this section.

6.240 *Ski landing conditions.* The structure of a rotorcraft equipped with skis shall be designed in compliance with the loading conditions set forth in paragraphs (a) through (c) of this section:

(a) *Up load conditions.*

(1) A vertical load of Pn and a horizontal load of $Pn/4$ shall be applied simultaneously at the pedestal bearings, P being the maximum static weight on each ski when the rotorcraft is loaded to the maximum design weight. The limit load factor n shall be determined in accordance with section 6.230 (d).

(2) A vertical load equal to 1.33 P shall be applied at the pedestal bearings. (For P see subparagraph (1) of this paragraph.)

(b) *Side load condition.* A side load of 0.35 Pn shall be applied in a horizontal plane perpendicular to the center line of the rotorcraft at the pedestal bearings. (For P see subparagraph (a) (1) of this section.)

(c) *Torque load condition.* A torque load equal to 1.33 P (ft.-lb.) shall be applied to the ski about the vertical axis through the center line of the pedestal bearings. (For P see subparagraph (a) (1) of this section.)

6.245 *Float landing conditions.* The structure of a rotorcraft equipped with floats shall be designed in compliance with the loading conditions set forth in paragraphs (a) and (b) of this section:

(a) *Up load conditions.*

(1) With the rotorcraft assumed in the static level attitude a load shall be applied so that the resultant water reaction passes vertically through the center of gravity of the rotorcraft. The limit load factor shall be determined in accordance with section 6.230 (d) or shall be assumed to be the same as the load factor determined for the ground type landing gear.

(2) The vertical load prescribed in subparagraph (1) of this paragraph shall be applied together with an aft component equal to 0.25 the vertical component.

(b) *Side load condition.* The vertical load in this condition equal to 0.75 the vertical load prescribed in paragraph (a) (1) of this section, divided equally between the floats, shall be applied together with a side component. The total side component shall be equal to 0.25 the total vertical load in this condition and shall be applied to one float only.

[6.246 *Tail-wheel type landing gear ground loading conditions.* The structure of a rotorcraft equipped with landing gears arranged such that two wheels are located forward and one wheel is located aft of the center of gravity shall be assumed to be subjected to the loading conditions in accordance with paragraphs (a) through (h) of this section:

[(a) *Level landing on forward gear only.* The rotorcraft shall be assumed to be in the level landing attitude with only the forward wheels contacting the ground.

[(1) Vertical loads shall be applied in accordance with the provisions of section 6.230.

[(2) The vertical loads specified in subparagraph (1) of this paragraph shall be combined with a drag load at each wheel axle of not less than 25 percent of the respective vertical load.

[(3) In the conditions of subparagraphs (1) and (2) of this paragraph, unbalanced pitching moments shall be assumed resisted by angular inertia forces.

[(b) *Level landing; all wheels contacting simultaneously.* The rotorcraft shall be assumed to be in the level landing attitude with all wheels contacting the ground simultaneously.

[(1) Vertical loads shall be applied in accordance with the provisions of section 6.230.

[(2) The vertical loads specified in subparagraph (1) of this paragraph shall be combined with a drag load at each wheel axle of not less than 25 percent of the respective vertical load. Unbalanced pitching moments shall be assumed resisted by angular inertia forces.

[(c) *Nose-up landing condition.* The rotorcraft shall be assumed to contact the ground on the rear wheel only at the maximum nose-up attitude to be expected under all operational landing conditions including landings in autorotation. The conditions of this paragraph need not be applied if it can be demonstrated that the probability of landing with initial contact on the rear wheel is extremely remote. In determining the applicable ground loads, it shall be acceptable to use a rational method to account for the distance between the direction of the rear wheel ground reactions and the rotorcraft c. g.

[(1) Vertical loads shall be applied in accordance with the provisions of section 6.230.

[(2) The vertical loads specified in subparagraph (1) of this paragraph shall be combined with a drag load at the wheel axle of not less than 25 percent of the vertical load.

[(d) *One-wheel landing condition.* The rotorcraft shall be assumed in the level attitude to contact the ground on one of the wheels located forward of the c. g. The vertical load shall be the same as that obtained on the one side in the condition specified in paragraph (a) (1) of this section. Unbalanced moments shall be assumed resisted by angular inertia forces.

[(e) *Side load landing condition.* The rotorcraft shall be assumed in the landing attitudes of paragraphs (a) and (b) of this section. Side loads in combination with one-half the maximum vertical ground reactions obtained in the landing conditions of paragraphs (a) (1) and (b) (1) of this section shall be applied at each wheel. The magnitude of the side loads on the forward wheels in each case shall be 0.8 of the vertical reaction (on one side) acting inward and 0.6 of the vertical reaction (on the other side) acting outward. The magnitude of the side load on the rear wheel shall be equal to 0.8 of the vertical reaction. These loads shall be applied at the ground contact point, unless the landing gear is of the full-swiveling type in which case the loads shall be applied at the center of the axle. When a lock, steering device, or shimmy damper is provided, the swiveled wheel shall also be assumed to be in the trailing position with the side load acting at the ground contact point.

[(f) *Braked roll condition.* The rotorcraft attitudes shall be assumed to be the same as those prescribed in paragraphs (a) and (b) of this section with the shock absorbers deflected to their static position. The limit vertical load shall be based upon a load factor of 1.33. A drag load equal to the vertical load multiplied by a coefficient of friction of 0.8 shall be applied at the ground contact point of each wheel equipped with brakes, except that the drag load need not exceed the maximum value based on limiting brake torque.

[(g) *Rear wheel turning condition.* The rotorcraft shall be assumed to be in the static ground attitude with the shock absorbers and tires deflected to their static position. A vertical ground reaction equal to the static load on the rear wheel in combination with a side component of equal magnitude shall be assumed. When a swivel is provided, the rear wheel shall be assumed to be swiveled 90 degrees to the rotorcraft longitudinal axis with the resultant load passing through the axle. When a lock, steering device, or shimmy damper is provided, the rear wheel shall also be assumed to be in the trailing position with the side load acting at the ground contact point.

[(h) *Taxying condition.* The rotorcraft and its landing gear shall be designed for loads which occur when the rotorcraft is taxied over the roughest ground which it is reasonable to expect in normal operation.]

[6.247 *Skid gear ground loading condition.* The structure of a rotorcraft equipped with skid type landing gear shall be assumed to be subjected to the loading conditions in accordance with paragraphs (a) through (d) of this section.

[(a) The design weight, center of gravity, and load factor shall be in accordance with the provisions of section 6.230. Structural yielding of the elastic spring member under the limit loading conditions shall be acceptable. The design ultimate loads considered for the elastic spring member need not exceed those obtained in a drop test of the skid gear from a drop height equal to 1.5 times that specified in section 6.237 (a).

[(b) The ground loads resulting from the landing conditions specified in paragraph (c) of this section shall be applied to the skid gear in its most critically deflected position for the particular landing condition being considered and a rational distribution of the ground reactions along the skid tube bottom shall be made.

[(c) The following landing conditions shall be considered:

[(1) *Level landing; vertical reactions.* The rotorcraft shall be assumed to contact the ground along the bottom of both skids. Vertical ground reactions shall be applied in accordance with the provisions of paragraphs (a) and (b) of this section.

[(2) *Level landing with drag.* The rotorcraft shall be assumed to contact the ground along the bottom of both skids with vertical ground reactions in combination with a horizontal drag reaction equal to 50 percent of the vertical reaction applied at the ground. The resultant ground load shall be equal to the vertical load specified in subparagraph (1) of this paragraph and shall be directed through the center of gravity of the rotorcraft.

[(3) *Level landing with side load.* The rotorcraft shall be assumed to contact the ground along the bottom of both skids with vertical ground reactions in combination with a horizontal side reaction equal to 25 percent of the vertical ground reaction. The vertical ground reaction shall be equal to the vertical load specified in subparagraph (1) of this paragraph and shall be equally divided between the two skids. The total side load shall be applied along the length of one skid only. Unbalanced moments shall be assumed resisted by angular inertia forces. Both the inward and outward acting side loading conditions for the skid gear shall be investigated.

[(4) *One-skid landing condition.* In the level attitude, the rotorcraft shall be assumed to contact the ground on one skid only. The vertical load shall be the same as that obtained on the one side in the condition specified in subparagraph (1) of this paragraph. Unbalanced moments shall be assumed to be resisted by angular inertia forces.

[(d) *Special conditions for the skid gear.*

[(1) A ground reaction load equal to 1.33 times the maximum weight of the rotorcraft acting up and aft at an angle of 45 degrees to the horizontal shall be assumed. The load shall be distributed symmetrically between the two skids and shall be assumed concentrated at the forward end of the straight portion of the skid tube. This loading condition shall apply only to the forward end of skid tube and its attachment to the rotorcraft.

[(2) A vertical ground reaction load equal to one-half the vertical load of § 6.247 (c) (1) shall be assumed with the rotorcraft in the level attitude. This load shall be applied to the skid tube and shall be assumed concentrated at a point midway between the skid tube attachments. This loading condition shall apply

only to the skid tube and its attachment to the rotorcraft.]

Main Component Requirements

6.250 ***Main rotor structure.*** **The requirements of paragraphs (a) through (f) of this section shall apply to the main rotor assemblies including hubs and blades.**

(a) The hubs, blades, blade attachments, and blade controls which are subject to alternating stresses shall be designed to withstand repeated loading conditions. The stresses of critical parts shall be determined in flight in all attitudes appropriate to the type of rotorcraft throughout the ranges of limitations prescribed in section 6.204. The service life of such parts shall be determined by fatigue tests or by other methods found acceptable by the Administrator.

(b) The main rotor structure shall be designed to withstand the critical flight loads prescribed in sections 6.210 through 6.213.

(c) The main rotor structure shall be designed to withstand the limit loads prescribed in sections 6.210 through 6.213 under conditions of autorotation necessary for normal operation. The rotor rpm used shall be such as to includs the effects of altitude.

(d) The rotor blades, hubs, and flapping hinges shall be designed to withstand a loading condition simulating the force of the blade impact against its stop during operation on the ground.

(e) The rotor assembly shall be designed to withstand loadings simulating other critical conditions which might be encountered in normal operation.

(f) The rotor assembly shall be designed to withstand, at all rotational speeds including zero, the maximum torque likely to be transmitted thereto in both directions. If a torque limiting device is provided in the transmission system the design limit torque need not be greater than the torque defined by the limiting device, except that in no case shall the design limit torque be less than the limit torque specified in section 6.251 (c). The design torque shall be distributed to the rotor blades in a rational manner.

6.250–1 *Service life of main rotors* (*CAA policies which apply to sec. 6.250* (*a*)). Several methods which have been found acceptable by the Administrator for determining the service life of main rotors are outlined in appendix A for the guidance of the industry in complying with section 6.250 (a).

(16 F. R. 3405, Apr. 19, 1951, effective May 1, 1951.)

6.251 ***Fuselage, landing gear, and rotor pylon structure.*** **The requirements of paragraphs (a) through (d) of this section shall apply to the fuselage, landing gear, and rotor pylon structure.**

(a) The structure shall be designed to withstand the critical loads prescribed in sections 6.210 through 6.213. It shall be permissible to represent the resultant rotor force as a single force applied at the hub attachment point. The balancing and inertia loads occurring under the accelerated flight conditions as well as the thrust from auxiliary rotors shall be considered.

(b) The structure shall be designed to withstand the applicable ground loads prescribed in sections 6.230 through 6.245.

(c) The engine mount and adjacent fuselage structure shall be designed to withstand loads occurring in the rotorcraft under the accelerated flight and landing conditions, including the effects of engine torque loads. In the case of engines having 5 or more cylinders, the limit torque shall be obtained by multiplying the mean torque, as defined by the power conditions in section 6.1 (g) (3), by a factor of 1.33. For 4-, 3-, and 2-cylinder engines the factors shall be 2, 3, and 4, respectively.

(d) The structure shall be designed to withstand the loads prescribed in section 6.250 (d) and (f).

Emergency Landing Conditions

6.260 ***General.*** **The requirements of paragraphs (a) through (c) of this section deal with emergency conditions of landing on land or water in which the safety of the occupants is considered, although it is accepted that parts of the rotorcraft 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. 6.355), will escape serious injury in

the event of a minor crash landing (with wheels up if the rotorcraft is equipped with retractable landing gear) in which the occupants experience the following ultimate inertia forces relative to the surrounding structure.

(1) Upward 1.5g (downward 4.0g).

(2) Forward 4.0g.

(3) Sideward 2.0g.

(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 rotorcraft structure can absorb the landing loads corresponding with the design maximum weight and an ultimate descent ve-

locity of 5 fps 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.

Design and Construction

General

6.300 *Scope.* The rotorcraft 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.

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

6.302 *Fabrication methods.* The methods of fabrication employed in constructing the rotorcraft 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.

6.303 *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.

6.304 *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 rotorcraft equipped with floats, special precautions shall be taken against corrosion from salt water, particularly where parts made from different metals are in close proximity.

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

6.306 *Material strength properties and design values.*

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

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

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

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

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

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

6.307 *Special factors.*

(a) *General.* 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 6.200 (b) 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 special factors set forth in paragraphs (b) through (d) of this section shall be acceptable for this purpose.

(b) *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 (c) of this section) is of greater magnitude than the casting factor.

(c) *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.

(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.

(d) *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 (c) of this section) is of greater magnitude than the fitting factor.

Main Rotor

6.310 *Main rotor blades; pressure venting and drainage.* Internal pressure venting of the main rotor blades shall be provided. Drain holes shall be provided and, in addition, the blades shall be designed to preclude the possibility of water becoming trapped in any section of the blade.

6.311 *Stops.* The rotor blades shall be provided with stops, as required for the particular design, to limit the travel of the blades about their various hinges. Provision shall be made to keep the blades from hitting the droop stops except during the starting and stopping of the rotor.

6.312 *Rotor and blade balance.* Rotors and blades shall be mass balanced to the degree necessary to prevent excessive vibration and to safeguard against flutter at all speeds up to the maximum forward speed.

6.313 *Rotor blade clearance.* Clearance shall be provided between the main rotor blades and all other parts of the structure to prevent the blades from striking any part of the structure during any operating condition of the rotorcraft.

Control Systems

6.320 *General.* All controls and control systems shall operate with ease, smoothness, and positiveness appropriate to their function. (See also secs. 6.350 and 6.353.)

6.321 *Control system stops.*

(a) All control systems shall be provided with stops which positively limit the range of motion of the pilot's controls.

(b) Control system stops shall be so located in the system that wear, slackness, or take-up adjustments will not affect appreciably the range of travel.

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

6.322 *Control system locks.* If a device is provided for locking the control system while the rotorcraft is on the ground or water, the provisions of paragraphs (a) and (b) of this section shall apply.

(a) A means shall be provided to give unmistakable warning to the pilot when the locking device is engaged.

(b) Means shall be provided to preclude the possibility of the lock becoming engaged during flight.

6.323 *Static tests.* Tests shall be conducted on control systems to show compliance with limit load requirements in accordance with the provisions of paragraphs (a) through (c) of this section.

(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. 6.307 and 6.325.)

6.324 *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 loads specified for the control system. In this test there shall be no jamming, excessive friction, or excessive deflection.

6.325 *Control system details.* All details of control systems shall be designed and installed to prevent jamming, chaffing, 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 rotorcraft.

6.326 *Spring devices.* The reliability of any spring devices used in the control system shall be established by tests simulating service conditions, unless it is demonstrated that failure of the spring will not cause flutter or unsafe flight characteristics.

6.327 *Autorotation control mechanism.* The main rotor blade pitch control mechanism shall be arranged to permit rapid entry into autorotative flight in the event of power failure.

Landing Gear

6.335 *Wheels.* Landing gear wheels shall be of an approved type. The maximum static load rating of each wheel shall not be less than the corresponding static ground reaction under the maximum weight of the rotorcraft and the critical center of gravity position. The maximum limit load rating of each wheel shall not be less than the maximum radial limit load determined in accordance with the applicable ground load requirements of this part.

6.336 *Brakes.* A braking device shall be installed, controllable by the pilot and usable during power-off landings, which is adequate to insure:

(a) Counteraction of any normal unbalanced torque when starting or stopping the rotor,

(b) Holding the rotorcraft parked on a 10° slope on a dry, smooth pavement.

6.337 *Tires.* Landing gear wheels shall be equipped with any make or type of tire provided that the tire is a proper fit on the rim of the wheel and provided that the approved tire rating is not exceeded. The maximum static load rating of the tire shall not be less than the static ground reaction obtained at the wheel, assuming the maximum design weight concentrated at the most unfavorable center of gravity position.

6.338 *Skis.* 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.

6.340 *Floats.* The requirements of sections 6.341 and 6.342 shall apply to the design of floats.

Floats

6.341 *Buoyancy (main floats).*

(a) Main floats shall have a buoyancy in excess of that required to support the maximum weight of the rotorcraft in fresh water as follows: (1) 50 percent in the case of single floats, (2) 60 percent in the case of multiple floats.

(b) Main floats shall contain at least four water-tight compartments of approximately equal volume.

6.342 *Float strength.* Floats shall be designed for the conditions set forth in paragraphs (a) and (b) of this section:

(a) *Bag type floats.* Bag type floats shall withstand the maximum pressure differential which might be developed at the maximum altitude for which certification with floats is sought. In addition, the float shall withstand the vertical loads prescribed in section 6.245 (a).

(b) *Rigid floats.* Rigid type floats shall withstand the vertical, horizontal, and side loads prescribed in section 6.245. The loads specified may be distributed along the length of the floats.

Personnel and Cargo Accommodations

6.350 *Pilot compartment; general.*

(a) The arrangement of the pilot compartment and its appurtenances shall provide safety and assurance that the pilot will be able to perform all of his duties and operate the controls in the correct manner without unreasonable concentration and fatigue.

(b) When provision is made for a second pilot, the rotorcraft shall be controllable with equal safety from both seats.

(c) Vibration and noise characteristics of cockpit appurtenances shall not interfere with the safe operation of the rotorcraft.

6.351 *Pilot compartment vision.* The pilot compartment shall be arranged to afford the pilot a sufficiently extensive, clear, and undistorted view for the safe operation of the rotorcraft. During flight in a moderate rain condition the pilot shall have an adequate view of the flight path in normal flight and landing, and have sufficient protection from the elements so that his vision is not unduly impaired. The pilot compartment shall be free of glare and reflections which would interfere with the pilot's vision. For rotocraft intended for night operation, the demonstration of these qualities shall include night flight tests.

6.352 *Pilot windshield and windows.* All glass panes shall be of a nonsplintering safety type.

6.353 *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. 6.737.)

(b) 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 pilots' clothing when seated. This shall be demonstrated for individuals ranging from 5′ 2″ to 6′ 0″ in height.

6.354 *Doors.* Closed cabins shall be provided with at least one adequate and easily accessible external door. No passenger door shall be so located with respect to the rotor discs as to endanger persons using the door.

6.355 *Seats and berths.* On rotorcraft, manufactured on or after the effective date of this part, all seats and berths, including their supporting structure shall be designed for the loads resulting from all specified flight and landing conditions, including the emergency landing conditions of section 6.260. Reactions from safety belts and harness shall be taken into account. In addition, pilot seats shall be designed for the reactions resulting from the application of pilot forces to the flight controls as prescribed in section 6.225 (a). (See sec. 6.101 (b) (4) for weight of occupants.)

6.355–1 *Application of loads (CAA policies which apply to sec. 6.355).* 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.)

(18 F. R. 5564, Sept. 17, 1953, effective Sept. 30, 1953.)

6.356 *Cargo and baggage compartments.* (See also sec. 6.382.)

(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 6.260.

(b) Provision 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) Provision shall be made to protect the passengers and crew from injury by the contents of any compartment when the ultimate inertia force acting forward is 4g.

6.357 *Emergency exits.*

(a) Closed cabins on rotorcraft carrying more than 5 persons shall be provided with an emergency exit. Additional exits shall be provided where the total seating capacity is more than 15. The provisions of subparagraphs (1) through (6) of this paragraph shall apply. (See also sec. 6.738 (c).)

(1) An emergency exit shall consist of a movable window or panel or of an additional external door which provides a clear and unobstructed opening, the minimum dimensions of which shall be such that a 19 inch by 26 inch ellipse may be completely inscribed therein.

(2) An emergency exit shall be readily accessible, shall not require exceptional agility of a person using it, and shall be so located as to facilitate egress without crowding in all probable attitudes in which the rotorcraft may be after a crash.

(3) The method of opening an emergency exit shall be simple and obvious, and the exit shall be so arranged and marked as to be readily located and operated even in darkness.

(4) Reasonable provisions shall be made against the jamming of emergency exits as a result of fuselage deformation.

(5) At least one emergency exit shall be on the opposite side of the cabin from the main door.

(6) The proper functioning of emergency exits shall be demonstrated by tests.

6.358 *Ventilation.* **The ventilating system for the pilot and passenger compartments shall be so designed as to preclude the presence of excessive quantities of fuel fumes and carbon monoxide. The concentration of carbon monoxide shall not exceed 1 part in 20,000 parts of air under conditions of forward flight or hovering in zero wind. For other conditions of operation, if the carbon monoxide concentration exceeds this value, suitable operating restrictions shall be provided.**

Fire Prevention

6.380 *General.* **The fire prevention requirements of this subpart apply to personnel and cargo compartments. Additional fire prevention requirements are prescribed in Subpart E, Powerplant Installation, and Subpart F, Equipment.**

6.381 *Cabin interiors.* **All compartments occupied or used by the crew or passengers shall comply with the provisions of paragraphs (a) through (c) of this section.**

(a) The materials in no case shall be less than flash-resistant.

(b) The wall and ceiling linings, the covering of all upholstery, 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.

6.382 *Cargo and baggage compartments.* **Cargo and baggage compartments shall be constructed of or completely lined with fire-resistant material, except that flame-resistant materials shall be acceptable in compartments which are readily accessible to a crew member in flight. Compartments shall include no controls, wiring, lines, equipment, or accessories the damage or failure of which would affect the safe operation of the rotorcraft, unless such items are shielded, isolated, or otherwise protected so that they cannot be damaged by movement of cargo in the com-**

partment, and so that any breakage or failure of such items will not create a fire hazard.

6.383 *Heating systems.*

(a) *General.* Heating systems involving the passage of cabin air over or in close proximity to the exhaust manifold shall not be used unless precautions are incorporated in the design to prevent the introduction of carbon monoxide into the cabin or pilot compartment.

(b) *Heat exchangers.* Heat exchangers shall be constructed of suitable materials, shall be cooled adequately under all conditions, and shall be capable of easy disassembly for inspection.

(c) *Combustion heaters.* Gasoline-operated combustion heaters shall be of an approved type and shall be installed so as to comply with the applicable sections of the powerplant installation requirements covering fire hazards and precautions. All applicable requirements concerning fuel tanks, lines, and exhaust systems shall be considered. (See secs. 6.422 through 6.428 and 6.463.) 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 for each heater to automatically shut off and hold off the ignition and fuel supply to the heater at a point remote from the heater when the heat exchanger temperature or ventilating air temperature exceeds safe limits or when either the combustion air flow or the ventilating air flow becomes inadequate for safe operation.

6.384 *Fire protection of structure, controls, and other parts.* All structure, controls, rotor mechanism, and other parts essential to a controlled landing of the rotorcraft which would be affected by powerplant fires shall either be of fireproof construction or shall be otherwise protected, so that they can perform their essential functions for at least 5 minutes under all foreseeable powerplant fire conditions. (See also secs. 6.480 and 6.483 (a).)

Miscellaneous

6.390 *Leveling marks.* Reference marks shall be provided for use in leveling the rotorcraft to facilitate weight and balance determinations on the ground.

6.391 *Ballast provisions.* Ballast provisions shall be so designed and constructed as to prevent the inadvertent shifting of the ballast in flight. (See also secs. 6.105, 6.738, and 6.741 (c).)

Powerplant Installation

General

6.400 *Scope and general design.*

(a) The powerplant installation shall be considered to include all components of the rotorcraft which are necessary for its propulsion with the exception of the structure of the main and auxiliary rotors. 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. 6.604 and 6.613 for instrument installation and marking.) The general provisions of paragraphs (b) through (d) of this section shall be applicable.

(b) 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 shall be provided to permit such inspection and maintenance as is necessary to assure continued airworthiness.

(d) 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 rotorcraft.

[6.400–1 *Powerplant installation components (CAA interpretations which apply to sec. 6.400).* The term "all components" includes engines and their parts, appurtenances, and accessories which are furnished by the engine manufacturer and all other components of the powerplant installation which are furnished by the rotorcraft manufacturer. For example: fuel pumps, lines, valves, and other components of the fuel system which are integral parts of the type certificated engine are also components of the rotorcraft powerplant installation.]

(23 F. R. 9018, Nov. 20, 1958, effective Dec. 22, 1958.)

6.401 *Engines.*

(a) *Engine type certification.* All engines shall be type certificated in accordance with the provisions of Part 13 of the Civil Air Regulations.

(b) *Engine cooling fan blade protection.* If an engine cooling fan is installed, means shall be provided to protect the rotorcraft and to permit a safe landing in the event of a fan blade failure. Compliance shall be shown with any one of the provisions of subparagraphs (1) through (3) of this paragraph.

(1) It shall be demonstrated that the fan blades will be contained in the event of failure;

(2) The fan is so located that a fan blade failure will not jeopardize the safety of the rotorcraft or its occupants; or

(3) It shall be demonstrated that the fan blade can withstand an ultimate load of 1.5 times the centrifugal force resulting from engine rpm limited by either:

(i) The engine terminal rpm which can occur under uncontrolled conditions, or

(ii) An overspeed limiting device.

6.402 *Engine vibration.* The engine shall be installed to preclude harmful vibration of any of the engine parts or any of the components of the rotorcraft. It shall be demonstrated by means of a vibration investigation that the addition of the rotor and the rotor drive system to the engine does not result in modification of engine vibration characteristics to the extent that the principal rotating portions of the engine are subjected to excessive vibratory stresses. It shall also be demonstrated that no portion of the rotor drive system is subjected to excessive vibratory stresses.

Rotor Drive System

6.410 *Rotor drive mechanism.* The rotor drive mechanism shall incorporate a unit which will automatically disengage the engine from the main and auxiliary rotors in the event of power failure. The rotor drive mechanism shall be so arranged that all rotors necessary for control of the rotorcraft in autorotative flight will continue to be driven by the main rotor(s) after disengagement of the engine from the main and auxiliary rotors. If a torque limiting device is employed in the rotor drive system (see sec. 6.250 (f)), such device shall be located to permit continued control of the rotorcraft after it becomes operative.

6.411 *Rotor brakes.* If a means is provided to control the rotation of the rotor drive system independent of the engine, the limitations on the use of such means shall be specified, and the control for this means shall be guarded to prevent inadvertent operation.

6.412 *Rotor drive and control mechanism endurance tests.*

(a) The rotor drive and control mechanism shall be tested for not less than 100 hours. The test shall be conducted on the rotorcraft, and the power shall be absorbed by the actual rotors to be installed, except that the use of other ground or flight test facilities with any other appropriate method of power absorption shall be acceptable provided that all conditions of support and vibration closely simulate the conditions which would exist during a test on the actual rotorcraft. The endurance tests shall include the tests prescribed in paragraphs (b) through (g) of this section. At the conclusion of the endurance testing, all parts shall be in a serviceable condition.

(b) A 60-hour portion of the endurance test shall be run at not less than the maximum continuous engine speed in conjunction with maximum continuous engine power. In this test the main rotor shall be set in the position which will give maximum longitudinal cyclic pitch change to simulate forward flight. The auxiliary rotor controls shall be in the position for normal operation under the conditions of the test.

(c) A 30-hour portion of the endurance test shall be run at not less than 90 percent of maximum continuous engine speed and 75 percent of maximum continuous engine power. The main and auxiliary rotor controls during this test shall be in the position for normal operation under the conditions of the test.

(d) A 10-hour portion of the endurance test shall be run at not less than take-off engine power and speed. The main and auxiliary rotor controls shall be in the normal position for vertical ascent during this test.

(e) The portions of the endurance test prescribed in paragraphs (b) and (c) of this section shall be conducted in intervals of not less than 30 minutes and may be accomplished either on the ground or in flight. The portion of the endurance test prescribed in paragraph (d) of this section may be conducted in intervals of 5 minutes or more.

(f) At intervals of not more than every 5 hours during the endurance tests prescribed in paragraphs (b), (c), and (d) of this section the engine shall be stopped rapidly enough to allow the engine and rotor drive to be automatically disengaged from the rotors.

(g) There shall be accomplished under the operating conditions specified in paragraph (b) of this section 500 complete cycles of lateral control and 500 complete cycles of longitudinal control of the main rotors, and 500 complete cycles of control of all auxiliary rotors. A complete control cycle shall be considered to involve movement of the controls from the neutral position, through both extreme positions, and back to the neutral position, except that control movement need not produce loads or flapping motions exceeding the maximum loads or motions encountered in flight. The control cycling may be accomplished during the testing prescribed in paragraph (b) of this section or may be accomplished separately.

6.413 *Additional tests.* Such additional dynamic, endurance, and operational tests or vibratory investigations shall be conducted as are found necessary by the Administrator to substantiate the airworthiness of the rotor drive mechanism.

6.414 *Shafting critical speed.* The critical speeds of all shafting shall be determined by actual demonstration, except that analytical methods shall be acceptable for determining these speeds if the Administrator finds that reliable methods of analysis are available for the particular design. If the critical speeds lie within or close to the operating ranges for idling, power-on, and autorotative conditions, it shall be demonstrated by tests that the resultant stresses are within safe limits. If analytical methods are used and indicate that no critical speeds lie within the permissible operating ranges, the margins between the calculated critical speeds and the limits of the permissible operating ranges shall be adequate to allow for possible variations of the computed values from actual values.

6.415 *Shafting joints.* All universal joints, slip joints, and other shafting joints shall have provision for lubrication, unless it is demonstrated that lack of lubrication will have no adverse effect on the operation of the rotorcraft.

Fuel System

6.420 *Capacity and feed.* The fuel supply system shall be arranged so that, in so far as practicable, the entire fuel supply can be utilized in the maximum inclinations of the fuselage for any sustained conditions of flight, and so that the feed ports will not be uncovered during normal maneuvers involving moderate rolling or sideslipping. On rotorcraft with more than one fuel tank (see sec. 6.422 (e)) the system shall feed fuel promptly after one tank is turned off and another tank is turned on, and there shall be installed in addition to the fuel quantity indicator (see sec. 6.604 (a) (1)) a warning device to indicate when the fuel in any tank becomes low.

NOTE. The fuel in any tank is considered to be low when there remains approximately a five-minute supply with the rotorcraft in the most critical sustained flight attitude.

6.421 *Unusable fuel supply.* The unusable fuel supply in each tank shall be that quantity at which the first evidence of malfunctioning occurs in any sustained flight condition at the most critical weight and center of gravity position within the approved limitations. The unusable fuel supply shall be determined for each tank used in normal operation. (See also secs. 6.104, 6.736, and 6.741 (g).)

6.422 *Fuel tank construction and installation.* Fuel tanks shall be designed and installed in accordance with the provisions of paragraphs (a) through (e) of this section.

(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) Fuel tanks shall be capable of withstanding, without failure or leakage, an internal pressure equal to the pressure developed during the maximum limit acceleration with full tanks, except that in no case shall the minimum internal pressure be less than 3.5 lb./sq. in. for conventional type tanks or less than 2.0 lb./sq. in. for bladder type tanks.

(c) Fuel tanks of 10 gallons or greater capacity shall incorporate internal baffles unless external support is provided to resist surging.

(d) Fuel tanks shall be separated from the engine compartment by a fire wall. At least one-half inch clear air space shall be provided between the tank and fire wall.

(e) Spaces adjacent to the surfaces of fuel tanks shall be ventilated so that fumes cannot accumulate in the tank compartment in case of leakage. If two or more tanks have their outlets interconnected, they shall be considered as one tank. The air spaces in such tanks shall be interconnected to prevent the flow of fuel from one tank to another as a result of a difference in pressure in the respective tank air spaces.

6.423 *Fuel tank details.*

(a) *Expansion space.* Fuel tanks shall be provided with an expansion space of not less than 2 percent of the tank capacity. It shall not be possible to fill the fuel tank expansion space inadvertently when the rotorcraft is in the normal ground attitude.

(b) *Sump.* Each fuel tank shall incorporate a sump and drain located at the point in the tank which is the lowest when the rotorcraft is in the normal ground attitude. The main fuel supply shall not be drawn from the bottom of the sump.

(c) *Filler connection.* The design of fuel tank filler connections shall be such as to prevent the entrance of fuel into the fuel tank compartment or to any other portion of the rotorcraft other than the tank itself. (See also sec, 6.738 (b) (1).)

(d) *Vents.* 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 air vents shall be arranged to minimize the possibility of stoppage by dirt or ice formation.

(e) *Outlet.* Fuel tank outlets shall be provided with large-mesh finger strainers.

6.424 *Fuel pumps.* If a mechanical pump is employed, an emergency pump shall also be installed to be available for immediate use in case of failure of the mechanical pump. Pumps of appropriate capacity may also be used for pumping fuel from an auxiliary tank to a main fuel tank. Mechanical pump systems shall be so arranged that they cannot feed from more than one tank at a time.

6.425 *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 rotorcraft between which relative motion could exist shall incorporate provisions for flexibility.

(c) Flexible hose shall be of an approved type.

(d) All fuel lines and fittings shall be of sufficient size so that the fuel flow, with the fuel being supplied to the carburetor at the minimum pressure for proper carburetor operation, is not less than the following:

(1) For gravity feed systems: 1.5 times the normal flow required to operate the engine at take-off power;

(2) For pump systems: 1.25 times the normal flow required to operate the engine at take-off power.

[(e) Rotocraft with suction lift fuel systems or other fuel system features conducive to vapor formation shall be demonstrated to be free from vapor lock when using fuel at a temperature of 110° F. under critical operating conditions.]

(f) A test for proof of compliance with the applicable flow requirements shall be conducted.

6.426 *Valves.* A positive and quick-acting valve which will shut off all fuel to each engine individually shall be provided. The control for this valve shall be within easy reach of appropriate flight personnel. In the case of rotorcraft employing more than one source of fuel supply, provision shall be made for independent feeding from each source. The shutoff valve shall not be located closer to the engine than the remote side of the fire wall.

6.427 *Strainers.* A strainer incorporating a sediment trap and drain shall be provided in the fuel system between the fuel tanks and the engine and shall be installed in an accessible position. The screen shall be easily removable for cleaning. If an engine-driven fuel pump is provided, the strainer shall be located between the fuel tank and the pump.

6.428 *Drains.* One or more accessible drains shall be provided at the lowest point in the fuel system to drain completely all parts of the system when the rotorcraft is in its normal postion on level ground. Such drains shall discharge clear of all parts of the rotorcraft and shall be equipped with safety locks to prevent accidental opening.

6.429 *Fuel quantity indicator.* The fuel quantity indicator (see sec. 6.613 (b)) shall be installed to indicate clearly to the flight crew the quantity of fuel in each tank while in flight. When two or more tanks are closely interconnected by a gravity feed system and vented, and when it is impossible to feed from each tank separately, only one fuel quantity indicator need be installed. If exposed sight gauges are employed they shall be installed and guarded to preclude the possibility of breakage or damage.

Oil System

6.440 *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. 6.604 and 6.735.)

(b) The usable oil capacity shall not be less than the product of the endurance of the rotorcraft under critical operating conditions and the maximum oil consumption of the engine under the same conditions, to which product a suitable margin shall be added to assure adequate circulation and cooling of the oil system. In lieu of a rational analysis of rotorcraft endurance and oil consumption, the usable oil capacity of 1 gallon for each 40 gallons of usable fuel quantity shall be considered acceptable. (See also sec. 6.101 (d) (3).)

(c) 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 by flight tests.

6.441 *Oil tank construction and installation.* Oil tanks shall be designed and installed in accordance with the provisions of paragraphs (a) through (e) of this section.

(a) Oil tanks shall be capable of withstanding without failure all vibration, inertia, fluid, and structural loads to which they may be subjected in operation.

(b) Oil tanks shall be capable of withstanding without failure or leakage an internal pressure of 5 *lb./sq. in.*

(c) Oil tanks shall be provided with an expansion space of not less than 10 percent of the tank capacity, nor less than one-half gallon. [It shall not be possible inadvertently to fill the oil tank expansion space when the rotorcraft is in the normal ground attitude.]

(d) Oil tanks shall be vented.

(e) Provision shall be made in the filler opening to prevent oil overflow from entering the compartment in which the oil tank is located. (See also sec. 6.738 (b) (2).)

6.442 *Oil lines and fittings.*

(a) Oil lines shall be supported to prevent excessive vibration.

(b) Oil lines which are connected to components of the rotorcraft between which relative motion could exist shall incorporate provisions for flexibility.

(c) Flexible hose shall be of an approved type.

(d) Oil lines shall have an inside diameter not less than the inside diameter of the engine inlet or outlet, and shall have no splices between connections.

6.443 *Oil drains.* One or more accessible drains shall be provided at the lowest point in the oil system to drain completely all parts of the system when the rotorcraft is in its normal position on level ground. Such drains shall discharge clear of all parts of the rotorcraft and shall be equipped with safety locks to prevent accidental opening.

6.444 *Oil quantity gauge.* An oil quantity indicator (see sec. 6.735) shall be installed to indicate during the filling operation the amount of oil in the oil tank.

6.445 *Oil temperature indication.* A means shall be provided for measuring during flight the oil temperature at the engine inlet. If a separate oil system is provided for the main rotor drive, a means shall also be provided to give a warning in flight when the oil temperature has exceeded a safe value. (See sec. 6.604.)

6.446 *Oil pressure indication.* If the main rotor drive incorporates an independent oil pressure system, a means shall be provided to give a warning in flight when the oil pressure has fallen below a safe value.

Cooling System

6.450 *General.* The cooling system shall be capable of maintaining engine temperatures within safe operating limits under all conditions of flight during a period at least equal to that established by the fuel capacity of the rotorcraft, assuming normal engine power and speeds.

6.451 *Cooling tests.* Compliance with the provisions of section 6.450 shall be demonstrated in flight tests in which engine temperature measurements are obtained under critical flight conditions. Such tests shall be conducted in air at temperatures corresponding with the maximum anticipated air temperatures as specified in paragraph (a) of this section. If the tests are conducted under conditions which deviate from the maximum anticipated air temperature, the recorded powerplant temperatures shall be corrected in accordance with the provisions of paragraphs (b) and (c) 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.

(a) *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.

(b) *Correction factor for cylinder head and oil inlet temperatures.* The cylinder head and oil inlet 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 cylinder head or oil inlet temperature recorded during the cooling test, unless a more rational correction is shown to be applicable.

(c) ***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.

Induction and Exhaust Systems

6.460 ***General.*** **The induction and exhaust systems shall be designed in accordance with accepted practice.**

6.461 ***Air induction.***

(a) The engine air induction system shall be designed to supply the proper quantity of air to the engine under all conditions of operation.

(b) Cold air intakes shall open completely outside the cowling unless the emergence of backfire flames is positively prevented.

(c) Carburetor air intakes shall be provided with drains. The drains shall not discharge fuel in the possible path of exhaust flames.

[6.461–1 *Induction system air filters (CAA policies which apply to sec. 6.461).* When air filters or equivalent fine mesh screens are provided in both the cold and warm air inlets a suitable bypass arrangement should be incorporated to assure continued engine operation in the event both filters become clogged with dirt, ice, or other foreign matter. The bypass may be operated either automatically or manually [1] or both.

[(a) The bypass should comply with the deicing and anti-icing provisions of section 6.462.

[(b) A bypass need not be provided for an induction system which employs an air filter or screen when:

[(1) The induction system is provided with sufficient preheat [2] to assure deicing of the filter or screen, and

[(2) The filter or screen is the self-cleaning type and so located that it can be deiced by the application of the heated air.]

(22 F. R. 4877, July 11, 1957, effective Aug. 1, 1957.)

[[1] For manual operation, the normal means for detecting engine power or r. p. m. losses due to restriction in carburetor airflow may be considered adequate warning for the crew to operate the bypass.

[[2] Recommended preheat is 100° F.]

6.462 ***Induction system de-icing and anti-icing provisions.***

(a) The engine air induction system shall incorporate means for the prevention and elimination of ice accumulations. Unless it is demonstrated that this can be accomplished by other means, compliance with the following heat rise provisions shall be demonstrated in air free of visible moisture at a temperature of 30° F. when the engine is operating at 75 percent of its maximum continuous power.

(b) Rotorcraft equipped with sea level engines employing conventional venturi carburetors shall have a preheater capable of providing a heat rise of 90° F.

(c) Rotorcraft equipped with sea level engines employing carburetors which embody features tending to reduce the possibility of ice formation shall be provided with a sheltered alternate source of air. The preheat supplied to this alternate air intake shall be not less than that provided by the engine cooling air downstream of the cylinders.

(d) Rotorcraft equipped with altitude engines employing conventional venturi carburetors shall have a preheater capable of providing a heat rise of 120° F.

(e) Rotorcraft 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., except that if a fluid deicing system is used the heat rise need not be greater than 40° F.

6.463 ***Exhaust manifolds.*** **(See also sec. 6.383.)**

(a) Exhaust manifolds shall be designed to provide for expansion, and shall be arranged and cooled so that local hot points cannot form.

(b) Exhaust manifolds shall be installed in accordance with the provisions of subparagraphs (1) through (3) of this paragraph:

(1) Exhaust manifolding shall be such that exhaust gases are discharged clear of cowling, rotorcraft structure, carburetor air intake, and fuel system parts or drains.

(2) Exhaust manifolding shall not be located immediately adjacent to or under

the carburetor or fuel system parts unless such parts are protected against leakage.

(3) Exhaust manifolding shall be such that exhaust gases do not discharge in a manner which would impair pilot vision at night due to glare.

Powerplant Controls and Accessories

6.470 *Powerplant controls; general.* The provisions of section 6.353 shall be applicable to all powerplant controls with respect to location and arrangement, and the provisions of section 6.737 shall be applicable to all powerplant controls with respect to marking. All flexible powerplant controls shall be of an approved type.

6.471 *Throttle 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.

6.472 *Ignition switches.*

(a) Means shall be provided for quickly shutting off all ignition by the grouping of switches or by providing a master ignition control.

(b) If a master ignition control is provided, a guard shall be incorporated to prevent inadvertent operation of the control.

6.473 *Mixture controls.* 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.

6.474 *Powerplant accessories.* 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.

Powerplant Fire Protection

6.480 *General.* The powerplant installation shall be protected against fire in accordance with sections 6.481 through 6.484. Additional fire prevention requirements are prescribed in Subpart D, Design and Construction, and Subpart F, Equipment.

NOTE: The powerplant fire protection provisions are intended to insure that the main and auxiliary rotors and controls remain operable, the essential rotorcraft structure remains intact, and that the passengers and crew are otherwise protected for a period of at least 5 minutes after the start of an engine fire to permit a controlled autorotational landing.

6.481 *Ventilation.* Compartments which include powerplant installation shall have provision for ventilation.

6.482 *Shut-off means.* Means shall be provided to shut off the flow in all lines carrying flammable fluids into the engine compartment, except that a shut-off means need not be provided in lines forming an integral part of an engine. Provision shall be made to guard against inadvertent operation of the shut-off means, and to make it possible for the crew to reopen the shut-off means in flight after it has once been closed. Shut-off valves and their controls shall be located on the remote side of the fire wall from the engine, unless it is shown that the valve will perform its intended functions under all fire conditions likely to result from an engine fire. In installations using engines of less than 500 cu. in. displacement, shut-off means need not be provided for engine oil systems.

6.483 *Fire wall.*

(a) Engines shall be isolated from personnel compartments by means of fire walls, shrouds, or other equivalent means. They shall be similarly isolated from the structure, controls, rotor mechanism, and other parts essential to a controlled landing of the rotorcraft, unless such parts are protected in accordance with the provisions of section 6.384. All auxiliary power units, fuel-burning heaters, and other combustion equipment which are intended for operation in flight shall be isolated from the remainder of the rotorcraft by means of fire walls, shrouds, or other equivalent means. In complying with the provisions of this paragraph, account shall be taken of the probable path of a fire as affected by the air flow in normal flight and in autorotation. (See also sec. 6.486.)

(b) Fire walls and shrouds shall be constructed in such a manner that no hazardous quantity of air, fluids, or flame can pass from the engine compartment to other portions of the rotorcraft.

(c) All openings in the fire wall or shroud shall be sealed with close fitting fireproof grommets, bushings, or fire-wall fittings.

(d) Fire walls and shrouds shall be constructed of fireproof material and shall be protected against corrosion.

6.484 *Engine cowling and engine compartment covering.*

(a) Cowling or engine compartment covering 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) Provision shall be made to permit rapid and complete drainage of all portions of the cowling or engine compartment in all normal ground and flight attitudes. Drains shall not discharge in locations which might cause a fire hazard.

(c) Cowling or engine compartment covering shall be constructed of fire-resistant material.

(d) Those portions of the cowling or engine compartment covering which would be subject to high temperatures due to their proximity to exhaust system parts or exhaust gas impingement shall be constructed of fireproof material.

6.485 *Lines and fittings.* All lines and fittings carrying flammable fluids or gases in areas subject to engine fire conditions 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 types. 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.

6.486 *Flammable fluids.*

(a) Fuel tanks shall be isolated from the engine by a fire wall or shroud. On all rotorcraft having engines of more than 900 cu. in. displacement, oil tanks and other flammable fluid tanks shall be similarly isolated unless the fluid contained, the design of the system, the materials used in the tank, the shutoff 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 and the isolating fire wall or shroud, unless other equivalent means are used to protect against heat transfer from the engine compartment to the flammable fluid.

Equipment

General

6.600 *Scope.* The required basic equipment as prescribed in this subpart is the minimum which shall be installed in the rotorcraft for certification. Such additional equipment as is necessary for a specific type of operation is prescribed in the operating rules of the Civil Air Regulations.

6.601 *Functional and installational requirements.* Each item of equipment installed in a rotorcraft 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 rotorcraft.

6.602 *Required basic equipment.* The equipment listed in sections 6.603 through 6.605 shall be the required basic equipment. (See sec. 6.600.)

6.603 *Flight and navigational instruments.* (See sec. 6.612 for installation requirements.) There shall be installed: (a) An air-speed indicator (see sec. 6.612 (a)), (b) an altimeter, (c) a magnetic direction indicator (see sec. 6.612 (c)).

6.604 *Powerplant instruments.* (See sec. 6.613 for installation requirements.)

(a) For each engine or tank there shall be installed: (1) A fuel quantity indicator (see sec. 6.613 (b)), (2) an oil pressure indicator, (3) an oil temperature indicator (see sec. 6.613 (g)), (4) a tachometer to indicate engine rpm and rotor rpm for the main rotor, or for each main rotor the speed of which can vary appreciably with respect to another main rotor.

(b) For each engine or tank (if required in reference section) there shall be installed: (1) a cylinder head temperature indicator (see sec. 6.613 (e)), (2) a fuel pressure indicator if pump-fed engines are used), (3) a manifold pressure indicator (if altitude engines are used), (4) an oil quantity indicator (see sec. 6.613 (d)).

(c) For each transmission or gear box having an independent oil system there shall be installed:

(1) An oil temperature indicator, and

(2) An oil pressure indicator if a pressure system is employed.

6.605 *Miscellaneous equipment.* There shall be installed:

(a) Approved seats for all occupants (see sec. 6.355), (b) approved safety belts for all occupants (see sec. 6.643), (c) a master switch arrangement (see secs. 6.623 and 6.624), (d) a source(s) of electrical energy (see secs. 6.620 through 6.622) where such electrical energy is necessary for operation of the rotorcraft, (e) electrical protective devices (see sec. 6.625).

Instruments; Installation

6.610 *General.* The provisions of sections 6.611 through 6.613 shall apply to the installation of instruments in rotorcraft.

6.611 *Arrangement and visibility of instrument installations.*

(a) Flight, navigation, and powerplant instruments for use by each pilot shall be easily visible to him.

(b) On multiengine rotorcraft, identical powerplant instruments for the several engines shall be so located as to prevent any confusion as to the engines to which they relate.

(c) The vibration characteristics of the instrument panel shall be such as not to impair seriously the readability or the accuracy of the instruments or to damage them.

6.612 *Flight and navigational instruments.*

(a) *Air-speed indicating system.* The air-speed indicating system shall be so installed that the air-speed indicator shall indicate true air speed at sea level under standard conditions to within an allowable installational error of not more than plus or minus 3 percent of the calibrated air speed or 5 mph, whichever is greater. The calibration shall be made in flight at all forward speeds of 10 mph or over. The allowable installation error shall not be exceeded at any forward speed of 20 mph and over. (See sec. 6.732.)

(b) *Static air-vent system.* All instruments provided with static air case connections shall be so vented that the influence of rotorcraft speed, the opening and closing of windows, air-flow variation, moisture, or other foreign matter will not seriously affect their accuracy.

(c) *Magnetic direction indicator.* The magnetic direction indicator shall be so installed that its accuracy shall not be excessively affected by the rotorcraft's vibration or magnetic fields. After the direction indicator has been compensated, the installation shall be such that the deviation in level flight does not exceed 10° on any heading. A suitable calibration placard shall be provided as specified in section 6.733.

6.613 *Powerplant instruments.*

(a) *Instrument lines.* Instrument lines shall comply with the provisions of section 6.425. In addition, 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.

(b) *Fuel quantity indicator.* 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 6.421. (See also sec. 6.736.)

(c) *Fuel flowmeter system.* When a flowmeter system is installed, the metering compo-

nent shall include a means for by-passing 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) Means shall be provided to indicate the quantity of oil in each tank when the rotorcraft is on the ground. (See sec. 6.735.)

(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) *Cylinder head temperature indicator.* A cylinder head temperature indicator shall be provided for each engine or rotorcraft equipped with cooling shutters. In the case of rotorcraft which do not have cooling shutters, an indicator shall be provided if compliance with the provisions of section 6.451 is demonstrated in a condition other than the most critical cooling flight condition.

(f) *Carburetor air temperature indicating system.* A carburetor air temperature indicating system shall be provided for each engine equipped with a preheater which is capable of providing a heat rise in excess of 60° F.

(g) *Oil temperature indicator.* Means shall be provided to indicate to the appropriate members of the flight crew, during flight, the oil inlet temperature of each engine.

(h) *Coolant temperature indicator.* Means shall be provided to indicate to the appropriate members of the flight crew, during flight, the coolant outlet temperature of each liquid-cooled engine.

Electrical Systems and Equipment

6.620 *Installation.*

(a) Electrical systems and equipment shall be free from hazards in themselves, in their method of operation, and in their effects on other parts of the rotorcraft. They shall be protected from fuel, oil, water, other detrimental substances, and from mechanical damage.

(b) The design of all components of the electrical system shall be appropriate for the intended use, and the components shall be capable of satisfactory operation over the entire range of environmental conditions encountered in the operation of the rotorcraft.

(c) Electrical sources of power shall have sufficient capacity during all normal flight operating conditions to supply the electrical load requirements without electrical or thermal distress. For emergency operating conditions the capacity of electrical power sources shall be sufficient for all electrical loads necessary to permit a safe landing.

6.621 *Batteries.* A battery or batteries shall be provided consistent with the needs of the electrical system in complying with the requirements of electrical power capacity. The installation shall provide adequate ventilation and drainage for the battery under all operating conditions, and means shall be provided to prevent corrosive battery substance from coming in contact with other parts of the rotorcraft during servicing or in flight.

6.622 *Generator system.*

(a) *Generator.* Sources of electrical power (including the battery) shall be designed to function coordinately, and shall also be capable of independent operation. The generator(s) shall be capable of delivering sufficient power to keep the batteries charged, and in addition shall provide for the normal electrical power requirements of the rotorcraft.

(b) *Generator controls.* Generator voltage control equipment shall be capable of regulating the generator output within rated limits.

(c) *Reverse current cut-off.* A generator reverse current cut-off shall disconnect the generator from the battery and from other generators when the generator is developing a voltage of such value that current sufficient to cause malfunctioning can flow into the generator.

6.623 *Master switch.* A master switch arrangement shall be provided which will disconnect all sources of electrical power from the main distribution system at a point adjacent to the power sources.

6.623–1 *Load circuit connections with respect to the master switch (CAA policies which apply to sec. 6.623).* All load circuits, except those circuits where interruption of service would result in the inability to maintain controlled flight or to effect a safe landing, should be connected to the electric power sources in such a manner that the master switch can interrupt the service.

(22 F. R. 4879, July 11, 1957, effective Aug. 1, 1957.)

6.624 *Master switch installation.* The master switch or its controls shall be so installed that it is easily discernible and accessible to a member of the crew in flight.

6.625 *Protective devices.* Protective devices (fuses or circuit breakers) shall be installed in the circuits to all electrical equipment, except that such items need not be installed in the main circuits of starter motors or in other circuits where no hazard is presented by their omission. If fuses are used, one spare of each rating or 50 percent spare fuses of each rating, whichever is the greater, shall be provided.

6.625–1 *Automatic reset circuit breakers (CAA policies which apply to sec. 6.625).* Automatic reset circuit breakers (which automatically reset themselves periodically) should not be applied as circuit protective devices.[3] They may be used as integral protectors for electrical equipment (for example thermal cutouts) provided that circuit protection is also installed to protect the cable to the equipment.

(19 F. R. 8140, Dec. 10, 1954, effective Dec. 15, 1954.)

6.625–2 *Circuit breakers (CAA policies which apply to sec. 6.625).* All resettable type circuit protective devices should be so designed that, when an overload or circuit fault exists, they will open the circuit irrespective of the position of the operating control.[4]

(21 F. R. 2585, Apr. 20, 1956, effective May 15, 1956.)

6.626 *Protective devices installation.* Protective devices in circuits essential to safety in flight shall be conveniently located and properly identified to facilitate replacement of fuses or resetting of circuit breakers in flight.

6.627 *Electric cables.* The electric cables used shall be in accordance with approved standards for aircraft electric cable of a slow-burning type. They shall have current-carrying capacity sufficient to deliver the necessary power to the items of equipment to which they are connected.

[6.627–1 *Electric cable for power distribution (CAA policies which apply to sec. 6.627).* The design for power distribution cable[5] should be such that probable environmental conditions[6] will not produce hazardous deterioration of the cable insulation, or cause a failure of the conductor. Cable insulation should be flame-resistant and should not emit toxic fumes when overheated. Cable conforming to Military Specification MIL–W–5086 or the equivalent is acceptable for this specification.]

(22 F. R. 6963, Aug. 29, 1957, effective Sept. 20, 1957.)

6.628 *Switches.* Switches shall be capable of carrying their rated current. They shall be accessible to the crew and shall be labeled as to operation and the circuit controlled.

Lights

6.630 *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.

6.631 *Landing lights.*

(a) When landing or hovering lights are required, they shall be of an approved type.

[3] 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 weight 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 reset operation, circuit protective devices should be of such design that a manual operation is required to restore service after tripping.

[4] Circuit protective devices which conform to the above description are known commercially as "trip-free," that is, the tripping mechanism cannot be overridden by the operating control. Such circuit protective devices can be reset on an overload or circuit fault, but will trip subsequently in accordance with their current-time characteristics.

[[5] For the purpose of this section, the term "power distribution cable" includes all electrical cable transmitting electric power from generators or batteries to load equipment, but does not include cable confined within metallic enclosures, such as in radio equipment.

[[6] Environmental conditions which should be considered: ambient temperature range which may exceed design limits of the cable; vibration leading to abrasive wear of cable insulation or conductor failure; presence of aircraft fluids, such as oil, gasoline, or water, which may have detrimental effects on cable insulation or increase its inflammability. (See sec. 6.620.)]

(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 operation including hovering and 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.

6.632 *Position light system installation.*

(a) *General.* The provisions of sections 6.632 through 6.635 shall be applicable to the position light system as a whole. The position light system shall include the items specified in paragraphs (b) through (e) 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 the rotorcraft in such a location that, with the rotorcraft 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 be a white light mounted as far aft as practicable. The light shall be of an approved type.

(d) *Circuit.* The two forward position lights and the rear position light shall constitute a single circuit.

(e) *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.

6.633 *Position light system dihedral angles.* The forward and rear position lights as installed on the rotorcraft 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 rotorcraft 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 rotorcraft 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.

6.634 ***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 rotorcraft. The light distribution and intensities of position lights shall comply with the provisions of paragraph (b) 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 6–1. (The horizontal plane is the plane containing the longitudinal axis of the rotorcraft and is perpendicular to the plane of symmetry of the rotorcraft.)

(2) *Intensities above and below horizontal.* The intensities in any vertical plane shall not be less than the appropriate value given in Figure 6–2, where I is the minimum intensity prescribed in Figure 6–1 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 6–3, 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 6–1 and 6–2 if the overlap intensities in relation to the main beam intensities are such as not to affect adversely signal clarity.

Dihedral angle	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 6–1.—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 6–2.—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 6–3.—Maximum Intensities in Overlapping Beams of Forward and Rear Position Lights.

[6.634–1 *Overlaps between high intensity forward position lights (CAA policies which apply to sec. 6.634 (b) (3)).* When the peak intensity of the forward position lights is greater than 100 candles, the maximum overlap intensities between them may exceed the values given in figure 6–3 provided the overlap intensity in Area A is not greater than 10 percent of peak position light intensity and the overlap intensity in Area B is not greater than 2.5 percent of peak position light intensity.[7]]

(23 F. R. 1001, Feb. 15, 1958, effective Mar. 10, 1958.)

6.635 *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 $x_0=x$.

6.636 *Riding light.*

(a) When a riding (anchor) light is required for a rotorcraft operated from water, it shall be capable of showing a white light for at least 2 miles at night under clear atmospheric conditions.

(b) Riding lights shall be installed so that they will show a maximum practicable unbroken light when the rotorcraft is moored or drifting on the water. Externally hung lights shall be permitted.

6.637 *Anti-collision light system.* An airplane to be eligible for night operation shall have installed an anti-collision light system. Such system 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 rotorcraft with due consideration to the physical configuration and flight characteristics of the rotorcraft. In any case, the field of coverage shall extend in all directions within 30° above and 30° below the horizontal plane of the rotorcraft, except that a solid angle or angles of obstructed visibility totaling not more than .03 steradians shall be permissible.

(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 rotorcraft'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 section 6.635 (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 6–4. The following relation shall be assumed:

$$I_e=\frac{\int_{t_1}^{t_2} I(t)dt}{0.2+(t_2-t_1)};$$

[7] Overlap intensities should be determined with the position lights installed in their actual rotorcraft locations, since adjacent rotorcraft structure will often provide some cutoff in the overlap area.]

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.

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 6–4.—Minimum Effective Intensities for Anticollision Lights.

6.637–1 *Anticollision light standards (CAA policies which apply to sec. 6.637).* The anticollision light standards in section 6.637 apply to rotorcraft for which an application for a type certificate is made on or after April 1, 1957. When anticollision lights are installed on rotorcraft for which an application for a type certificate was made before April 1, 1957, the applicant may conform either to section 6.637 or to the standards listed below:

(a) Anticollision lights (when installed) should be of the rotating beacon type installed on top of the fuselage in such a location that the light will not be detrimental to the crew's vision and will not detract from the conspicuity of the position lights. If there is no acceptable location on top of the fuselage, a bottom fuselage installation may be used.

(b) The color of the anticollision light should be aviation red in accordance with the specifications of section 6.635.

(c) The arrangement of the anticollision light, i. e., number of light sources, beam width, speed of rotation, etc., should be such as to give an effective flash frequency of not less than 40 and not more than 100 cycles per minute with an on-off ratio of not less than 1:75.

(22 F. R. 10016, Dec. 13, 1957, effective Jan. 15, 1958.)

Safety Equipment

6.640 ***General.*** **Required safety equipment which the crew is expected to operate at a time of emergency, such as flares and automatic life-raft releases, shall be readily accessible. (See also sec. 6.738 (e).)**

6.641 ***Flares.*** **When parachute flares are installed, they shall be of an approved type, and their installation shall be in accordance with section 6.642.**

6.642 ***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 rotorcraft and its occupants.

(c) If recoil loads are involved in the ejection of the flares, the structure of the rotorcraft shall be designed to withstand such loads.

6.643 ***Safety belts.*** **Rotorcraft manufactured on or after the effective date of this part shall be equipped with safety belts of an approved type. (See sec. 6.18.) In no case shall the rated strength of the safety belt be less than that corresponding with the ultimate load factors specified, 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 specified. (See sec. 6.260.)**

6.644 ***Emergency flotation and signaling equipment.*** **When emergency flotation and signaling equipment is required by the operating rules of the Civil Air Regulations, such equipment shall comply with the provisions of paragraphs (a) through (c) of this section.**

(a) Rafts and life preservers shall be of an approved type and shall be so installed as to be readily available to the crew and passengers.

(b) Rafts released automatically or released by the pilot shall be attached to the rotorcraft by means of lines to keep them alongside the rotorcraft. The strength of the lines shall be such that they will break before submerging the empty raft.

(c) Signaling devices shall be free from hazard in their operation and shall be installed in an accessible location.

Miscellaneous Equipment

6.650 *Hydraulic systems.*

(a) *Design.* Hydraulic systems and elements shall withstand, without exceeding the yield point, all structural loads which are expected to be imposed in addition to the hydraulic loads.

(b) *Tests.* Hydraulic systems shall be substantiated by proof pressure tests. When proof tested, no part of a hydraulic system shall fail, malfunction, or experience a permanent set. The proof load of any system shall be 1.5 times the maximum operating pressure of that system.

(c) *Accumulators.* Hydraulic accumulators or pressurized reservoirs shall not be installed on the engine side of the fire wall, except when they form an integral part of the engine.

Operating Limitations and Information

General

6.700 *Scope.*

(a) The operating limitations in sections 6.710 through 6.718 shall be established as prescribed in this part.

(b) The operating limitations, together with any other information concerning the rotorcraft found necessary for safety during operation, shall be included in the Rotorcraft Flight Manual (sec. 6.740), shall be expressed as markings and placards (sec. 6.730), and shall be made available by such other means as will convey the information to the crew members.

Operating Limitations

6.710 *Air-speed limitations; general.* When air-speed limitations are a function of weight, weight distribution, altitude, rotor speed, power, or other factors, the values corresponding with all critical combinations of these values shall be established.

6.711 *Never-exceed speed* V_{NE}.

(a) The never-exceed speed shall be established. It shall not be less than the best rate of climb speed with all engines at maximum continuous power, nor greater than either of the following: (1) $0.9V$ established in accordance with section 6.204, (2) 0.9 times the maximum speed demonstrated in accordance with section 6.140.

(b) It shall be permissible to vary the never-exceed speed with altitude and rotor rpm, provided that the ranges of these variables are sufficiently large to allow an operationally practical and safe variation of the never-exceed speeds.

6.712 *Operating speed range.* An operating speed range shall be established for each rotorcraft.

6.713 *Rotor speed.* Rotor r. p. m. limitations shall be established as set forth in paragraphs (a) and (b) of this section. (See also sec. 6.710.)

(a) *Maximum power off (autorotation).* Not to exceed 95 percent of the maximum design r. p. m. determined under section 6.204 (b) or 95 percent of the maximum r. p. m. demonstrated during the type tests (see sec. 6.103 (b)), whichever is lower.

(b) *Minimum.*

(1) *Power off.* Not less than 105 percent of the higher of the following: (i) The minimum demonstrated during the type tests (see sec. 6.103 (b)), (ii) the minimum determined by design substantiation.

(2) *Power on.* Not less than the higher of the following: (i) The minimum demonstrated during the type tests (see sec. 6.103 (a)), (ii) the minimum determined by design substantiation and not higher than a value determined in compliance with section 6.103 (a).

6.714 *Powerplant limitations.* The powerplant limitations set forth in paragraphs (a) through (c) of this section shall be established for the rotorcraft. They shall not exceed the corresponding limits established as a part of the type certification of the engine installed on the rotorcraft.

(a) *Take-off operation.* The take-off operation shall be limited by:

(1) The maximum rotational speed, which shall not be greater than the maximum value

determined by the rotor design, nor greater than the maximum value demonstrated during type tests,

(2) The maximum permissible manifold pressure,

(3) The time limit upon the use of the corresponding power,

(4) The maximum allowable cylinder head, coolant outlet, or oil temperatures, if applicable when the time limit of subparagraph (3) of this paragraph exceeds two minutes.

(b) *Continuous operation.* The continuous operation shall be limited by:

(1) The maximum rotational speed, which shall not be greater than the maximum value determined by the rotor design, nor greater than the maximum value demonstrated during type tests,

(2) The minimum rotational speed demonstrated in compliance with the rotor speed requirements as prescribed in section 6.713 (b) (2). (See secs. 6.103, 6.710, and 6.711.)

(c) *Fuel octane rating.* The minimum octane rating of fuel shall be limited to that required for satisfactory operation of the powerplant within the limitations prescribed in paragraphs (a) and (b) of this section.

6.715 *Limiting height-speed envelope.* If a range of heights exists at any speed, including zero, within which it is not possible to make a safe landing following power failure, the range of heights and its variation with forward speed shall be established together with any other pertinent information, such as type of landing surface. (See sec. 6.741 (f).) Such an envelope shall be established in full autorotation for single-engine helicopters and with one engine inoperative for multiengine helicopters provided that engine isolation design features are incorporated to assure continued operation of the remaining engines. (See sec. 6.741 (f).)

6.716 *Rotorcraft weight and center of gravity limitations.* The rotorcraft weight and center of gravity limitations to be established are those required to be determined by sections 6.101 and 6.102.

6.717 *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 6.718. 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.

6.718 *Types of operation.* The type of operation to which a rotorcraft is limited shall be established on the basis of flight characteristics and the equipment installed. (See the operating parts of the Civil Air Regulations.)

6.719 *Maintenance manual.* The applicant shall furnish with each rotorcraft a maintenance manual to contain information which he considers essential for the proper maintenance of the rotorcraft. The maintenance manual shall include recommended limits on service life or retirement periods for major components of the rotorcraft. Such components shall be identified by serial number or by other equivalent means.

Markings and Placards

6.730 *General.*

(a) The markings and placards specified in sections 6.731 through 6.738 are required for all rotorcraft.

(b) Markings and placards shall be disdisplayed in conspicuous places and shall be such that they cannot be easily erased, disfigured, or obscured.

(c) Additional information, placards, and instrument markings having a direct and important bearing on safe operation of the rotorcraft shall be required when unusual design, operating, or handling characteristics so warrant.

6.731 *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.

6.732 *Air-speed indicator.* Instrument indications shall be in terms of indicated air speed. The markings set forth in paragraphs (a) through (c) of this section shall be used to indicate to the pilot the maximum and minimum permissible speeds and the normal precautionary operating ranges. (See secs. 6.612 (a), 6.710, 6.711, 6.712, 6.713, and 6.715.)

(a) A red radial line shall be used to indicate the limit beyond which operation is dangerous.

(b) A yellow arc shall be used to indicate the precautionary operating range.

(c) A green arc shall be used to indicate the safe operating range.

6.733 *Magnetic direction indicator.* A placard shall be installed on or in close proximity to the magnetic direction indicator which shall comply with the requirements of paragraphs (a) through (c) of this section. (See sec. 6.612 (c).)

(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.

6.734 *Powerplant instruments; general.* All required powerplant instruments shall be marked in accordance with paragraphs (a) through (c) of this section. (See sec. 6.613.)

(a) The maximum and the minimum (if applicable) safe operation 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 operating limits.

(c) The take-off and precautionary ranges shall be marked with a yellow arc.

6.735 *Oil quantity indicator.* Oil quantity indicators shall be marked in sufficient increments to indicate readily and accurately the quantity of oil. (See sec. 6.613 (d).)

6.736 *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. (See secs. 6.421 and 6.613 (b).) A notation in the Rotorcraft Flight Manual shall be made to indicate that the fuel remaining in the tank when the quantity indicator reaches zero is not usable in flight. (See sec. 6.741 (g).)

6.737 *Control markings.*

(a) *General.* All cockpit controls including those referred to in paragraphs (b) and (c) of this section shall be plainly marked as to their function and method of operation. (See sec. 6.353.)

(b) *Powerplant fuel controls.* The powerplant fuel controls shall be marked in accordance with subparagraphs (1) through (4) of this paragraph.

(1) Controls for fuel tank selector valves shall be marked to indicate the position corresponding with each tank with all existing 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 to indicate to the flight personnel the order in which the tanks must be used.

(3) On multiengine rotorcraft, controls for engine valves shall be marked to indicate the position corresponding with each engine.

(4) The capacity of each tank shall be indicated adjacent to or on the fuel tank selector control.

(c) *Accessory and auxiliary controls.* Accessory and auxiliary controls shall be marked in accordance with subparagraphs (1) and (2) of this paragraph.

(1) Where visual indicators are essential to the operation of the rotorcraft (such as a rotor pitch or retractable landing gear indicator), they shall be marked in such a manner that the crew members at all times can determine the position of the unit.

(2) Emergency controls shall be colored red and shall be marked to indicate their method of operation.

6.738 *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. When the maximum permissible weight to be carried in a seat is less than 170 pounds (see sec. 6.101 (b) (4)), a placard shall be permanently attached to the seat structure stating the maximum allowable weight of the occupant to be carried.

(b) *Fuel and oil filler openings.* The information required by subparagraphs (1) and (2) of this paragraph 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. 6.423 (c).)

(2) The word "oil" and the oil tank capacity. (See sec. 6.441 (e).)

(c) *Emergency exit placards.* Emergency exit placards and operating controls shall be colored red. A placard shall be located adjacent to the controls which clearly indicates the location of the exit and the method of operation. (See sec. 6.357.)

(d) *Operating limitation placard.* A placard shall be provided in clear view of the pilot stating: "This (helicopter, gyrodyne, etc.) must be operated in compliance with the operating limitations specified in the CAA approved Rotorcraft Flight Manual."

(e) *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 plainly marked as to their method of operation.

(2) When fire extinguishers and signaling and other life-saving equipment are carried in lockers, compartments, etc., these locations shall be marked accordingly.

Rotorcraft Flight Manual

6.740 *General.*

(a) A Rotorcraft Flight Manual shall be furnished with each rotorcraft, except that a Rotorcraft Flight Manual is not required for helicopters certificated under this part; instead, the information prescribed in this part for inclusion in the Rotorcraft Flight Manual shall be made available to the operator by the manufacturer in the form of clearly stated placards, markings, or manuals. If all of the operating limitations are not included in the form of placards and markings on the helicopter then the portion of the manual supplied by the manufacturer containing the operating limitations prescribed in section 6.741 shall be approved and furnished with each helicopter.

(b) The portions of the manual listed in sections 6.741 through 6.744 as are appropriate to the rotorcraft 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.

6.741 *Operating limitations.* The operating limitations set forth in paragraphs (a) through (g) of this section shall be furnished with each rotorcraft.

(a) *Air-speed and rotor limitations.* Sufficient information shall include the information necessary for the marking of the limitations on or adjacent to the indicators as required. (See sec. 6.732.) In addition, the significance of the limitations and of the color coding used shall be explained.

(b) *Powerplant limitations.* Information shall be included to outline and to explain all powerplant limitations (see sec. 6.714) and to permit marking the instruments as required by sections 6.734 through 6.736.

(c) *Weight and loading distribution.* The rotorcraft weights and center of gravity limits required by sections 6.101 and 6.102 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 crew.* When a flight crew of more than one is required, the number and functions of the minimum flight crew determined in accordance with section 6.717 shall be described.

(e) *Type of operation.* The type(s) of operation(s) shall be listed for which the rotorcraft and its equipment installations have been approved. (See sec. 6.718.)

(f) *Limiting heights.* Sufficient information shall be included to outline the limiting heights and corresponding speeds for safe landing after power failure. (See sec. 6.715.)

(g) *Unusable fuel.* If the unusable fuel supply in any tank exceeds one gallon or 5 percent of the tank capacity, whichever is the greater, warning shall be provided to indicate to the flight personnel that the fuel remaining in the tank when the quantity indicator reads zero cannot be used safely in flight. (See sec. 6.421.)

6.742 *Operating procedures.* The section of the manual devoted to operating procedures shall contain information concerning normal and emergency procedures and other pertinent information including take-off and landing procedures and their appropriate air speeds peculiar to the rotorcraft's operating characteristics which are necessary for safe operation.

6.743 *Performance information.* Information relative to the items of performance set forth in paragraphs (a) and (b) of this section shall be included.

(a) The steady rates of climb and hovering ceilings together with the corresponding air speeds and other pertinent information, including the calculated effect of altitude and temperature. (See secs. 6.112 and 6.113.)

(b) Maximum wind allowable for safe operation near the ground. (See sec. 6.121 (d).)

6.744 *Marking and placard information.* (See sec. 6.730.)

Rotorcraft Identification Data

6.750 *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 the Civil Air Regulations.

6.751 *Identification marks.* The nationality and registration marks shall be permanently affixed in accordance with section 1.100 of the Civil Air Regulations.

Appendix A

Methods of Rotor Service Life Determination

Introduction

Service experience in the helicopter field indicates that fatigue considerations are of extreme importance in the design of the rotating major load-carrying members of the helicopter. In view of the importance of this problem, designers are urged to give great care to the detail design of rotor blades, hub retention systems and controls in order that stresses associated with oscillatory loading be kept well below the allowable material endurance limit. As far as practicable, the design should be clean, care being taken to reduce stress concentrations to a minimum. Since lack of quality control may easily result in large variations in fatigue life, great care should be taken to insure that production parts and assemblies are made with the same care as the components used in any fatigue test.

Although a uniform approach to rotor fatigue problems is desirable, it is recognized that in such a relatively new field, new design features, methods of fabrication or configurations may require variations and deviations from the methods described herein. Engineering judgment should therefore be exercised in each case.

Although there is some question as to whether a completely rational method exists for the prediction of the fatigue life of a built-up structure subject to random loading, nevertheless it is believed that an engineering approach to the subject can be attained through the application of the Cumulative Damage Hypothesis. This hypothesis asserts that every cycle of stress above an "endurance limit" produces damage proportional to the ratio of cycles run at that stress to the fatigue life at that stress level. Laboratory tests of this hypothesis indicate that it is reasonably valid when the stress cycles are of random magnitude. That is, stress spectra in which all high-stress magnitudes are applied consecutively and then all low-stress magnitudes applied, do not obey the hypothesis. Despite the approximations involved in the hypothesis and the lack of an adequate theory connecting the hypothesis with more basic properties of materials, it attempts to take more factors into account than any other method developed so far.

In any rational determination of the fatigue life of a structure, three basic factors must be known. These factors are:

Knowledge of the stresses and associated flight maneuvers to be expected in normal operation;

Knowledge of the frequency of occurrence of specific loadings;

Knowledge of the fatigue strength characteristics of the structure.

Flight Stress Measurements

It is generally agreed that because of the approximations employed in rotor load and stress distribution analyses, it is not possible at present to determine analytically a reasonable approach to rotor fatigue stress levels.

Rotor stress levels are therefore determined by means of carefully controlled, instrumented flight strain gage testing. These tests are aimed at the determination of the magnitude of steady and oscillatory stresses associated with normal helicopter operation and the correlation of the occurrence of critical stresses with specific maneuvers or operating conditions. In some cases the information so obtained can be used to limit or placard against specific maneuvers. In other cases where prohibition of specific maneuvers or operations is not feasible the information so obtained can be of use in setting up a test program which would determine the fatigue life of the part.

Prior to conducting a flight strain gage testing program, some rational evaluation of the critical stress areas must be made in order to determine the proper distribution of gages. A qualitative study is usually made by means of brittle coatings (such as Stresscoat), by photo-elastic methods or by analytic means. In conducting flight strain measurements, besides the proper distribution of strain gages on hubs, blades, blade attachments and control members, provision is usually made for recording the collective pitch setting of the rotor blades and the center of gravity acceleration during maneuvers. This is done so that it can be ascertained that for maneuvers in which a rapid control movement is utilized the severity of application of control is representative of that which can be encountered during actual service operation.

Table 1 contains a suggested list of maneuvers for investigation in a flight strain survey. These maneuvers are usually investigated over the complete r. p. m. range (from minimum design r. p. m. to maximum design r. p. m.) as well as the complete speed, altitude, center of gravity and weight ranges.

Frequency of Loading

The second item of great importance in the determination of service life, is the matter of determining the percentage of total operating time associated with each flight maneuver. At best, this evaluation can only be a statistical one and will of necessity be a function of the purpose for which the particular helicopter is intended to be used. Obviously a helicopter used solely for crop dusting would have a different time distribution for various maneuvers than one which is to be used for mail or passenger ferry service between a local airport and the center of a nearby city. At present, because of the limited number of helicopters in use this problem can be handled by means of reasonable, conservative approximations. As the types of operation increase, with the rapidly expanding field of helicopter operation, this problem will undoubtedly require reevaluation.

Table 1 represents the considered opinion of a number of helicopter specialists regarding the maneuvers to be investigated (over the complete r. p. m., speed, c. g., weight and altitude ranges) as well as an appropriate percentage distribution of the occurrence of these maneuvers.

TABLE 1

Percent Occurrence

I GROUND CONDITIONS	
(a) Rapid increase of r. p. m. on ground to quickly engage clutch	0.5
(b) Taxiing with full cyclic control	.5
(c) Jump takeoff	.5
II HOVERING	
(a) Steady hovering	.5
(b) Lateral reversal	1.0
(c) Longitudinal reversal	1.5
(d) Rudder reversal	1.0
III FORWARD FLIGHT POWER ON	
(a) Level Flight—20% V_{NE}	5.0
(b) Level Flight—40% V_{NE}	10.0
(c) Level Flight—60% V_{NE}	18.0
(d) Level Flight—80% V_{NE}	18.0
(e) Maximum Level Flight (but not greater than V_{NE})	10.0
(f) V_{NE}	3.0
(g) 111% V_{NE}	.5
(h) Right Turns	3.0
(i) Left Turns	3.0
(j) Climb (Max. Continuous Power)	4.0
(k) Cyclic and collective pull-ups from level flight	.5
(l) Change to autorotation from power-on flight	.5
(m) Partial power descent (including condition of zero flow through rotor)	2.0
(n) Landing approach	3.0
(o) Lateral reversals at V_H	.5
(p) Longitudinal reversals at V_H	.5
(q) Rudder reversals at V_H	.5
(r) Climb (Takeoff Power)	2.0
IV AUTOROTATION—POWER OFF	
(a) Steady forward flight	2.5
(b) Right turns	1.0
(c) Left turns	1.0
(d) Lateral reversals	.5
(e) Longitudinal reversals	.5
(f) Rudder reversals	.5
(g) Cyclic and collective pull-ups	2.0
(h) Landings (including flares)	2.5
	100.0

Fatigue Strength

The third phase of the fatigue evaluation program involves the determination of the fatigue strength of the actual structure. Although the fatigue characteristics of simple material specimens are often available, the direct application of this information to built-up structures is questionable. The available material data modified by appropriate stress concentration factors can undoubtedly be used as an important tool in design. However, propeller and helicopter rotor experience indicates that various factors may reduce the fatigue strength of a built-up structure below that of material specimens with severe notched stress concentrations. It therefore is necessary that endurance tests of the critical parts be conducted by applying steady and oscillatory loads in a manner simulating the loading actually encountered in service.

Although the foregoing indicates the difficulty in correlating material fatigue data with that of a built-up structure, nevertheless it is recognized that minimum acceptable stress levels can be established, such that, if the maximum measured stresses in a component be lower than the established levels, no fatigue testing need be required. The following technique which is based on the use of a Goodman Diagram for the material modified by suitable factors to account for stress concentration factors plus a factor of safety is considered acceptable for the establishment of this minimum stress level.

1. Establish the Goodman Diagram from material data for the perfect specimen. This line will mark the endurance limit for various vibratory and steady stress levels.

2. The allowable full reversal stress for the material should then be reduced to account for the stress concentration factor present in the actual rotor part. The stress concentration factor chosen should adequately account for surface finish, fabrication methods, probability of galling as well as the stress concentrations around notches, threads, holes, fillets, etc. The resulting line on the Goodman Diagram will then be the failure boundary line for the part.

3. A margin of safety of two should be applied to the failure boundary curve in order to establish an operating boundary line. Thus the operating boundary line would have a slope of ½ the failure boundary curve.

4. If the flight strain measurements indicate that all nominal operating stresses[1] fall below the operating boundary line, no fatigue testing is required.

When the measured stresses are above the operating boundary line (see Figure 1) fatigue tests of the actual component are required.

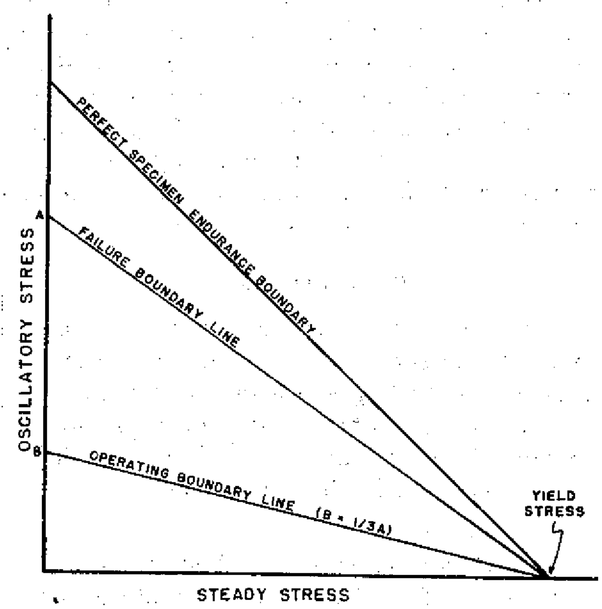

Figure 1.

Several methods of fatigue testing are currently available. The various methods such as laboratory, flight endurance or whirl stand testing methods are of course applicable only to the extent that the range of steady and vibratory flight stresses can be duplicated in the fatigue test procedure. Because of the greater degree of control which can be maintained in the laboratory, this method is recommended. However, flight or whirl stand testing is acceptable in lieu of laboratory testing if they are conducted under controlled conditions.

[1] Nominal operating stress: It is usually not possible to place the strain gage so that the stress at the critical section is measured. Instead, the gage is located at a reference point close to the critical section. The measured stress data can be reduced to equivalent loads. Subsequent application of conventional methods of stress analysis would convert these loads to stresses at the critical section (neglecting stress concentration factor).

Methods of Loading

(A) Laboratory

The laboratory method of determining the fatigue strength involves testing in a fatigue machine the critical section or sections of a rotor component. In this procedure small sections can be tested under carefully controlled conditions.

(B) Flight

The flight method of fatigue testing involves the use of the entire helicopter itself as a fatigue machine. This method, if employed, should be conducted under such controlled conditions that the level of stresses and number of fatigue cycles are known accurately enough during the test to determine the fatigue limit and service life of the critical components of the rotor system.

(C) Whirl Stand

The whirl stand procedure can be considered to be a variation of the flight test method. This involves testing complete rotor components on a test stand. The validity of this method is predicated on the ability to duplicate flight stress conditions in the test set-up.

Test Procedures

Several procedures are available for the determination of the fatigue strength of the critical component. Fatigue strength evaluation through (A) the establishment of *S–N* curves, (B) by testing in cyclical units or a suitable combination of these two procedures is considered to be acceptable.

(A) Establishment of *S–N* Curves

An *S–N* curve for a particular section can be established by testing samples of the critical section at a fixed steady stress and varying the oscillatory component of the stress. Thus, if at a steady tensile stress of level A and oscillatory stress of level B, the sample is fatigue tested to failure, failure occurring after N_1 cycles, a point on the *S–N* diagram for steady stress level A is determined. Additional points can be determined by maintaining the same steady stress A and choosing a different oscillatory stress for each sample. One such curve is needed for each critical steady stress level. Because of scatter usually associated with fatigue testing, a large number of specimens are tested in order to establish these curves. This procedure of establishing *S–N* curves can theoretically be achieved either by laboratory or whirl stand testing, however, for obvious practical reasons this procedure is usually reserved for laboratory testing.

Since it may be impossible to handle the complete blade and retension system with one setup due to practical limitations of applying required loads to the structure for establishing a representative *S–N* diagram for the rotor, it may be desirable to establish a set of criteria for hub and retention portions of the rotor separately from the blade. Also, since the critical loads entering the hub retention can be along different axes, it may be necessary to determine an *S–N* curve for each axis individually, i. e., one for the major axis and another for the minor axis since one may be critical for certain r. p. m. or maneuvers and the other at a different set of conditions.

Stress raisers have little effect on the static failing load owing to plastic deformation relieving the high stress. Similarly, for oscillatory or repeated high-loads, the effect of stress raisers on the fatigue strength is diminished by the above form of stress relief. At low loads, however, the stress raisers are fully effective in reducing the fatigue strength, which then approaches that appropriate to the nominal stress concentration.

In general, tests have shown that the fatigue stress concentration factor although lower than the theoretical factor (determined by photoelastic or other rational methods) varies with the loading, decreasing sharply in the region of the yield stress. An arbitrarily chosen high-stress level might therefore result in the critical section being beyond the yield point with resultant stress relief and reduced stress concentration factor whereas a neighboring section might be operating close to the yield stress and fail first, even though for the actual operating stress range the first section would be critical. Therefore, as a general rule it is not advisable to conduct fatigue tests at arbitrarily chosen levels appreciably higher than actual operating stress levels.

From the flight stress measurements, the frequency of occurrence of the flight maneuvers and the *S–N*. curves, the fatigue life of the part can be calculated.

While all maneuvers are to be conducted over the complete speed, center of gravity, altitude, rotor r. p. m. and weight ranges, only the combination of those conditions which produce the most critical stress for any one maneuver should be used in calculating the fatigue life. The percentage of occurrence value given in Table 1 should be used with this critical condition for the maneuver. Thus the stress associated with the most critical r. p. m. center of gravity, altitude and weight for level flight, power on at 20% V_{NE} would be considered to occur for 5% of the life in the fatigue evaluation. An example of a fatigue life determination is given at the end of appendix A.

(B) Testing in Cyclical Units

This procedure involves the testing of each specimen at a series of stress levels, the number of cycles to be run at each level being proportional to the expected percentage of time associated with the particular sought condition giving rise to the specific stress level. Since the life of the part is unknown beforehand, the stress levels must be covered in arbitrarily chosen cyclical units. Thus, if units of 100 hours are chosen, then reference to Table 1 would indicate 0.5 hour of rapid increase of r. p. m. on the ground to quickly engage clutch, 0.5 hour jump takeoff, 10 hours at 20% V_{NE} for level flight, etc. Then if a failure occurred at some time during such a unit, the fatigue life would be determined by the number of completed units. Thus, if the unit was 100 hours and failure occurred during the 14th unit, the fatigue life would be based on 13 completed units (i. e., 1,300 hours). It should be noted that the Cumulative Damage Hypothesis which is being used herein for fatigue life evaluation has been found to be valid only when the stress cycles are of random magnitude. Therefore, if the cyclical unit procedure is adopted, care should be taken to avoid the application of all high stress levels consecutively and then all low stresses. It is therefore likewise desirable to keep the units of time at reasonably low levels.

(C) Acceptable Modified Procedures

As mentioned previously, rational modifications or combinations of the above procedures may be made. Thus, if it is desired to limit the scope of fatigue testing, a single *S-N* curve based on the highest measured mean stress could be utilized in the fatigue life calculations. Another acceptable approach would be to demonstrate that the most critical stress level was below the endurance limit. This could be demonstrated by testing at the highest stress level to 10^7 cycles for ferrous materials and 5 x 10^7 cycles for nonferrous materials. An acceptable combination of *S-N* and cyclic unit approach would involve the establishment of the knee of the *S-N* curve (endurance limit) and the flight conditions which resulted in stresses falling below the endurance limit. The method of cyclic testing could then be employed only for those flight conditions which would cause fatigue damage. Thus, if it is established that all level flight conditions result in stresses below the endurance limit, the length of the fatigue test by cyclic units could be appreciably reduced.

Fatigue Life vs. Service Life

Since actual operating conditions involve factors the quantitative effects of which cannot readily be ascertained, it becomes necessary to distinguish between fatigue life as determined by laboratory or other accelerated fatigue tests and service life which is interpreted as the required retirement life of the part. Furthermore, because of material and fabrication variations, even under idealized laboratory conditions it has been estimated that approximately thirty test specimens are required to establish each *S–N* curve. In view of the required time and high costs involved, it must be recognized that only a limited amount of testing can be economically tolerated by most manufacturers. It is therefore important that a minimum fatigue test program be determined and that a service life which is less than the calculated fatigue life, but consistent with the degree of fatigue testing, be established.

Service Life

For some designs, it may be possible to demonstrate that all flight and ground load stresses are below the endurance limit for the critical parts of the rotor. For such cases, no limit need be imposed on the service life.

Compliance with either of the following conditions may be considered to be a minimum acceptable level of demonstrating that all stresses are below the endurance limit.

1. If all measured stresses fall below the operating boundary line (Figure 1), no fatigue testing is required.

2. Fatigue testing at the mean stress associated with the most critical mean-oscillatory stress level measured in flight. No failure should occur before 10^7 cycles for ferrous materials nor before 5 x 10^7 cycles for nonferrous materials. The minimum number of test specimens required is dependent on the oscillatory test level, in the following manner:

(*a*) A minimum of 4 test specimens if the oscillatory level is chosen at 1.1 times the critical oscillatory stress level.

(*b*) A minimum of 3 test specimens if the oscillatory level is chosen at 1.25 times the critical oscillatory stress level.

(*c*) A minimum of 2 test specimens if the oscillatory level is chosen at 1.5 times the critical oscillatory stress level.

(*d*) One specimen if the oscillatory level is chosen at twice the critical oscillatory stress level.

It is to be noted at this point that the previous reference recommending against the use of arbitrary stress levels appreciably higher than actual operating stress levels is considered to be inapplicable in this case. This is due to the fact that the stresses involved here are low since the test involved is aimed at demonstrating that the arbitrarily raised stresses are still below the endurance limit.

Where finite fatigue life is indicated and *S–N* curves are employed in determining this life, a minimum of 4 points on each *S–N* curve should be established. If it is desired to limit the fatigue tests, a single *S–N* curve based on the highest measured mean stress could be utilized in the fatigue life calculations. However, if this approach tends to unduly limit the fatigue life, a family of curves can be developed from two established *S–N* curves by means of Goodman or similar diagrams. Service life should then be established at 75% of the calculated fatigue life but should be no greater than 2,500 hours. Where the fatigue life is established by cyclic variation of load, a minimum of 4 specimens should be tested. The fatigue life should be based on the specimen in which the smallest number of such cycles is completed. The service life should be established at 75% of this fatigue life but should be no greater than 2,500 hours. At the expiration of the established service life, the critical part should be retired from service. Where the service life is limited by the arbitrary 2,500-hour figure, the service life can be extended beyond this figure after thorough inspection of several specimens which successfully reach the 2,500-hour limit. However, the upper limit to this extension is limited to 75% of the demonstrated fatigue life.

Example of Fatigue Life Determination From *S–N* Data

If the normal life of a specimen at a certain stress level is N, and if n be the number of cycles actually run at that level, then as a consequence of cumulative damage theory, a fatigue specimen stressed at several different stress levels in random order will fail when

$$\Sigma \frac{n_i}{N_i} = 1$$

Where the summation is taken over all values of i corresponding to the repeated stresses imposed on the specimen.

Using the above expression, it is possible to determine the fatigue life in hours of a part subject to random application of stresses above the endurance limit, if the fraction or percentage of total life expectancy at each stress level is known.

Thus, if:

L=total life of part in hours

x=life in hours at stress level (1)

y=life in hours at stress level (2)

a=fraction of total life at level (1)

b=fraction of total life at level (2)

then:

$$\frac{n_1}{N_1}=\frac{aL}{x}$$

$$\frac{n_2}{N_2}=\frac{bL}{y}$$

and

$$\Sigma\frac{n}{N}=\frac{aL}{x}+\frac{bL}{y}=1$$

or

$$L=\frac{100}{\frac{a}{x}+\frac{b}{y}}=\frac{100}{\Sigma\frac{\text{Percent of life for particular maneuver}}{\text{Endurance life in hours at that maneuver}}}$$

In the life determination, the highest measured stress associated with a particular maneuver should be used. Thus, in Table 1, the most critical steady hovering condition should be investigated (from minimum design r. p. m. to maximum design r. p. m.) at the most critical weight and center of gravity condition, and the 0.5% occurrence of hovering should be based on this critical condition.

This method can be illustrated further by referring to a specific example. Suppose that for only two maneuvers, lateral reversal and autorotation landing, the measured stresses are above the endurance limits. The life of the structure can be determined as follows:

TABLE 2

Flight Condition:	*Lateral Reversal Hovering, 300 r. p. m.*	*Auto-rotation Landing 320 r. p. m.*
1. Vibratory Stress (from flight test) psi	4, 900	2, 500
2. Steady Stress (from flight test) psi	8, 600	7, 690
3. Endurance in cycles (from *S–N* curve)	1.1 x 10^5	5.5 x 10^6
4. Cycles of critical stress per minute	300	320
5. Endurance in hours $\left(\frac{(3)}{\text{cpm x 60}}\right)$	6. 11	286. 46
6. Percent of life at flight condition	1. 0%	2. 5%

$$L=\frac{100}{\frac{1}{6.11}+\frac{2.5}{286.46}}=\frac{100}{.1637+.0087}=580\text{ hrs.}$$

Service Life=75% of calculated life=435 hrs.

It should be noted that in the above example it is conservatively assumed that the peak stresses associated with each maneuver have been taken for the duration of the maneuver. Since in some cases this may be unduly conservative, the actual measured distribution of stress levels associated with each maneuver can be employed in the fatigue life determination.

[Appendix B

[Special Civil Air Regulations Which Affect Part 6

[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 Reguations. 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 extent 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 experiments 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.]

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